Fetal, Perinatal, Neonatal and Infant Skeletal Palaeopathology as an Indicator of Maternal Health and Population Stress

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I certify that all material in this thesis which is not my own work has been identified and that no material has previously been submitted and approved for the award of a degree by this or any other University.

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Abstract

The palaeopathology of very young individuals offers valuable information for the study of maternal, fetal, perinatal, neonatal and infant health in past populations. The primary aims of this research are to differentiate skeletal pathology from normal appearance in very young individuals, to assess the relationship between the palaeopathology of very young individuals and maternal physiological stress, and to evaluate the ways in which past communities responded to perinatal, infant and maternal mortality. The palaeopathology described below is determined through non-destructive methods analysis of skeletal remains and involves macroscopic examination and metrical analysis. The research sample is drawn from seven archaeological collections (Ardreigh, n=87; Baron Court Farm, n=55; Çatalhöyük, n=86; Gussage All Saints, n=35; Wetwang Slack, n=36; Wharram Percy, n=83; Yewden villa, n=56), two reference collections (Royal College of London, n=199; Scheuer, n=29), one of which also includes archaeological material, and five modern perinatal pathology cases. The identified skeletal pathology is considerable and ranges from minor morphological variation through to agenesis, and trauma associated with obstetric complications. There is strong evidence in the form and severity of palaeopathology for compromised maternal condition during pregnancy. Skeletal pathology was evident in two thirds of the young individuals analysed with the majority of these falling into the perinatal and neonatal age categories.

There is evidence for population specific skeletal pathology, particularly with respect to non-metric variants such as intrajugular bridging and vertebral border shifting. Several causes of mortality were positively identified and many individuals display skeletal pathology indicative of a significantly compromised physiological state during gestation and early infancy. Maternal health prior to and during pregnancy is demonstrated to have had a considerable impact on the development and growth of their offspring. The palaeopathology of the past populations studied revealed that they experienced undernutrition and malnutrition, exposure to infectious diseases, accidental and intentional physical trauma and periods of social disruption. These communities also had access to supportive treatment and intervention that is evidenced in the numerous cases of healed and healing skeletal pathology. The response of the living towards the death of mothers and very young individuals in the

past populations studied is revealed through their funerary treatment of these individuals and provides insight into the broader socio-cultural and personal contributions to burial practices in each community.

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Glossary

Terms used in the text and database

Term	Definition
Acrania	Dysmorphy and partial agenesis of cranial vault elements
Agenesis	Failure to develop, developmental absence of element of part thereof
Alloimmune	Immune response to antibodies from another individual in the same species
Anaemia	Reduction in red blood cells and haemoglobin
Anencephaly	Agenesis of brain tissue with associated agenesis and dysmorphy of cranial elements
Asphyxia	Deprivation of oxygen
Avulsion fracture	Removal of bone at the attachment site of a ligament or tendon
Carious lesion	(Dental caries) decay of the enamel surface
Cephalocele	Protrusion of brain tissue and meninges through the cranium
Chiari malformation	Protrusion of brain tissue into the spinal canal. Type II malformation involves cerebellar and brain stem protrusion through the foramen magnum.
Congenital	An abnormality that develops at or before birth, may develop later
Craniorachischisis totalis	Non-closure of the entire neural tube. Involves the cranial vault and vertebral elements C1-S5.
Craniosynostosis	Premature fusion of cranial sutures resulting in abnormal cranial shape
Cribra cranii	Porous lesions of the ectocranial surface
Cribra orbitalia	Porous lesions of the orbit
Diffuse Idiopathic Skeletal Hyperostosis (DISH)	Ossification of connective tissues of the vertebral column, particularly ligaments
Dysmorphy	Abnormality in the structure of the element
Eburnation	Degeneration of a joint leading to ‘polishing’ of the articular surface(s)
Enamel hypoplasia	Abnormal decrease in enamel formation
Encephalocele	Incomplete closure of the anterior neural tube resulting in a bifid cranial vault with protrusion of brain tissues
Exstrophy of the bladder	Protrusion of the bladder through the abdominal wall
Gemination	Developmental deformity in tooth bud resulting in multiple or split crowns
Harris lines	Zones of increased bone density arising from periods of arrested growth, particularly of long bones
Hypoplasia	Abnormal decrease in the form of the element
Hypoxia	Insufficient or interrupted oxygen supply

Glossary continued…

Term	Definition
Iniencephaly	Extreme retroflection of the cranium with the posterior vault in articulation with the cervical neural arches
Klippel-Feil syndrome	Developmental fusion of at least two cervical vertebrae. May also affect vertebrae in the thoracic and lumbar regions.
Osteomyelitic lesion	Infection of the bone with a draining cloaca
Palaeopathology	The study of 'suffering' in past populations. The differential diagnosis of trauma, disease and disorder in past populations.
Periosteal lesion	Periostosis = inflammation of the periosteal layer
Physiological stress	Disruption to physiological processes. Evidence for this in past populations is obtained through osteological analysis and evident in skeletal pathology and variation.
Porotic hyperostosis	Porotic lesions of the bone surface, particularly the cranial vault
Pre-eclampsia	Maternal hypertension, onset during pregnancy
Rachischisis	Non-closure of the entire vertebral neural tube from C1-S5
Schmorl's nodes	Cyst-like lesions forming within the vertebral body
Sepsis	Physiological response to infection that damages organs and soft tissue
Spina bifida	Midline defect caused by non-closure of the neural arches
Stenosis	Abnormal narrowing of a foramen or vessel
Talipes calcaneovalgus	Extreme dorsiflexion of the foot
Teratoma	Tumour
Thrombocytopenia	Reduction in the number of thrombocytes (platelets), leading to clotting insufficiency
Thrombotic vasculopathy	Group of pathological expressions involving vascular tissues, particularly of the placenta
Trepanation	Treatment technique involving removal of a portion of the cranial vault, generally to relieve internal pressure
Vertebral shifting	The expression of vertebral characteristics in the vertebra(ae) of an adjacent zone
Villous immaturity	Abnormal villous (of the placenta) appearance and function

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Chapter One

Introduction

> "Infant mortality studies have the potential to provide information on the population's ability to adapt to its environment, seasonality of mortality, cultural practices, demography, maternal health, disease epidemics, birthing practices, infant feeding and social attitudes towards children."
> (Lewis 2007, 83-84)

Our understanding of past societies and cultures has been informed predominantly through archaeological investigation and interpretations of the subsequent results. These interpretations have evolved over time and reflect socio-cultural preconceptions and the changing perspectives of archaeological theory. This is evident in the numerous archaeological site reports published during the last century. Examples of this are the inclusion of pages of detailed analysis of craniometrics and its implications for racial heritage (Keith, 1921), or the assumption that a 'formal' burial is one in which the articulated human remains have been delineated or covered by flint nodules and all other burials are informal deposits associated with domestic refuse (Wainwright 1979, 191). It is clear that the contextual information and raw data presented in past reports remain a significant contribution to furthering our understanding of these past places and people, although any interpretation should always involve critical assessment.

The motivation for undertaking the current research stemmed from a desire to assess critically modern assumptions of infant mortality, maternal health and the maternal experience in past populations with a focus on challenging interpretations that are not supported by the evidence. It rapidly became apparent that conclusions regarding the burials of very young individuals from archaeological contexts were being drawn with little if any analysis of the remains themselves. Given the considerable potential that can be realised through the detailed analysis of adult skeletal remains, the research was approached from the perspective that a substantial proportion of this potential must also be held in the skeletal remains of very young individuals.

This research arose primarily out of frustration with the imprecise nature and often misleading interpretations of existing information regarding past populations, particularly with respect to very young individuals. The primary aim of the research focussed on the form of skeletal pathology and whether it could be differentiated reasonably from the normal appearance of the developing skeleton. Following this, the second objective was to determine if there was evidence that a compromised maternal condition (physiological stress) during pregnancy could be reflected in the skeletal remains of her child. If it was possible to demonstrate maternal stress through the palaeopathology of very young individuals, could this information then be extrapolated to provide information on population stress within each of the communities studied? Contextual and skeletal evidence offers a wealth of contemporary information for investigating cultural buffering behaviours in response to perinatal, infant and maternal mortality in these past populations. These lines of inquiry also suggested the possibility of capturing differences in the prevalence of pathological conditions observed in the remains of very young individuals across the sample populations.

The form that skeletal pathology can take is limited by the range of possible osseous responses in the developing skeleton. Bioarchaeological analysis of skeletal remains offers a direct pathway to uncovering specific details of the short lives of very young individuals. By restricting the window of the life course to only include individuals under six months, including premature individuals, a sample population is likely to capture the majority of very young mortalities within a general burial population and also enable the timing of onset to be refined for various observed skeletal pathologies.

There has been a renewed interest in the palaeopathology of very young individuals and more in-depth investigations into the identification of pathological conditions in the developing skeleton. As the primary focus of the research is the palaeopathology of very young individuals, the temporal, geographical, or cultural aspects of past populations were not considered to be key selection criteria. The analysis of palaeopathology in these individuals had a twofold purpose: to ascertain the maternal and population experience of stress within each past community; and to ascertain common aspects of palaeopathology that can be applied more generally as indicators for compromised maternal condition in other burial populations.

The research presents a considerable range of skeletal pathology, the majority of which was observed in preterm individuals and those that survived for several weeks after birth. It also describes the evidence for maternal health that is accessible through palaeopathological analysis of the very young individuals in the selected burial populations. This research hypothesises that the detailed analysis of the skeletal remains of very young individuals for evidence of compromised development or physiology provides the basis for analysing previous interpretations of neonatal and infant mortality critically, such as infanticide; a practice that had been suggested on the grounds of high neonatal mortality alone.

The research will demonstrate the range of skeletal pathology that can be identified in the remains of very young individuals. It will show that the type and degree of palaeopathology is an indication of the physiological condition of the individual, and potentially of the mother. Furthermore, the evidence for physiological stress in both the mother and offspring is situated within the archaeological context for each past population and informs on the extent of physiological stress experienced by the respective communities. An estimation of population stress in past communities included in the research is informed by the skeletal pathology of very young individuals and supported by the contextual evidence.

It cannot be assumed that unfamiliar and unrecognisable aspects of past cultural behaviours connected with infant mortality and burial were more or less important than modern responses. Nor can the personal or community impacts of infant and maternal mortality in past populations be determined. However, this research will demonstrate the complexity of public response through the archaeological evidence that is associated with funerary behaviours. The funerary treatment and context of the burials of very young individuals in the burial populations analysed, considerably broadens our understanding of past community responses to mortality and maternal care.

The following thesis presents an overview of palaeopathology in very young individuals and its association with maternal health. It also investigates the potential for assessing population stress within smaller communities on the basis of palaeopathology. The results of an analysis of skeletal pathology evident in the remains of very young individuals in seven burial populations recovered from archaeological settlement contexts is presented along with an assessment of comparative skeletal pathology in two reference collections and several modern pathology cases. The archaeological skeletal remains analysed derive from the Neolithic through to the medieval period. The choice of collections was based upon several criteria; the inclusion of a relatively large number of very young individuals, availability for analysis, good bone preservation, association of burials with a contemporary settlement, broad contextual information for the burials and associated settlements, and where possible two contemporary collections were included for each period. The selected collections provide a span of period and place and their analysis enables the consideration of the variation in the palaeopathology of very young individuals across these parameters.

Chapter 2 summarises previous research into skeletal development and maternal health and considers the supposed under-enumeration of perinatal and infant burials from archaeological sites, particularly those located in Britain. It summarises the gaps in knowledge regarding the palaeopathology of very young individuals and goes on to detail the scope of the research undertaken and its interpretation. Chapter 3 presents the environmental, cultural, and economical contexts of each of the archaeological settlement sites associated with the burial populations. It also considers the evidence for the funerary practices in each temporal period and at each location. It highlights the importance of the reference collections used for comparison of skeletal pathology in very young individuals and the value that the incorporation of these collections and specimens have added to the research.

Chapter 4 provides details of the data collection, metric analysis and recording methods. This is followed by the selection criteria for the burial populations and the approach to estimation of age at death that is employed throughout the thesis. Finally, there is a brief discussion on the identification, description and differential diagnosis of observed palaeopathology. Chapter 5 presents the results for the general burial population associated with each of the archaeological sites. This combines summaries of previous osteological analysis and a re-assessment of skeletal remains, providing information on palaeodemography, stature, skeletal pathology and anomalies for each of the archaeological burial populations studied.

Chapter 6 focuses on the skeletal pathology displayed in the remains of very young individuals that is associated directly with the very young individual rather than a reflection of maternal influence. It provides a detailed overview of skeletal development, the appearance of skeletal pathology in very young individuals and how these can be employed as indicators of physiological stress. The majority of this chapter is given over to the description of observed skeletal pathology and morphology and is divided into sections dealing with developmental disturbance and anomalies, periostosis and trauma. Chapter 7 discusses the influence of the maternal physiological condition prior to and during gestation on fetal development. It presents the observed skeletal pathology that is considered to be strongly associated with maternal influence. The pathology is divided into two sub-sections; developmental disturbances and metabolic impact. The former sub-section includes genetically and environmentally influenced pathological skeletal expression such as morphological anomalies, vertebral border shifting, neural tube defects and Trisomy 21. The latter sub-section includes palaeopathology that is systemic, and covers observed limb anomalies, disrupted ossification, inflammation, and endocranial lesions. Endocranial lesions are described for each of the major cranial vault elements involved and a discussion of their aetiology is included.

Chapter 8 consolidates and contextualises the palaeopathology for each period. The indications for population stress in the living communities associated with each of the burial populations are considered and the observed skeletal indicators of stress and the fetal response to maternal stress are discussed. Evidence for public responses to mortality of very young individuals, including cultural buffering and infanticide, within each of the past populations is also examined along with the complexities of personal and public behaviour. The beginning of Chapter 9 discusses the results and acknowledges the limitations of the research. The form and distribution of palaeopathology, the potential impacts of the maternal condition on the developing fetus, and general population stress are also discussed. The remainder of the chapter includes a discussion of the cultural response to mortality through consideration of the support provided to mothers and their infants. A summary of the evidence and its interpretation is provided for each of the past communities associated with the burial populations. Chapter 9 closes with a note on the importance of incorporating reference collections and of inter-disciplinary collaboration with specialists to establish a robust foundation for inquiry. Finally, Chapter 10 summarises the conclusions of the research and proposes areas of further research.

Chapter Two

Background

2.1 Introduction

The study of palaeopathology provides the structure for accessing and interpreting the life experiences of individuals in past populations. The processes involved are relatively straightforward for the researcher considering adult skeletal remains, in which indicators of physiological stress, such as antemortem trauma, joint degeneration and chronic infection, may be clearly discernible. The evidence of physiological stress is generally more difficult to distinguish in the skeletal remains of very young individuals. This is primarily due to the similarities in appearance between the developing bone surface and osteogenic and osteolytic pathological changes. A compounding factor is the researcher's understanding of the variable appearance of skeletal elements throughout their early development. Familiarity with the appearance and form of fetal, perinatal and infant skeletal remains, and of developmental pathology and its skeletal expression, will significantly reduce the inherent complexity of analysing skeletal remains of these individuals.

The palaeopathology of very young individuals as an area of research is experiencing a renewed focus within bioarchaeology (Goodman and Armelagos, 1989; Lewis, 2007; Mensforth *et al.*, 1978). The rapid growth rate of the developing fetus provides unique potential to capture changes in maternal health during pregnancy and to observe a large range of developmental anomalies that affect the immature skeleton. Despite the intrinsic limitations in the identification of skeletal palaeopathology, the skeletal remains of very young individuals are recognised as the most sensitive record available of stress and health in past populations (Lewis, 2007). Moreover, the sustained well-being of social groups is predicated on the survival and health of these youngest members of society. A bioarchaeological approach to the palaeopathological analysis of very young individuals can provide information about two individuals, the very young individual and its mother. It can also offer an insight into the community response to the mortality of these individuals.

2.2 Previous Research

2.2.1 Maternal Health

Maternal health is understood to have strong implications for the development and health of the fetus (Lewis, 2007). More recently research has investigated the impacts of maternal stress on the health and long-term well-being of the child (Aizer and Currie, 2014; Almond and Currie, 2011; Lin and Liu, 2013). A considerable number of social studies have also been undertaken into the factors of maternal health that influence fetal development and growth (Baibazarova *et al.*, 2013; O'Donnell *et al.*, 2009; Rodney and Mulligan, 2014; Sandman *et al.*, 2012; Smith *et al.*, 1998; Weinstock, 2008). Maternal undernutrition is one form of environmental stress that has been identified as a significant contributor to poor fetal growth; this effect has been demonstrated to persist through subsequent generations (Gowland, 2015; Heijmans *et al.*, 2008; Leichtig *et al.,* 1975; Roseboom *et al.*, 2001; Uauy *et al.*, 2011). Studies of extreme undernutrition experienced during the Second World War and the effects on pregnant women found that neonatal vitality and birth weight were significantly reduced (Antonov, 1947; Smith, 1947; Stein *et al.*, 1975).

Research on maternal health during pregnancy has also considered the effect of maternal stress on gene expression in the offspring and the subsequent implications this may have on long term physical and mental health (Cao-Lei *et al.*, 2014; Charil *et al.*, 2010; Glover *et al.*, 2010; Schlotz and Phillips, 2009; Veru, *et al.*, 2014; Weinstock, 2008). Despite the multitude of contributing factors towards maternal stress, detrimental effects on the development of the fetus require a significantly compromised maternal condition. If the mother has a nutritional deficiency prior to becoming pregnant, the development of the embryo is likely to be affected in the very early stages of gestation and any disturbances to normal development is likely to persist throughout the remainder of the pregnancy. This is most clearly seen in cases of maternal vitamin B_{12} and folate deficiency in which the fetus can suffer from haemorrhage, dysmorphic skeletal development, or disturbed neurological development (De Benoist, 2008). Recent advances in modern screening and public awareness have highlighted areas of fetal risk, such as maternal folate deficiency, with many countries implementing dietary supplementation programmes to address associated maternal and neonatal mortality and birth defects directly (de Jong-van den Berg, 2008; Hertrampf and Cortés, 2008; Olsen and Knudsen, 2008; Ray 2008; Zhu and Ling, 2008).

2.2.2 Skeletal Development

Recent work has drawn attention to the importance of the skeletal remains of very young individuals, and also highlighted the relatively limited understanding of palaeopathology of the developing skeleton. Baker *et al.* (2005) and Scheuer and Black (2000, 2004) have published detailed work on juvenile osteology and skeletal development, and Lewis' publications (2000, 2004, and 2007) emphasised the key research areas of bioarchaeology and palaeopathology of the very young. It is acknowledged that very young individuals are remarkably sensitive to environmental stress (Goodman and Armelagos, 1989). Developmental errors that occur during the embryonic stage and the first eight weeks of gestation can result in morphological changes to precursor structures of the skeletal elements (Barnes, 2012; Cohen and Scheimberg, 2014). These changes are discernible in the skeletal remains of very young individuals from an early stage of fetal growth.

The importance of maternal health, prior to and throughout pregnancy, for optimal fetal outcome is widely recognised. However, the impacts of poor maternal health on the developing fetus are not necessarily reflected in the developing skeletal remains. The majority of clinical studies on neonatal pathology tend to omit the skeletal implications in their consideration of the physical impacts, and focus on the soft tissue involvement. An example of this is the relatively frequent observation of endocranial lesions in the skeletal remains of very young individuals recovered from archaeological contexts. Bussel *et al*. (1997) and Rooks *et al*. (2008) investigated neonatal intracranial haemorrhage in clinical contexts and suggested several aetiologies. They did not consider the skeletal impacts of intracranial haemorrhage, despite all intracranial haemorrhagic presentations having the potential to alter the endocranial surface of the fetal vault elements. Endocranial lesions have since been described (Hershkovitz *et al*., 2002; Lewis, 2004), and even though there is widespread acknowledgement within the bioarchaeological community of these lesions in the remains of very young individuals, our understanding of these lesions and their aetiology could be improved through collaborative research with medical professionals.

The variability in growth within and across populations has drawn considerable attention in an effort to identify possible contributing factors (Eveleth and Tanner, 1990; Sinclair, 1978; Tanner, 1978). It has been demonstrated that several socio-economic factors such as low income levels contribute to delayed postnatal ossification rates and dental eruption times (Garn *et al*., 1965b; Garn *et al*., 1973a; Garn *et al*., 1973b; Garn *et al.*, 1973c; Garn and Burdi, 1971). Clinical studies document the differences in developmental timing and skeletal morphology between the sexes in pre-term individuals (Choi and Trotter, 1970; Pedersen, 1982; Schutkowski, 1993; Sundick, 1977). The timing of appearance of ossification centres and the mineralisation of deciduous dentition also displays considerable variation (AlQahtani *et al*., 2010; Garn *et al*., 1966; Mayhall 1992). Radiographic studies of postnatal development and growth provided a significant contribution to our understanding of skeletal development and the differences between the sexes in childhood (Noback, 1943; O'Rahilly and Gardner, 1972; O'Rahilly and Meyer, 1956).

Similar studies of fetal skeletal development throughout gestation have necessarily been conducted on stillborn or aborted individuals; the majority of medical reference collections are derived from such sources. Microscopic research has also been undertaken into prenatal skeletal development, with the most sensitive methods including histological serial sections (Roche, 1986). Alizarin staining is also frequently performed to highlight areas of ossification for teaching purposes. The use of alizarin is considered to be more sensitive to ossification than radiography, which shows a delay in the earliest evidence of ossification (Bagnall *et al*. 1982; Gregory *et al*., 2004; Noback, 1944; Noback and Robertson, 1951; Putchler *et al*., 1969).

As mentioned above, congenital abnormalities are also known to be strongly connected with maternal health and other contributing factors during pregnancy. Barnes' (1994) review of developmental defects of cranial and vertebral elements and Ortner's (2003) compendium of skeletal palaeopathology from archaeological contexts are two of the primary palaeopathology resources used in identifying major groups of skeletal pathology. These resources also provide substantial archaeological reference material demonstrating the range of skeletal expression in known conditions.

2.2.3 Invisibility and Infanticide

It was previously considered that the under-enumeration of very young individuals represented in the skeletal remains from archaeological sites was attributed to their size, fragility and poor preservation (Bello *et al*., 2002; Bello *et al*., 2003; Goode *et al*., 1993; Johnston and Zimmer, 1989; Kerley, 1976). Experiments in bone taphonomy undertaken by Von Endt and Ortner (1984) have been cited in support of the assumption that bone size affects preservation directly in the burial environment. However, the experimental parameters employed during their research render the findings inapplicable to the preservation of the skeletal remains of very young individuals that have been recovered from archaeological contexts. The highly fragmented pieces of bovine tibia used by Von Endt and Ortner do not resemble the bone structure of skeletal elements of very young human individuals, particularly with respect to the thickness and density of cortical bone. It follows that their conclusion that smaller bones do not survive as well as larger bones has substantial caveats.

Using a different approach, Guy *et al*. (1997) proposed that the chemical properties of developing bones gave rise to their differential survival in the burial environment. Yet it has been demonstrated that these skeletal elements are equally mineralised as those of adults, and the fragility of developing skeletal elements arises from their more vascular nature compared with those of adults (Bello *et al*. 2006; Gordon and Buikstra, 1981). The number of very small, fragile skeletal elements that frequently survive the burial environment intact, highlight the discrepancy between these results concerning bone survival and the remains recovered from archaeological contexts. These skeletal elements have the same capacity for preservation as larger, more mature skeletal elements from contemporary burial environments (Ascádi and Nemeskéri, 1970; Saunders, 1992; Scheuer and Black, 2004). Smaller elements that survive the burial environment are at increased risk from mechanical damage and disturbance if buried shallowly. They are also more likely to be overlooked or misidentified by non-specialists, particularly when the remains are disarticulated. The preconceived and inaccurate assumption that the remains of many very young individuals are missing because of a lack of preservation (Lewis 2007) discounts the likelihood that the very young individuals recovered from archaeological contexts reflect natural mortality within these populations, or perhaps were buried in other locations. It is acknowledged that some burial environments do present adverse taphonomic conditions for the survival of skeletal elements, limiting the recovery of skeletal remains. The treatment of the remains prior to burial may also influence their survival in the burial environment.

The recovery of the skeletal remains of very young individuals from archaeological contexts is hampered by the ongoing issue of misidentification of skeletal remains during excavation or of the skeletal remains of very young individuals not being recognised at all (Gowland *et al*., 2014; Sundick, 1978). Misidentification leads to a significant reduction in the possible retrieval rate of very young individuals (Haglund, 1997; Lewis, 2007; Mays, 2010). The excavation techniques employed can also affect the recovery rate as a number of the elements in a perinatal skeleton are smaller than a 2mm sieve mesh diameter, and are not immediately recognisable as skeletal elements. The juvenile osteology reference text produced by Scheuer and Black (2004) provides detailed descriptions of skeletal element morphology and ossification throughout gestation and is an invaluable identification resource with the capacity to significantly improve the rate of identification and recovery of preterm, neonatal and infant skeletal remains from archaeological contexts.

A perception of high neonatal and infant mortality in the past has led researchers to propose infanticide as a widespread cultural practice in past populations (Harris, 1982; Mays, 1993; Smith and Kahila, 1992; Williamson, 1978). Several authors have challenged this assumption and it has been demonstrated that regression equations for estimating age at death from long bone lengths result in an artificially reduced distribution around full-term gestation (Gowland *et al*., 2014; Gowland and Chamberlain, 2002; Millett and Gowland, 2015). The suggestion that infanticide was practised in past populations may derive from a lack of identifiable significance related to burial sites of very young individuals. As such it may have been assumed that these very young individuals and their funerary treatment demonstrated a lack of importance attributed to the victims of perinatal mortality on the part of their community. The skeletal remains of very young individuals have variously been interpreted as evidence of casual disposal, structured deposits and formal burial (Wainwright, 1979; Cunliffe, 1995; Moore, 2007). The differentiation between these is primarily dependent upon context and funerary treatment of the remains, however an important caveat is the unknown cultural beliefs and practices that resulted in the burial of very young individuals and any associated significance to the individual being buried. To date, there is no bioarchaeological evidence that infanticide was practiced in Roman Britain, or any other period for which we have very young remains (Gowland *et al.,* 2014). It more likely that the clusters of these burials that have been recovered from archaeological contexts were deliberately placed in very specific and relevant locations.

It is highly probable that so many of these very young individuals are recovered from distinct burial locations because they were placed there intentionally as a form of socially sanctioned cultural buffering designed to address the community impacts of neonatal and infant mortality. The cillíni in Ireland are an example of this form of cultural buffering. These burial grounds are used exclusively for the burial of very young individuals and they tend to cluster in defined areas, particularly within enclosed sites (Finlay, 2000). The clustered burials of very young individuals from archaeological contexts provide evidence of a specific cultural response to their mortality in past populations, and may have functioned in a similar way to cillíni.

Given the limited medical intervention available in past populations, it should not be surprising to find that the majority of very young individuals that have been recovered from archaeological contexts died around the end of gestation. Clearly, this does not preclude the practice of infanticide, which has ethnographic support as a means of controlling neonatal survival, however it does not follow that infanticide is the primary explanation for locations in which the number of very young individuals is perceived to be higher than expected. Any interpretations suggesting the involvement of infanticide should be well-founded within the contextual evidence, which informs our understanding of neonatal and infant mortality and cultural response in past populations.

2.3 Gaps in Current Knowledge

The skeletal remains of very young individuals have not always drawn considerable focus within palaeopathological research (Chamberlain, 2000; Cox and Mays, 2000; Goodman and Armelagos, 1989; Humphrey, 2000; Lewis, 2000, 2007; Pennington, 1996). The analysis of neonatal skeletal remains from archaeological contexts has often been afforded only cursory attention, with some archaeological reports including a summary sentence or two at the end of an in-depth analysis of older individuals. In other published excavation reports a limited analysis of very young remains has been included, but such analyses are often brief with little if any detailed information included on the palaeopathology of these individuals. This was predominantly the consequence of an assumption that nothing can be surmised from the analysis of the skeletal remains of very young individuals, of limited specialist training in the skeletal pathology of very young individuals, and of a definitive means for describing palaeopathology in developing skeletal elements.

Neonatal pathologists and clinicians are largely unaware of the skeletal impacts for many of the conditions they treat (Anand and Nair, 2014; Bussel et al., 1997), and the scope for investigating these is legally restrictive and socially constrained (Scheuer and Black, 2004). Modern clinical sampling and research into the pathology of very young individuals is often focussed on soft tissue pathology. Skeletal impact is largely overlooked in conditions where it is not a primary concern for the health of the patient. In cases where the skeleton is impacted significantly, such as in non-viable abnormalities, considerable research has been undertaken on very young individuals and developmental pathology (see for example, Wyatt-Ashmead et al., 2014). Far less research has concentrated on the skeletal manifestations of more common soft tissue conditions. This situation has resulted in a void in which our limited knowledge of fetal skeletal pathology, its forms and aetiologies, hinders advancement.

A little understood and neglected area of osteology is the early morphological variation of developing skeletal elements (Scheuer and Black, 2004). Without this knowledge it is particularly difficult to attempt an accurate estimation of age at death for fetal skeletal remains. The ossification centres of skeletal elements undergo considerable shifts in morphology throughout the early stages of development. The available reference texts facilitate the positive identification of many of these elements in children, but not in very young individuals. This is a considerable restriction in the analysis of fetal and neonatal remains. The identification of ossification centres and epiphyses and their use in age estimation is substantially restricted by this gap in knowledge, resulting in the underutilisation of this readily available skeletal resource.

2.4 Scope of Research

2.4.1 Aims and Objectives

The primary aim of the current research is to consider the aetiology of skeletal pathologies and anomalies evident in the skeletal remains of very young individuals and to consider the possible connections with the maternal condition prior to and during gestation. Following on from this, a secondary aim is to determine if the potential information regarding the physiological condition of the very young individuals and their mothers can provide insight into the health status of the living population. The key objective of the current research is to be intentionally critical of published interpretations regarding community responses to very young mortalities in past populations. Using a bioarchaeological approach to the research, incorporating an examination of the funerary practices associated with the skeletal remains of very young individuals, increases the potential for new interpretations of the socio-cultural responses to their deaths within the past populations studied.

The incorporation of burial populations from different locations and temporal periods enables a comparison of skeletal pathology to assess common characteristics and identify population specific expressions. The detailed bioarchaeological analysis and interpretation of the skeletal pathology of very young individuals recovered from archaeological contexts forms the basis for addressing the research aims and objectives. The results of this research will contribute new information regarding maternal health and the youngest individuals in rural and urban populations from one of the earliest urban populations, Neolithic Çatalhöyük, through to the medieval era.

The use of documented medical reference collections and modern clinical research provides a foundation for the anatomical comparison of pathology in the developing skeleton. The current research enables the differentiation between pathological and non-pathological skeletal appearance in fetal, neonatal and infant skeletal remains by the intentional selection of diverse past populations. The form and degree of osseous remodelling and lesion development will be considered as an indicator for the capacity of both the developing fetus and the mother to recover from episodes of significant maternal physiological stress. This approach underpins the estimation of timing and the severity of intrauterine stress and developmental pathology.

2.4.2 Palaeopathology of the Developing Skeleton

Published descriptions of non-specific lesions are varied and often contradictory, with limited cross-disciplinary collaboration. Too often a lack of scientific rigour and detailed description perpetuates the use of pathological examples without critical review, further reducing their usefulness as a diagnostic resource. Accurate descriptions of normal skeletal development and growth provide a basis for the identification of palaeopathology in fetal, neonatal and infant skeletal remains. A large and varied sample will enable the identification of common skeletal characteristics and variation, and in turn distinguish pathological expression in the skeletal remains of very young individuals.

The limitations of differential diagnosis on the basis of archaeological examples of palaeopathology lie primarily in the absence of confirmed aetiology. An integral part of the current research design is the collaboration with a perinatal pathologist to alleviate this significant limitation of working with archaeological collections, although such remains are not abundant. The incorporation of comparative anatomy and pathology specimens will facilitate the differentiation between pathological and non-pathological skeletal expression in very young individuals from archaeological contexts.

2.4.3 Archaeological Samples

The current research analyses burial populations derived from archaeological contexts, however modern reference collections are incorporated into this analysis to ensure consistency of identification and provide aetiological comparisons. The significant ethical issues and cultural restrictions involved in the study of modern fetal, neonatal and infant skeletal pathology are largely avoided by using archaeological remains. Archaeological skeletal material offers a sizeable resource, although it does not usually have associated information regarding the medical history of the individuals represented. In contrast, this information exists for modern medical cases but access is limited by the sensitivity of the subject, availability of skeletal remains and resulting limited discourse with external disciplines.

The expression of skeletal pathology found in archaeological samples enables a more in-depth understanding of the pathological process involved in its development, and of an individual’s ability to adapt to sustained physiological stress. As chronic diseases that impact the skeleton would have developed without the intervention of modern medicine, their pathological expression is significantly greater in archaeological remains compared to more modern cases (Ortner, 2003). This is also true for fetal skeletal pathologies influenced by maternal physiological stress.

The skeletal remains of very young individuals analysed in the course of this research include some of the largest recovered collections of juvenile remains from archaeological contexts. This archaeological material of relatively distinct burial populations is derived from living populations with considerably different temporal, environmental, and socio-cultural contexts. The use of these collections in the current research provides a significant body of comparative data for understanding the palaeopathology of very young individuals and past population health and well-being.

2.4.4 Stress

Stress is an overarching term for the many forms of physical and emotional assault on the human condition that have the potential to impact an individual's physiological state. Its effects on the body can be experienced as acute episodes, a sustained chronic condition, or a combination of the two. Research on the relationship between stress and physical health was pioneered by Selye, who observed an initial physiological response followed by a period of adaptation. He noted that when a state of chronic stress is maintained the individual may experience periods of physiological fatigue during which the initial response to the causative agent is expressed (Selye, 1936; 1957; and 1976). This pattern of seemingly recurrent ill health can be identified in skeletal remains where lesions associated with a particular aetiology display varying states of activity and healing. Following Selye's research, interest in the identification and regulation of stress developed across multiple disciplines and the identification of stress indicators in skeletal remains became a key area of investigation in palaeopathology.

Significant advances have been made in our understanding of stress and adult palaeopathology (Klaus, 2014; Temple and Goodman, 2014), yet the impacts of stress upon the developing fetus have generally not been considered in the analysis of fetal and neonatal skeletal remains retrieved from archaeological contexts. The results of clinical studies on the implications of socio-economic and traumatic maternal stress for positive pregnancy outcomes (Rodney and Mulligan, 2014) have not been taken full advantage of in the analysis and interpretation of skeletal remains from past populations. It is an apparent misconception that the palaeopathology of very young individuals in the archaeological record is unlikely to be a particularly useful or significant source of knowledge. This may derive from the absence of a consistent and accepted method for identifying skeletal pathology in very young individuals.

2.4.5 Fetal Response

Research has demonstrated that socio-economic influences such as nutrition, disease and social status have the capacity to impact the developing fetus (Antonov, 1947; Barker *et al*., 1993; Frisancho *et al*., 1970; Garn *et al*., 1973a; Garn *et al*., 1973c; Haeffner *et al*., 2002; Komlos and Kriwy, 2002; Lechtig *et al*., 1975; Smith, 1947). These impacts range from minor disturbances in growth and development to pathological conditions that are incompatible with life, for example severe neural tube defects. Evidence of the fetal response to maternal physiological stress is detectable in pathological changes to the developing skeleton. The degree and form of the pathological response is largely dependent upon the type, severity and duration of the stress experienced by the mother, among other variables.

Specific diseases such as congenital syphilis and spina bifida are reflected in the disturbed development of the dentition and skeletal remains of affected individuals from past populations. These pathologies are generally identified in children and older individuals, but as the conditions develop *in utero* they can also be detected in the remains of very young individuals. Non-specific pathological responses of the fetal skeleton include dysmorphy, asymmetry and lesions, all of which develop in direct relation to soft tissue pathology. Some of these pathologies retain their initial form as the fetus continues to develop, however the majority of skeletal lesions will change in appearance depending upon their aetiology and duration. The intrauterine remodelling of lesions is closely associated with the maternal physiological condition, and occasionally independent factors affecting only the developing fetus such as placental insufficiency. As the continued intrauterine development of a lesion suggests a prolonged period during which the maternal condition was compromised, the appearance of skeletal lesions in perinatal individuals has the potential to inform on the maternal condition prior to and during gestation.

2.5 Interpreting the Evidence

2.5.1 The Osteological Paradox

The relationship between the expression and severity of skeletal pathology, usually in the form of lesions, and the relative health of an individual with respect to their physiological resistance to the condition is referred to as the osteological paradox (Wood *et al*., 1992; Knüsel and Ogden, 2008). The concept has been employed to highlight the perceived divide between the severity of skeletal impact and the relative frailty of the individual displaying the pathology (Wood *et al*., 1992). However, the relationship between skeletal pathology and individual frailty is not a case of direct inference, and the interpretation of skeletal lesions should also consider the broader bioarchaeological context of the remains (Goodman, 1993). The main premise of the osteological paradox is that the presence of skeletal lesions indicates that the individual survived with the condition long enough for the skeleton to be affected. This implies that individuals with pathological lesions of the skeleton were physiologically less frail than those individuals who were exposed to the same causative agents but died prior to the skeleton being affected (Wood *et al*., 1992). There are considerable limitations in the osteological paradox; particularly that it does not consider the likely possibility of multiple factors affecting an individual's response to physiological stress, and the significance of age at death. Another limitation is that an individual's resistance is rarely in relation to a single condition, with multiple factors influencing pathological expression and the individual's survival. It is therefore important to consider the bioarchaeological context of the skeletal remains in order to reach a more plausible interpretation (Cohen *et al*., 1994; Goodman, 1993; Siek, 2013).

2.5.2 Differential Diagnosis

Differential diagnosis is a process that narrows the possible aetiologies to which an individual's skeletal pathology can be attributed. This process relies upon descriptions of skeletal pathology associated with congenital and acquired conditions and diseases. The analysis and interpretation of skeletal pathology incorporates the process of differential diagnosis along with the consideration of other contributing factors such as access to treatment and cultural responses to disease in the past. Detailed descriptions of the type and extent of lesion, the anatomical location on the affected element and where multiple elements are involved, the distribution over the skeleton are compiled. The individual's age and biological sex also inform the possible aetiologies that can result in the observed skeletal pathology. Using a bioarchaeological approach, differential diagnosis also incorporates the context of the burial environment and information concerning the contemporary living population to arrive at the best fit for the individual's pathology and the wider context of their living environment.

Modern medicine and recent advances in the field of palaeopathology have provided detailed criteria for the differential diagnosis of several diseases (Aufderheide and Rodriguez-Martin, 1998; Ortner, 2003). These are predominantly described for adult individuals, although recent work has also contributed towards identifying the expression of diseases in very young individuals (Lewis, 2004). Caution must be applied when using modern comparative cases to identify conditions reflected in skeletal remains of very young individuals from past populations. This is largely because clinical studies do not often provide sufficient detail regarding the skeletal impacts of pathological conditions in very young individuals. As mentioned above, medical intervention has also significantly affected the skeletal expression of pathological conditions presenting an added complexity to the identification of possible aetiologies (Ortner, 2003). The expression of skeletal lesions in fetal and neonatal individuals is a reflection of the maternal condition prior to and during pregnancy. These skeletal impacts register within the much shorter and well-documented timeframe of gestation. It is therefore theoretically possible to estimate the timing of the causative condition by considering the developmental stage of the affected skeleton.

2.6 Summary

Fetal, neonatal and infant skeletal palaeopathology is experiencing a renewed surge of inquiry with enormous potential. The skeletal remains of very young individuals have relatively recently been recognised as a unique source of information for past population health. As the developing skeleton is extremely sensitive to changes in maternal health and environmental stress, the skeletal remains of very young individuals can provide a wealth of information on the health of these individuals and also of their mothers and the wider community (Chamberlain, 2000; Lewis, 2007; Tibbetts, 2012).

The current research will complement advances already made in the field of juvenile palaeopathology (Brickley and Ives 2006; Lewis 2004; Ortner, 2003) and will propose new interpretations regarding the identification of lesions, very young mortality, maternal health, and infanticide in past populations. The scope of this research integrates an analysis of the forms of fetal, neonatal and infant skeletal pathology in the sample populations, evidence for compromised maternal health and population stress, and the cultural responses to fetal, neonatal, infant and maternal mortality in past populations. Although this is a wide net to cast in terms of information and interpretation, it is a fundamental step towards creating a valuable foundation for future studies into the palaeopathology of very young individuals and maternal health in past populations.

Chapter Three

Context

3.1 Introduction

The current research is firmly situated within the available contextual evidence to maximise the relevance and plausibility of any conclusions and interpretations derived from the analysis of individual human remains. This evidence includes not only the information derived through archaeological excavation but also surviving records from the historical periods. These accounts provide insight into the cultural and social aspects of living and dying within the communities below.

This chapter provides site-specific contextual information within the relevant temporal span and contains details of the living environment, culture, local economy and funerary practices that have been revealed through archaeological investigations at the various locations. Descriptions of the reference collections used, the origin of their material and their research value are also included. The following are the archaeological and reference collections used in the current research.

Archaeological

- Neolithic: Çatalhöyük (Turkey)
- Iron Age: Wetwang Slack (Yorkshire, UK) and Gussage All Saints (Dorset, UK),
- Roman: Yewden Villa (Buckinghamshire, UK) and Barton Court Farm (Oxfordshire, UK)
- Medieval: Wharram Percy (Yorkshire, UK) and Ardreigh (Co. Kildare, Ireland)

Reference

- Wellcome Museum of Anatomy and Pathology, Royal College of Surgeons (London)
- Scheuer Collection, Centre for Anatomy and Human Identification (University of Dundee)
- Clinical, (various hospitals in southwest England)

3.2 Neolithic

The Neolithic period of central Anatolia spanned an early Pre-Pottery phase from 9600 BC through to the Early Chalcolithic (6000 BC). One of the earliest and largest known Neolithic urban settlement sites in central Anatolia is located on the Konya plain at Çatalhöyük (Figure 3.1). The site was occupied throughout the Neolithic with settlement activity centred on the east mound; this part of the site was continuously occupied between 7100 BC and 6000 BC (Bayliss *et al*., 2015; Marciniak *et al.,* 2015). Within this period, the community of Çatalhöyük experienced a marked increase in population density with intensification of building and other activities from 6700 BC to 6400 BC during the Pottery phase (Larsen *et al*., 2013). The individuals analysed for the current research are predominantly from the later phase of occupation that followed the peak in population density.

Figure 3.1. Map of Turkey showing the location of Çatalhöyük.

3.2.1 Environment

During the Neolithic period the landscape of the Konya plain was a mixture of alluvial land and freshwater marshes (Kuzucuoğlu, 2002). Within the wetland environment of the Neolithic plain the outcrops of lime-rich marlstone were ideal locations for settlement and many were occupied throughout the period (Hodder 2013, 15). The plant remains recovered during excavation provide evidence of a range of wet and dry land environments as well as wetlands around the settlement at Çatalhöyük (Ryan, 2013). This local diversity in environment would have provided a sustainable landscape for an early form of mixed agriculture that minimised the risk attached to the later practice of intensive agriculture of domesticated species (Ryan, 2013).

3.2.2 Culture

The exceptional sequence and preservation at Çatalhöyük, along with artefacts and skeletal remains, provides a wealth of information for analysis. The Neolithic settlement is particularly well-known for its adjoining dwellings which were accessed through the roof, the decorated, plastered interiors and the occupants' practice of intramural burial (Hodder, 2016). The settlement buildings at Çatalhöyük were roughly rectangular and closely constructed, usually without any separating space (Cutting, 2005) (Figure 3.2). Although closely constructed, the buildings did not share external walls and any communication between buildings was across the tops of the adjoining buildings (Sagona, 2009). The buildings were constructed of mud brick with wooden beams providing support for the roof and walls. Interestingly, the sequence of buildings in the later phases of occupation respects the boundaries of preceding structures, with each subsequent building being built upon the footprint of the former. These repeatedly rebuilt buildings are referred to as 'history houses' if they have more than ten burials in at least one of the building phases (Hodder, 2016). When the life of a building was complete its walls were reduced to approximately one metre and the contained space filled with compacted rubble. This formed the foundation base for the construction of the next building (Haddow *et al.*, 2016a).

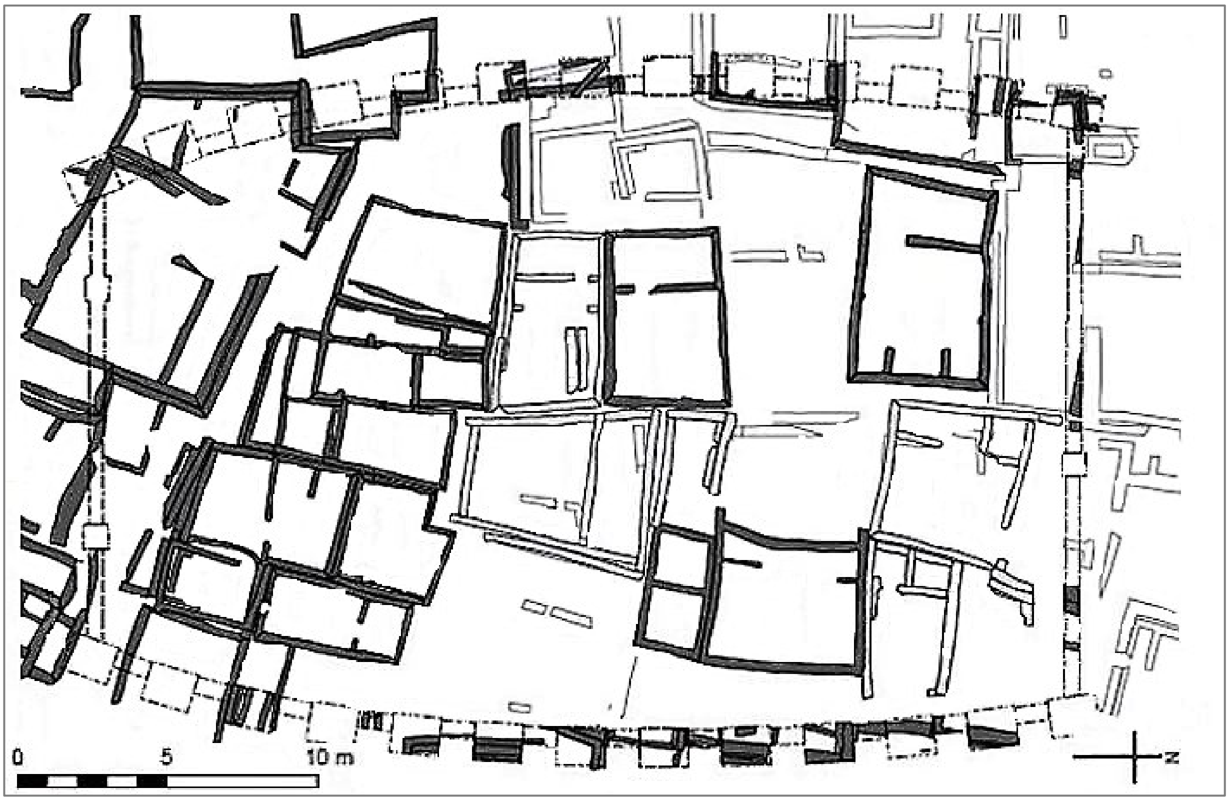


Figure 3.2. Excavation plan of the North area demonstrating the close structure of the Çatalhöyük settlement (Çatalhöyük Research Project).

The interiors of the buildings contained platforms, storage side rooms, wall niches, plastered reliefs and 'shrines' (Mellaart, 1967). Analysis of the interior surfaces reveals that they were frequently plastered and decorated, with successive plastering events occurring regularly throughout use of the building and the floors were regularly swept clean (Haddow *et al*., 2016a; Ryan, 2013; Sagona, 2009). Decorations consisting of geometric and linear patterns, handprints and figurative representations were painted over the plastered surfaces inside the buildings (Figure 3.3). These decorations were often repeated following subsequent layers of plaster (Mellaart, 1967). Numerous clay figurines in animal and human form have been recovered from the site, the most renowned being a fleshy female referred to as a symbolic representation of fertility (Meskell, 2016).

Figure 3.3. Internal wall decorations of animal figures (left, Çatalhöyük Research Project) recreated in the experimental house and geometric patterns on the walls of building 80 (B. Tibbetts).

The living environment within the houses was reasonably confined. With the roof entry also serving as an escape for smoke from the oven. Experiments have demonstrated that the interior of the house was not smoke filled. There is evidence in some buildings of smaller openings higher up on the walls which would allow natural light to enter the internal spaces and allow airflow. A computational study by Cox (2014) of the shifting light entering the house through the ladder-hole demonstrated that for a large portion of the day the interior of the house was well-lit. Given the interior lighting, detailed tasks would not have been difficult to undertake. It is evident that the inhabitants of Çatalhöyük also performed tasks on the roofs of the buildings and in other open areas around the settlement.

The architecture of the settlement in which the buildings did not have openings at ground level suggests an intentional design to possibly provide the occupants with protection from external threats. The compact architectural style of the settlement also enabled the occupants to optimise available building space upon the mound (Figure 3.4). The Neolithic settlements south of the Taurus Mountains have a distinctly more open plan with free space around buildings and entry at ground level (Sagona, 2009). The suggestion that the end of the Pre-Pottery Neolithic coincided with an increase in social conflict (Sagona, 2009) may explain these regional differences in settlement style of the communities living either side of the Taurus Mountains.

Figure 3.4. Representation of the Neolithic settlement at Çatalhöyük (D. Lewandowski).

3.2.3 Economy

Subsistence agriculture and trade provided the basis for the Neolithic economy at Çatalhöyük. Palaeobotanical analysis has revealed that the diet consisted of domesticated plants such as emmer wheat, barley, peas and lentils (Asouti and Fairbairn, 2002; Bogaard *et al.,* 2013; Fairbairn *et al*., 2005). Sheep, goat and cattle were domesticated and provided a substantial proportion of the meat in the diet (Mulville *et al*., 2016), while the meat and plant components of the diet were supplemented through hunting red deer, fox and water fowl, and foraging for hackberries, nuts, borage and pulses (Mulville *et al*., 2016; Bogaard *et al*., 2013). Cattle milk also contributed to the diet and was processed into yoghurt, sour milk and cheese (Der and Fernandini 2016; Schoop, 1998). Apart from dietary requirements, wild plant species were used for a variety of purposes including temper in brick, fuel, basketry, matting and other textiles, symbolic ornamentation, and craft activities (Rosen, 2005; Ryan, 2013).

Besides the local agricultural produce, the community at Çatalhöyük had access to a supply of goods from sources that are a considerable distance from the Konya plain through trade connections. Shells were sourced from both the Red Sea and the Mediterranean (Bar-Yosef Mayer *et al*., 2015) while other items such as timber and obsidian derived from more local locations (Sagona, 2009).

3.2.4 Funerary practices

The funerary practice at Çatalhöyük was intramural burial with the dead being interred under the living space floors within the buildings (Figure 3.5) (Boz and Hager, 2013). As with the many successive events of internal plastering and decoration, the intramural burials were deposited throughout the use of a building space, which in some cases was as long as 100 years (Hodder and Cessford, 2004; Matthews, 2005; Twiss *et al*., 2008). The selection process for where an individual was buried appears to have been based upon factors other than biological relatedness as research has shown that individuals buried within the same house were usually not biologically connected (Hillson *et al*., 2013; Pilloud and Larsen, 2011).

Figure 3.5. Subfloor burials under the southeast platform in building 80 (B. Tibbetts). Note the tight flexion of the burial on the right.

The majority of individuals buried during the Neolithic occupation at Çatalhöyük were in tightly flexed positions. Skeletal elements often retain surface staining where binding or strapping was once positioned (Haddow *et al*., 2016b) and occasionally remnants of binding or strapping survive the burial environment *in situ*. This practice of tightly binding and otherwise containing the body, although clearly the result of complex behaviours, also appears to be directly associated with convenience of size for burial, and perhaps prior storage. Very young individuals were not consistently buried in the tightly flexed positions observed in the burials of older individuals. This is likely to be a reflection of their small size requiring less physical manipulation prior to burial. Some burial deposits include multiple young individuals of similar developmental ages and may indicate contemporary deaths. While the majority of individuals were primary single deposits, others were added to existing burial deposits of older individuals. Analysis has yet to be undertaken to determine any genetic relationship between these individuals.

The more open body position of skeletal remains and the composition of organic material included in their burials may be a reflection of burial shortly after death and the seasonal occurrence of higher birth rates. In comparison, the tightly flexed body position observed in the majority of older individuals is more easily achieved following soft tissue reduction through decomposition, suggesting that these remains were being retained for a limited period prior to burial. The evidence for burial shortly after death for very young individuals indicates that there may have been a cultural perception towards the timing of burial that placed importance on a brief interval between death and burial for very young individuals, but not for older individuals.

Individuals were buried with a variety of items of personal adornment such as shells and bead necklaces. Other items recovered from burial deposits include wooden bowls, chert scrapers and obsidian biface projectile points, worked bone and organic materials (Haddow *et al*., 2016b). The number and type of items included with burials varies widely, highlighting the complexity of the cultural practices involved with burial.

It appears that all members of the community at Çatalhöyük were included in the normal subfloor burial practice regardless of age at death. The number and inclusive nature of the burials at Çatalhöyük suggest that the majority of deaths were managed by the resident community and deposited within the settlement. The complexity of the funerary behaviours is evident in the considerable variation of the burial characteristics such as body position, grave goods and inclusions, but these do not appear to be dependent upon the age or sex of the deceased.

The practice of re-opening adult burials and removing selected elements, such as crania, is relatively common at Çatalhöyük and was widely practiced in this region during the Neolithic (Andrews *et al*., 2005; Boz and Hager, 2013; Haddow *et al.,* 2016b; Mellaart, 1967; Molleson *et al*., 2005). This practice may have been associated with rituals involving ancestors and social remembrance, and clearly indicates a continued cultural and/or social identity of the item that was removed and curated within the community.

3.3 Iron Age

The Iron Age in Britain covers a period of prehistory from approximately 800 BC to the 1st century AD. The sizeable amount of material recovered from Iron Age sites in Britain has provided the basis for research into social and cultural aspects of life during this period, including the changes attributed to increased contact with Roman culture. The Iron Age sites (Figure 3.6) included in the current research both date to the second half of the period. The settlement at Gussage All Saints starts at approximately the same time but continues through to the 1st century AD (Wainwright, 1979). Wetwang Slack has a long history of land use from the Neolithic period, but the Iron Age settlement and contemporary cemetery activity dates from the 4th to the earlier 2nd centuries BC and lasted for less than 150 years (Jay *et al*., 2012).

3.3.1 Environment

The settlement of Gussage All Saints is situated within a landscape of chalk geography, located on a ridge above a valley with a permanent water source. There are several small contemporary settlements in the area and a substantial amount of surviving evidence for long-term land-use associated with crop cultivation and animal management is visible in the surrounding landscape in the form of earthworks and field systems (Davis, 2011). The Wetwang Slack site lies within a dry valley in the Yorkshire Wolds. The local environment is rural although the land is unlikely to have been fertile enough to support intensive cultivation of domesticated cereal crops in the Iron Age (Dent, 1984). The chalk geography of the region gave rise to the eroded gravel of the valleys, and has facilitated an impressive level of preservation.

Figure 3.6. Partial map of the United Kingdom showing the locations of Gussage All Saints and Wetwang Slack.

3.3.2 Culture

Gussage All Saints settlement takes the form of an enclosure settlement consisting of multiple structures within a larger, ditched enclosure (Figure 3.7). The internal structures were often roundhouses constructed from wattle and daub with thatched roofs. The remains of several structures have been recovered from within the Gussage All Saints enclosure ditches, including a large trapezoid structure that may have functioned as a stock-enclosure and a large ring-ditch building, both of which had substantial timber gateways (Wainwright, 1979). The large ring-ditch structure was approximately thirty metres in diameter and appears to have been reinforced towards the end of the settlement occupation (Wainwright, 1979). This structure is likely to have been used as a communal space of some importance.

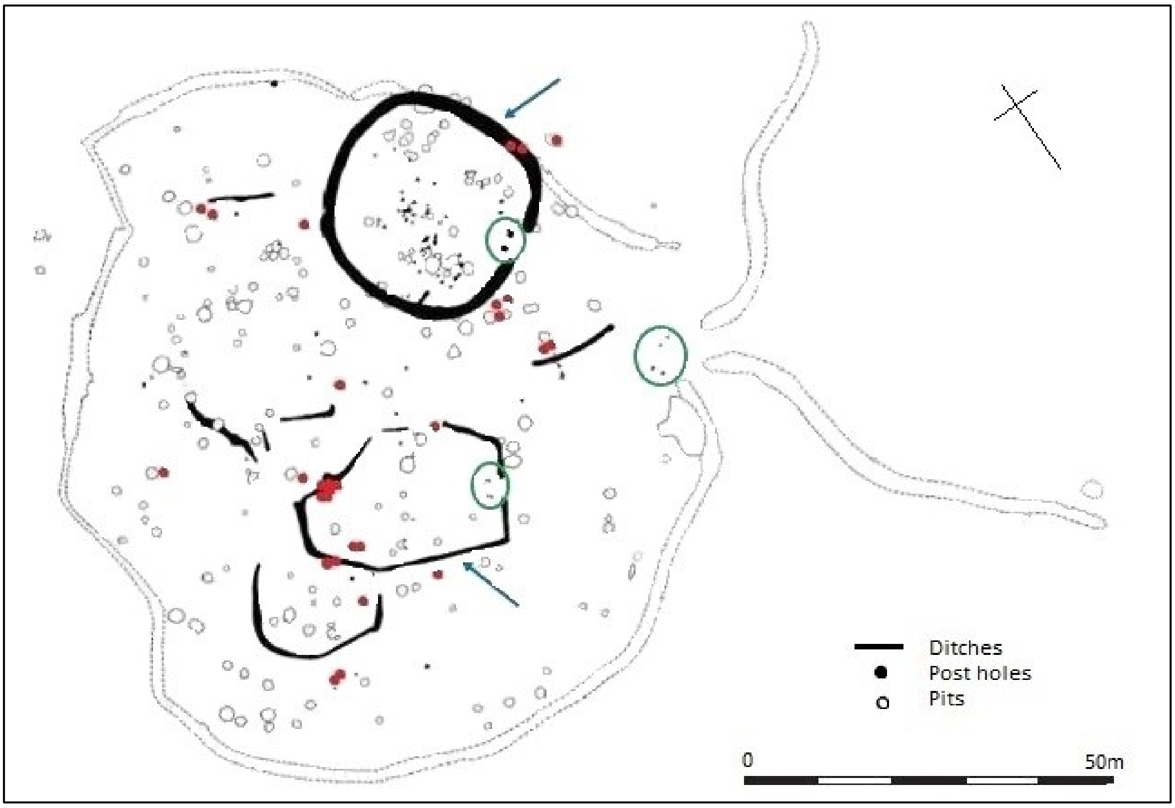


Figure 3.7. Excavation plan of the Gussage All Saints settlement. Burials of very young individuals are marked in red, trapezoid structure (bottom blue arrow), ring-ditch building (top arrow), timber gateways (green circles) (adapted from Wainwright, 1979).

The settlement plan towards the end of the Iron Age occupation reveals a change in layout within the enclosure from one contained space to a separation of internal spaces using ditches and smaller enclosures. This arrangement is significantly different to the more open settlement plan of the early Iron Age (Wainwright, 1979). The changes in internal layout of the settlement and the reinforcement of structures is possibly a reflection of social changes experienced by the community during the later Iron Age occupation. A disruption to social stability in the area is further supported by the skeletal evidence of inter-personal violence among the adult remains and a smaller contemporary associated settlement on the other side of the valley that appears to have splintered off the main site (Wainwright, 1979).

Domestic life in the Iron Age settlement of Gussage All Saints revolved around agricultural activities. The items recovered during excavation provide insight into the range of everyday activities undertaken within the community, and include combs, knives, brooches, quern stones, awls, loom weights, and spindle-whorls (Wainwright, 1979). These objects indicate that the population of Gussage All Saints was involved in the production of textiles, processing plant products into flour and had a range of smaller tools, items of personal adornment and grooming.

Wetwang Slack consisted of over seventy roundhouses stretching along the valley floor trackway for a distance of over one kilometre (Figure 3.8). The settlement is continuous with that at Garton Slack and was most likely considered as a single location during its Iron Age occupation (Dent, 1984). The roundhouses were constructed with walls of daub with thatched roofs, a common form of building construction throughout the Iron Age in Britain. Structural evidence in the form of postholes suggests an internal division of space using partitions, although the postholes could equally be interpreted as furnishings or equipment such as a loom (Dent, 1984).

The Iron Age community of Wetwang Slack is identified as having key characteristics of the Arras culture, identified by items of material culture, its distinct funerary practices of square enclosure burials and 'chariot' burials and named after the location of the first recovered 'chariot' burial (Dent, 1984; Halkon, 2013). The similarities of the Arras culture to other continental groups such as the Parisi, appear to be the result of a transmission of information rather than direct migration (Halkon, 2013). Jay and Richards (2006) performed isotopic analysis of the human remains from the cemetery and found no supporting evidence for an immigrant group from the continent.

Dent (1984) estimated a living population for the Wetwang Slack settlement of 35-50 individuals over its occupation, based on the settlement and the extent and period of use of the cemetery. Although relatively small, the population had access to luxury items beyond everyday requirements suggesting the established success of the community. A wide selection of personal attire items were recovered from the burials including brooches, dress pins, woollen textile, jewellery, bracelets, rings of glass, jet, amber, chalk, bronze and iron, and necklaces of glass, jet and shale beads (Dent, 1984).

Analysis of the burial population also revealed evidence of inter-personal violence between adults that included sharp and blunt force peri-mortem trauma (Dent, 1984). The archaeological material presented above provides an image of an established and economically successful community at Wetwang Slack that also experienced periods of social unrest leading to interpersonal of violence.

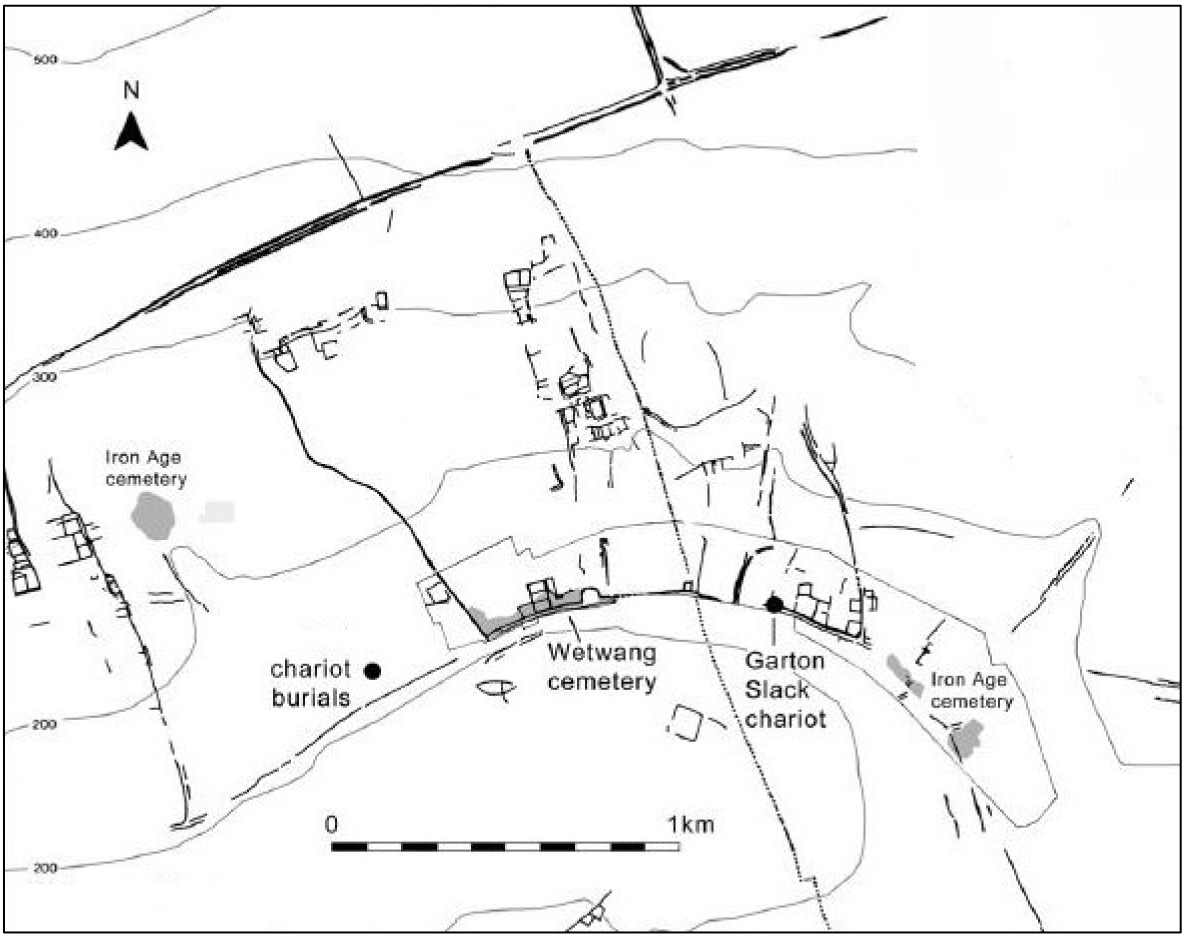


Figure 3.8. Map of the area around Wetwang Slack and Garton Slack. Cemeteries are shaded and chariot burials are marked (adapted from Jay et al., 2012).

3.3.3 Economy

Both Gussage All Saints and Wetwang Slack were primarily agricultural settlements. At Gussage All Saints there was an intensification in the cultivation and processing of cereal crops (Wainwright, 1979) that coincided with a change in the main crop from barley to wheat (Evans and Jones, 1979). Domesticated stock animals at Gussage All Saints were dominated by sheep, but also included cattle, pigs and goats (Harcourt, 1979). Along with the increased intensity in crop-related activities, there is also evidence for more intensive textile production demonstrated by the significant increase in the number of spindle-whorls and sheep towards the end of the Iron Age occupation (Wainwright, 1979).

There is substantial support for other forms of industry at Gussage All Saints, including complex casting and metalworking (Spratling, 1979). The high quality of the metalwork, its artwork and style is comparable to other contemporary finds within Britain (Foster, 1980) and the majority is related to horse equipment used in conjunction with carts, representing approximately fifty sets (Spratling, 1979). This is an unusually high estimate for use within the community and suggests the equipment was intended for trade or may have been commissioned. Apart from metalwork, pottery was also locally produced (Wainwright, 1979). This changed towards the end of the Iron Age occupation when pottery was predominantly imported from the southern coast region of Wareham-Poole, Dorset (Cunliffe, 2005). This evidence of long-distance trade networks is not uncommon and was an established mode of exchange throughout the occupation of Gussage All Saints (Moore, 2007).

The lifestyle of the population at Wetwang Slack did not differ significantly from those at other agricultural settlements of the period. Items including loom weights, weaving combs and a shuttle were recovered from pits within settlement structures (Dent, 1984) suggesting that textile production took place within the domestic sphere. Archaeological investigation has demonstrated that the cultivation, processing and storage of grain crops was consistent throughout the Iron Age occupation of Wetwang Slack and that barley and oats were cultivated in small fields in and around the settlement (Dent, 1982).

As well as the cultivation of food crops, the community of Wetwang Slack managed animal stocks of sheep and pigs (Dent, 1984; Jay *et al*., 2012). Analysis has provided information on the diet of individuals from the burial population, revealing that they consumed predominantly locally produced animal and plant foods (Jay *et al*., 2013). The living population also had access to marine foods, but these did not form a significant contribution to the diet (Jay and Richards, 2006). Although the burials and grave goods indicate differences in social status for some individuals, Jay and Richards (2006) found that the dietary evidence showed no such differentiation within the burial population. Peck's (2013) analysis of two contemporary sites to Wetwang Slack revealed that there was no apparent difference in diet among populations with evidence of social status groupings. The community at Wetwang Slack appears to have had equal access to resources regardless of social standing. During the late Iron Age there was a clear shift in the external pressures affecting the settlement that resulted in the relocation of the open settlement from the valley floor to a new enclosed settlement on a hilltop to the north of the valley during the late Iron Age (Dent, 1984).

3.3.4 Funerary practices

The funerary practices of Iron Age communities in Britain take a variety of forms that have an element of regional variation (Whimster, 1981). Much of this variation may be due to the landscape and resources available, but ultimately would have been determined by the dominant cultural practice in each region. With regard to inhumation burials of articulated human skeletal remains, these are commonly found in association with Iron Age settlement sites particularly in areas where the geology is conducive to the preservation of bone, as in southern England (Bristow, 1998; Collis, 1984; Cunliffe, 2005; Groube and Bowden, 1982; Whimster, 1981).

Among the inhumation burials there is variation in preference for body orientation or position however, the practicalities of placing an adult into a deep, sub-circular pit usually result in some degree of flexion of the body. The inhumation burials of older individuals are either located within the settlement area or in a burial ground associated with the settlement. Where there is no separate burial ground for them, very young individuals are often buried within settlement contexts. In particular, they have been recovered from pits and ditches associated with internal settlement structures, such as roundhouses (Cunliffe, 1995; Whimster, 1981). At Wetwang Slack, these burials were located in close association with existing enclosure burials in the cemetery (Dent, 1984). In contrast to Wetwang Slack, the burials at Gussage All Saints were deposited within the settlement enclosure in ditches and purpose-dug or disused pits. One limitation to understanding the distribution of burials from Iron Age settlement sites is that excavation has not extended far beyond the limits of the settlement, and so it may be that associated burial grounds do exist but have yet to be discovered. This is the case at Gussage All Saints where only settlement enclosure was excavated.

The relatively large burial populations of Gussage All Saints and Wetwang Slack provide a unique opportunity to investigate population health and demographics in the context of small agricultural communities. Several of the burials of very young individuals at Gussage All Saints were multiple burials. These have previously been interpreted as evidence of epidemic events (Wainwright, 1979), but could potentially indicate harsher periods in the lives of the community.

As well as articulated inhumation burials, it is usual to find an amount of disarticulated adult skeletal material within settlement sites. The disarticulated adult remains from Gussage All Saints may be interpreted as secondary deposits following a period of excarnation through exposure (Carr and Knüsel, 1997). Some of the disarticulated elements have evidence of peri-mortem cranial trauma and modification that is strongly suggestive of inter-personal violence and a funerary practice that involved excarnation and secondary burial (Redfern, 2008).

Further insight into the cultural beliefs of Iron Age populations can be gained by considering non-human deposits within settlements. At Gussage All Saints these include the burial of a cow that died during labour and was buried intact with her calf (Harcourt, 1979). The obvious resources that a cow could have provided in terms of meat, bone, and hide were not exploited by the community. This behaviour suggests that there were cultural restrictions in place that prevented the exploitation of certain resources. Another deposit within the Gussage All Saints settlement involved a quern stone of non-local material that had been buried in near perfect condition (Buckley, 1979). Moore (2007) suggests that this type of structured deposit is likely to have connections with cultural belief systems.

In comparison with the Gussage All Saints burials, those at Wetwang Slack appear to have been intentionally located apart from the settlement area. The cemetery developed in a roughly linear, bi-directional progression along the valley floor, with initial spacing being filled by later burials. The resulting cemetery is clustered along the trackway through the valley and includes individuals of all ages (Figure 3.9). The cemetery at Wetwang Slack is the largest Iron Age cemetery population recovered in Britain to date. The majority of primary burials were deposited in the centre of sub-rectangular ditched enclosures and covered by small barrows. Later burials were frequently placed in close association with primary burials and often cut into the primary burial platform or through the burial enclosure ditch. Other burials were placed outside the ditched enclosure burials. All but one of the burials of very young individuals recovered from Wetwang Slack were from primary burials that were outside the ditched enclosure burials of older individuals. At least 446 individuals were buried within the cemetery at Wetwang Slack and more than half of these were in enclosure burials (Dent, 1984).

There is no evidence for excarnation by exposure prior to secondary burial, or other treatments of the body such as cremation at Wetwang Slack. All individuals within the burial population were primary inhumations, although many had been disturbed by later burials and subsequent land modification of the valley (Dent, 1984).

Within the burials, the body was usually placed on the left side in a flexed position, with the head oriented to the north.

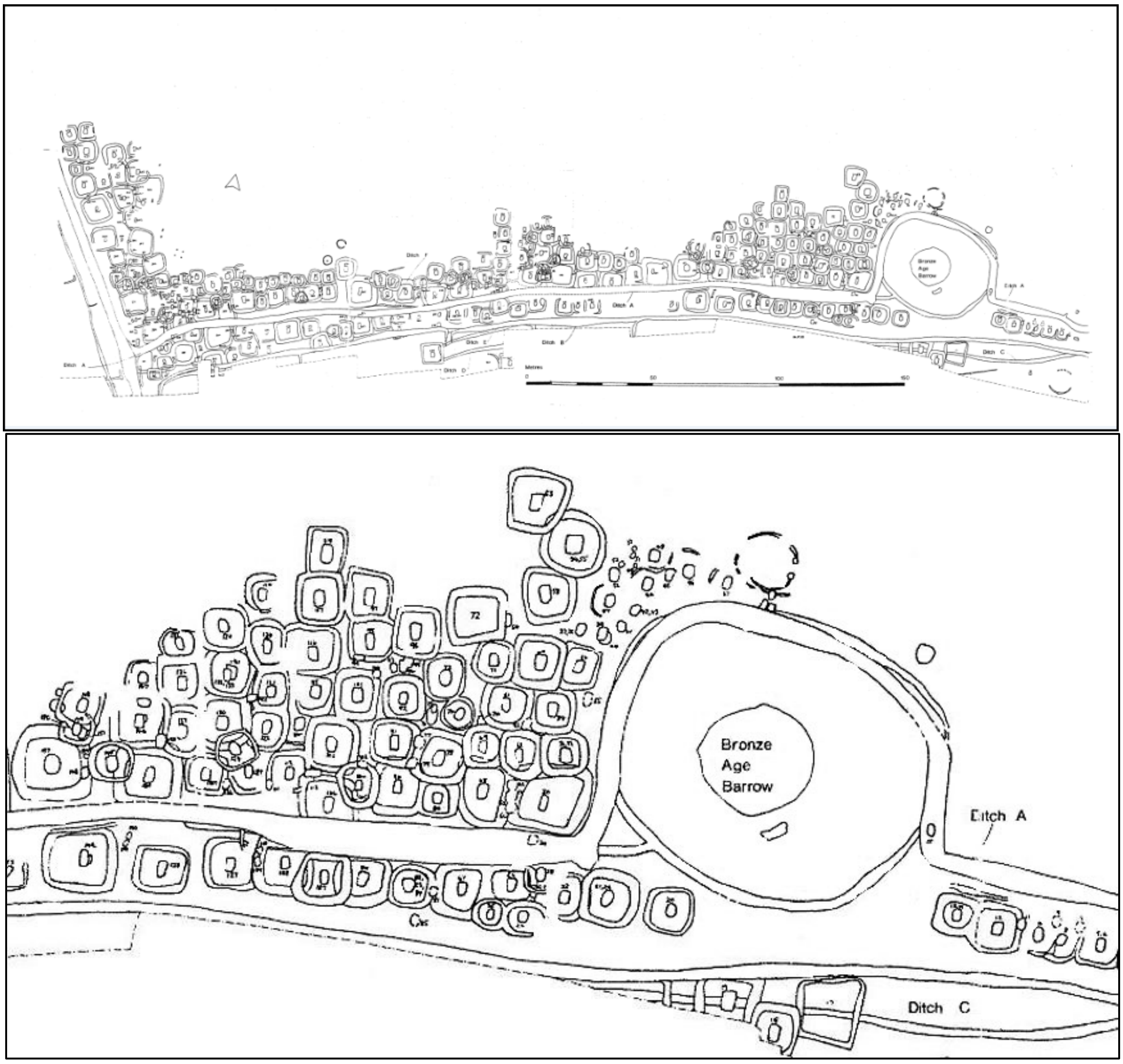


Figure 3.9. Plan of the barrow cemetery at Wetwang Slack (above) and a detailed section of the cemetery (below) (adapted from, Dent, 1982).

Pottery items were occasionally included in the burials at Wetwang Slack. These sometimes contained sheep and pig bones which have been interpreted as representing small cuts of meat that may have been intended as food offerings for the deceased (Dent, 1984). Evidence for the treatment of the body is clear in several burials that included items associated with the fastening of a shroud. For example, the bone and iron pin fastenings found positioned over the face (Dent, 1984). Items recovered from the burials other than the above include fastening devices, items of personal adornment, containers and weapons (Dent, 1984). An analysis of the skeletal material revealed that burials were placed in groupings of related individuals on the basis of shared relatively rare skeletal traits, including metopism, extra-sutural ossicles, agenesis of the third molar and sacralisation of the fifth lumbar vertebra (Dent, 1984). This is not an unexpected finding for a cemetery associated with a small established community.

The cart burials from Wetwang Slack and the surrounding area provide the largest cluster of cart burials in Britain (Jay *et al*., 2012). Three adult individuals were buried with carts at Wetwang Slack; one female and two males. The carts were two-wheeled vehicles driven by two horses (Dent, 1985). In preparation for inclusion in a burial, they were dismantled and the body was placed within the cart box (Figure 3.10). Several items were included with these burials and provide strong support that the individuals were important within the community. Of the three cart burials, the female was buried with an intricate fur-lined pouch decorated in small blue beads that contained an iron mirror, and the males were buried with swords, shields and spearheads (Dent, 1985). The archaeological remains of Iron Age Wetwang Slack and Gussage All Saints reveal much about these small, established agricultural communities and the individuals within them during the final phases of occupation.

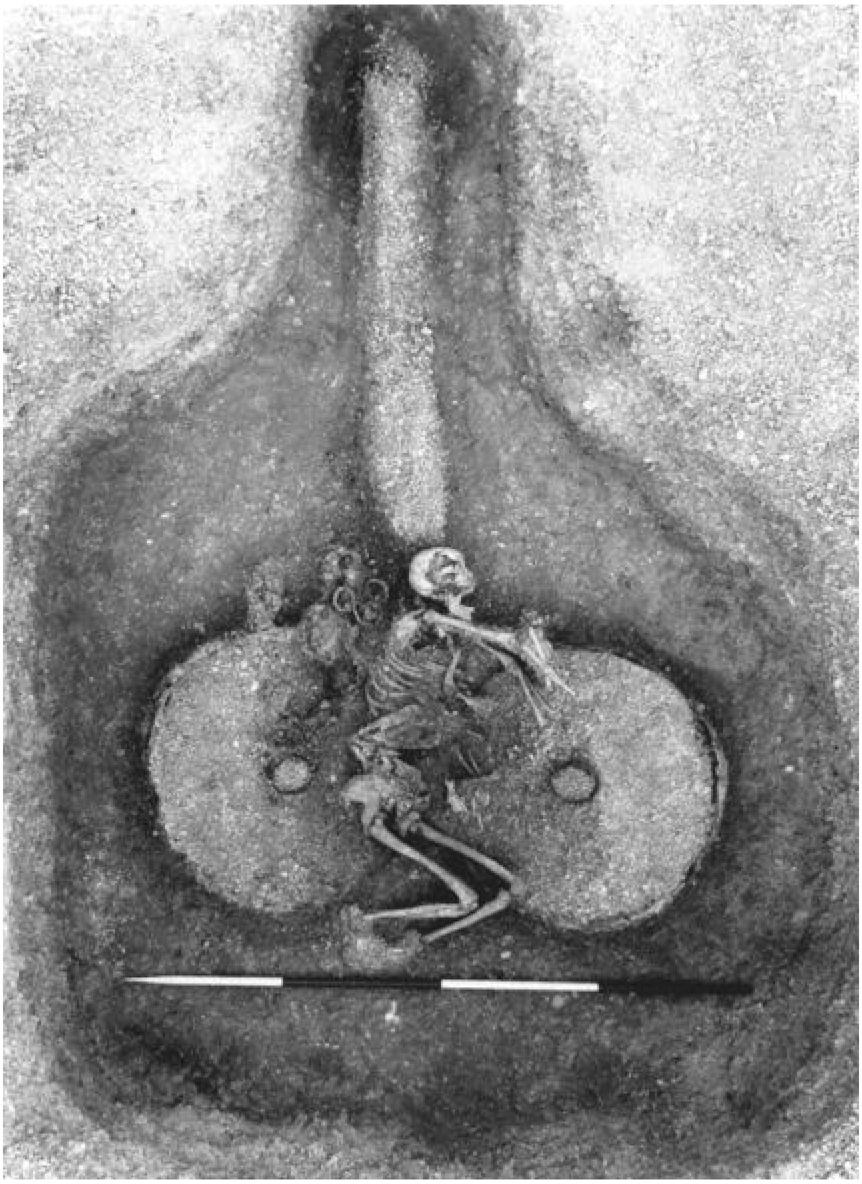


Figure 3.10. The chariot burial of an adult female at Wetwang Slack (Dent, 1985).

3.4 Roman

The Roman period of occupation in Britain commenced at the time of the conquest in AD 43. Urban centres began to decline as the Roman Empire diminished towards the end of the 4th century AD. This had a flow-on effect for smaller rural centres and settlements across Britain. Many sites were abandoned, although some were later re-occupied during the Saxon period as was Barton Court Farm. The current research focuses on the final phases of Roman occupation at both sites; during the 4th century AD at Barton Court Farm, and from the 3rd into the 4th century AD at Yewden villa (Cocks, 1921; Eyers, 2011; Miles, 1986).

3.4.1 Environment

Both Roman settlement sites are on different reaches of the river Thames in the upper Thames valley (Figure 3.11). The settlements are located on drier land above the river and each sits within a complex network of fields and earthworks (Cocks, 1921; Miles, 1986). The surrounding landscape is similar at both locations and would have been mostly open grazing pasture with pockets of arable land, mature woodland, and wetter ground closer to the water (Eyers, 2011; Jones and Robinson, 1986; Robinson *et al*., 1986). Prior to the Roman period of occupation the landscape had already undergone modifications to suit an agriculture based local economy.

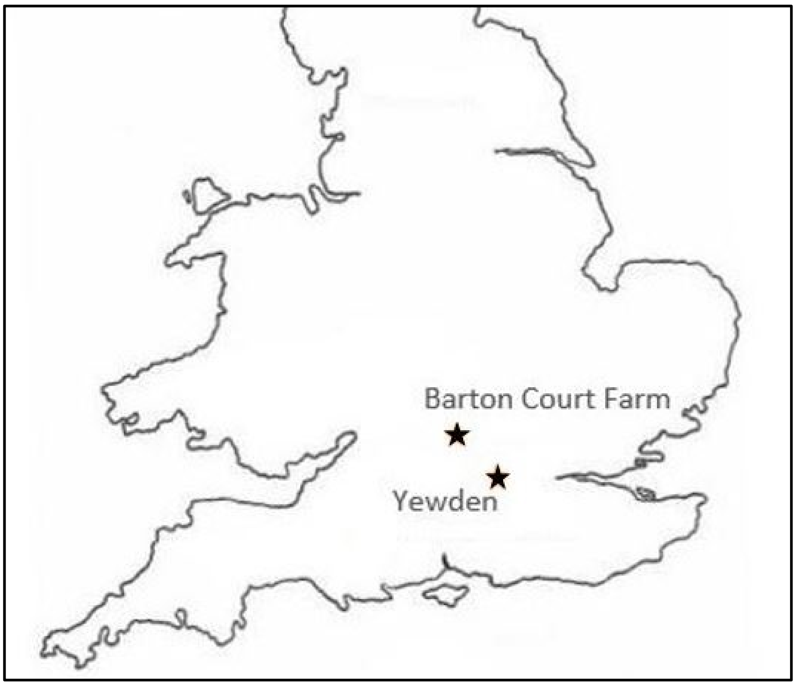


Figure 3.11. Partial map of the United Kingdom showing the locations of Barton Court Farm and Yewden villa.

3.4.2 Culture

Many aspects of Roman culture are widely documented by ancient historical sources and extensively supplemented through the archaeological record. A wealth of information about facets of everyday life during the Roman period in Britain is available through published works (for a selection see Allason-Jones, 2011; Bradley, 1991; Harlow and Larsson, 2012; Henig, 1984; Pearce *et al*., 2000; Philpott, 1991; Puttock, 2002; Watts, 1989). Characteristics of Roman culture are apparent in the archaeological remains of most settlements of the period where it is evident that

Romanisation had an impact on the population, however it should be remembered that an influx of Roman culture did not necessarily remove the undercurrent of Iron Age culture. It is widely recognised that the majority of rural settlements continued to be occupied by their pre-Roman populations who appear to have integrated aspects of the Roman culture into their own (Millett, 2003).

The Roman villa sites analysed below were both predominantly agricultural settlements with crop cultivation and domesticated stock animals. The Barton Court Farm villa enclosure was situated within in a field system that was itself surrounded by an outer boundary ditch (Figure 3.12) (Miles, 1986). The main dwelling within the villa enclosure was constructed towards the end of the 3rd century AD and consisted of eight rooms at ground level, including a corridor room and a cellar (Miles *et al*., 1986a). The settlement also included a second smaller building, wells and grain-drying ovens. The main villa dwelling was timber-framed with stone foundations and tiled roofing. Structural elements confirm that the internal spaces had plastered walls and tessellated floors, while fragments of window glass indicate that the windows were sealed. Later renovations included timber annexes and the excavation of a cellar with external access via stairs (Miles *et al*., 1986a). The main dwelling was demolished at the end of the 4th century AD, marking the end of this phase of occupation. Finds from within the settlement complex include personal items such as bracelets of jet, bronze and shale, bronze rings, and leather shoes. Pottery and glass containers were also recovered along with wooden buckets and fixtures from the well equipment (Miles *et al*., 1986a). A range of furniture, fittings and household items were also recovered that provide a broad picture of the built environment within the villa settlement.

The Yewden villa complex was also surrounded by a boundary wall and enclosed five buildings, a well and grain-drying ovens (Figure 3.13). The settlement buildings were similar to those at Barton Court Farm; timber-framed construction finished with wattle and daub. The foundations of these buildings were mortared flint and the roofing was constructed of tiles or thatch (Figure 3.14) (Eyers, 2011). The main villa dwelling consisted of seven rooms down the centre of the building's long axis with a corridor either side and five rooms at the ends. These twelve rooms formed the ground floor internal space and it is likely that a second storey would have afforded an equal area. Some of the internal floors recovered during excavation were tessellated while others were simple concrete or compacted chalk (Eyers, 2011). The internal walls of the main building were plastered and decorated in coloured designs of red, yellow, orange, green and white (Cocks, 1921). There was also provision for a heated bath in one of the small rooms at the southern end of the building (Cocks, 1921). Four more buildings were located within the villa enclosure. The second structure appears to have been used as a workhouse or barn and included a grain-drying oven and a hypocaust. The third building was similar in size and contained two double grain-drying ovens; its primary function appears to have been connected with the processing of cereal grain. The final two buildings were smaller in scale than the other enclosure buildings. One contained two grain-drying ovens and a well and the other had two rooms, each with a small grain-drying oven (Cocks, 1921).

High status finds associated with all phases of Roman occupation were recovered within the villa enclosure. Personal items include brooches, rings and toilet accessories (nail cleaners, ear scoops and tweezers), while other items provide insight into activities and furnishings within the settlement. These include styli and ligulae, smithing and carpentry tools, hinges and latches, keys, knives, handles, nails, small sickles, glass bottles and spearheads (Cocks, 1921; Williams, 2011).

The finds associated with high social status suggest that Yewden was an established and successful rural villa settlement (Cocks, 1921; Eyers, 2008). Figurines and other objects associated with ritual activity are more concrete in their interpretation. Probable votive deposits of destroyed, unused pottery that may have decorative links to the goddess Juno were recovered as were deposits including votive miniature weapons crafted from animal bone (Cocks, 1921). Direct associations can be inferred for the following: a jade Egyptian scarab beetle with the cult of Isis (Cocks, 1921), a figurine of the goddess Venus and another of Dea Nutrix (Eyers, 2011). All of these associations are related to females, as are the majority of personal items recovered. This has led to suggestions that Yewden villa had a high proportion of females within the population and may even have functioned as a brothel with associated victims of infanticide (Eyers, 2011; Mays, 2003; Mays and Eyers, 2011). Subsequent analysis of the mortality profile and skeletal pathology of the Yewden burial population has thrown considerable doubt on this interpretation of the evidence (Gowland and Chamberlain, 2002; Gowland *et al*., 2014; Hassan *et al*., 2014; Moore, 2009) (see Chapter 8, Section 8.4.1 for discussion).

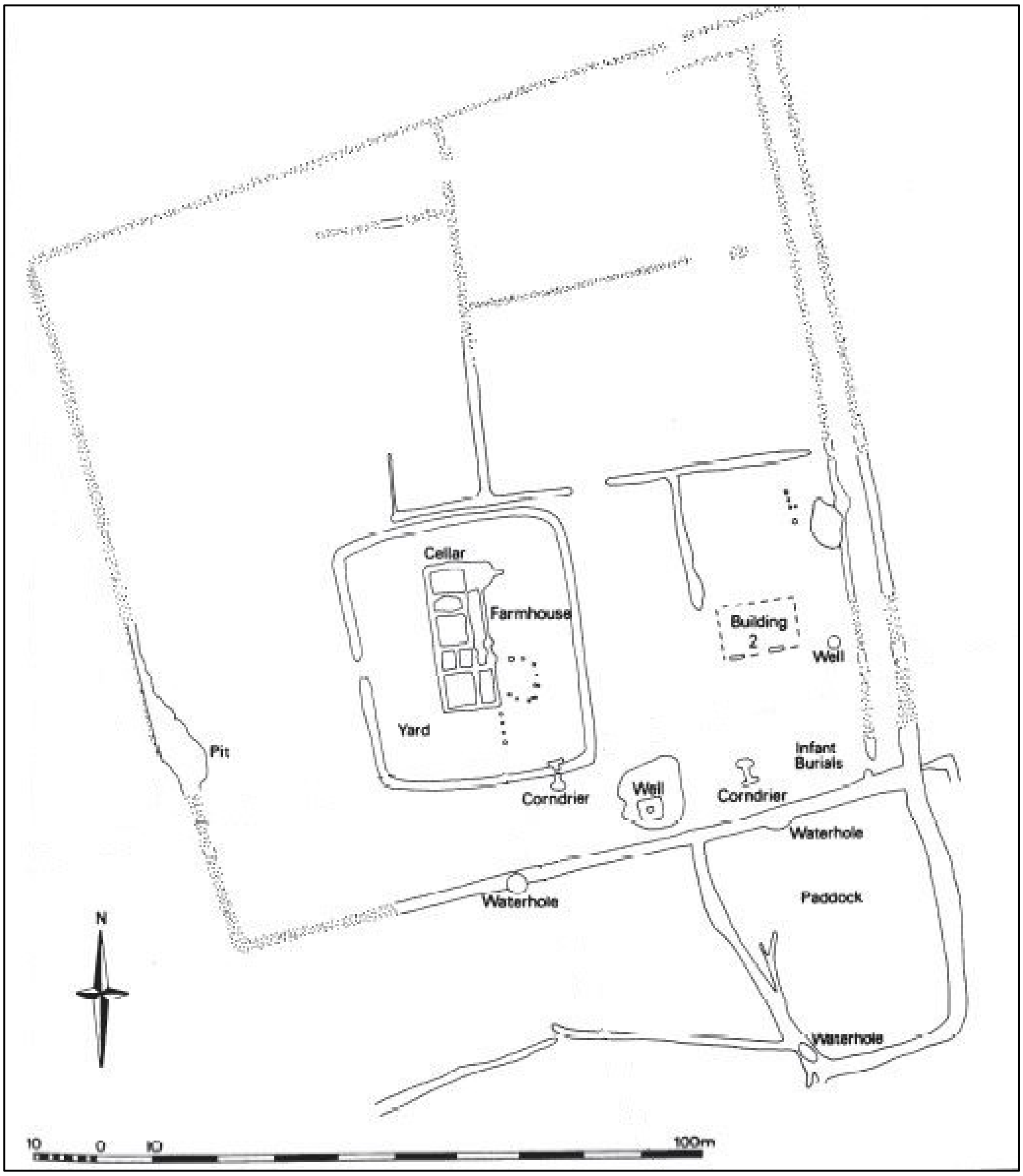


Figure 3.12. Excavation plan of the Barton Court Farm Roman villa site (adapted from Miles, 1986).

Figure 3.13. Excavation plan of the Yewden Roman villa site with perinate burials indicated by red dots (top). The majority of burials are located outside of the northern boundary wall of the villa (bottom) (adapted from Cocks, 1921).

Figure 3.14. Representation of the Roman villa settlement at Yewden, looking towards the River Thames (A. Jewsbury).

3.4.3 Economy

The economy of these two Roman villa sites was predominantly agricultural and incorporated small scale domestic manufacture in the form of processing cereal and animal products. The land around Barton Court Farm may have been more productive as grazing pasture, but there is ample evidence of grain-drying ovens that suggest cereal crops of spelt wheat and barley were cultivated in quantity (Jones and Robinson, 1986). Flax was also grown and may have been used to produce linen or pressed for cooking oil (Jones and Robinson, 1986). Two millstones that had been sourced from Yorkshire and used in the construction of the well, are likely to have functioned as part of a water mill (Miles, 1986). Quern stones for processing dried grain into flour were also recovered from contexts within the villa enclosure. The diet of the villa inhabitants included food sourced from the local environment such as hazelnut and apple, and animals such as red and roe deer, eel, fish and water fowl (Miles *et al*., 1986b; Robinson *et al*., 1986). Domestic stock animals including cattle and sheep were used for meat, hides, wool, cheese and milk (Robinson *et al.,* 1986). Small scale cultivation of dill, coriander, opium poppy and plum also took place. There is also evidence of oyster consumption, a luxury food item that would have been supplied through trade along the River Thames (Robinson *et al*., 1986).

Apart from providing meat and hides, cattle were also used for pulling transport and agricultural equipment while horses were ridden and used as pack animals

(Robinson *et al*., 1986). The shears and spindle-whorls recovered during excavation demonstrate that wool collection and processing was a substantial part of the villa economy. The iron nails, keys, tools, and slag support the existence of a blacksmith working within the site (Miles *et al*., 1986b). Although much of the production at Barton Court Farm was for internal use, the villa estate was situated within an established trade network. Tracks and roads linked settlements to larger urban centres such as Abingdon that was a market town during the Roman period, and the Thames provided a direct connection with London and Oxford (Miles, 1986).

Much of the agricultural activity undertaken at Barton Court Farm also took place at Yewden villa. Scythes and plough shares along with grain-drying ovens provide evidence of crop cultivation in the surrounding fields and processing within the villa enclosure (Cocks, 1921). It appears that the economy of Yewden villa was based primarily in production for local consumption only and would not have resulted in enough surplus for export (Eyers, 2011). The faunal remains at Yewden villa include wild and domesticated species such as red and roe deer, rabbit, cattle, sheep, goat, pig, horse, dog, and wild and domestic fowl. The diet of the Yewden inhabitants was varied and apart from the above included non-local luxury consumables such as oysters. Other than contributing to the diet of the inhabitants, the sheep, cattle and horses were also a source of wool, hides and traction or transport labour.

Helm and Carruthers (2011) suggest that preserved germinated grain along with detached cereal sprouts supports an interpretation of malting. Grain was dried and then allowed to germinate prior to further processing. This form of evidence is present at both Barton Court Farm and Yewden villa (Campbell, 2011; Jones and Robinson, 1986). The grain-drying ovens at both sites may also have been used to dehydrate cereal crop prior to grinding the grain into flour. The cereal crops cultivated at Yewden villa were spelt wheat and barley (Eyers, 2011).

Yewden villa was primarily connected via the river Thames to London and other towns along its route. These links with the river and the associated road networks would have extended the range of connection with other settlements in the region and further afield (Eyers, 2011). The reach of trade networks is evident at Yewden villa in the recovered imported pottery that derived from Gaul and also included fine Samianware items (Cocks, 1921; Eyers, 2011). The Yewden villa settlement appears to have been reasonably wealthy throughout its Roman occupation as evidenced by the number of high status finds that have been recovered. Given the variability of trade and economic security throughout this period, it is probable that the villa estate had supplementary sources of income that were independently stable with respect to the wider economy of the region, for example the provision of skilled obstetric support.

Slavery was an integral part of the Roman economy and readily identified in the larger urban and military centres. Although it could be inferred that substantial villa estates such as Barton Court Farm and Yewden counted individuals identified as slaves within their communities, there is no evidence to support a large number of slaves at either of the settlements. This does not preclude a small number of servants living with the family, which may not have differed greatly from rural settlements dating to the pre-Roman period.

3.4.4 Funerary practices

There were several socially acceptable forms of funerary practice within Roman culture including inhumation and cremation (Alcock, 1980; Watts, 1998). These burials were usually placed within a cemetery associated with centres of habitation. An exception to this rule was permitted for the burial of very young individuals within the domestic sphere (Miles *et al*., 1986b; Millett and Gowland, 2015; Redfern and Gowland, 2012). The placement of burials of very young individuals within settlements was practiced at both Barton Court Farm and Yewden villas, while the older individuals at Barton Court Farm were buried in one of two associated cemeteries (Miles, 1986). A late Romano-British cemetery dating to the 4th century AD was located to the northeast of the settlement, at Barrow Hills Field (Atkinson, 1952), and a second cemetery was uncovered closer to the farmstead (Miles *et al*., 1986b). The Barrow Hills Field cemetery contained the graves of thirty-five adult individuals. The size of this cemetery and its likely period of use indicate that it served a small, local community. Miles (1986) estimated a living population of fewer than ten adults at Barton Court Farm during the 4th century AD, which suggests that the cemetery in Barrow Hills Field may well have been the burial place for the adults of Barton Court Farm. An associated cemetery has yet to be identified for Yewden villa (Eyers, 2011).

The majority of very young individuals at Barton Court Farm were buried in the southeast corner of the villa enclosure and date to the final phase of Roman occupation (Miles *et al.,* 1986b). Three of these individuals were buried with animal crania; two with a dog cranium and one with a sheep cranium (Miles *et al*., 1986a;

Robinson *et al*., 1986). The infant mortality rate during the 4th century AD has been estimated at one death every two years (Miles *et al*., 1986a), however the lack of a significant burial population of older individuals limits the validity of this estimated infant mortality rate. The adult remains from the Barrow Hills Field cemetery were highly fragmentary and crushed. At the time of Atkinson's publication in 1952 the remains had not been analysed; if they have since been analysed, this information has not been published. One interesting feature of two of the burials is the evidence for a deviant funerary practice of decapitation burial in which the cranium is placed between the lower limbs in an otherwise articulated primary burial with the body in an extended, supine position. Two adults (Sk. 10 and Sk. 14) were found to have been buried in this way. Another individual (Sk. 16) was positioned on its left side, but the body had either been placed or had fallen into a prone position (Atkinson 1952). The inclusion of animal crania with burials and the deviant burial of some adults strongly suggests that there were complex behaviours involved in the funerary practices of the communities of Barton Court Farm and surrounding area.

The burials at Yewden villa are also dominated by the very young. The only older individuals from the site are part of a ritual deposit with building materials that were recovered from one of the wells (Cocks, 1921; Scott, 1991). Deposits of two animal crania, a pony and a pine martin, also occur within the Yewden villa enclosure and both date to the 3rd century AD (Eyers, 2011). The deposits of animal crania and structured deposits indicate the presence of shared cultural behaviours that involved consistent funerary practices and ritual associations across multiple contemporary villa sites (Branigan, 1972; Scott, 1991). The burials recovered from the Barton Court Farm and Yewden villa sites provide evidence of multifaceted ritual behaviours that involved the burial of human remains. Some of these behaviours appear to have controlled the burial location and type of deposition for individuals of specific age groups, as reflected in the locations selected for the burial of very young individuals; within the domestic environment or in association with agricultural processing areas. The evidence for a persistent association between the burials of very young individuals and burial location into the Anglo-Saxon period at Barton Court Farm is supported by the burial of two pregnant females in the principal domestic building (Miles 1986; Millett and Gowland, 2015).

3.5 Medieval

Two medieval sites were included in the current research, one in northern England and the other in Ireland. At both sites, there is a long history of occupation with prehistoric and early historic archaeology. Both sites also appear to have had an early church constructed during the Christian period around the 9th century AD (Harding and Wrathmell, 2007a; Moloney *et al*., 2016). The medieval rural village of Ardreigh (Figure 3.15) was fist mentioned in historical records in 1171 AD after which it appears to have become an established settlement (Carty, 2012). It was in decline by the 14th century AD and largely deserted by the 16th century (Moloney *et al*., 2016). While Ardreigh declined, the nearby centre of Athy flourished and grew to be the dominant town in the area (Glasscock, 2008). The village of Wharram Percy (Figure 3.16) experienced a similar period of growth and decline. From the 12th century AD there was an established settlement and its church served several other villages in the surrounding area, however by the early part of the 16th century AD, the village had become deserted (Harding and Wrathmell, 2007a). Despite the longstanding presence of the village, Wharram Percy was essentially a poor rural settlement that experienced many years of hardship (Beresford, 1979, 1987; Beresford and Hurst, 1976, 1990).

Figure 3.15. Map of Ireland showing the location of Ardreigh, Co. Kildare.

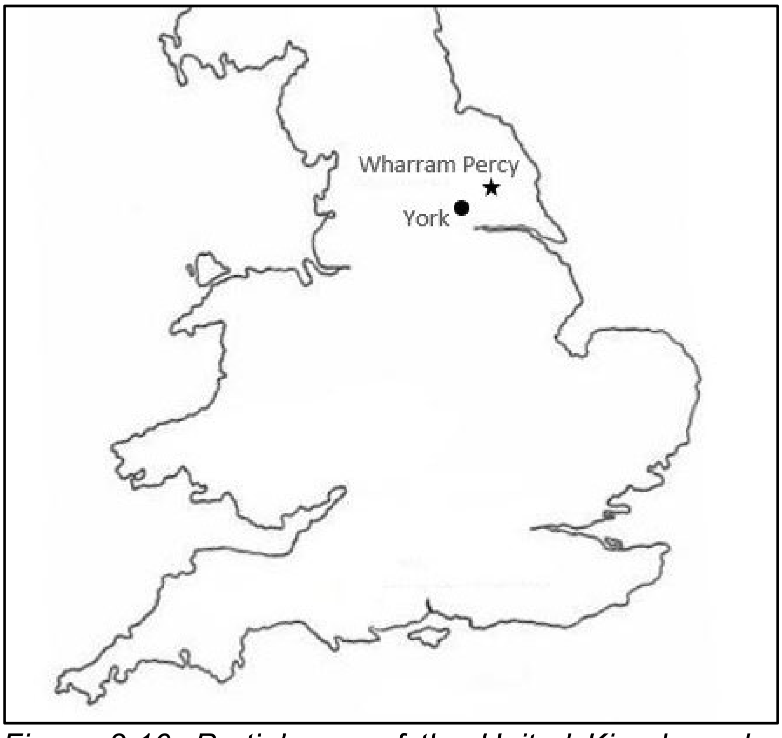


Figure 3.16. Partial map of the United Kingdom showing the location of Wharram Percy.

3.5.1 Environment

The environment in both locations was established agricultural land dominated by animal grazing with small scale crop cultivation. Each settlement was equidistant to the coast and to large urban centres; York and Dublin. The region around Ardreigh contained pockets of woodland amongst open spaces, with tree species that included ash, oak, hazel and apple (Moloney *et al*., 2016). Much of the surrounding land had been cleared during the Iron Age leaving expanses of open land for grazing and agriculture. The settlement itself was located at a ford of the River Barrow, a major transportation and trade route throughout the medieval period (Glasscock, 2008). Wharram Percy village was also situated in a landscape cleared for grazing and agriculture. The settlement was established on the western slope of the valley on a chalky plateau, above a water source with water mills (Beresford, 1979).

3.5.2 Culture

The relatively short-lived settlements of Ardreigh and Wharram Percy provide a precise temporal and spatial capture of rural life in the respective areas of Ireland and England during the medieval period. The villages were both small communities and functioned as part of wealthier landowner holdings; a motte and bailey castle near Ardreigh was the seat of local authority during the late medieval occupation of the area (Glasscock, 2008). The village of Wharram Percy was under the control of Norman aristocracy (Roffe, 2000). This was the usual arrangement for land control during the medieval period (Bailey, 1996; Bigmore, 1982).

Each family within the villages would have had their own housing, although at Wharram Percy there is evidence for poorer sectors of the community who may have lived in shared spaces. There is limited archaeological evidence for medieval housing in Ireland, although the village of Ardreigh was an Anglo-Norman settlement and as such it was likely fashioned after contemporary building styles in England (Glasscock, 2008). The typical housing in England was of simple timber construction with wattle and daub or turf walls and a thatched roof. There is evidence for the internal division of space using walls of wattle hurdles (Hurst and Beresford, 1989). Apart from the human inhabitants, dwellings generally incorporated space for the livestock. This was usually one end of the main living area or in some cases, a separate building adjoining the main dwelling (Aalen, 2003). In the village of Ardreigh, each dwelling was positioned at the front of a narrow rectangular plot of land, referred to as burgage plots, along the roadway (Figure 3.17). A similar arrangement can be seen at Wharram Percy (Figure 3.18) (Harding and Wrathmell, 2007a).

As a predominantly agricultural settlement, Ardreigh was affected by the frequent murrains (infectious diseases resulting in epidemic mortality) of both cattle and sheep documented throughout the period, crop failures and harsher climatic conditions. These had devastating effects on the local economy and led to famine, malnutrition, poverty and starvation (Jordan, 1996). The early part of the 14th century AD saw widespread economic depression with many inhabitants of smaller rural settlements moving to larger urban centres (Glasscock, 2008).

Figure 3.17. Representation of the Medieval settlement of Ardreigh (J. Millar).

Figure 3.18. Representation of the Medieval settlement of Wharram Percy (S. Conlin, Historic England Photographic Library).

Evidence of interpersonal violence is clearly seen in the prevalence of blunt and sharp force trauma to the cranium in adult individuals within the Ardreigh burial population. All of the affected individuals recovered from their injuries (Carty, 2012). This points to knowledgeable and effective medical treatment being available to those in need. There are several similar cases of trauma from Wharram Percy, which may be the result of interpersonal violence (Wrathmell, 2012). Like the individuals at Ardreigh with cranial trauma, those at Wharram Percy also appear to have had access to medical treatment and care as the trauma inflicted was not always fatal (Mays, 2007). Skeletal evidence suggests that the men and women of Wharram Percy shared the physical workload (Mays, 2007) as would be expected of an agricultural community. It is likely that the inhabitants of Ardreigh would also have done so.

Apart from the cultural and environmental impacts that affected the settlements of Ardreigh and Wharram Percy, the initial and subsequent outbreaks of the Black Death from the middle of the 14th century AD had a devastating effect on populations (Aberth, 2010). The close proximity of settlements and trade connections would have enabled the plague to spread quickly from major ports to outlying settlements. At Wharram Percy at least one third of the population was killed by the first documented

English outbreak in AD 1348 (Beresford, 1979) and the majority of burials excavated from the cemetery date to before AD 1350 (Bayliss *et al*., 2007).

3.5.3 Economy

As stated above, the economies of Ardreigh and Wharram Percy were primarily agricultural. Small scale crop cultivation is likely to have taken place within individually managed plots of land, while domesticated stock were grazed on the land surrounding each settlement. At Ardreigh the locally cultivated agricultural crops included wheat, barley, oats and peas (Moloney *et al*., 2016). The variety of agricultural crop remains suggest that crop rotation was practiced as a means of maintaining land productivity.

Farmed animals at both Ardreigh and Wharram Percy included cattle, sheep and pig (Glasscock, 2008; Richardson, 2007). Domestic fowl, fish and marine molluscs supplemented the diet at Wharram Percy (Richardson, 2007). Apart from the provision of dietary protein and milk, animal by-products such as skins, wool and bone were also used for textiles, tools and other objects. Evidence for domestic activities and production within the villages is seen in the items recovered from dwelling contexts. These include spindle-whorls, loom weights, rubbing stones, querns and various construction elements, (Clark *et al*., 2007; Elsdon *et al*., 2007). Tools related to small scale production including blacksmithing, leatherworking, carpentry, glass and bone tool manufacture, animal husbandry and cultivation were also found (Goodall*, et al*., 2007).

Both villages had direct trade connections with the coast and large market centres and each had its own market (Harding and Wrathmell, 2007b; Moloney *et al*., 2016). This would have facilitated a moderate influx of supplementary resources and goods in exchange for those produced onsite (Bailey, 1996). These regular markets provided a means of more widespread trade evidenced by the pottery recovered from Ardreigh that was produced in Dublin and as far afield as southwest France. Items of personal adornment and hygiene were also found on both settlement sites. At Wharram Percy, these include an array of dress pins, brooches, jewellery, buttons, combs and tweezers (Goodall, 2007). Bone gaming pieces and die recovered from Wharram Percy also reveal aspects of recreational life within the village (Riddler, 2007).

3.5.4 Funerary practices

The permanent church and cemetery at both Ardreigh and Wharram Percy point to a longstanding cultural adherence to the early Christian church within their respective communities (Everson and Stocker, 2012; Moloney *et al*., 2016). The village of Ardreigh would have developed around the established monastic community at Athy, evidenced by the nearby priory hospital and Dominican friary (Hannon, 1891). The archaeology at Wharram Percy also provides evidence of an early church, one that underwent multiple reconstructions during the life of the village (Harding and Marlow-Mann, 2007). The primary funerary practice upheld by the medieval Christian religion was inhumation within a consecrated cemetery. Individuals were normally buried in individual graves, the body positioned supinely. Most individuals were buried in a coffin where available, or clothed in a shroud (Clark, 2007). Burials were ordered in rows within the graveyard and often had markers that reduced the risk of disturbance by later burials. All members of a community were usually buried within the cemetery or inside the church itself; exceptions were the unbaptised, criminals and victims of suicide (Gittos, 2002). There is no archaeological evidence for individuals excluded from the cemetery but buried in other areas associated with the settlement.

The inhabitants of Ardreigh and Wharram Percy were buried according to these Christian customs. Both villages had associated cemeteries that contained a large number of burials indicating that these were the primary burial grounds for the local communities. The Ardreigh burial population is one of the largest recovered from medieval contexts in Ireland (Moloney *et al*., 2016), with 1259 individuals recovered and a further 211 individuals represented in the disarticulated remains (Figure 3.19) (Troy, 2010). The selective excavation at Wharram Percy recovered a portion of the burial population from around the church (Figure 3.20) and it is likely that a considerable number remain buried (Mays, 2007). The cemetery and church at Wharram Percy serviced its own community as well as those of other settlements within the parish (Harding and Wrathmell, 2007a). There appears to have been a designated area for the burial of very young individuals at Wharram Percy, with the majority of very young individuals buried to the north of the church (Mays, 2007). The western area of the Wharram Percy cemetery did not have any coffin remains and may have been the preferred location for burial of the poorest individuals in the community (Heighway, 2007). Although the incidence of coffin use at Wharram Percy is low compared to other contemporary sites, there is widespread evidence of shrouds being used (Clark, 2007).

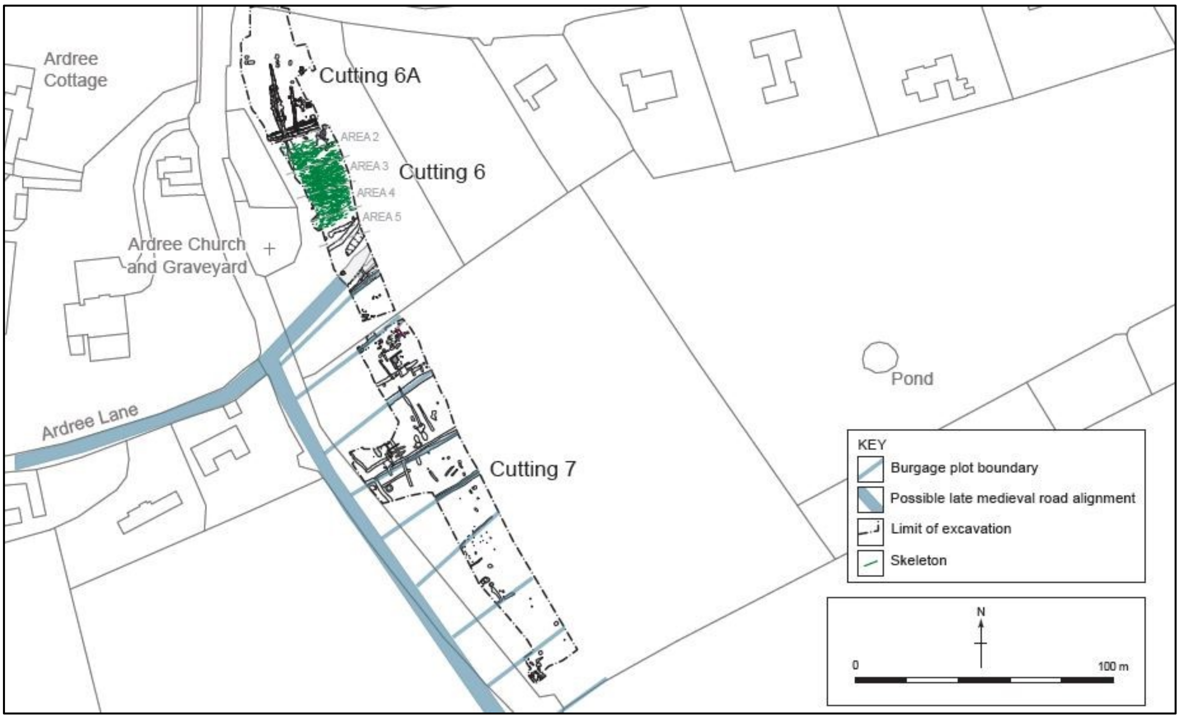


Figure 3.19. Plan of the Ardreigh site showing the areas excavated (adapted from Moloney et al., 2016). Burials are indicated by the green lines in Cutting 6.

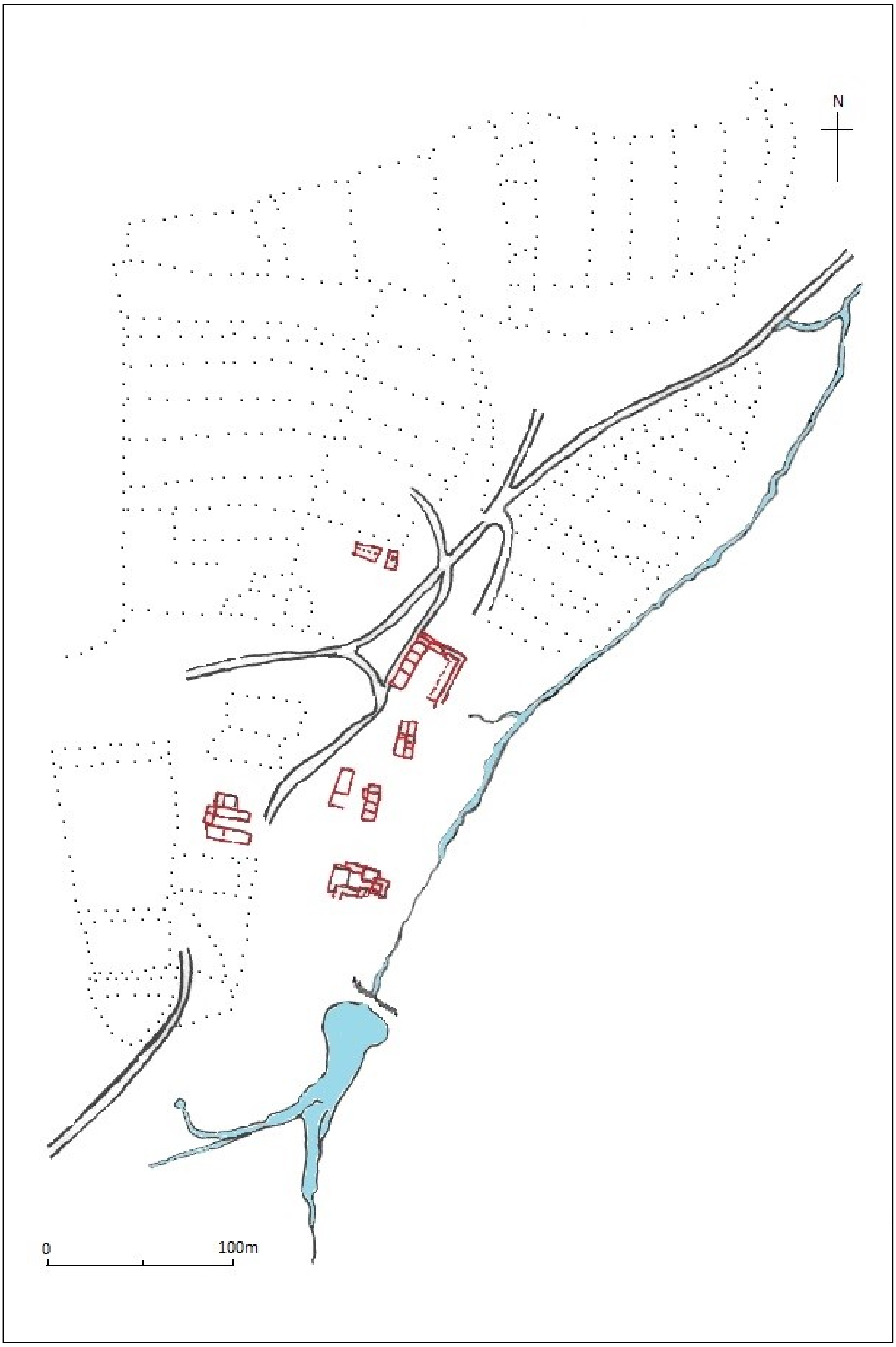


Figure 3.20. Plan of the Wharram Percy settlement. Surviving structures are highlighted in red (adapted from Historic England).

3.6 Reference

3.6.1 Importance

The reference collections incorporated in the current research provide examples for comparison and confirmation of age at death, development of the juvenile skeleton, and the aetiologies of observed skeletal pathology. Without reference to modern medical knowledge and documented collections it would not be possible to confirm any potentially pathological changes observed in skeletal remains. The value of reference collections is balanced in some cases by the quality of detailed documentation. Historical medical diagnoses should be examined critically prior to using specimens as confirmation of aetiology. In order to increase the reliability of the reference collections used in the current research, priority was given to collections with medical confirmation of skeletal pathology. The Scheuer collection was included to assess some of the specimens used in the production of leading reference volumes.

3.6.2 Royal College of Surgeons, London

The Wellcome Museum of Anatomy and Pathology at the Royal College of Surgeons (RCS) in London contains a unique reference collection of the pathology of gestation. The collection includes a comprehensive series of normal developmental progression of the skeleton and soft tissue throughout gestation. The specimens are derived from medical research and all have associated documentation. The collection also includes a specific group of developmental pathology of the neural tube and cranium. A total of 199 individuals were analysed and all pathological cases were fully described as part of this doctoral research. The developmental and pathological specimens held in the RCS collections are an invaluable resource for the identification of individual skeletal elements through their early development and the range in expression of pathological modifications. They enable comparative research between confirmed pathology aetiologies and archaeological specimens. It is acknowledged that medical specimens can at best only provide an approximation of age because the point of conception, from which gestation age is calculated, is rarely known.

3.6.3 Scheuer Collection, Centre for Anatomy and Human Identification

The Scheuer collection at the University of Dundee contains the skeletal remains of over one hundred sub-adult individuals. Within the collection, thirty individuals were aged under six postnatal months at the time of death. The specimens were sourced from a variety of archaeological and anatomical collections from the United Kingdom and Europe. The majority of the specimens are disarticulated skeletons, although several are entirely or partially articulated with the preservation of connective tissue. The youngest individuals in the collection are predominantly undocumented; only one has a probable cause of death and estimated age recorded and eight are identified as originating from a particular burial location. The age at death for the remainder of these individuals was estimated using standard osteological methods. The Scheuer collection is the primary source used in the production of leading reference texts on juvenile skeletal development and identification (Schaefer *et al*., 2009; Scheuer and Black, 2000; Scheuer and Black, 2004).

3.6.4 Clinical, England

The clinical reference material was selected from recent cases of perinatal mortality within the United Kingdom. Collaboration was initiated with one of the four regional neonatal pathologists and individual cases were identified for inclusion in the research through consultation. Only non-malformed individuals were used in the reference sample. Each individual was identified as male or female and an age at death given in weeks of gestation. Confirmation of the cause of death was also provided to allow for further selection if required. The causes of death were infection, immaturity, cord obstruction and the timing of death was either intrauterine or intrapartum (see Table 7.13 for details). The clinical reference material includes photographic records of endocranial surfaces for the cranial vault. This form of reference material enables the concise and detailed analysis of archaeological specimens that exhibit a range of endocranial vault surfaces. It also provides the basis for differentiating between the appearance of normal endocranial surfaces and areas exhibiting pathological periostosis.

The incorporation of recent clinical reference material with confirmed documentation is invaluable to the current research. The certainty of aetiology and absence of pathological response is an aspect that many researchers using undocumented skeletal material are resigned to do without, which severely limits our ability to arrive at conclusive interpretations.

3.7 Summary

This chapter has presented contextual information for each of the settlement populations analysed in the current research. By outlining the differing cultures and periods of time, a broad picture of the lifestyle, environment and external pressures can be constructed to better understand the life experience of the inhabitants at these sites. Along with the consideration of archaeological material, the importance of using reference collections with confirmed aetiologies in the critical analysis of the human remains has been stressed. Despite the wide variation in settlement context, the collections have all been drawn from populations defined by specific locations and periods of time. Within their respective contexts, these burial populations can provide detailed insight into each particular community, supplementing interpretations already proposed through previous research.

Chapter Four

Research Methods

4.1 Introduction

The skeletal remains of very young individuals from archaeological contexts are considered useful for palaeodemographic studies and investigations into socio-cultural practices of past populations. Following an increased visibility of research focussed on this age group, there has been a change in perception of the potential information available from the analysis of the skeletal remains of very young individuals, resulting in many collections being re-analysed.

The current research into the palaeopathology of very young individuals and maternal health incorporates recognised osteological approaches to the analysis of developing skeletal remains. This research enhances the available contextual information and extends existing interpretations of the burials of very young individuals that have been recovered from archaeological contexts. The combined bioarchaeological research approach builds upon the use of osteological metrics by integrating skeletal development details and pathological changes to provide a more complete interpretation of the skeletal remains within the context of each population studied. The contextual analysis complements the quantitative data collected for each individual resulting in the most comprehensive interpretation possible within the limitations of the research.

4.2 Data Collection

4.2.1 Ensuring Data Integrity

The availability of and access to human remains often influences which remains are analysed. Unless future research requirements justify the continuing curation of excavated human remains, it is not unusual for them to be returned for reburial (Brickley and McKinley 2004; Buikstra and Gordon, 1981; Buikstra and Ubelaker, 1994; Roberts, 2009), after which they are subject to accelerated deterioration and unlikely to be available for re-analysis. The preservation condition of curated skeletal remains can also limit research access, which may be refused in cases where the remains are very fragile. In instances such as these, it is paramount that the integrity of the data collected from available skeletal material is protected against ambiguity, corruption, and loss, as future opportunities for analysis and recording are not guaranteed.

Throughout the current research, the integrity of the data collected has been a primary consideration in order to maximise its longevity and usefulness for future research. The data will be archived to facilitate retrieval and enable replication and incorporation of the current work into future research. It is important that data collection and digital information storage support data integrity, not only as part of a sound research design, but also because the current research contributes to a new field of inquiry.

4.2.2 Measurements

All direct measurements of dry bone were taken with a digital caliper (resolution 0.1mm) and all arc measurements were taken with a precision tape measure (resolution 0.1mm). Depth measurements were taken with a fine tip probe in conjunction with a digital caliper. Where fragmentation and damaged edges occurred, estimated measurements were recorded (e.g. 3.4e mm). These estimations were only recorded in cases where the missing amount of bone surface was minimal and the majority of the epiphyseal surface was intact. The equipment used for data collection was calibrated frequently to ensure consistency in measurement accuracy. Where new equipment was introduced, this was calibrated against the existing equipment to ensure consistency. Photographic records were taken of all observed skeletal pathology, and show multiple angles where relevant. Images were recorded using a digital camera and incorporated a photographic scale.

To ensure universal accessibility to the skeletal data collected, formal osteological and anatomical terminology is used for description and identification when referring to elements and related pathology (Abrahams *et al*., 2008; Hillson, 1996; Ortner, 1994; Scheuer and Black, 2004; White and Folkens, 2005). All skeletal measurements were taken according to the descriptions and landmarks used for each element as provided in Fazekas and Kósa (1978) and Schaefer *et al.* (2009). These include length, width, height, arc and chord, and metaphyseal surface (growth plate) dimensions for whole elements as well as intra-element features. A list of the measurements recorded, with corresponding abbreviations and the measurement descriptions are provided in Appendices 1a and 1b. The dentition was recorded using the Zsigmondy-Palmer system in which the dentition is noted by allocating the lettering A B C D E for individual deciduous teeth in each quadrant and the numbers one to eight for permanent teeth. Table 4.1 demonstrates the notation used for each tooth. Teeth that were not present with the curated remains were recorded with a dash. Through the process of data collection and analysis, it became apparent that particular measurements, such as the clavicle length, were less applicable than others with regard to estimating age and development. This was usually because the age estimation covered several weeks and was therefore not as useful as other elements with a narrower estimated age range. The variable measurements were recorded for comparison, but were not included as determining factors in the age and development estimations.

Table 4.1. Dental recording notation used in the current research.

Dental Arc	**Right**	**Left**
Deciduous Maxillary	E D C B A	A B C D E
Deciduous Mandibular	E D C B A	A B C D E
Permanent Maxillary	8 7 6 5 4 3 2 1	1 2 3 4 5 6 7 8
Permanent Mandibular	8 7 6 5 4 3 2 1	1 2 3 4 5 6 7 8

4.2.3 Recording

Skeletal measurements and developmental indicators are indexed by individual and collection. The raw data includes Excel spreadsheets, age-specific skeletal inventories and templates, and photographs taken during analysis. Each individual studied has a separate skeletal record within an Access database that collates the osteological analysis results. The skeletal pathology recorded for older individuals includes dental pathology such as enamel hypoplasia and carious lesions, periostosis, porous lesions, degenerative and activity related pathology, and skeletal trauma.

The poor recovery of very young individuals from archaeological contexts was previously considered to be a factor of the poor preservation condition of the bone

(Buikstra and Cook, 1980; Von Endt and Ortner, 1984; Walker *et al*., 1988). More recent research has demonstrated that, although these skeletal elements are not fully developed, they are usually as well preserved as adult skeletal remains recovered from the same burial environment (Buckberry, 2000; Lewis, 2007; Mays, 2010). Provided the burial environment is conducive to good preservation conditions for human bone, the under-enumeration of very young individuals recovered from archaeological contexts is most plausibly attributed to poor identification resulting in reduced retrieval and recording error.

Standard osteological recording plans for very young individuals provide limited scope for recording developing skeletal elements in detail. This is predominantly an effect of using stylised depictions of elements and limiting the number of elements represented. The use of age-specific recording forms developed by the author (Appendices 2 to 9), provides a means of recording greater detail, thereby improving the calculation of skeletal completeness and accuracy in assessing the distribution of pathology. These forms also facilitate the identification of developing skeletal elements for untrained researchers and can be used in the field as a reference for excavators unfamiliar with fetal and perinatal elements.

The use of these new forms also contributes to addressing the under-enumeration of very young individuals recovered from archaeological sites. By increasing awareness of the existence and appearance of the skeletal elements present in very young individuals, the new recording forms have improved recovery rates of elements that are usually overlooked, such as ossification centres, distal phalanges, epiphyses, and crown cusps (Lewis, 2007). In doing so, the use of the new forms has the potential to improve accuracy of age estimation in very young individuals.

The recording inventories and plans used during data collection were developed following an assessment of published studies and descriptions of skeletal development (Hall *et al*., 2012; Noback, 1944; Noback and Robertson, 1951; Scheuer and Black, 2000) and examination of curated collections (Royal College of Surgeons, London), archaeological skeletal remains and documented specimens. Normal variation in the timing of appearance and fusion of ossification centres was considered in determining which elements were to be included on each recording form. Each element was included from its earliest confirmed identification within each age range, and depicted to reflect morphological changes in its development.

It is possible to identify some of the smaller skeletal elements such as the carpals, tarsals and epiphyses through the detailed examination of fetal and perinatal skeletal remains, particularly those of individuals in which articulation is evident. This approach to the identification of ossification centres may enable an earlier age of appearance to be confirmed for some elements when the age at death of the individual is known. As well as refining age estimation through identifying early ossification centres, the visual format of the recording templates and inventories developed for the current research offers an accurate and rapid means of assessing completeness.

4.2.4 Inter-Observer Error

All measurements taken during the skeletal analysis and all observations of skeletal pathology were recorded by the author. It is acknowledged that the risk of error is increased by using a single observer. To evaluate the reliability of the measurement methods for accurate replication, an inter-observer error test was undertaken at an early stage of the research. Two observers experienced in the measurement of human skeletal remains were required to measure skeletal elements using the descriptions provided in Fazekas and Kósa (1978) and Schaefer *et al.* (2009). Each observer was provided with the skeletal remains of a neonatal individual from an archaeological collection and required to record 82 measurements from 48 skeletal elements.

Assessment of the Technical Error of Measurements (TEM) was conducted for each observer in comparison with the author's original measurements of the same skeletal elements. The inter-observer error was calculated between each observer and the author, using the following formula:

$$\text{TEM} = \sqrt{\sum D^2}\ /2n$$

where D is the difference between the first and second measurement, and n is the number of measurements taken during the test (Frisancho, 1990; Gore and Pederson, 2000; Himes, 1989; Lewis, 1999; Perini *et al*., 2005).

To assess the percentage of accuracy for each measurement, the coefficient of reliability (R) was calculated using the formula:

$$R = 1 – (\text{TEM}^2/\text{SD}^2)$$

Where the SD is the standard deviation of the sample population. The standard for an acceptable amount of measurement error using the TEM calculation is R > 95% (Ulijaszek and Kerr, 1999).

The inter-observer TEM assessment for the first observer was 0.09 with 97% accuracy, and for the second observer the TEM was 0.20 with 98% accuracy. The intra-observer error was calculated for repeated measurements taken at monthly intervals by the author on the same specimen. The interval of one month was chosen in order to replicate the effects of time between sampling events on recording accuracy. The author's TEM was calculated as 0.04-0.05, with an R value of 0.99. These results confirm that the methods for recording skeletal measurements are robust when taken by experienced observers trained in osteological metric analysis, and can be relied upon for a high degree of accuracy (Gore and Pederson, 2000). The assessment of the author's TEM and accuracy in recording demonstrate that the risk of error involved in using only one observer for the collection of metric data is very low and unlikely to impact the integrity of the data.

The age of very young individuals is estimated using reference tables developed from the analysis of documented individuals. These tables provide an age estimate for selected skeletal elements in two-week intervals from early gestation (Fazekas and Kósa, 1978; Schaefer *et al*., 2009). The two-week intervals in the age estimation tables cover a larger measurement range than the difference of measurements calculated during the TEM assessment. As such, the variation in recorded measurements is too minor to shift the age estimation to another two-week interval. In terms of accurately interpreting skeletal measurements for the purpose of age estimation, the TEM was not considered to be a significant variable.

4.3 Sample Populations

4.3.1 Selection

Skeletal collections were selected for inclusion in the current research on the basis that they met certain criteria directed towards answering the research objectives. The most important consideration was that a sufficiently large sample of very young individuals could be analysed to provide significant results and allow the author to draw constructive conclusions. For this reason, smaller collections or those with few very young individuals were not included in the study. Primarily, a collection had to include a significant proportion of very young individuals, with preference given to collections that included more than 30 individuals aged less than one month postnatal, including premature and fetal individuals. Exceptions to this size limitation were made for documented reference collections.

In order to move towards an understanding of how past communities were impacted by and responded to perinatal mortality, those collections that were derived from distinct, stable past populations were selected. These were anticipated to be representative of populations that were less likely to have experienced high inter-population movement of individuals. The author's intention was to limit the variability introduced by large fluid populations, thereby allowing conclusions to be specific for each population studied.

The preservation condition and completeness of the skeletal remains was another consideration in the selection of curated collections. Skeletal elements needed to be in a good state of preservation in order to conduct a thorough osteological analysis without causing damage to the remains. Although it is possible to identify pathology on fragmented and poorly preserved skeletal remains, if only a few elements or regions of the individual's skeleton are represented any conclusions drawn from the analysis will be limited. Within suitable collections, individuals were prioritised for analysis on the basis of completeness.

Preference was given to collections derived from archaeological burial populations for which there is associated information on the social and cultural context. Medical and mixed context reference collections were incorporated into the research to provide a basis for the comparison of pathological conditions and biological development.

The identification of specific observed pathological expressions was not always possible as some of the key reference collections derive from mixed contexts that are incompletely documented. For this reason, accurately documented reference samples from modern clinical pathology were incorporated as a check against curated documented collections. The use of documented reference collections also allowed the author to test the accuracy of the osteological methods used on archaeological remains for estimating age at death. Table 4.2 provides a list of collections with details of the type of collection and the number of individuals analysed during the current research.

If the collections included in the current research were analysed using only the evidence from mixed source reference collections with unreliable documentation, the results would necessarily be a reflection of the range of pathology and development expressed in those reference collections (Bocquet-Appel and Masset, 1982; 1985). By using accurately documented medical cases in conjunction with other reference collections to define and describe specific skeletal pathologies, this risk is significantly reduced. It is anticipated that the varied reference sources incorporated into the present research will lead to the results being a closer approximation of the age and health of the very young individuals analysed.

For the collections that include adult skeletal remains, information on general population health and development was drawn from the relevant published site and osteological reports. The adults from two of the smaller collections (Gussage All Saints and Yewden villa) were re-analysed during the current research as were the ten females identified as victims of maternal mortality within the collections (Ardreigh, Barton Court Farm, Çatalhöyük, Wetwang Slack and Wharram Percy).

Table 4.2. Collections included in the research with the number of individuals analysed. (denotes adult individuals who were not identified as victims of maternal mortality).*

Collection	Type	Period	Very Young Individuals	Adults
Ardreigh, Ireland	Archaeological	Medieval	87	3
Barton Court Farm, Oxfordshire	Archaeological	Roman	55	2
Çatalhöyük, Turkey	Archaeological	Neolithic	86	1
Gussage All Saints, Dorset	Archaeological	Iron Age	35	9*
Wetwang Slack, Yorkshire	Archaeological	Iron Age	36	2
Wharram Percy, Yorkshire	Archaeological	Medieval	83	2
Yewden Villa, Buckinghamshire	Archaeological	Roman	56	3*
Scheuer, Dundee	Reference (mixed context, partially documented)	Mixed	29	NA
Royal College of Surgeons, London	Reference (documented)	Mid-late 20th century	199	NA
Clinical (UK)	Reference	21st century	5	NA
Total			671	22

The selection of sample populations as outlined above intentionally places restrictions on the type of population that was analysed in the process of the current research. In spite of these restrictions, once a collection was selected for analysis, as many of the very young individuals were analysed as possible. In the majority of cases this included every individual aged under six post-natal months at time of death, and in smaller collections, all individuals were analysed regardless of age at death. This broader inclusion for analysis was undertaken to provide a general overview of population health and physiological stress. It also takes into account epigenetic influences on the genetic control of development by comparing appearance and completeness of skeletal remains for all individuals within burial populations. This may perhaps enable the differentiation of these influences from older childhood growth and development. A large sample size within each burial population is likely to reflect the skeletal variation of genetic expression, and may also allow for the identification of uterine and post-uterine influences on genetic predisposition.

4.3.2 Preliminary Analysis

The preliminary analysis involved assessing the skeletal remains for their suitability to the research. This included identification and confirmation of the number of individuals represented in each collection, their approximate age at death, completeness of each skeleton and its state of preservation. The condition of the skeletal remains was determined using a scale that considers several aspects of each element; cortical and metaphyseal surface appearance, visibility of surface features, survival of trabecular bone, and the presence of epiphyses (Table 4.3). The metaphyseal surfaces of the developing skeleton have a much more porous appearance compared with the cortical surfaces and are usually darker in appearance as a result of variable mineral staining.

As noted above, the preservation condition of developing skeletal remains is expected to be similar to that of contemporary adult skeletal elements from the same burial contexts. Despite similar preservation conditions, the skeletal remains of very young individuals are more susceptible to post-excavation damage through mishandling and incorrect storage. This is especially the case when skeletal elements are stored in a single container without protective wrapping or separation. Unfortunately, the author has observed collections that have been curated without the removal of heavy clumps of sediment. This resulted in crushing of fragile elements and fragmentation of elements partially enclosed in the sediment clumps. If the skeletal elements were too fragile or fragmentary during preliminary analysis, the individuals were excluded from further analysis. In cases where handling and analysis was likely to cause further damage, age was estimated by comparing element dimensions and development within the collection and any visible pathological conditions were noted.

Table 4.3. Preservation condition scale for skeletal remains (adapted from McKinley, 2004).

Condition	**Description**
Excellent	Cortical and metaphyseal surfaces intact, surface features clearly visible, presence of epiphyses
Good	Minor erosion of cortical and metaphyseal surfaces, surface features clearly visible, trabecular bone intact, presence of epiphyses
Fair	Moderate erosion of cortical and metaphyseal surfaces, moderate erosion of surface features, minor erosion of trabecular bone, presence of epiphyses with surface erosion
Poor	Extensive erosion of cortical and metaphyseal surfaces, surface features not visible, moderate erosion of trabecular bone, absence of epiphyses
Very Poor	Extensive erosion of cortical and metaphyseal surfaces, complete erosion of trabecular bone, absence of epiphyses

Following an initial estimation of age, the completeness for each individual could be determined as a percentage of the expected skeletal complement (Baker *et al*., 2005; Scheuer and Black, 2000, 2004). The number of expected skeletal elements used to calculate completeness of the remains is dependent upon age but is also influenced by individual variation in the number of smaller elements and timing of appearance (Baker *et al*., 2005; Fazekas and Kósa, 1978; Scheuer and Black, 2004). For the majority of individuals recovered from archaeological contexts, the expected skeletal complement is usually greater than the number of observed elements. This may arise through misidentification, fragmentation, and non-recovery from the burial environment. Where incomplete and fragmented elements were recovered for an individual, comparison with the remainder of the skeleton was undertaken to ascertain the number of complete elements represented; completeness was predominantly the initial calculation in the analysis of cranial vault elements. It was not uncommon to identify additional individuals through this process. The number of additional individuals represented by the fragmented or extra skeletal elements was calculated using a minimum count for each element in conjunction with comparison of size and condition, and with reference to the burial context.

Although the expected skeletal complement is used to calculate completeness of individual remains, it is not expected that any individual recovered from an archaeological context will be complete, unless it was deposited in a primary, undisturbed burial. It is the author's experience that even in primary undisturbed burials, many of the more fragile cranial elements do not survive the archaeological environment intact and may be difficult to identify from surviving fragments. It is anticipated that for the majority of individuals from curated collections, few of the very small elements, such as epiphyses and ossification centres, will have been correctly identified and recovered.

In several archaeological collections it was necessary to undertake cleaning, identification and correct storage prior to analysis. This was often the case when the skeletal remains were in their excavated state and at significant risk of considerable damage. Techniques such as dry brushing were used to clean skeletal elements enclosed in sediment. Where the sediment was consolidated, it was left unsealed within a controlled environment for 24 hours to assist in cleaning. The atmospheric humidity softened the sediment allowing any bone contained within it to be more easily removed without damage. In order to maintain their condition, skeletal elements were identified and curated following professional guidelines for the curation of human skeletal remains (Roberts, 2009). This process will also enable future analyses to be undertaken with minimal impact to the condition of the skeletal remains by reducing handling.

4.4 Age Estimation

Biological age of the very young individuals was estimated by comparing the skeletal elements with expected growth and development patterns of dentition and the skeleton. These patterns are based upon the documented development of individuals and are described from clinical studies and reference collections (Adalian *et al*., 2002; AlQahtani *et al*., 2010; Bowman *et al*., 1992; Coqueugniot and Weaver, 2007; Demirjian *et al*., 1973; Demirjian and Levesque, 1980; Fazekas and Kósa, 1978; Lewis and Garn, 1960; Liversidge, 1994; Liversidge *et al*., 1998; Moorrees, *et al*., 1963a; Scheuer and Black, 2000; Smith, 1991; Ubelaker, 1987). It is acknowledged that the documented medical history for some of these individuals may be inaccurate or missing. The only accurately documented reference available, in terms of aetiology and skeletal pathology, is derived from current clinical practice; this source of information has been utilised in the current research. Gestation age is usually an approximation, as it is calculated from the point of conception. As such, the ages at death provided for the very young individuals analysed in this research are estimates balanced on the available developmental sequences and intra-population comparisons. A range of appendicular and axial skeletal elements were used to estimate the developmental age of the skeleton, which was then compared with that of the dentition derived using cusp formation and crown coalition. This comparison enabled differential diagnosis of individuals in which there was inconsistent skeletal development. This inconsistency, which was usually represented as a difference of more than four weeks between the estimated developmental age of dentition and infra-cranial remains, was considered to be the result of variable growth influenced by environmental factors.

Multiple methods were applied to estimate age at death from the skeletal remains. These included the presence and morphology of ossification centres, element and epiphyseal fusion, the dimensions of specific skeletal elements, and the development of dentition. To improve the accuracy of the measurements taken, they were also taken for individuals from medical and archaeological collections in which individual age at death was documented. As some aspects of osseous development can be population-specific, comparison between widely disparate samples and comparative collections was avoided. In cases where it was suspected that osseous development was consistently different from that of other populations studied, age estimation was undertaken with reference to developmental sequences and the skeletal development and age indicators of older individuals within the same burial population.

Archaeological collections are generally undocumented in terms of medical history for the individuals they contain. In most of these collections, individual age was estimated using long bone measurements and dental age estimations. As the majority of these individuals are of unknown age at death and sex, there is no way of testing the results for accuracy. This issue can be partially ameliorated by assessing the dental and skeletal age of a large number of individuals of all ages within a burial population, or the entire population where possible. By taking this approach the researcher has the scope to cross-check age estimates between mature and very young individuals, which is more likely to highlight possible endemic sources of error such as shorter adult stature or growth anomalies.

Although reference collections have been used to provide accurate estimates of age, these estimates are not directly transferable to other collections. So, although comparative methods are most widely relied upon for estimating skeletal developmental age in very young individuals, the author acknowledges that they are at best an approximation. It is particularly important in cases where there is evident skeletal pathology or dysmorphy, that modern clinical examples and collections containing very young individuals with documented medical histories are considered in order to strengthen estimates of developmental age for archaeological skeletal remains of the very young.

4.4.1 Estimation methods

It is recognised that development of the dentition is more highly correlated with chronological age and less affected by population variation when compared with age estimation using long bone length (Ubelaker, 1987). Studies of living populations demonstrate that dental age estimates more closely reflect chronological age than do skeletal age estimates (Bowman *et al*., 1992; Demirjian, 1986; Lewis and Garn, 1960; Smith, 1991). This is a strong indication that skeletal development is more susceptible to external factors than is dental development. The estimation of age at death of very young individuals analysed for the current research was calculated using both skeletal development (element metrics, fusion, and element appearance) and dental development (cusp development and fusion, root development, and dental eruption). The raw data collected for each individual analysed is included in the electronic appendices. This information formed the basis for estimating the age at death of very young individuals and also provided detail on metric variation between populations, allowing the identification of potential population-specific skeletal variants and anomalies. The results for each age-at-death estimate were considered within the bioarchaeological context of the remains and in conjunction with any evident pathological conditions.

The current research is focussed on very young individuals, and as such, preference was given to dental crown development for the estimation of dental age. Dental age was not estimated using eruption sequences unless there was clear evidence of dental crown wear or calculus confirming that the tooth had erupted. The *London Atlas of Tooth Development and Eruption* (AlQahtani *et al*., 2010) was used as the standard to estimate dental age of very young individuals. Preference was given to this standard over others because it provides greater detail and narrower age groupings in the final trimester of pregnancy and in the first six postnatal months. Where individual dental development fell between defined stages, a combination of the AlQahtani (2010), Schour and Massler (1941), and Ubelaker (1989) estimation charts was used to find the best fit.

Other methods of estimating the development stage of dentition derive from radiographic studies of modern children (Demirjian, *et al*., 1973; Moorrees, *et al*., 1963a, 1963b), direct measurement of archaeological specimens (Liversidge, *et al*., 1998), or a combination of methods (Liversidge and Molleson, 2004; Ubelaker, 1989). Research into tooth emergence is less relevant to age estimation in very young individuals than dental development, as these studies are usually undertaken on older children (Haavikko, 1970; Hurme, 1948). The estimation of biological age using standards developed from non-modern collections entails some degree of uncertainty as the sample populations used to derive the methods were not necessarily documented and so the results are subsequently limited in their application.

The estimation of skeletal element development relies upon the size and morphology of the element, stage of ossification, degree of fusion (Scheuer and Black, 2000), and the appearance of the bone surface. Skeletal development reference tables are used for comparison when estimating skeletal age, but these carry an inherent error in that many comparative development tables and regressions have been derived from undocumented remains or remains from medical collections. An important example is the skeletal remains used by Fazekas and Kósa, which were selected from stillborn and neonatal cases for which there was no evident skeletal or systemic pathological condition noted, yet cause of death was not identified. Fazekas and Kósa (1978) acknowledge the limited applicability of their findings to other collections and populations based upon their selective use of fetal and neonatal skeletal remains. Despite this considerable limitation, the dimension tables produced by Fazekas and Kósa continue to provide the basis for age estimation in very young individuals in the principal reference resource currently available for the juvenile osteology (Schaefer *et al*., 2000). This highlights the need for further development in this area to consolidate our knowledge and improve upon resource applicability.

4.4.2 Age Categories

A consistent nomenclature for age categories is important when undertaking inter-population comparisons. Although biological age is a direct measurement of physical development, it is often confused with social and cultural terminology. As a result, there is considerable variation in published age categories, especially when referring to very young individuals. This can be a limiting factor when undertaking comparative studies from the literature (Lewis, 2007; Scheuer and Black, 2004). The lack of consistency in age categories is an ongoing dilemma in current research and literature across various disciplines (Lewis 2007; Zuckerman *et al*., 2014), however it is becoming standard practice to define age categories to allow for conversion. The present research employs the age categories listed in Table 4.4. These are derived from clinical and archaeological age categories, but give preference to the biological changes in skeletal development while deliberately avoiding any perceived connections with socio-cultural interpretations. The age categories have been defined to allow for sufficient distinction between the development ages undergoing the most rapid skeletal changes.

Table 4.4. Age categorisation terminology used in the current research (adapted from Schaefer et al., 2009).

Category	**Biological Age**
Fetal	< 23 weeks gestation
Perinatal	24 – 40 weeks gestation
Neonatal	Birth – 27 days
Infant	1 – 12 months
Early Child	1 – 6 years
Late Child	7 – 12 years
Adolescent	13 – 17 years
Young Adult	18 – 25 years
Middle Adult	26 – 35 years
Older Adult	36 – 45 years
Mature Adult	46+ years

Those that were born full-term, but may not have survived as long as one month are referred to as neonates. Younger individuals will be referred to as perinatal unless their skeletal development indicates an age younger than 23 gestational weeks, in which case they are fetal. Where the estimated age at death is older than one postnatal month but less than one year, individuals are referred to as infants. This grouping of ages is predominantly one that enables analysis and comparison. The author acknowledges its limitations and that a proportion of the individuals analysed are likely to have incorrect age estimates. The scope of the current research and the analytical means employed do not include definitive testing, which may still result in a considerable margin of error as is expected when working with undocumented remains.

The approach taken in the current research of using comparative developmental ranges derived from known-age collections and clinical studies, provided a probable age range based upon the appearance and fusion of ossified elements, in conjunction with the development stage of the dentition. Further comparative analysis was undertaken within populations to identify indicators for the presence of population-specific variation in biological age. This is an important consideration in limiting the error inherent in the use of standard comparative populations that are not directly comparable to the populations being studied. Intra-population comparisons of skeletal development provided a population-specific context for the interpretation of estimated ages derived from skeletal element measurements.

4.5 Palaeopathology

To clarify and describe diagnostic features for differentiating between normal and pathological appearance of fetal, neonatal and infant skeletal elements, the current research focuses on the skeletal development of young individuals recovered from archaeological contexts. The lack of consensus within the field of palaeopathology with regard to the identification and description of skeletal pathology in very young individuals (Brickley and Ives, 2006; Dawson, 2014; Lewis, 2004) is a considerable limitation to furthering our understanding in this area of research (Zuckerman *et al*., 2014). During the early stages of skeletal development normal ossification processes can result in bone surfaces that appear pathological (Scheuer and Black, 2004), while the same appearance in older individuals is likely to be pathological. This highlights the importance of differentiating between normal, healthy osseous development and pathological osseous response in the skeletal remains of very young individuals.

4.5.1 Identification and description

The accurate description of observed skeletal pathology is an important part of the current research. It will inform the differentiation between normal development and pathological response. The ossification processes involved in the development of the juvenile skeleton include stages with a bone surface that may have a similar appearance to a pathological response; both are rapidly forming woven bone. This has the potential to lead to confusion in the differential diagnosis of pathology in very young individuals. As the skeletal development in very young individuals is rapid, the changes observed in the skeletal remains of these individuals present a unique opportunity to distinguish between normal and disrupted ossification.

All palaeopathological changes observed in the skeletal remains were identified by skeletal region, and the type and form of osseous response was described using standard terminology (Ortner, 1994). Areas of bone affected by lesion activity were measured (area and lesion depth) and photographed. Figures 4.1, 4.2 and 4.3 illustrate the range in appearance of the endocranial surface of three cranial vault elements: the frontal, parietal, and occipital squama. These examples are from neonatal skeletal remains recovered from archaeological contexts. As the developing elements have different surface appearances and textures depending on the stage of development and the specific element, the accurate identification of skeletal element fragments is very important. Familiarity with the range of surface appearances in a single element will enable the researcher to accurately identify the elements represented in fragmentary remains and to differentiate pathological from non-pathological surface appearance.

Figure 4.1. Variation in endocranial surface appearance in the neonatal frontal (top: Wetwang Slack Sk. 389, Barton Court Farm Sk. 869, Ardreigh Sk. 956; bottom: Wharram Percy Sk. NA149B, Ardreigh Sk. 1255, Wharram Percy Sk. NA193).

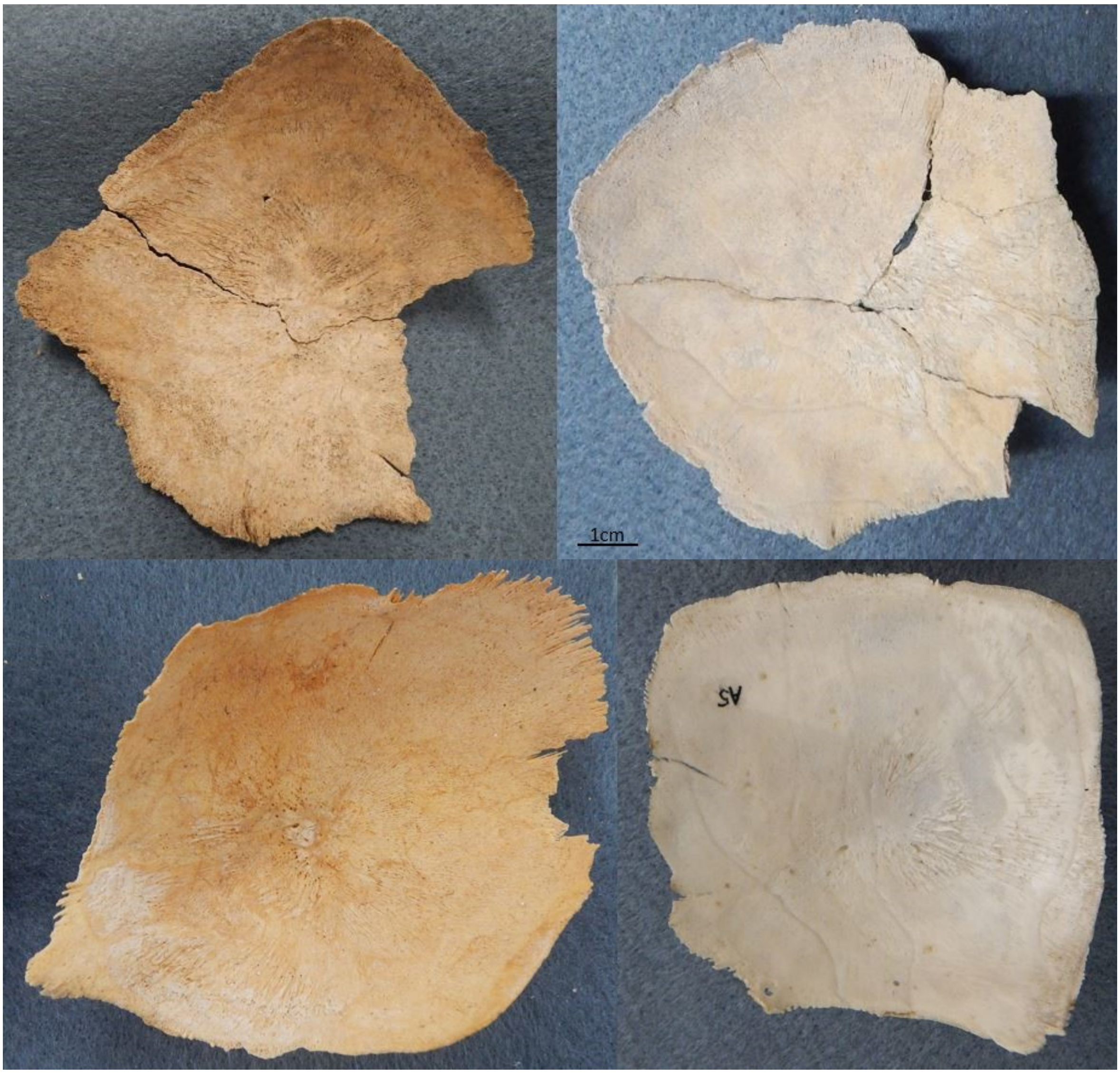


Figure 4.2. Variation in endocranial surface appearance in the neonatal parietal (top: Ardreigh Sk. 1956 and Wharram Percy Sk. NA193; bottom: Scheuer Sk. 161 and Sk. 5).

As the skeletal remains of very young individuals are frequently fragmentary, the first step in considering possible pathology is to correctly identify the fragments to element. Following this, the appearance of the fragment can be considered with reference to the normal appearance for that element. For example, the ectocranial surface of the temporal squama has a significantly rougher and more porous appearance compared with the frontal or parietal. Misidentification of a temporal fragment as belonging to either the frontal or parietal would lead the observer to erroneously consider the fragment as displaying a pathological bone response. Equally, sound knowledge of the soft tissue anatomy and attachment sites in relation to skeletal elements is also vital for understanding the implications of changes in skeletal morphology.

Figure 4.3. Variation in endocranial surface appearance in the neonatal occipital (top: Scheuer Sk. 5 and Ardreigh Sk. 1270; bottom: Gussage All Saints Sk. 661 and Barton Court Farm Sk. 1256).

Prior to the analysis of archaeological collections, the author undertook a study of the various developmental pathologies that affect the skeleton, including the morphology and physiological impact of pathological changes. This research incorporated medical pathology collections, consultation with clinical specialists and reference volumes for specific skeletal pathologies in very young individuals (Barnes, 1994; Hall *et al*., 2012). A knowledge of the breadth and form of fetal skeletal pathologies was instrumental in that many of the extreme pathological expressions of fetal elements would not have been recognised otherwise. The intention of this additional area of research was to identify, in curated collections and during excavation, evidence for extreme conditions that would have been non-viable and therefore provide a possible means for determining cause of death.

4.5.2 Differential diagnosis

Differential diagnosis was primarily undertaken for very young individuals displaying skeletal pathology. Clinical parallels, perinatal pathology reports and documented archaeological specimens provided reference material for the consideration of aetiologies. This reference material included the works of Aufderheide and Rodriguez-Martin (1998), Brickley and Ives (2006), Lewis (2004), Ortner (2003), and Scheuer and Black (2004). The aetiology of known pathological conditions was also taken into consideration when proposing interpretations of the empirical data within the context of each burial population. For the skeletal remains of very young individuals that did not display overt skeletal pathology but were estimated to have died prior to full-term, possible prematurity was considered a contributing factor to their deaths. It is also possible that these individuals may have experienced restricted intrauterine growth.

4.6 Summary

The bioarchaeological approach to the research incorporated several analytical methods including osteological analysis, skeletal development, developmental and acquired skeletal pathology, and the socio-cultural context of burial for very young individuals. The provision of clear descriptions of the methods used, and consistent terminology and recording, ensure that the research can be replicated and that the raw data can be incorporated into future analyses. The development and use of age-specific skeletal recording plans and inventories for very young individuals allowed a detailed record to be made of the skeletal remains and any associated pathology.

Chapter Five

Results

5.1 Introduction

This chapter presents a summary of general results from the skeletal analysis of the burial populations from archaeological contexts. The results provide general skeletal information for each population with the focus of each pathology section placed on the adult individuals. Any published details regarding the pathology of the burial populations have been included and new observations have been added to the information currently available. Key aspects of the skeletal remains that are fundamental considerations in the interpretation of skeletal pathology, such as preservation and age at death, are discussed in this chapter.

5.2 Preservation Condition

In the present work, the condition of skeletal remains refers to the state of the skeletal elements following excavation and curation. The preservation condition can be reasonably expected to remain stable following the best practice recommendations for cleaning, curation and maintenance of human skeletal remains (BABAO Working-group for ethics and practice, 2011; Roberts, 2009). Curated skeletal remains are at most risk of damage during periods of handling, provided that they are stored appropriately. The condition of the skeletal remains included in this study was assessed during analysis through the macroscopic examination of bone surfaces for degradation and damage.

The individuals analysed displayed a range of post-excavation damage from minor fragmentation of flat and long bones, to crushing of elements and cortical degradation from acidic packaging. Unfortunately, the majority of damage observed appeared to result from unsuitable packaging and storage. The remains of very young individuals were often stored in boxes that were too small for the entire skeleton to fit comfortably causing elements to fracture when forced to fit. Fragile elements were regularly found to have been placed under heavier elements, which contributed to crushing and fragmentation. In the Ardreigh and Wharram Percy collections it was common to find that the remains of very young individuals had been packaged in the recommended plastic bags, but had then been placed at the bottom of a full size human remains storage box with adult remains overlying them. Occasionally the remains of very young individuals were stored loose within a box that also contained burial inclusions such as stones, iron and ceramic objects, and faunal remains.

Many of the skeletal remains in the Wetwang Slack collection had been packaged inappropriately without being cleaned. In this collection, large consolidated lumps of sediment containing skeletal remains were bagged together with fragile loose elements, resulting in crushing and further fragmentation of the remains. The complete lack of appropriate protective packaging and storage, and the placement of heavier objects over fragile bones has resulted in considerable damage to the skeletal remains held in this and other collections. This unfortunate circumstance may be a reflection of an historical perception of the relative insignificance of very young individuals in relation to those of older individuals and other objects of material culture recovered from archaeological sites. During access to the collections, the author documented current states of preservation and improved the packaging of skeletal remains where required.

All but one of the archaeological collections analysed are static curated collections that are primarily accessed for research. The Çatalhöyük collection is the exception to this as it increases annually with newly recovered skeletal remains from the active excavation project taking place at the site. Reference collections, by their nature, also tend to increase their holdings over time as new specimens are added. While the Çatalhöyük collection is only accessed for research, the reference collections are used for teaching as well as independent research. It was anticipated that all of the collections would have a low level of damage resulting from handling, but as handling is usually supervised or undertaken by individuals with expertise, this damage should be minimal. As described above, the author observed considerably more damage than expected, indicating that there is scope for improvement in both policy and practice relating to the storage and handling of curated human skeletal remains within these collections.

A condition score was determined for each individual analysed according to the criteria in Table 4.3. As the bone surfaces of developing skeletal elements are immature and there are often multiple surface appearance types within one element, the preservation condition was assessed as a whole for the skeleton. It was anticipated that any significant variation within the skeleton would be noted as a separate score. The condition scores for the skeletal remains analysed ranged from excellent (1) to very poor (5), however there were no instances where the condition was too poor for the positive identification of an element. The scores for each individual are provided on their respective records within the database.

The condition of developing skeletal remains was the same if not slightly better than that of the adult remains in all of the archaeological collections analysed. This difference in condition is likely to be a result of the adult remains being handled more frequently than the remains of younger individuals. In the Gussage All Saints collection, the adult remains were in considerably poorer condition than those of the very young individuals. This appears to be a direct result of differences in the packaging; the remains of very young individuals were stored individually in small boxes without packaging while the remains of adults were wrapped in newspaper (from 1972!) within their storage boxes. The acidity of the newspaper in close contact with the adult remains has caused significant deterioration of the cortical surfaces. The remains of very young individuals, although loose within each small box, have been stored within locally isolated stable environments and have a much better condition by comparison. The storage facilities for four of the collections analysed are also subject to considerable seasonal variation in temperature and humidity. Unstable storage environments will affect the preservation of curated skeletal remains over time.

5.3 Completeness

Completeness of skeletal remains is a reflection of several factors related to the body prior to deposition, its survival in the burial environment, and its later excavation. The recovery of skeletal elements through excavation is dependent upon the expertise of the excavator, the methods used, and the type of deposition. Recovery of adult skeletal remains from articulated burials is primarily affected by soil composition, erosion and the disruption by subsequent animal or human activity. Where survival in the burial environment is good, it is usual to recover a large percentage of the adult skeleton from an articulated primary burial.

Although the majority of the very young individuals analysed were articulated primary burials, it is not uncommon to find incomplete skeletal remains that have been previously disturbed. This is usually the result of subsequent grave digging and filling that leads to disarticulated elements being included in the fill of primary burials. Disarticulated elements within the fill of articulated burials suggest that graves within a defined burial ground were not permanently marked and that bodies may not have been protected within the grave however, it should be considered that burials may have been marked by other means, including the use of degradable materials. Continued occupation and agricultural activity, such as ploughing, also contribute to the disruption of archaeological contexts and the distribution of skeletal remains over a wider area.

Where it was evident that single skeleton numbers included the remains of more than one individual, an additional skeleton number was recorded (e.g. 285.2 or 34.1b). It has been possible to identify several very young individuals within the disarticulated remains analysed for the current research and to re-associate some disarticulated elements with articulated individuals. The disarticulated remains that cannot be separated as individuals have been considered in terms of minimum number of individuals (MNI). The majority of skeletal remains analysed for the current research represent single individuals despite many being incomplete at the time of excavation. Where a very young individual was less than 25% complete but did not match individuals with missing elements, or other disarticulated remains, it was included in the analysis as a separate skeleton number. In some collections disarticulated remains were curated according to context rather than individual and are likely to represent more than one individual.

Skeletal completeness for the individuals analysed in each collection is provided below in Table 5.1. Most very young individuals were missing the smallest elements such as distal phalanges, sacral arches and tooth buds, indicating that recovery of the smaller skeletal elements was incomplete at the majority of sites. The completeness for all individuals included in the analysis is provided in the respective records within the database.

Table 5.1. Skeletal completeness of the very young individuals in the archaeological collections analysed.

Collection	**< 25%**	**25% – 50%**	**50% - 75%**	**> 75%**
Çatalhöyük	11 (13%)	16 (19%)	31 (36%)	28 (32%)
Gussage All Saints	19 (54%)	4 (12%)	12 (34%)	-
Wetwang Slack	24 (67%)	7 (19%)	4 (11%)	1 (3%)
Barton Court Farm	23 (42%)	8 (15%)	4 (7%)	20 (36%)
Yewden Villa	37 (66%)	13 (23%)	6 (11%)	-
Ardreigh	13 (15%)	21 (24%)	24 (28%)	29 (33%)
Wharram Percy	5 (6%)	33 (40%)	37 (45%)	8 (9%)
Total (of 438)	**132 (30%)**	**102 (23%)**	**118 (27%)**	**86 (20%)**

5.4 Age Estimation

The skeletal remains of all individuals that died prior to six postnatal months, including pre-term individuals, formed the primary dataset for analysis within the current research. Where possible, older infants that died in the second half of their first year were also examined for evidence of skeletal pathology, developmental delays and non-metric traits. The number of individuals in each age category is provided below in Table 5.2. For the purposes of this study, any individual with an age at death of 37 weeks *in utero* or less was considered to be non-viable at birth based upon the under-development of vital organs and the absence of medical support. Neonatal research has shown that there are still considerable complications from immaturity at 38 weeks and that babies born between 39 and 40 weeks are more likely to be viable (Clark and Fleischman, 2011; Sengupta *et al*., 2013). Given this understanding of the risks of prematurity and the calculation of approximate age at death for perinatal individuals, it is highly unlikely that all individuals dying between 38-40 weeks were viable at birth if live-born, regardless of pathology. This further impacts the interpretation of infanticide on the basis of high perinatal and neonatal mortality recorded for individuals within this age range, a topic that will be discussed in Chapter 8.

Table 5.2. Number of very young individuals analysed in each collection, by age category.

	Fetal	Perinatal	Neonatal	Infant				Total
Collection	(<23w)	(24-40w)	(41w-0.9m)	(1-2.9m)	(3-5.9m)	(6-8.9m)	(9-12m)	
Ardreigh	1	29	27	10	11	5	4	87
Barton Court Farm	0	44	7	0	3	1	0	55
Çatalhöyük	0	63	6	5	7	5	0	86
Gussage All Saints	0	32	3	0	0	0	0	35
Wetwang Slack	0	16	15	0	2	1	2	36
Wharram Percy	0	31	18	17	12	5	0	83
Yewden Villa	0	51	2	0	1	0	2	56
Clinical	0	5	0	0	0	0	0	5
RCS	169	9	21	0	0	0	0	199
Scheuer	4	18	3	1	0	2	1	29
Total	174	298	102	33	36	19	9	671

As discussed above in Chapter 4, the estimation of juvenile age at death is dependent upon many contributing factors and can be heavily influenced by the reference collection used to determine comparative tables and regression equations. For adults these comparative statistics are usually derived from modern reference samples (Genovés, 1967; Trotter and Gleser, 1958; Trotter, 1970), but even these have been demonstrated to be problematic (see White and Folkens, 2005). Consideration of the appropriateness of the comparative population to the sample being analysed is essential in identifying the best fit. The most comprehensive comparative tables for the analysis of juvenile age at death are provided by Schaefer *et al*. (2009). These tables were calculated from modern and historic populations dating from the 18th to the 20th century AD, using dry bone from fetal autopsy and cemetery samples as well as radiographic studies on living individuals (Black and Scheuer, 1996; Fazekas and Kósa, 1978; Maresh, 1970; Molleson and Cox, 1993; Saunders *et al*., 1993; Scheuer and MacLaughlin-Black, 1994).

Population-specific stature trends should also be considered when estimating age for juvenile skeletal remains from diaphysis length. An approximation of age at death for perinatal individuals and young infants may be over- or under-estimated if the population has an optimal adult stature that is taller or shorter than average, respectively. For this reason, the age at death distribution for very young individuals has been interpreted within the context of the adult stature and general population pathology for each collection.

5.5 Collections

The remainder of this chapter provides details of the skeletal and dental pathology for adults and sub-adult individuals aged over one year in each archaeological collection. The information is drawn from both published osteological reports and observations made during the analysis.

5.5.1 Çatalhöyük

5.5.1.1 Age Estimation

Nineteen of the 86 sub-adult individuals in the Çatalhöyük collection that were analysed for the current research display disparities between the age estimations based on dental development and those based on the development and fusion of the remainder of the skeleton (Table 5.3). This was not observed in the other collections in such numbers or with such substantial differences in estimated ages. Two individuals have dental development ages that are considerably older than the age at death indicated by the development and fusion of the remainder of the skeleton. Seventeen other individuals have dental development ages that are younger than those indicated by the remainder of the skeleton. These age estimation disparities are likely to be a reflection of the Çatalhöyük population's physiological response to environmental stress, a point that will be considered in Chapter 8, and the genetic influences on stature.

Table 5.3. Age estimation disparities between dental and skeletal development for the very young individuals in the Çatalhöyük sample.

Skeleton	**Dental Age**	**Skeletal Age**	**Skeleton**	**Dental Age**	**Skeletal Age**
1498	6-9m	14m	10390	30-34w	38-40w
1916	3-6m	9m	10391	30-36w	40w
1950	3-6m	0-1m	12506	30-34w	38-40w
2532	3-6m	1-2m	12542	34-38w	40w
10333	30-36w	38-40w	12570	30-34w	40w
10335	30-36w	38-40w	13395	30-34w	36w
10361	30-36w	38-40w	14005	34-38w	40w
10366.1	28-34w	38-40w	14101	34-38w	40w
10368	30-34w	38w	15739	30-34w	38-40w
10389	30-34w	38-40w			

To assess the age at death for these individuals, an overall age estimate for each individual was reached by considering the skeletal development in conjunction with any pathology and giving more weight to the estimate provided by dental development. The majority of dental and skeletal age estimates were in agreement or had a degree of overlap in the range of estimated age. For individuals with age estimates that had minimal overlap, the age that both estimates had in common was taken as the most likely age at death. The age-at-death distribution for the very young Çatalhöyük individuals analysed is provided in Figure 5.1.

There have been over 500 individuals recovered during excavation (Hillson *et al.*, 2013; Haddow, 2014; 2015; and 2016), of which at least 150 are individuals aged under one year. The youngest individual analysed in the collection to date was approximately 26 weeks gestation and a further 17 individuals had died at or before 36 weeks gestation. The remaining 45 perinatal individuals in the analysis sample were aged 37 to 40 weeks gestation. Any existing skeletal pathology in very young individuals as well as the population specific adult stature range should be considered for their possible impacts upon growth and development in very young individuals

It may be argued that the occurrence of very young individuals with advanced skeletal development relative to their dental development is a reflection of a population that is genetically taller than average. This does not appear to be the case for the population sampled at Çatalhöyük. In a study of the adult skeletons, Larsen *et al.* (2015) concluded that the individuals from Çatalhöyük were relatively short in stature in comparison with other Neolithic populations. The average stature for adult males is

164cm (n=56) and 153cm (n=57) for females (Hillson *et al*. 2013, 370). The comparative Neolithic samples provide estimated average male stature between 161cm and 171cm (n=344), and average female stature between 152cm and 158cm (n=261) (Hillson *et al*., 2013). Although the adult population exhibit average statures that are slightly shorter than the period average for each sex (male 166cm and female 155cm), they do still fall within the expected range. Larsen *et al*. (2015) comment that the environmental conditions enabled normal growth and development within the Çatalhöyük community, however their study did not include individuals younger than six postnatal months.

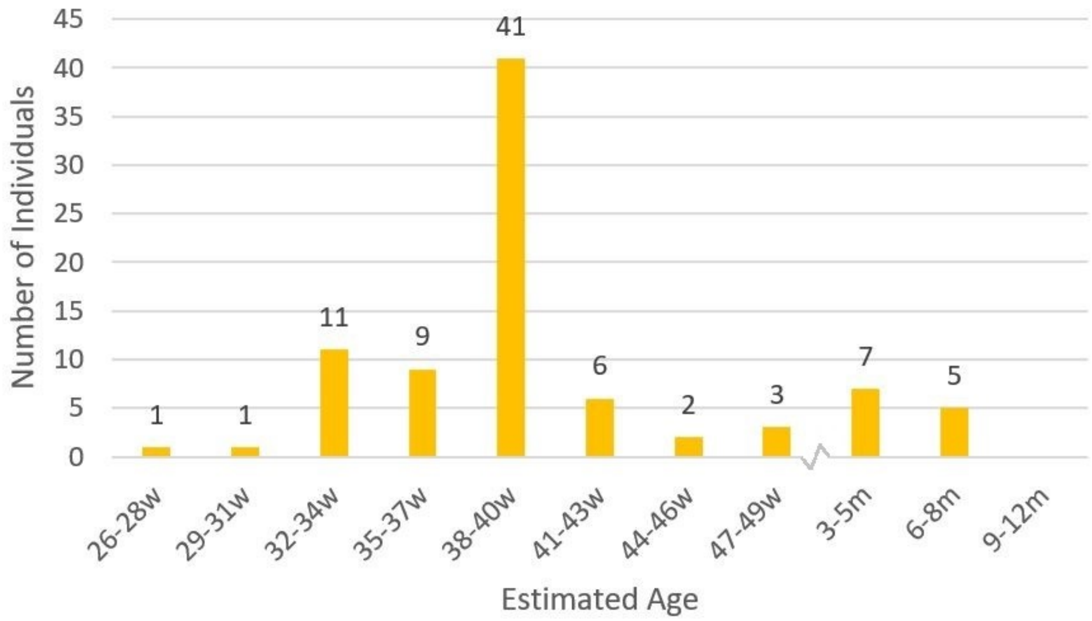


Figure 5.1. Age-at-death Distribution of the Neolithic sample from Çatalhöyük, Turkey.

5.5.1.2 Population Pathology

Cranial

Dental pathology in the form of carious lesions was observed within the burial population at Çatalhöyük. Although these lesions have been observed in deciduous dentition, they are predominantly found in permanent dentition, suggesting relatively poor oral hygiene with cumulative effects in older individuals. Carious lesions have been analysed in the permanent dentition of a subsample of individuals from the burial population. Within the subsample analysed, no carious lesions of the permanent dentition were observed in adolescents, however the permanent teeth of adults had carious lesions that affected more than one surface of the affected tooth (370/1124, 33% of young adults; 423/1124, 37% of middle adults; and 228/1124, 20% of older adults) (Hillson and Boz, 2013). There is a strong correlation between the presence of dental caries and individual age (Hillson and Boz, 2013), inferring cumulative effects of diet and oral hygiene. No other significant dental pathologies have been published from the Çatalhöyük burial population. The dental pathology of the Çatalhöyük adults is most plausibly related to cariogenic elements of the diet, particularly processed starches, in conjunction with moderate levels of oral hygiene.

Post-Cranial

Periosteal lesions were present in 12% (20/166) of adults and 17% (38/213) of sub-adults (Sadvari and Larsen 2013). Of those individuals with periosteal lesions, approximately half had multiple lesions that were suggestive of systemic conditions, while the remainder of individuals had isolated lesions that most likely formed in response to non-specific infection and injury. Larsen *et al*. (2015) note the increasing frequency of degenerative joint disease (DJD) with age among the adults, which is not unexpected for activity-related pathology within an agricultural community. Larsen *et al*. (2015) also comment on the unusually high prevalence of periostosis in neonates (19.8%) and infants (30.6%) compared with older sub-adults (6.5% and 14% for children and adolescents respectively). Although presumably unconnected with the aetiology of sub-adult periostosis, it is interesting that there is a higher frequency of periostosis among sub-adult individuals that were buried in 'history houses' compared with the rest of the burial population (Larsen *et al*., 2015). It is possible that the community associated burial locations with particular visible pathologies, although further research would be required to confirm a connection between individual pathology and burial location.

One adult female (Sk. 13162, 25-35 years) sustained significant injuries that resulted in fractures to the left scapula and pelvis. This adult female was buried when pregnant and the analysis of the remains of both mother and full-term fetus will be discussed below in Chapters 7 and 8. The left scapula has a partially healed complete fracture of the acromion process and the pelvic fracture is a bilateral fracture to the pubic rami, also partially healed at the time of death. The similar state of remodelling for these fractures strongly suggests that they were sustained at the same time, possibly in a single event. Fracture of the acromion process can be sustained through "direct impact or forceful abduction of the shoulder" (Dandy and Edwards 2003), while fractures of the pubic rami are associated with direct impact. Although displacement of fractured pubic rami is unusual, injury to the surrounding soft tissues and organs is possible (Dandy and Edwards 2003). Clinical treatment for a fractured acromion is minimal if there is no associated connective tissue injury or displacement of the process (Dandy and Edwards 2003). Although it is expected that such injuries would cause significant pain, neither should result to permanent disability unless there are soft tissue complications. The fractures to the scapula and pelvis of Sk. 13162 had not been previously recognised.

5.5.2 Wetwang Slack

5.5.2.1 Age Estimation

Within the burial population at Wetwang Slack, there were very few adults aged over 45 years at death and none were estimated to be older than 60 years (Dawes, 1981). The percentage of each age group within the burial population (n=429) indicates that the highest mortality risk was experienced in the middle adult age category (Table 5.4). Mature adults appear to be under-represented in the burial population. Dent (1984) calculated life expectancy at birth to be 27.1 years, which corresponds with the highest percentage of the burial population by age category.

Table 5.4. Distribution by age category of the Wetwang Slack burial population.

Age Category	Number of Individuals (% of burial population)
Infants (birth to 11.9m)	54 (12.6%)
Sub-adults (1-16.9y)	64 (14.9%)
Young Adult (17-24.9y)	57 (13.3%)
Middle Adult (25-34.9y)	134 (31.2%)
Older Adult (35-45y)	109 (25.4%)
Mature Adult (45+y)	11 (2.6%)
Total	429

Dent (1984) recorded 54 individuals aged under 12 postnatal months in the collection that had been recovered from both the cemetery and domestic contexts. Three of these individuals could not be located within the collection during analysis. Of the remaining 51 individuals, 15 individuals were excluded from the analysis on the basis that they were too fragile to be handled. Despite this, all fragile remains were visually examined without handling and any evident pathology noted. No metric analysis was undertaken for these individuals. The 36 remaining individuals, consisting of 13 individuals from the cemetery and 23 individuals from domestic contexts, were analysed for the current research.

The analysis revealed that 16 individuals were perinatal (aged 34-40 weeks) and 15 were aged between birth and one month at time of death. No individuals aged less than 34 weeks gestation at death were recovered. Only five infants that had survived past the first postnatal month, but for less than one year, were present in the burial population (Figure 5.2). The age estimates based on skeletal and dental development were consistent for each of the very young individuals analysed in the Wetwang Slack collection (Table 5.5). This indicates that any adverse environmental conditions that may have been present during pregnancy and early infancy did not interfere with the timing of normal skeletal development.

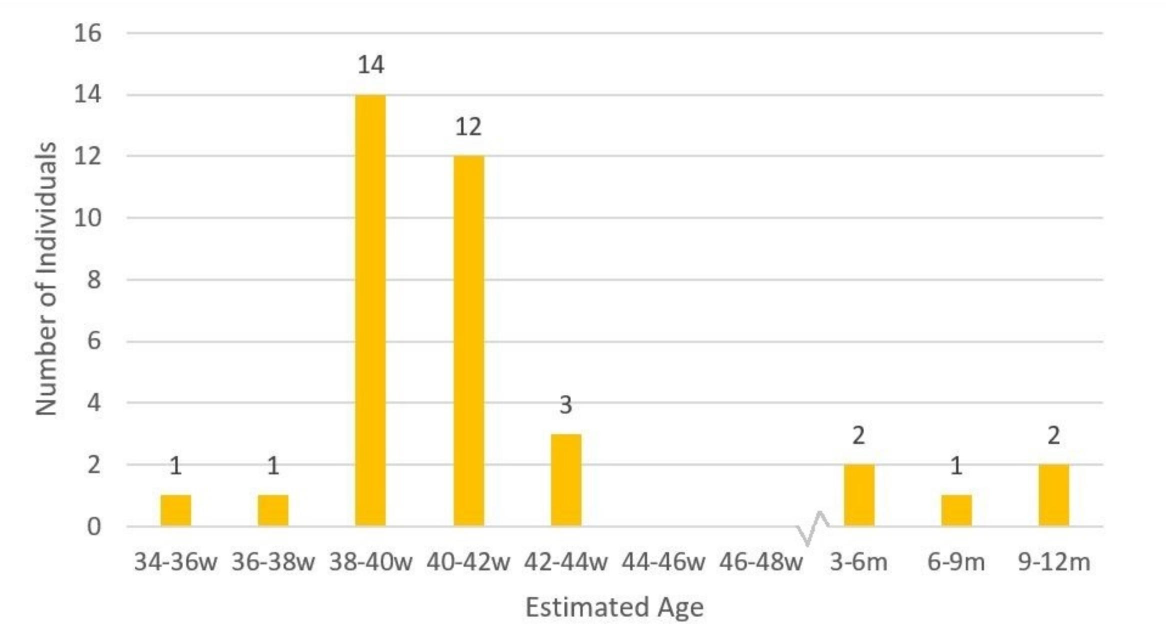


Figure 5.2. Age-at-death Distribution of the sample from Wetwang Slack, Yorkshire.

Table 5.5. Age estimation using dental and skeletal development for the very young Wetwang Slack individuals with dentition.

Skeleton	Dental Age	Skeletal Age	Skeleton	Dental Age	Skeletal Age
22	0-1m	0-1m	174	0-1m	0-1m
52	0-1m	34-38	326	3-6m	40+
78	9-12m	40+	392	0-1m	40
159	0-1m	0-1m	411	3-6m	40+
162	9-12m	12m			

The average adult stature ranges for the two Iron Age burial populations studied are provided below in Table 5.6. Dawes (1981) concluded that the population of Wetwang Slack was shorter in stature than average for the period. However, the stature ranges and averages reported by Roberts and Cox (2003) for the Iron Age in Britain show that the individuals from Wetwang Slack had a wider stature range for both sexes that included several individuals of tall stature. As demonstrated in Figure 5.3, the stature distribution for both sexes contains a larger number of individuals of lower stature than the period range. The few taller individuals of each sex are clear outliers in the stature distribution. This is in contrast to the adults of Gussage All Saints whose attained statures fell within the normal range for the period.

Table 5.6. Adult stature for the burial populations of Wetwang Slack and Gussage All Saints. All heights given in centimetres.

	Male		Female	
	Range	Average	Range	Average
Wetwang Slack (Dawes, 1975-1981 records)	157-184 (n=118)	167	140-170 (n=156)	156
Gussage All Saints (Keepax, 1979)	164-169 (n=3)	166	155-162 (n=6)	157
Iron Age Britain (Roberts & Cox 2003, 103)	164-174 (n=113)	168	154-164 (n=72)	162

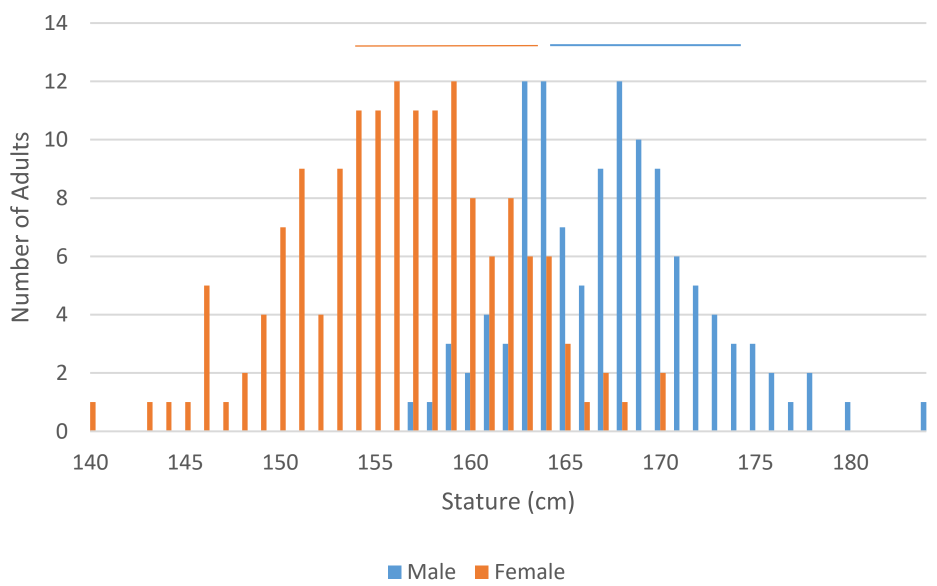


Figure 5.3. Distribution of male and female adult stature in the Wetwang Slack burial population. The horizontal lines mark the Iron Age stature range for both sexes.

Two adult females that had died and were buried while pregnant (Sk. 156, 25-35 years and Sk. 309, 35-45 years). In the case of individual Sk. 156, it appears that the presence of a full-term fetus was only realised following excavation as only two elements are recorded; a neural arch and the proximal half of a perinatal humerus. The second, a premature fetus, was associated with Sk. 309 *in situ* and was given a separate burial number, however this number was not recorded as associated with the mother's burial number and the connection has now been lost. Although this individual's remains cannot be re-associated with the mother's, they are held within the collection. It is not possible to use metric analysis to estimate the age at death of the fetus belonging to individual Sk. 309, however it can be approximated from the notes recorded by Dawes (1978 record cards) in which she documents that "the body of the pre-sphenoid was not fused to the lesser wings and that the temporal wings [greater wings] were also unfused." It is usual for the greater wings to fuse with the rest of the sphenoid body during the first year following birth, however the lesser wings would normally fuse with the pre-sphenoid during the middle of pregnancy (Scheuer and Black 2004). This suggests that individual Sk. 309 may have died during the middle of her pregnancy, an interpretation supported by Dawes.

The age at death distribution of the very young individuals analysed strongly suggests that the majority of pregnancies were carried to term, with the highest mortality occurring in the period from birth to one month. This is a period recognised as one of significantly high morbidity risk to the neonate. Dawes comments (1981, 744) that "it is perfectly reasonable that numbers of stillborn and neonatal deaths would be found in even a tiny settlement where one or more women of child-bearing age resided for a number of years." Following the first postnatal month, there is a marked reduction in deaths until approximately three months. For the remainder of the first postnatal year there is a low occurrence of infant mortality. This low persistent infant mortality is likely to reflect a range of possible assaults on infant immunity and may be associated with the introduction of supplementary foods during weaning.

5.5.2.2 Population Pathology

Cranial

The dental pathology noted in the adult skeletal remains with surviving dentition included caries (108/318, 34%), periodontal disease, dental abscess (52/318, 16%), calculus (201/318, 63%), dental enamel hypoplasia (DEH), and antemortem tooth loss (155/318, 49%) (Dawes, 1981). The effects of periodontal disease were considered to be the main cause of antemortem tooth loss in adults (Dawes, 1981). Two adults had dental enamel hypoplasia (on the incisors and canines of Sk. 309, 35-45 years, and on the premolars of Sk. 156, 25-35 years). In both of these individuals the enamel hypoplasia formed horizontal linear markings on the crowns of teeth, which is the result of an interruption in the formation of the dentine at the developing crown margin. Dentine formation can be affected in this way from a significant episode of physiological stress (Duray, 1996; Goodman and Rose, 1990; Hillson, 1992; King *et al*., 2005; Malville, 1997), with the defect becoming observable as the crown continues to develop. As dental crowns develop in a known sequence, the particular tooth affected and the height of the defect on the crown will identify the probable timeframe for physiological stress encountered during childhood (Hillson, 1992, 1996; King *et al*., 2002; Malville, 1997). This can be estimated for the two women with DEH. Individual Sk. 309 was affected between the ages of two and four years, while individual Sk. 156 was affected between five and seven years, assuming normal timing of dental development.

Post-cranial

Of the adult individuals, approximately one third of each sex had degenerative joint disease and arthroses, especially of the vertebral column, knee, hip, shoulder, hand and foot (Dawes, 1981). Fourteen of these individuals had developed osteoarthritis (Dent 1984). Dawes (1981) also recorded evidence of soft tissue pathology in a few of the adults. This included a psoas abscess of the left ilium (Sk. 386, male 35+ years); a large renal stone (Sk. 215, male 30-40 years); and a calcified teratoma within the abdominal region (Sk. 257, female 20-25 years and Sk. 18, male 35-45 years). She also noted a high concentration of medullary trabeculae that she interpreted as an osseous response to anaemia or infection (Dawes, 1981).

Trauma

There is considerable evidence of healed and partially healed skeletal trauma in the remains of older individuals within the Wetwang Slack burial population. This skeletal pathology sheds light on the forms of injury and ability of the affected to recover. It also demonstrates that there was no evident difference between the sexes in the skeletal trauma sustained. Several individuals sustained ante-mortem fractures to the nose (Sk. 47, male 25-35 years and Sk. 226, female 35-40 years), forearm (Sk.

358, male 25-35 years) and ribs, the majority of which were healed prior to the individual’s death. One adult male (Sk. 307, 25-35 years) sustained a fracture of the left femur with separation of the neck from the diaphysis and involvement of the acetabulum (Dawes, 1981). There was active osteomyelitis at the time of death which would have allowed the infection to drain. Osteomyelitic lesions were also present in the left fibula of individual Sk. 108 (female, 20-25 years) and in the left humeral head of individual Sk. 59 (female, 25-35 years) (Dawes, 1981). Evidence of sharp force trauma among the adult remains includes the cranial fracture of individual Sk. 114 (male, 17-20 years) and, tentatively by association, a spearhead (108mm x 20mm) recovered from the abdominal region of a female (Sk. 211, 25-35 years). Another adult male (Sk. 119, 20-24 years) had evidence of healed blunt force trauma to the cranium (Dent, 1984).

Individual Sk. 156 (female 25-35 years) had sustained a non-displaced fracture of the wing of the right ilium several months prior to her death as there is evidence of healing with a callus along the fracture. An iliac wing fracture is usually the result of a direct force or crush injury, and will heal without intervention unless there are complications from soft tissue involvement (Dandy and Edwards 2003). This adult female was pregnant at the time of her death, and it is possible that the full-term died *in utero* from complications arising from the mother’s injuries.

Congenital Anomalies

Several inherited non-metric traits were observed during the initial analysis of the skeletal material. These include wormian ossicles, persistence of the metopic suture, a caudal shift of the fifth lumbar vertebra (sacralisation), and non-fusion of the lumbar neural arches to the vertebral body (Dent 1984). The observation of these non-metric traits suggests that the population of Wetwang Slack shared a relatively limited gene pool that enabled the repetitive expression of genetically-linked skeletal traits. Individual Sk. 309 displays asymmetry of the lower limbs, with asymmetric articular surfaces of the patellae (greater articular angle on the left side) and of the sacral auricular surfaces (greater degeneration on the right side), indicating a mal-alignment of the hip joints that may have impacted mobility during life.

5.5.3 Gussage All Saints

5.5.3.1 Age Estimation

The burial population of Gussage All Saints included 35 very young individuals and 9 adults. The older individuals examined were aged between 18 and over 50 years at the time of death, however there are no middle adults (25 – 35 years) included in the burial population. Nor were there any individuals aged between one postnatal month and 18 years in the burial population of this phase of occupation. In total, three young adults (Sk. 31, Sk. 62, and Sk. 285), two older adults (Sk. 387 and Sk. 410) and four mature adults (Sk. 139, Sk. 204, Sk. 205, and Sk. 359) were recovered from burials within the settlement site. The age-at-death distribution of the very young individuals is shown below in Figure 5.4. The age estimates based on skeletal and dental development of the very young individuals indicate that there is no apparent disruption between the timing skeletal and dental development (Table 5.7).

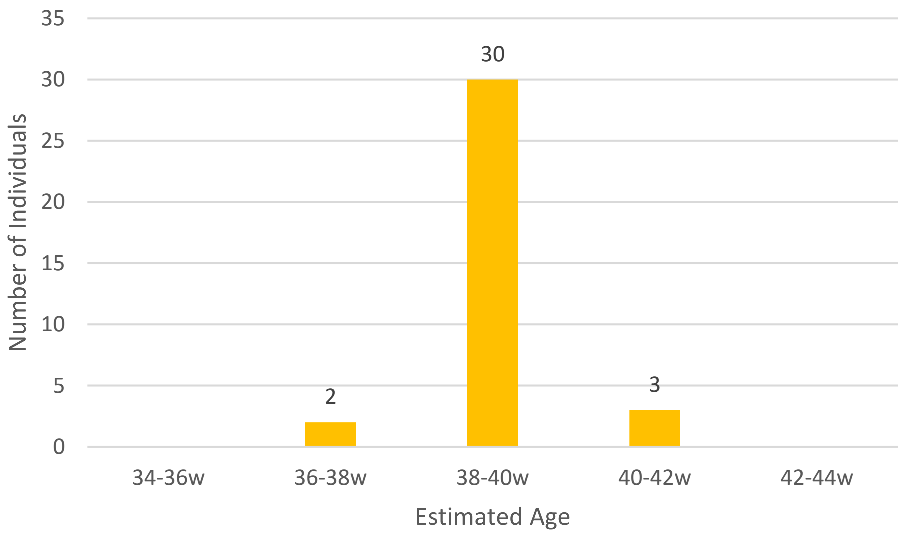


Figure 5.4. Age-at-death Distribution of the sample from Gussage All Saints, Dorset.

Table 5.7. Age estimation using dental and skeletal development for the very young Gussage All Saints individuals.

Skeleton	Dental Age	Skeletal Age	Skeleton	Dental Age	Skeletal Age
130.4	38-40	40	34.3	38-40	38-40
132.10d	38-40	40	96	38-40	38-40
132.9	38-40	40	130.7	38-40	38-40
285.1	38-40	0-1m	131A	38-40	38-40
661	38-40	0-1m	132.10b	38-40	38-40
285.2	38-40	36-38	293.5	38-40	38-40
34.1	38-40	38-40	418	38-40	38-40
34.2	38-40	38-40	132.5	38-40	40-42

The range and average stature of the adult individuals within the Gussage All Saints burial population is given above in Table 5.6. The statures of these individuals fall within the period ranges for Iron Age Britain (Roberts and Cox 2003) but are towards the lower end of the range with the average stature for each sex shorter than the period average. This may indicate that the population experienced some form of environmental stress that prevented adults from attaining optimum stature prior to skeletal maturation, or a genetically shorter population. It is acknowledged that the small number of adults from this site may have introduced bias into the distribution of adult stature.

It is unusual that the burial population does not contain any children or adolescents, or indeed any middle adults. This age at death distribution may be a reflection of a living population in which certain age groups had been removed to other locations during life or a group of individuals selected for burial within the settlement area, or indeed countless other possibilities. It is unlikely, however to be a true representation of the entire population of Gussage All Saints.

5.5.3.2 Population Pathology

Cranial

The adult skeletal remains from Gussage All Saints demonstrate a generally poor oral health among the older individuals in the burial population. Dental pathology among the adults includes a case of anomalous dental wear (Sk. 204, female 45+ years) with the maxillary anterior dentition much more heavily worn compared to the anterior mandibular dentition (Keepax, 1979). This is likely to be the result of undertaking activities that resulted in advanced maxillary occlusal wear of the incisors (Lukacs and Pastor, 1988). A summary of the dental pathology for the adult individuals is provided below in Table 5.6. It is apparent that the prevalence of dental abscess and antemortem tooth loss increases in adults older than 45 years. There is no evident association between age and number of dental caries. The alveolar bone recession observed in all adult individuals was considered to be associated with periodontal disease (Keepax, 1979). Individual Sk. 139 (female, 45+ years) shows inconsistent age estimates between her dentition (that of an elderly adult) and the remainder of her skeleton which has relatively little evidence of the advanced degenerative joint disease anticipated in an elderly individual. It may be that the age of this individual has been over-estimated and that her advanced dental wear may be related to activity rather than age-related.

Table 5.8. Dental pathology present in the adult remains from Gussage All Saints. (adapted from Keepax, 1979).

Individual	Teeth Present	Calculus	Abscess	Caries	Antemortem Tooth Loss	Alveolar Bone Recession
31 (16-19y)	31	Slight	1	5	1	Slight
285 (20-22y)	29	Slight	1	5	3	Slight
62 (20-25y)	30	Slight	1	12	1	Slight
387 (35-45y)	30	Slight	3	9	2	Slight
410 (35-45y)	29	Slight	1	4	2	Slight
139 (45+y)	9	Slight	2	2	19	Moderate
204 (45+y)	19	Slight	6	20	11	Moderate
205 (45+y)	12	Slight	5	6	13	Considerable
359 (45+y)	3	Slight	1	3	24	Considerable
Totals	192		21	66	76	

Post-cranial

The skeletal remains of adolescents and adults usually exhibit a progression of degenerative conditions relative to age. Within the Gussage All Saints burial population, the evidence for degenerative joint disease in the adults includes eburnation, vertebral collapse and lipping, and osteoarthritic changes in the knee joint and the smaller joints of the hands and feet (Keepax, 1979). These are all considered to be normal degenerative changes, but may be exacerbated and advanced by physical activity or other existing pathology.

Trauma

There is a relatively high incidence of fracture and osteoarthritis in the adult remains that is likely to be related to the level and degree of physical activity undertaken. Other forms of trauma observed in the disarticulated adult remains include evidence of dismembering in the form of cut-marks, animal gnawing, and blunt force trauma. This type of trauma has been suggested as evidence of excarnation activities, and the cut-marks and blunt force trauma may also relate to the mode of death (Carr and Knüsel, 1997; Redfern, 2008).

One individual (Sk. 285, male 20-22 years) sustained a series of peri-mortem sharp force traumas that are very likely to have resulted in his death. This male had a healed mid-shaft fracture of the right humerus and a healed sharp-force trauma to the posterior of the left parietal. This included at least five separate sharp-force cuts to the proximal lateral aspect of the left humeral diaphysis, a shallow cut to the tibia (un-sided fragment), and a shallow slicing cut to the sternal end of the left clavicle. The remainder of his skeletal trauma showed no evidence of healing.

Consultation with a weaponry and historic combat expert suggested that the perimortem injuries sustained by individual Sk. 285 followed a strategic assault in which the leg was targeted first in order to limit mobility, followed by the shield arm, assuming right handedness (Michael Smallridge, pers. comm. July 2012). The injuries to the left humerus were caused by strikes from two different directions. Although there is no evidence that this individual was armed with a weapon and shield, the injuries follow a classic pattern identified through the use of these items, suggesting that he was using defensive and offensive objects in a similar manner. Individual Sk. 285 is the only individual within the burial population that had sustained significant sharp-force trauma as the result of interpersonal violence during the peri-mortem period.

In a comparative study between contemporary settlements in the area, Peck (2013) found a significant difference in the prevalence of skeletal trauma and degenerative joint disease (DJD) in adults between social groupings, with those identified as ‘non-elite’ expressing more of these pathologies than those identified as ‘elite’. He attributed this difference to modes of physical activity undertaken by individuals and their inherent risks, but found that all adult individuals shared similar degrees of dental pathology, cribra orbitalia and periostosis indicating a shared diet and risk of systemic conditions.

5.5.4 Yewden Villa

5.5.4.1 Age Estimation

The three adults recovered during excavations were aged according to dental wear, skeletal fusion and degenerative pathology. Two of the adults were male (Sk. A and B) and were aged between 17 and 25 years, while the third adult was female (Sk. C) and aged between 25 and 35 years at time of death. The stature estimates for the adults are 169.5cm (Sk. A), 171.1cm (Sk. B), and 157.8cm (Sk. C). These statures fall within the ranges recorded for Roman Britain and are close to the average statures for each sex within this period. The range for males (n=1296) was 159-178cm (av. 169cm) and for females (n=1042) was 150-168cm (159cm) (Roberts and Cox 2003).

The sub-adults within the burial population were aged between the third trimester of pregnancy and six years. The majority of very young individuals died between the ages of 26 and 41 weeks gestation. The age at death estimates of these very young individuals indicate that there is no apparent disruption between the timing skeletal and dental development (Table 5.9). These youngest sub-adults are represented by 25 discrete individuals, 18 partial individuals, and at least another seven individuals from disarticulated remains. Mays *et al.* (2011) identified 35 perinatal individuals and 24 disarticulated perinatal remains, however an assessment of the minimum number of individuals (MNI) by size, appearance and skeletal element indicates that the majority of disarticulated remains represent the surviving elements of discrete burials. In this case, there may be the remains of as many as 50 perinatal individuals currently curated within the collection. An age-at-death distribution of the very young individuals is given in Figure 5.5.

Table 5.9. Age estimation using dental and skeletal development for the very young Yewden villa individuals.

Skeleton	Dental Age	Skeletal Age	Skeleton	Dental Age	Skeletal Age
3	0-1m	40	24	36-40	40
4	0-1m	40	28	0-1m	40
5	38-40	40	31	3-6m	5 months
6	36-40	34-36	38	36-40	36-38
12	36-40	40	40	36-40	38-40
16	36-40	38-40	43	36-40	38-40
21	9-12m	12 months			

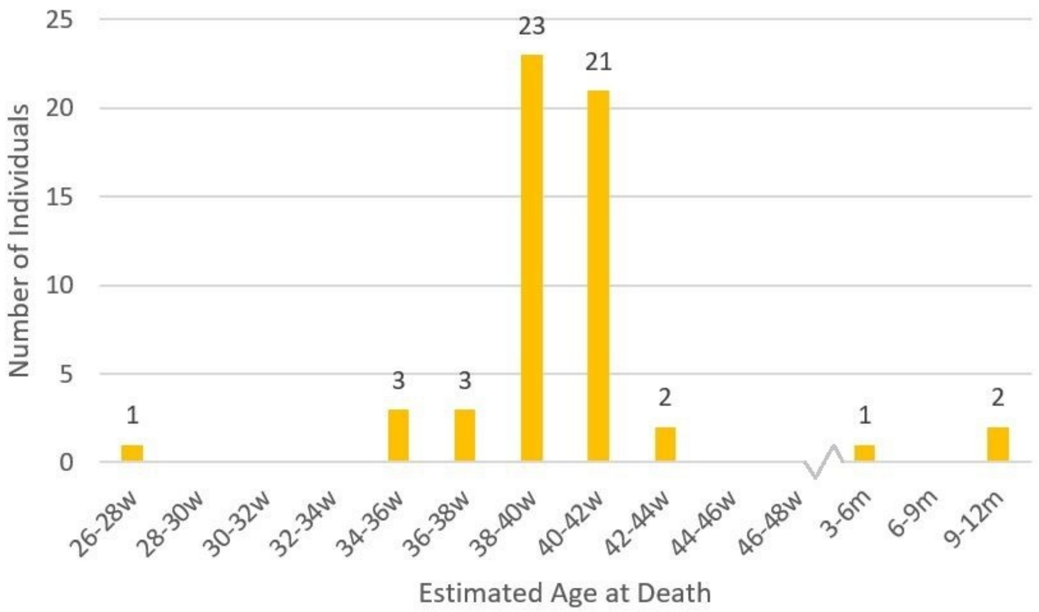


Figure 5.5. Age-at-death Distribution of the sample from Yewden Villa, Buckinghamshire.

It is recognised that the 97 newborn individuals listed in the original excavation report (Cocks, 1921) are not all held within the current collection and it is assumed that a substantial portion of this number have been lost since the initial curation of the human remains. The older sub-adults include three infants aged 6-12 months (Sk. 21, 31 and 59), two children aged 1-2 years (Sk. 46 and MNI of 1 from disarticulated remains) and one child of approximately 6 years (Sk. 60).

5.5.4.2 Population Pathology

Cranial

The children and adults in the burial population have generally good oral health, with little evidence of calculus and periodontal disease. The adult female (Sk. C) has a carious lesion in the right mandibular first molar, ante-mortem loss of the left mandibular first molar, and also displays a congenital absence of her third molars (Eyers, 2011). There is no dental pathology of note in the other two adults.

Post-cranial

One of the adult males (Sk. B) has a porous lesion on the medial aspect of the right tibia that shows considerable remodelling from healing. Mays *et al*. (2011) suggest that this pathology is most likely in response to a soft tissue injury and associated infection. Cocks (1921) commented that adults B and C both had squatting facets present on the distal tibiae, however this skeletal trait was not mentioned in the publication of the cemetery analysis (Eyers, 2011).

Trauma

Three perinatal individuals (Sk. 5, 7, and 38, all 38-40 weeks) have apparent cut-marks to the lower limbs that are likely to be associated with repositioning the limbs using small tools in order to facilitate a breech delivery. These cases will be discussed in further detail within Chapter 6. There is no evident trauma on the skeletal remains of the older children or adults recovered from the settlement area (Cocks, 1921; Eyers, 2011). The individuals recovered from within the settlement area at Yewden villa are unlikely to represent the living population of the site. It is expected that further investigation of the area around the villa site will provide evidence of other landscape modifications, including a formal burial area.

5.5.5 Barton Court Farm

5.5.5.1 Age Estimation

No adult individuals were recovered from the settlement area of Barton Court Farm that date to the Roman period of occupation. It is assumed that two cemeteries located in the fields surrounding the villa site were used by the local communities (Miles *et al*., 1986a), which would explain the absence of older individuals within the excavated settlement site. The remains of two pregnant adult females were recovered during excavation, but these date to the Anglo-Saxon period.

The 55 sub-adult individuals analysed for the current research were all aged less than one year at the time of death. The age at death estimates of the very young individuals in the Barton Court Farm burial population indicate that there is no apparent disruption between the timing skeletal and dental development (Table 5.10). There were four infants; three aged between three and six postnatal months and one aged approximately six to nine postnatal months. The remainder of the sub-adult individuals (n=51) were aged between 34 weeks gestation and one postnatal month at the time of death. Figure 5.6 provides an age-at-death distribution of the very young individuals from Barton Court Farm.

Table 5.10. Age estimation using dental and skeletal development for the very young Barton Court Farm individuals.

Skeleton	Dental Age	Skeletal Age	Skeleton	Dental Age	Skeletal Age
784	38-40	40	2	38-40	38-40
860	38-40	40	103	38-40	38-40
905i	38-40	40	196	38-40	38-40
916	38-40	40	616	38-40	38-40
202	0-1m	0-1m	619	38-40	38-40
286	38-40	0-1m	678	38-40	38-40
869	38-40	0-1m	904	38-40	38-40
913	38-40	0-1m	1076	38-40	38-40
917i	1-2m	1-2m	UB5	38-40	38-40

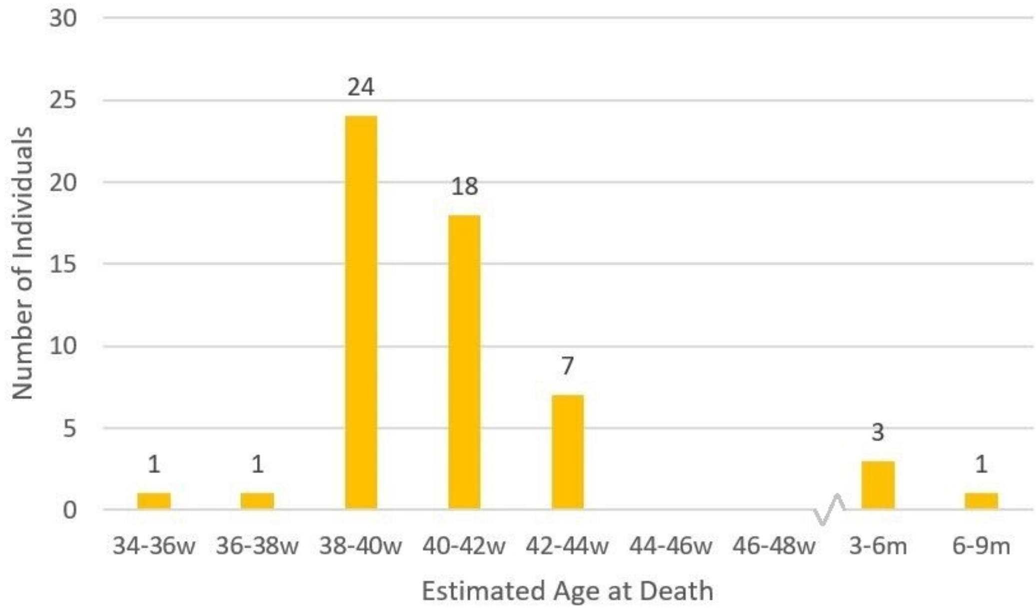


Figure 5.6. Age-at-death Distribution of the sample from Barton Court Farm, Oxfordshire.

5.5.5.2 Population Pathology

There is no information available on the general health or pathology of the Roman population living at Barton Court Farm; identification of the community cemetery has yet to be confirmed. The only articulated adult remains recovered during excavation were dated to the Iron Age (Sk. 459 and 680) and the Anglo-Saxon (Sk. 258, 271, 807, 820 and 1171) periods (Miles 1986). Atkinson (1952) reports on the contemporary Barrow Hills Field cemetery that is located less than one kilometre to the northeast of the villa site. The entire area of this cemetery was excavated and the articulated remains of 35 adults were recovered (Atkinson, 1952). The Barrow Hills Field burial population were aged between 20 and 40 years at death and there is no evidence for the inclusion of any juveniles. At the time of his publication Atkinson (1952) declared that it was impossible to have the skeletal remains from Barrow Hills Field cemetery analysed; the author is not aware of any analysis that has taken place since the 1950s.

5.5.6 Ardreigh

5.5.6.1 Age Estimation

Troy (2010) reports that 60 percent of the sub-adult burial population of Ardreigh died within the first six years of life. The majority of the adults within the burial population died between the ages of 25 and 35 years (n=270), which is a significant increase from the mortality in the 18-25 years group (n=151) (Table 5.11). Age was estimated for the 89 individuals aged under 12 months revealing that this grouping included one fetal individual (Sk. 5833, 16 weeks), 29 perinatal (28-40 weeks), 27 neonatal (40-44 weeks), and 30 infant (1-12 months) individuals.

Table 5.11. Demography of the Ardreigh burial population.

Sub-adults	**Number of Individuals**	**Percentage of Sub-adults**
Fetal	1	0.003
Perinatal	29	6.9
Neonatal	27	6.4
Infant	30	7.1
Early Child	159	37.4
Late Child	111	26.1
Adolescent	62	14.6
Sub-adults (unaged)	5	1.2
Total Sub-adults	**424**	
Adults	**Number of Individuals**	**Percentage of Adults**
Young Adult	151	18.4
Middle Adult	270	32.8
Older Adult	201	24.5
Mature Adult	97	11.8
Adults (unaged)	103	12.5
Total Adults	**822**	

All but four individuals had consistent age estimates for skeletal and dental development (Table 5.12). The four individuals with inconsistent age estimates were one perinate (Sk. 1397), one neonate (Sk. 5633) and two infants (Sk. 514 and Sk. 1739). These individuals had lower skeletal development age estimates compared with their dental development age. The difference was at least one month, with skeletal growth always lagging behind dental development. Individual 514 had a dental age of approximately four months with skeletal growth at one month, but also displayed advanced development of the petrous temporal beyond four months in that the subarcuate fossa had partially closed; a change in morphology that commences towards the end of the first postnatal year (Hilding, 1987). An age-at-death distribution of the very young individuals is provided below in Figure 5.7.

Table 5.12. Age estimation using dental and skeletal development for the very young Ardreigh individuals.

Skeleton	Dental Age	Skeletal Age	Skeleton	Dental Age	Skeletal Age
45	0-2m	0-2m	1061	0-2m	0-2m
304	0-2m	38-40	1233	3-6m	3-6m
360	0-1m	38-40	1244	36-40	36-38
368	0-1m	40-42	1255	38w-1m	0-3m
373	0-1m	1-3m	1257	1-3m	38-40
377	1-3m	0-1m	1258	3-6m	6-12m
514	1-4m	0-1m	1270	1-3m	0-1m
665	6-12m	6-12m	1271	6m	6-12m
666	1-4m	0-6m	1302	36-40	36-38
705	6-12m	6-12m	1305	3-6m	3-6m
743	1-6m	3-6m	1349	1-3m	3-4m
767	3-6m	1-3m	1367	0-2m	1-3m
771	1-3m	38-40	1397	0-1m	24-28
774	0-1m	0-1m	1442	38-40	38-40
784	6-12m	8-12m	1444	38-40	0-2m
792	1-3m	38-40	1446	0-1m	38-40
801	36-40	38-40	1648	38-40	38-40
803	3-6m	6-12m	1665	1-3m	2-3m
812	0-2m	0-1m	1716	36-40	38-40
830	36-40	40	1732	2-4m	0-2m
839	0-2m	38-40	1735	1-3m	1-3m
848	0-3m	40	1739	3-6m	0-2m
850	0-1m	40	1770	30-36	36-38
875	0-2m	0-1m	1816	0-2m	1-3m
898	38w-1m	40	1840	3-6m	3-6m
899	1-3m	3-6m	1911	0-1m	0-1m
905	34-40	36-38w	1956	0-1m	40-42
906	1-3m	2-3m	3184	6-12m	6-12m
924	6-12m	6-12m	5633	0-1m	34-36
956	0-2m	0-3m	5680	0-1m	38-40
958	1-3m	0-1m			

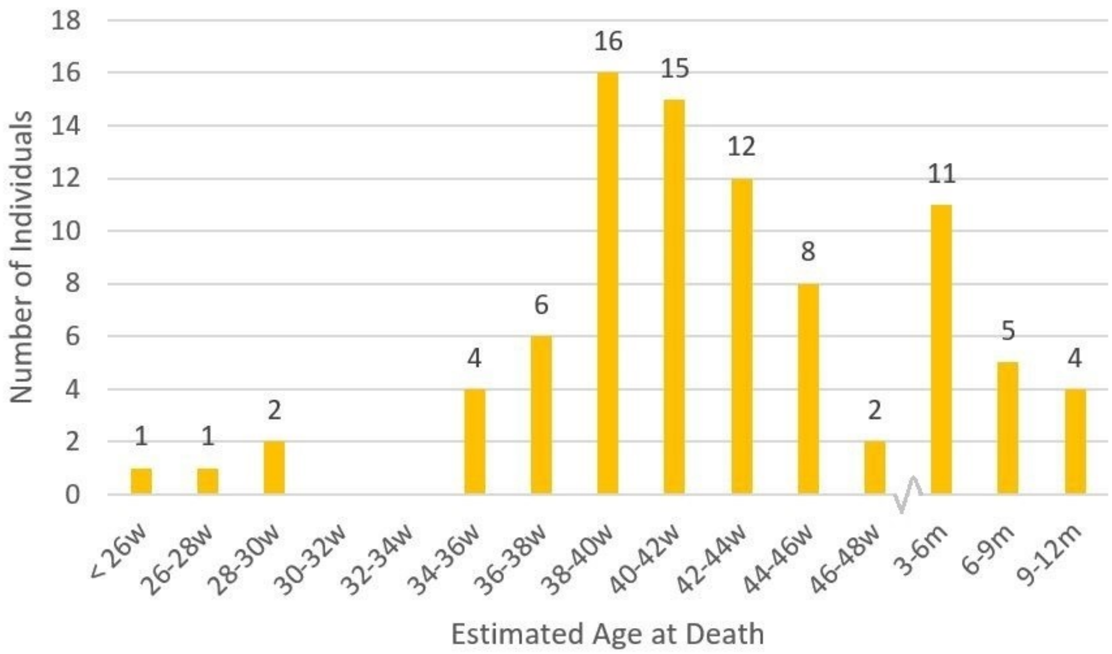


Figure 5.7. Age-at-death Distribution of the sample from the medieval cemetery at Ardreigh, Co. Kildare.

The adult stature for males (n=321) and females (n=351) in the Ardreigh burial population is provided below in Table 5.13, along with the stature for adults within the Wharram Percy burial population and the early and late medieval stature ranges for Britain.

Table 5.13. Adult stature for the burial populations of Ardreigh and Wharram Percy. All heights given in centimetres.

	Male		Female	
	Range	Average	Range	Average
Ardreigh (Troy 2010, 18)	154-186 (n=321)	170	142-175 (n=351)	159
Wharram Percy (Mays 2007, 337-348)	151-181 (n=169)	168	147-169 (n=119)	158
Early medieval (Roberts& Cox 2003, 195)	170-182 (n=996)	172	152-170 (n=751)	161
Late medieval (Roberts& Cox 2003, 248)	167-174 (n=8494)	171	154-165 (n=7929)	159

Figure 5.8 shows the stature distribution for each of the sexes within the Ardreigh burial population. It can be seen that the majority of individuals in the female distribution fall within the ranges of the early and late medieval periods, with fewer individuals of shorter (6% and 10%, respectively) or taller (0.8% and 4%, respectively) stature. These outliers extend the stature range for Ardreigh adult females but do not

greatly affect the average. In comparison, the adult males in the burial population of Ardreigh do not fall predominantly within either the early or late medieval ranges. The number of males below the early medieval limit of 170 cm is 103 (32%) and above the limit of 182cm is five (2%). For the late medieval range, 54 (17%) males are lower and 44 (14%) are higher.

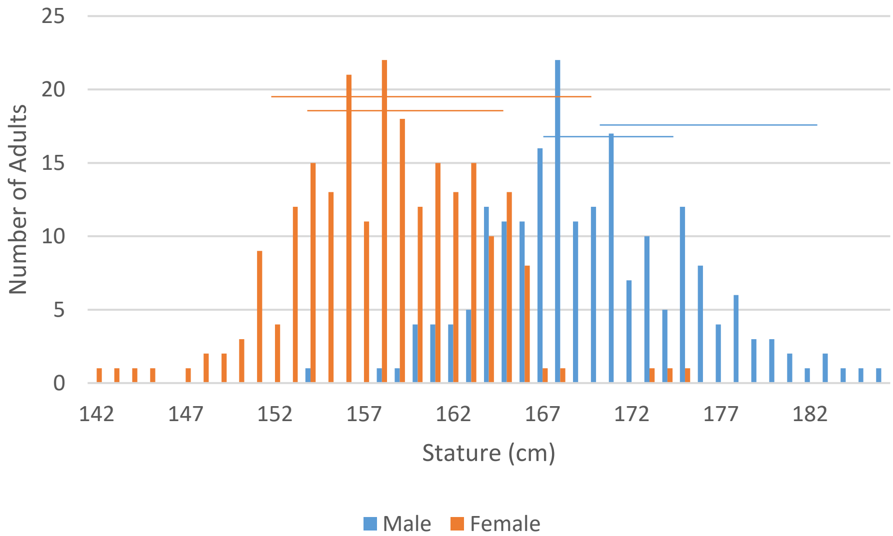


Figure 5.8. Distribution of male and female adult stature in the Ardreigh burial population. The horizontal bars indicate the early (top bar) and late (bottom bar) medieval comparative ranges for each sex.

This shift in distribution demonstrates that there were more adult males of lower stature, which may indicate that the males within the Ardreigh population were more susceptible to growth disturbance in early childhood affecting the attainment of optimal adult stature for this population. A similar occurrence of adult males of lower than average stature was observed within the medieval burial population of Ballyhanna, Co. Donegal, where it was suggested that the most likely causative factors were impacts upon childhood health that prevented these individuals from obtaining optimal stature (McKenzie and Murphy 2011). The same cannot be said of the females within the population who appear to have attained optimal adult stature and whose statures fit more closely with those of other medieval populations across Britain.

5.5.6.2 Population Pathology

Cranial

The dental pathology evident in the individuals from the cemetery at Ardreigh included dental caries, calculus, abscess and periodontal disease. Each of these forms of dental pathology was more prevalent in adults compared with sub-adults, as would be expected. In both age groupings the occurrence of calculus and carious lesions was higher than periodontal disease and abscess, although this difference was more marked in sub-adults than adults. Only 2% (5/239) of the sub-adults with dentition had abscesses and 3% (12/239) had evidence of periodontal disease compared with 23% (122/537) and 40% (219/537) for adults, respectively. Dental enamel hypoplasia (DEH) was present in 25% (60/239) of sub-adults with dentition and 36% (195/537) of the adults (Troy, 2010). No cases of DEH were observed in individuals aged under six postnatal months.

When DEH is considered for each age category, the occurrence increases from 2.7% (3/112) in young children (1-6 years) to 40% (31/78) in older children (7-12 years) and 53% (26/49) in adolescents (13-17 years). Younger adults (18-35 years) display more DEH (144/312, 46%) than adults older than 35 years (50/219, 23%) (Troy, 2010). The higher occurrence of DEH in individuals aged between 13 and 35 years may indicate that these individuals were more physiologically resistant to environmental stress as they survived longer than younger individuals with DEH.

Nutritional deficiencies are likely to be the underlying causes for the prevalence of cribra orbitalia in children and adolescents and porotic hyperostosis in older adults. Troy (2010, 54) attributes the elevated occurrence of cribra orbitalia in adult females within the Ardreigh burial population (21.8% compared to 18.1% in adult males) to pregnancy and breastfeeding.

Post-cranial

Degenerative joint disease was present in one third of the adult population, with the most commonly affected joints being the shoulder, elbow, and hip (Troy, 2010). There was no significant difference between the sexes in the occurrence or severity of joint degeneration. Schmorl's nodes were present in 30% (246/822) of adults and in both sexes (Troy, 2010). Although an exact aetiology is unconfirmed, these lesions are believed to be evidence of inflammatory responses to increased loading on the vertebral column (Kyere *et al*., 2012). There was a higher occurrence of Schmorl's nodes in males of all ages which has been interpreted as an earlier age for the commencement of strenuous manual labour among boys (Troy, 2010), a common practice in the medieval period (Orme, 2001).

Two children (Sk. 1686, 7-8 years and Sk. 1943, 10-13 years), one adolescent (Sk. 1675, 14-15 years) and an older adult (Sk. 5649, 35-45 years) are likely to have been affected by scurvy (Aufderheide and Rodriguez-Martin, 1998; Ortner, 2003; Troy, 2010). The original skeletal analysis of the collection found that skeletal pathology indicative of tuberculosis was present in six individuals. Vertebral and rib lesions were evident in two older children (Sk. 1296, 6-8 years and Sk. 1686, 7-8 years) and one adolescent (Sk. 1786, 12-15 years). The other three individuals have rib lesions indicative of tuberculosis (Sk. 858, 6-7 years, Sk. 1517, 10-12 years, and Sk. F115, 25-29 years) (Troy, 2010).

Trauma

Trauma was evident in the form of fractures in 113 individuals including 11 sub-adults. The skeletal regions most frequently affected among the male individuals were the ribs and cranium, while females had most fractures in the ulnae, vertebrae and ribs (Troy, 2010). The elements most affected by fractures in sub-adults are the major long bones of the lower limb. With regard to the sharp and blunt force traumas to the cranium observed in adults, more males than females were affected (Carty, 2012). The number and state of healing in cranial trauma suggests that the majority were inflicted upon male individuals in their 20s with all cranial fractures in male adults having healed before the age of 30 (Troy, 2010). Of the four adult females with cranial fractures, those resulting from blunt force had healed by the time of death, but the sharp force fractures displayed partial or no evidence of healing at the time of death. Healing was evident in the majority of the sub-adults with long bone fractures, although there does not appear to have been an effective means of re-aligning displaced fractures prior to healing (Troy, 2010). The disarticulated remains included an adult tibia and fibula that had been successfully amputated and had healed well, and the occipital of a sub-adult with evidence for trepanation, again with ante-mortem healing (Troy 2010).

Congenital Anomalies

Troy (2010) identified one adult female (Sk. 5678, 45+ years) with a cranial shift of complete occipitalisation of the first cervical vertebra, nine adults with caudal shifts of sacralisation of L5 to S1 and one adult male (Sk. 286) with lumbarisation of T12 to

L1. Analysis for the current research identified a further adult female (Sk. 1087, 18-25 years) with a cranial shift at the occipital-cervical border. Within the articulated burial population spina bifida occulta was recorded in 16 individuals (one adolescent and 15 adults) (Troy, 2010). Two of these cases involved the sacral elements (Troy 2010).

5.5.7 Wharram Percy

5.5.7.1 Age Estimation

Excavation of the church and cemetery at Wharram Percy recovered the remains of 687 individuals, approximately half of which could be assigned to a particular phase of occupation (Mays 2007). Although the cemetery was in use between AD 950 and AD 1850, the majority of the phased burials are medieval and it is likely that this is also the case for the un-phased burials. The recovered burial population consists of 360 adults and 327 juveniles (individuals younger than 18 years). The juveniles included 101 individuals aged under 12 months, 131 individuals aged between one and six years (early child category), 66 later children (7-12 years), and 29 adolescents (13-17 years) (Mays, 2007). Of the 101 individuals aged under 12 months, one (Sk. NA155) could not be located and 17 others were omitted from the research on the grounds of fragmentary and very incomplete remains. Figure 5.9 provides a distribution of the 83 individuals analysed for the current research. Only one individual (Sk. NA209) had a difference between dental and skeletal age estimates. The dental age of this individual is between 1 and 3 postnatal months, while the skeletal age estimation is approximately 40 weeks (Table 5.14).

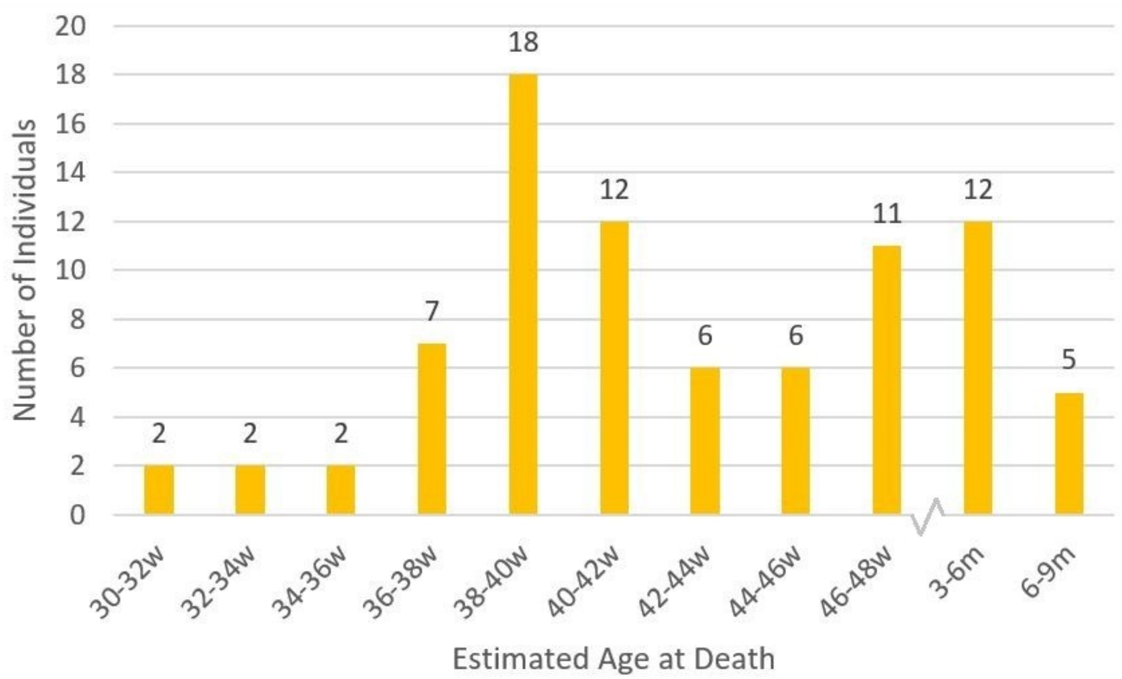


Figure 5.9. Age-at-death Distribution of the sample from the cemetery at Wharram Percy, Yorkshire.

Of the 83 individuals analysed, there are six perinatal individuals that died prior to 36 weeks gestation and a further seven that died between 36 and 38 weeks gestation. These youngest individuals would most likely have died from complications related to prematurity. Delivery prior to 39 weeks gestation is associated with increased risk to the late-term neonate from insufficient lung development, hypothermia, infection, feeding difficulties, hypoglycaemia and jaundice (Melamed *et al*., 2009). Eighteen individuals died between 38 and 40 weeks gestation and a further 18 between birth and one month. Of the remaining very young individuals, 17 died between one and two months, 12 between three and six months, and five during the second half of the first year.

In a study of skeletal asymmetry within the Wharram Percy burial population, Storm (2009) found that the low levels of skeletal asymmetry in juvenile remains were likely to be a reflection of early mortality (63.3% for individuals aged under five years). Non-congenital skeletal asymmetry develops through muscle use and activity, and so it follows that the majority of very young individuals died prior to any such changes becoming detectable. High juvenile mortality in combination with the evidence for adult asymmetry resulting from strenuous activity associated with an agricultural lifestyle (Storm 2009), it is likely that the Wharram Percy population may have experienced high levels of environmental stress.

Table 5.14. Age estimation using dental and skeletal development for the very young Wharram Percy individuals.

Skeleton	Dental Age	Skeletal Age	Skeleton	Dental Age	Skeletal Age
EE052	6-9m	6-12m	NA106	1-3m	2-3m
EE053	3-6m	3-6m	NA119	6-9m	9-12m
EE054	3-6m	1-3m	NA129	36-40	38
EE059	36-40	38-40	NA139	1-3m	2-3m
EE078	0-1m	1m	NA149B	0-1m	40
EE088	40-42	38-40	NA150	3-6m	3-6m
G313	0-1m	38-40	NA159	1-3m	2-3m
G338	1-3m	0-1m	NA160	0-1m	0-1m
G470	1-3m	1m	NA169	6-9m	3-6m
G476	36-40	34-36	NA170A	1-3m	1m
G492	38-40	40	NA191	1-3m	2-3m
G534	3-6m	3-4m	NA193	0-1m	0-1m
G686	3-6m	1-3m	NA194	3-6m	2-3m
NA004A	38-40	40	NA203A	3-6m	9m
NA014A	1-3m	1-2m	NA209	3-6m	40
NA037A	0-1m	40	NA220	1-3m	1-3m
NA043	3-6m	2-3m	NA221	1-3m	3m
NA043A	6-9m	6-9m	NA231	0-1m	0-1m
NA052	1-3m	1-2m	NA232	0-1m	0-1m
NA055	1-3m	0-1m	V03	36-40	38
NA060	1-3m	2-3m	V06	0-1m	1-2m
NA061	36-40	36	V10	6-9m	6-9m
NA064	0-1m	0-1m	V17	3-6m	2-3m
NA069	36-40	38-40	V60	1-3m	0-1m
NA085	1-3m	2-3m	WCO042	3-6m	3m
NA092	3-6m	3m	WCO104	3-6m	3-6m
NA093	1-3m	3-6m			

The stature estimates for adults within the Wharram Percy burial population are provided above in Table 5.13. As shown, these calculated statures have a wider range than those reported by Roberts and Cox (2003) for the early and late medieval periods in Britain. Figure 5.10 illustrates the distribution of male and female estimated stature for the Wharram Percy adults. When the Wharram Percy adult stature is compared with the early and late medieval ranges, the males diverge more than the females. There are 94 (55%) males shorter than 170cm and 56 (33%) shorter than 167cm for the early and late medieval lower limits of male stature, respectively. No males had taller stature estimates than the early medieval limit of 182cm, however 24 (14%) males were taller than the late medieval limit of 174cm. In comparison, the Wharram Percy adult females had fewer individuals outside of the period estimates. Again, there were no taller females than the early medieval limit of 170cm, but there were seven (6%) females taller than the late medieval limit of 165cm. Sixteen (13%) females were shorter than the early medieval limit of 152cm and 26 (22%) were shorter than the late medieval limit of 154cm. It is evident from these comparisons that there were considerably more males than females who had shorter stature estimates than the medieval ranges. This broader stature distribution with more individuals of shorter stature has resulted in slightly lower average statures for both sexes in comparison with other medieval sites. Overall, the female statures at Wharram Percy were closer to the period range and average than were those of the adult males.

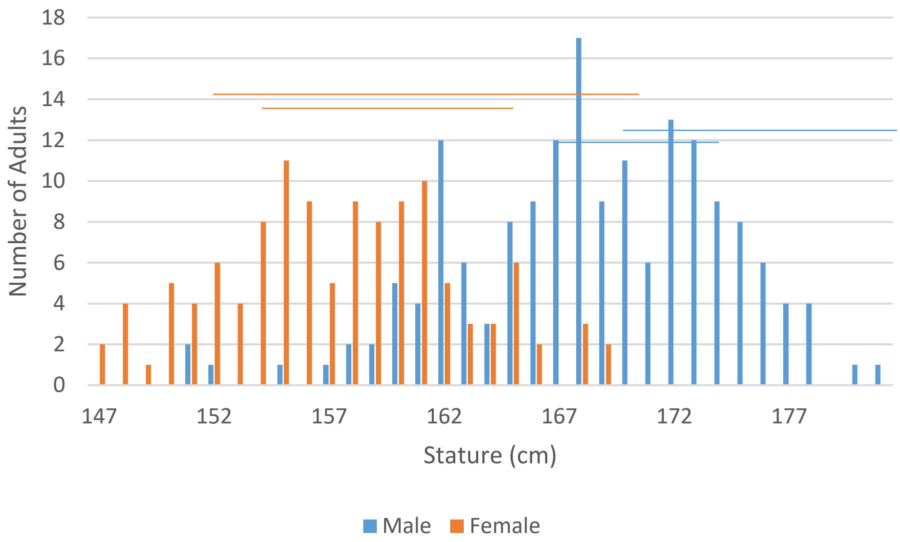


Figure 5.10. Distribution of male and female adult stature in the Wharram Percy burial population. The horizontal bars indicate the early (top bar) and late (bottom bar) medieval comparative ranges for each sex.

Given that the age at death distribution of very young individuals is not particularly skewed towards the younger ages it is suggested that physiological impacts during gestation and infancy affected an individual's growth during childhood as well as their ability to attain optimal stature, and this appears to have been more so the case for males than females. It is possible that the population of Wharram Percy may have been genetically predisposed to shorter adult stature than other comparative populations, which may be reflected in limbs of shorter length and under-estimated gestational age. However, the association between attained adult stature and length at birth is not a direct one and is strongly influenced by external environmental factors.

5.5.7.2 Population Pathology

Cranial

Dental caries were present in 16% (31/194) of juveniles and 67% (190/280) of adults, while only 2% (4/190) of juveniles had ante-mortem tooth loss compared to 61% (169/277) of adults (Mays 2007). There were 156 (156/277, 56%) adults with surviving dentition that had evidence of dental abscess. Six juveniles (6/190, 3%) also had abscesses in the dentition that were associated with exposure of the dental pulp (Mays 2007). Of the adults with dentition present, 89% (240/269) had dental calculus compared to only 23% (43/188) of the juveniles (Mays 2007). Dental enamel hypoplasia was observed in 32% of adults (69/214) and 25% (24/94) of juveniles (Mays 2007). The age of DEH formation was predominantly between the ages of two and five years, indicating that dental development was impacted by physiological stresses during this period of childhood. Porotic hyperostosis in the forms of cribra orbitalia and cribra cranii was also present in the burial population at Wharram Percy. Cribra orbitalia was observed in 31% (76/247) of juveniles and 19% (49/255) of the adults (Mays 2007). Seven individuals also had cribra cranii (Mays 2007).

Post-cranial

DNA analysis has confirmed that individual G438 had tuberculosis, with related extensive skeletal pathology (Mays 2007). This adult female was buried with a premature individual (Sk. G457). Premature rupture of membranes, stillbirth and preterm labour are all known effects of maternal tuberculosis (Getahun *et al*., 2012; Jana *et al*., 1994, 1999), and this is the most likely explanation for the death of individual Sk. G457. Related complications to early labour may have also caused the death of the mother. Although DNA analysis was not possible for the premature fetus, the shared vertebral shifts in both the adult female and the perinate provide further support that these two individuals were mother and child.

Nine adults had lesions characteristic of tuberculosis and one juvenile had rhino-maxillary lesions attributed to leprosy (Mays 2007). Aside from these individuals, there were a further 58 individuals (including 22 juveniles aged less than 10 years) with non-specific periostosis, predominantly affecting the leg. Eight juvenile individuals had skeletal changes characteristic of rickets. All of these individuals were aged less than two years. Mays (2007) recorded degenerative joint disease (DJD) in 58% (n=211) of the adults, and specific DJD of the vertebral column in 97% (n=227) of the adults. Diffuse idiopathic skeletal hyperostosis (DISH) was noted in 29 individuals aged over 40 years, but only three of these cases involved three or more vertebral bodies.

Trauma

Four individuals had evidence of sharp-force trauma to the cranium, two of which showed healing. A further six individuals had sustained cranial blunt-force trauma, with only one of these not exhibiting any signs of healing. An adult male (Sk. G715, 35-45 years) received successful treatment for a cranial injury or infection in the form of trepanation. There is significant evidence of healing and remodelling to the bone surface surrounding the lesion (Mays 2007), indicating that the trepanation treatment was successful to some degree. Other fractures of the post-cranial skeleton observed in adults include the ribs, vertebrae, clavicles, and long bones. The majority of these fractures display healing with minimal displacement. A few individuals display evidence of avulsion fractures, dislocation and fractures to the epiphyseal plate during childhood or adolescence (Mays 2007). Schmorl's nodes were noted in 39% (n=118) of adults and are likely to be related to injury from physical activity, particularly weight-bearing that results in compression of the vertebral column.

Congenital Anomalies

Individual NA170 (female, 20-25 years) has incomplete lumbarisation of S1 (see Figure 7.3, Chapter 7), a bilateral maxillary sinus infection, and articular facets of the thoracic spinous processes. There is no evidence of vertebral body collapse, although extensive tuberculous lesions are present on much of the lower vertebral column.

Mays (2007) noted 53 non-metric skeletal traits that are considered to be genetically controlled within the burial population of Wharram Percy. These included some traits that can be observed in the skeletal remains of very young individuals such as a divided hypoglossal canal, extra-sutural ossicles, posterior atlas bridging, supra-condyloid process of the humerus, and sixth sacral vertebra. Sacral spina bifida occulta was present in 3% of the adults and another 15 individuals (aged 5 to 50+ years) were affected in the cervical or lumbar regions of the vertebral column (Mays

2007). The identification of spina bifida occulta is possible in very young individuals, but mild forms can only be confirmed *in situ* prior to excavation. More prominent forms can be identified macroscopically through the assessment of neural arch morphology.

Cranial and caudal shifts were noted in the vertebral columns of several individuals and most often occurred at the occipito-cervical and lumbo-sacral borders (Mays 2007). Mays (2007) omitted juveniles from his analysis of non-metric traits on the basis that traits can be age-correlated. However, vertebral shifts in two neonates and one infant (Sk. EE54, Sk. NA170A and Sk. NA55) were identified on the basis of neural arch characteristics during the osteological analysis of the very young individuals undertaken by the author.

5.6 Summary

Results from the general analysis of the burial populations revealed that the majority of skeletal remains were in good preservation condition despite the wide variation in temporal period and the length of post-excavation storage. The curation conditions following excavation have contributed significantly to the deterioration of the remains through crushing, fragmentation and in one case, degradation of the cortical surface. The completeness of the adult remains, where present, was consistently higher than that of very young individuals across all collections. In many collections, this is an artefact of the excavation methods and the experience of the excavator in recognising small ossification centres and developing skeletal elements. The disarticulated remains of very young individuals that were encountered in the collections are, in the majority of cases, the result of disturbance to shallow primary burials.

Age estimation for the burial populations has identified that some burial grounds did not include all age groups. This under-representation of certain ages is not related to preservation, but is a reflection of the selection process for burial location, funerary treatment and possibly, changes in the demographic profile of the living population. The ages estimated for the very young individuals analysed revealed that two of the burial populations contained individuals with significant disparities between age at death estimated using skeletal and dental development; Çatalhöyük, 19 individuals and Ardreigh, 4 individuals. The implication of this type of discrepancy in individuals of such young ages is that the maternal condition during pregnancy had an impact on intrauterine growth. In the burial populations of Çatalhöyük, Wetwang Slack, Ardreigh and Wharram Percy it seems that a significant proportion of the individuals surviving into adulthood were unable to recover growth delays prior to skeletal maturation with more adults of significantly shorter stature compared to the period and location specific ranges. Interestingly, the Ardreigh burial population contained more males of shorter stature than expected, suggesting that in this population the males were more affected than females in their ability to achieve optimal stature.

All populations analysed had varying degrees of dental pathology, most of which is associated with consumption of dietary carbohydrates and poor oral hygiene. There were also a few individuals with anomalous activity-related dental wear. Dental enamel hypoplasia is a direct reflection of physiological stress experienced by individuals during childhood, but was not observed in all of the populations analysed.

Disruption to normal development of the skeleton during childhood is also present in porotic hyperostosis, cribra orbitalia and long bone deformity. These pathologies have been attributed to scurvy, rickets, and general malnutrition, whether through dietary deficiencies or infection. Tuberculosis and leprosy are also present in a small percentage of individuals, and maternal tuberculosis may be directly associated with the death of one adult female and her fetus. Tuberculosis has a skeletal expression in 3-5% of sufferers (Resnick and Niwayama, 1995), indicating that the low observation rates of tuberculosis-related skeletal lesions in the collections above could be an under-representation of the number of individuals within each community who were infected with tuberculosis. The World Health Organization estimates that 1/3 of the world’s current population has latent tuberculosis, which can become an active infection under environmental stress (WHO, 2016).

Skeletal pathology evident in the burial populations studied, includes periosteal lesions, fracture, trauma, degenerative joint disease and other activity-related pathology. It has been demonstrated that the majority of fractures to the long bones and ribs healed while the individual was alive. Several individuals had evidence of blunt and sharp force trauma to the cranium, and two individuals had received successful treatment involving trepanation. Many of the fractures present in the burial populations are likely to have been the result of accidental injury through every day activities, although a few were inflicted through inter-personal violence.

Genetically linked anomalies of the vertebral column and other non-metric traits were observed in all populations. The prevalence of these genetically linked traits is higher in some populations than others, suggesting relatively closed gene pools. Some skeletal traits appear to be more common in particular temporal periods or limited to a few populations. For example, sacralisation of L5 was observed in the Wetwang Slack, Ardreigh and Wharram Percy burial populations, occipitalisation of C1 was only observed in the Ardreigh burial population, extra-sutural ossicles were observed in the Wetwang Slack and Wharram Percy burial populations, and the intra-jugular process was observed in the Wharram Percy burial population. In those few adult women who have skeletal anomalies and are associated with perinatal individuals, the anomaly is also expressed in the perinate's skeletal remains. This genetic aspect of skeletal anomalies offers a means of associating the remains of very young individuals with a particular adult group within which certain anomalies are more prevalent.

In summary, the information obtained through macroscopic analysis of the burial populations as described above, has provided a personal and population-specific view of community health in the past. This forms the basis for the consideration of the palaeopathology of very young individuals and the relationship between maternal health and fetal, neonatal and infant development in the following chapters.

Chapter Six

Skeletal Pathology of the Very Young

6.1 Introduction

An interest in human anatomy can be traced beyond scholars such as Galen, Vesalius, and William Harvey to the evidence of prehistoric treatments that required a rudimentary knowledge of human anatomy. Anatomical research during more recent periods was primarily undertaken on adults; predominantly males (Dittmar and Mitchell, 2016). Despite this resource bias, the many curated specimens of very young individuals provide clear evidence that they too were important subjects of anatomical investigation and medical research (Mitchell *et al*., 2011). The gaps in our current understanding of skeletal pathology in very young individuals may have developed through this early focus on adult anatomy, however they are also perpetuated by a continuing focus on soft tissue pathology in the very young as a priority for improving neonatal outcomes. Considerable advances have been made in ethical practice and the legislation surrounding the use of human remains (The Stationery Office - Human Tissue Act UK 2004). Although significant changes have been implemented since the period of early, often illegal anatomical research, recent cases of research on legally obtained human remains, such as that leading to the Alder Hey inquiry (Dittmar and Mitchell, 2016) have highlighted the importance of professional conduct in the furthering of medical knowledge and have driven changes to the laws pertaining to human remains (Ellis, 2004; Redfern *et al*., 2001).

Current understanding of the gross anatomy and pathology of fetal and perinatal individuals has been built upon the detailed information gained during routine postmortem autopsies (Scheimberg and Cohen *et al.*, 2013). These are now performed in order to ascertain cause of death and assess risk for future pregnancies (Ernst, 2015; Fleischman, 2016; SCRN, 2011). As a part of this process the skeletal system is routinely examined through postmortem radiography for confirmation of age at death and development, and for the identification of skeletal anomalies (Ernst, 2015). Physical macroscopic examination of the skeleton through postmortem autopsy however, only scrutinises the following: cranial form and abnormalities, hard palate and dentition, auditory canal, dimensions of the thorax, alignment and defects of the vertebral column, and abnormalities of the limbs (Ernst, 2015). These observations do not involve exposure of the cortical surfaces for examination, neither does routine autopsy permit the dissection of the extremities. Although the brain and dura are examined as part of a perinatal autopsy, the endocranial surfaces are not. Given these procedural restrictions, it is not surprising that many perinatal pathologists are relatively unfamiliar with the surface appearance of perinatal skeletal elements, particularly the endocranial surfaces and extremities.

The analysis of archaeological collections involves the challenge of differentiating between normal and pathological bone appearance. As a consequence, osteologists have considerably more detailed knowledge of the macroscopic appearance of skeletal elements and are more readily able to identify abnormal characteristics. Pathological appearance may be relatively easily identified, however its aetiology is often difficult to resolve through differential diagnosis, particularly given the lack of archaeological remains with associated medical histories. Although there are far fewer restrictions applied to the study of juvenile skeletal remains from archaeological contexts, the study of palaeopathology in very young individuals continues to draw heavily from medical practice and clinical research. The medical process of differential diagnosis, which incorporates clinical parallels and their underlying conditions, is used to identify the most likely aetiologies for the skeletal pathology observed in archaeological specimens. Collaboration with perinatal pathologists provides vital resources in terms of identifying pathological expression and access to the remains of individuals with confirmed medical histories. It also holds the potential to assist in the determination of palaeopathology-specific aetiologies and the advancement of the palaeopathology of very young individuals. The current research was significantly enhanced through such a collaboration that enabled differential diagnoses of observed skeletal anomalies and potential pathological expressions in archaeological specimens. Clarification of potential causative factors in the development of skeletal pathology and anomalies was informative and allowed elements of conjecture to be qualified, providing support to the suggested aetiologies presented below.

This chapter provides brief descriptions of normal development and macroscopic appearance in the developing perinatal skeleton. Where skeletal pathology that is more readily attributable to the development of the very young individual and is not necessarily associated with the maternal condition was encountered, detailed descriptions are provided and possible aetiology is discussed. Trends of skeletal pathology in very young individuals across the study populations are identified, the aetiology of pathology cases and the significance of specific pathology within each population are discussed with regard to their connection to development disturbance.

6.2 Skeletal Development

Detailed publications on developmental osteology, such as reference works (Cunningham *et al*., 2016) have facilitated significant advances in the bioarchaeology of very young individuals. The recovery of skeletal remains of very young individuals during excavation has been greatly improved as a result of field guides and quick reference laboratory manuals (Baker *et al*., 2005; Schaefer *et al*., 2009), and the increasing use of scientific analytical methods has broadened the framework for interpreting juvenile skeletal remains. These resources among others, provide the basis for the bioarchaeological study of juveniles and have stimulated a considerable volume of publications focussed on the skeletal remains of very young individuals and chlidren. They have also substantially improved our understanding of the developing skeleton.

The elements of the human skeleton are formed primarily through two processes, endochondral and intramembranous ossification. Endochondral ossification refers to the gradual development of bone within a cartilaginous precursor of the element. This ossification process typically occurs in elements where trabecular bone forms the internal supporting structure (Scheuer and Black 2004), particularly in smaller elements such as carpals, epiphyses, and the ends of long bones. Intramembranous ossification occurs within hyper-vascular membranes rather than cartilaginous tissues (Scheuer and Black 2004) and results in a radiating structure of interconnecting trabeculae. As ossification progresses, spaces within the newly ossifying structure are filled in and a cortical layer develops. The predominant form of ossification for the perinatal skeletal elements is given below (Table 6.1).

Table 6.1. Primary ossification of the developing skeleton (adapted from Scheuer and Black, 2000).

Skeletal Region	**Endochondral**	**Intramembranous**
Cranial	Temporal (petrous), occipital (basilar and lateral parts), sphenoid (body, lesser wings)	Temporal (squama), parietal, frontal, nasal, ethmoid, vomer, zygomatic, occipital (squama), sphenoid (majority of greater wing), maxilla, palatine, mandible (majority)
Vertebral	Centra, dens, hyoid (body), sacral alae	Hyoid (horns), neural arches
Thoracic	Manubrium, sternebrae	Ribs
Pectoral and Pelvic		Scapula, clavicle, ilium, ischium, pubis
Appendicular	Patella, epiphyses	Long bone diaphyses
Extremities	Carpals, tarsals, sesamoids	Phalanges, metacarpals, metatarsals

6.2.1 Normal Appearance

The normal appearance of skeletal elements can vary considerably during the course of their development. Many of the surfaces of perinatal elements have a woven appearance. While bone surfaces in the highly vascular metaphyseal regions of active ossification have a porous billowed appearance (Scheuer and Black 2004). The process of ossification does not occur concurrently across the developing skeleton and as such, the appearance of each element differs according to its particular stage of development. For example, the parietal of a mid-term individual is finely structured and transparent with minimal ossification between the trabecular mesh, however the same element in a neonatal individual has smooth well-developed cortical layers that obscure the inner trabecular network (Figure 6.1).

The perinatal vault elements have three ossified layers; inner and outer cortical layers and a developing diploic layer. Lewis (2004) states that there is only a single layer present at birth with clear definition of the three layers not observable until the fourth year of infancy. However, the three layers are clearly visible in dry bone that has fractured (Figure 6.2). It is also possible to identify the distinct layers in microradiographs of a six month old fetus, providing evidence that although very rudimentary, the basic structure of these elements is present prior to birth (Vignaud-Pasquier *et al*., 1964).

Figure 6.1. Macroscopic appearance of the developing parietal, endocranial surface (L-R: Scheuer Sk. 6, 24-26 weeks and Clinical A, 40 weeks).

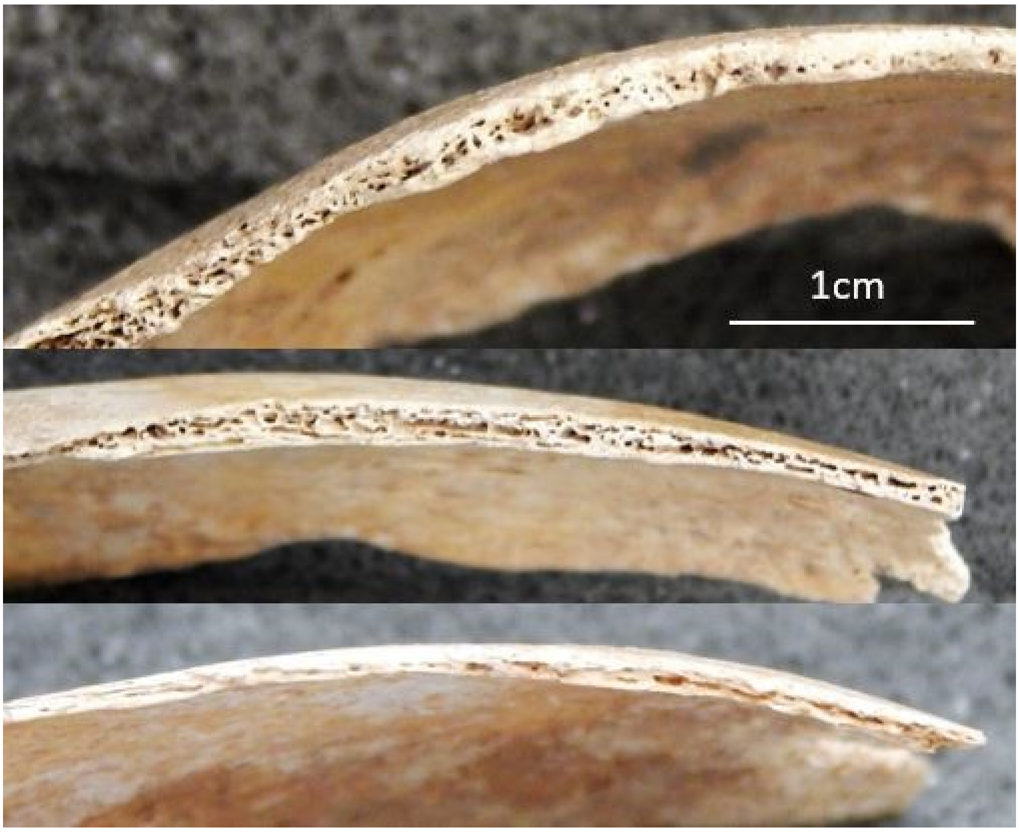


Figure 6.2. Clearly defined layers of the perinatal (36-40 weeks) vault showing inner and outer layers and a developing diploe (Top-Bottom: frontal, parietal, occipital squama).

The majority of the perinatal postcranial elements share similar gross macroscopic cortical appearances to those of the cranium. The exceptions are the vertebral centra and the developing carpals and tarsals, which have highly porous surfaces that are closer in appearance to metaphyseal surfaces (Figure 6.3). Muscle and connective tissue attachment sites are discernible in the developing cortical surfaces, particularly those of the larger long bones (Figure 6.4). Each element usually has at least two different surface appearances that distinguish different architectural functions. For example, the perinatal ilium has four distinct surface appearances; a mostly smooth medial surface, a woven lateral surface, a raised auricular surface, and the porous metaphyseal surfaces of the crest and acetabulum (Figure 6.5). The surface appearance of each perinatal element and its developmental changes can provide information on individual variation, development and pathology.

Figure 6.3. The porous surface of thoracic centra (Ardreigh Sk. 304) (top) and tarsals (Scheuer Sk. 88) (bottom), both perinatal individuals (38-40 weeks).

Figure 6.4. Attachment site of m. pronator teres (circle) on a perinatal radius.

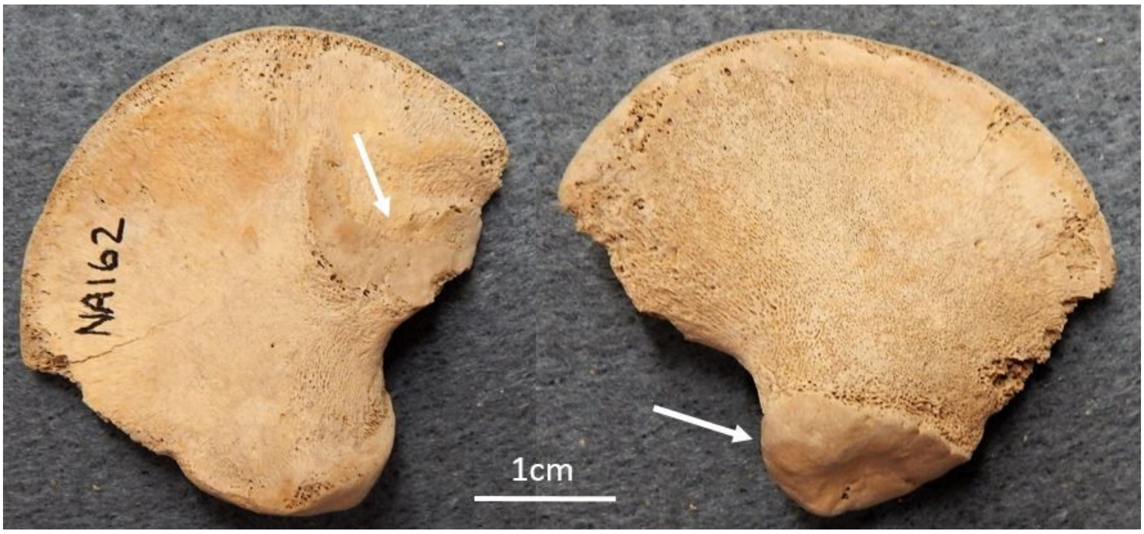


Figure 6.5. Different surface appearances of the perinatal right ilium. Arrows point to the auricular surface (left) and the acetabulum (right). Note the smooth medial surface (left) and the woven lateral surface (right).

6.3 Pathological Development and Appearance

Pathological appearance of skeletal remains is usually differentiated from normal morphological variation by a significant change in morphology, surface appearance, dimension and position within the skeleton. In very young individuals however, skeletal pathology may also be determined by an out-of-phase stage of development. This might include delayed development of a particular element, development in advance of the remainder of the skeleton, early or delayed fusion, non-fusion, supernumerary elements, and partial or complete agenesis. Some pathological conditions involve the soft tissues and affect the position but not the form of skeletal elements, for example spina bifida occulta. These pathologies are difficult to identify in archaeological remains unless they have been assessed *in situ* prior to lifting the remains from their burial environment.

Pathological changes observed in developing elements are often subtle and may be confused with normal morphological variation. Scheuer and Black (2004) comment on the interpretation of exposed trabecular structures in immature skeletal elements as pathological in origin. They highlight that the incomplete appearance of cortical bone and an externally visible trabecular structure is not necessarily pathological, but may be indicative of early skeletal development. The relationship between skeletal anomalies, their surrounding soft tissues and the remainder of the skeleton is also a key consideration in determining whether any changes observed are indeed pathological for that particular individual. The individuals with skeletal pathology observed during analysis of the collections are listed below in Table 6.2. As expected of collections of this nature, the reference collections that derive from medical specimens (Clinical, Royal College of Surgeons, and Scheuer collections) have a relatively high number of very young individuals with skeletal pathology when compared to the archaeological collections.

Table 6.2. The individuals in each age category with observed skeletal pathology. Percentages are of the total individuals in each age category within the relevant collection. Totals are the number of individuals with pathology within site or age category.

	Fetal	**Perinatal**	**Neonatal**	**Infant**				**Totals**
Collection	**(<24w)**	**(24-40 w)**	**(41-44w)**	**(45w-2.9 m)**	**(3-5.9 m)**	**(6-8.9 m)**	**(9-12 m)**	
Ardreigh	0/1	17/29 (59%)	15/27 (56%)	5/10 (50%)	6/11 (55%)	2/5 (40%)	1/4 (25%)	46/87 (53%)
Barton Court Farm	-	26/44 (59%)	4/7 (57%)	-	3 (100%)	0/1	-	33/55 (60%)
Çatalhöyük	-	24/63 (38%)	1/6 (16%)	0/5	4/7 (57%)	0/5		29/86 (34%)
Gussage All Saints	-	19/32 (59%)	3 (100%)	-	-	-	-	22/35 (63%)
Wetwang Slack	-	7/16 (44%)	14/15 (93%)	-	2 (100%)	1 (100%)	2 (100%)	26/36 (72%)
Wharram Percy	-	21/31 (68%)	15/18 (83%)	14/17 (82%)	12 (100%)	4/5 (80%)		66/83 (80%)
Yewden Villa	-	27/51 (53%)	2 (100%)	-	1 (100%)	-	1/2 (50%)	31/56 (55%)
Clinical	-	5 (100%)	-	-	-	-	-	5/5 (100%)
Royal College	149/169 (88%)	7/9 (78%)	19/21 (90%)	-	-	-	-	175/199 (88%)
Scheuer	0/4	14/18 (78%)	3 (100%)	0/1	-	2 (100%)	1 (100%)	20/29 (69%)
Totals	**149/174**	**167/298**	**76/102**	**19/33**	**28/36**	**9/19**	**5/9**	**453/671**

6.3.1 Skeletal Indicators of Stress

The development of the skeleton is primarily dependent upon the early stages of embryonic development. Changes that affect the form of the embryo during early pregnancy will have an impact on the developing skeletal elements and soft tissues. The adaptive nature of the skeleton is demonstrated through structural modifications in response to any pathology of precursor structures and soft tissue. Significant pathological changes to the appearance of developing skeletal elements are not only observable, but have potentially serious implications for the protection of vital systems and neonatal viability. Given the relatively short length of time for skeletal development prior to birth, it is not surprising that pathological changes in the immature skeletal elements may be subtle and easily overlooked. However, in cases of extreme skeletal pathology the elements may not be recognisable, even to the experienced osteologist.

6.4 Development Disturbance

Developmental disturbance may be indicated by alterations in development sequences or changes in the appearance and fusion of skeletal elements. Within the skeleton, dentition is considered to be less susceptible to disturbances in growth and development than the remainder of the elements (Bowman *et al*., 1992; Demirjian, 1986; Garn *et al*., 1959, 1965a; Lewis and Garn, 1960; Smith, 1991). Very few individuals in the collections analysed, displayed pathology of the dentition compared to the considerable number of individuals with other forms of skeletal pathology.

6.4.1 Dental Anomalies

Two infants display gemination of the deciduous dentition, a mild form of dental pathology with the appearance of an incomplete division of the crown (Guimarães Cabral *et al*. 2008; Neville *et al*. 2016) (Table 6.3). Differentiation between the fusion of two teeth (Meadors and Jones, 1992) and the division of a single tooth is made on the number of teeth present, rather than the characteristics of the affected tooth, as these may be observed in either form. Only one of the anomalous teeth shows evidence of a double root that may be an indication of fusion rather than gemination in this individual (Sk. 784). The remainder of the gemination teeth observed have a single root (Figure 6.6).

Table 6.3. Individuals with dental pathology in the form of gemination.

Collection	**Individual**	**Age**	**Affected Dentition**
Ardreigh	784	6-12 months	Right maxillary central and lateral incisors
Scheuer	91	6-9 months	Left maxillary lateral incisor and right mandibular central incisor

Figure 6.6. Gemination of maxillary right incisors in deciduous dentition (Ardreigh Sk. 784, 6-12 months). Labial view (top) and lingual view (bottom). The normal left lateral maxillary incisor is shown on the right for comparison.

6.4.2 Craniolacunia and Perforation

Thinning of the inner table of the cranial vault to the point of transparency, referred to as craniolacunia, was only observed in perinatal individuals. This form of vault pathology is attributed to dysplasia of the developing vault elements through defects in the underlying dura (Castriota-Scanderbeg and Dallapiccola 2005). Craniolacunia was previously considered to be a response of the cranial vault to congenital hydrocephaly, however it is now associated with soft tissue defects of the spinal cord and brain such as Chiari malformations (Castriota-Scanderbeg and Dallapiccola 2005). This group of malformations involve the cranial base, in particular the posterior aspect of the foramen magnum, and herniation of the brain tissue through the foramen magnum or an occipital or cervical cephalocele (Castriota-Scanderbeg and Dallapiccola 2005). In isolation, craniolacunia resolves during the first year of infancy, however those infants with associated severe Chiari type malformations (types II or III) are unlikely to survive past early infancy (Castriota-Scanderbeg and Dallapiccola 2005; Stevenson 2004).

The Royal College of Surgeons medical reference collection includes seventeen fetal and perinatal individuals with craniolacunia or complete perforation of both tables. Although no individuals from the archaeological collections had craniolacunia that had developed into vault fenestrations, five did exhibit areas of thinning and transparency. Three perinatal individuals (Çatalhöyük Sk. 2199, 38-40 weeks and Sk. 10368, 38 weeks, and Scheuer Sk. 7, 38-40 weeks) and two infants (Wharram Percy Sk. NA194, 3-6 months and Scheuer collection Sk. 91, 6-9 months) had thinning of the cranial vault elements. One of the perinatal individuals (Çatalhöyük Sk. 10368) had significant thinning of the orbital plate that had resulted in perforation. These bilateral single perforations of the orbital plate appear to be associated with increased porosity of the orbital plate, and have clear concentric bands of bone around the margins of the perforation (Figure 6.7).

Figure 6.7. Bilateral abnormal thinning and perforation of the orbital plate (Çatalhöyük Sk. 10368, 38 weeks).

Two individuals from the Ardreigh burial population had other anomalies of the occipital that may be related to soft-tissues of the brain and the cranial vascular system. Infant (Sk. 1840, 3-6 months) displays division of the cerebral fossae of the occipital squama (Figure 6.8). There is no evident thinning of the squama associated with this developmental anomaly and the cerebellar fossae appear normal.

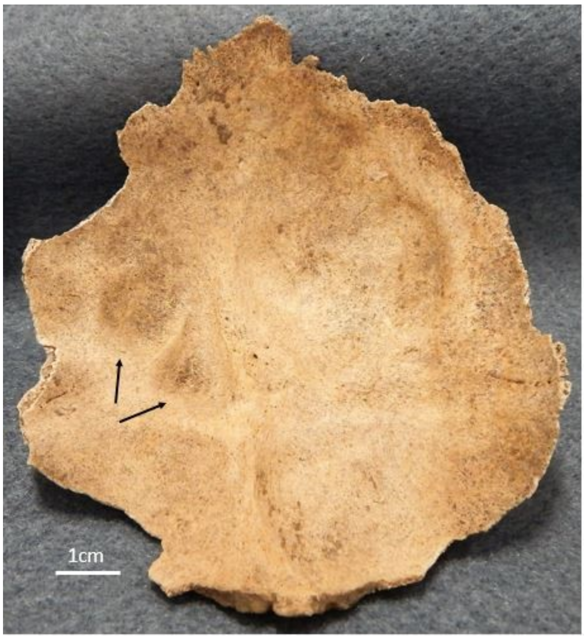


Figure 6.8. Pronounced division of the right cerebral fossa (arrows indicate partitioning of fossa) (Ardreigh Sk. 1840, 3-6 months).

The second individual is another infant, Sk. 924 (6-9 months). In this individual there is bilateral perforation of the partes lateralis of the occipital. These perforations have irregular margins and are positioned within the sigmoid sulcus and when viewed ectocranially they are located at the posterior margin of the occipital condyle (Figure 6.9). The perforations may be associated with the posterior condylar canal; non-pathological variation in the location of the canal is commonly observed in adult crania where a posterior position is referred to as the retrosinus form of the canal (Kothandaraman and Lokanadham, 2015). The vessels that pass through the posterior condylar canal are the posterior condylar vein and the meningeal branches of the occipital artery (Gray, 2001). It has been proposed that the posterior condylar canal may function to provide “additional drainage into extracranial veins” (Kothandaraman and Lokanadham 2015, 223). Gray (2001) notes that the posterior condylar fossa may be perforated by a foramen and that a bilateral expression, as seen in Sk. 924, is the least common variation of perforating foramina. If the bilateral perforation of the cranial base observed in Sk. 924 is pathological in origin, then a possible aetiology may be related to the morphology of the sigmoid sinus and potentially to an increase of the intravenous pressure affecting bone formation in the base of the sinus.

Figure 6.9. Bilateral perforation of the partes lateralis (Ardreigh Sk. 924, 6-9 months).

6.4.3 Hypoplasia

A neonatal individual from the Barton Court Farm burial population (Sk. 869, 0-1 month) has a hypoplastic left pubis with thickening of the superior ramus and potential agenesis of the pubic symphysis (Figure 6.10). Both ilia and ischia are present and display normal morphology and the completeness of the remainder of the skeletal remains discounts alternative identification of the dysmorphic element, however it is possible that the pubis was bipartite and the smaller portion was not recovered. The development of double ossification centres in the pubis has been described (Caffey and Madell, 1956; Keats and Anderson, 2013). In individuals with double ossification centres of the pubis, these will usually fuse during early infancy (Eich *et al*., 1992). In contrast, agenesis of the pubic symphysis is associated with congenital exstrophy of the bladder, arising from a failure of normal embryonic development (Inouye *et al*., 2014; Ortner 2003; Sponseller *et al*., 1995). Exstrophy of the bladder is a rare congenital condition that occurs more often in males than females and affects the pelvic elements with absence of the pubic symphysis, agenesis or reduction of the pubic ramus and lateral rotation of the remaining pelvic elements (Inouye *et al*., 2014; Jeffs and Lepor, 1986; Sponseller *et al*., 1995). Although agenesis of the pubic symphysis is compatible with life, the risk of infection in cases of bladder exstrophy is considerably elevated by exposure of the bladder and surrounding soft tissues to the external environment. The ilia of this individual display unusual porosity of the auricular surface that may be associated with a change in the sacroiliac joint (Bedeschi Rego de Mattos *et al*. 2011) (Figure 6.11). However, the incomplete development of the pelvic joints at this very young age is a limitation in ascribing potential aetiologies. The lower vertebral elements and femora of Sk. 869 do not display any evident skeletal pathology that would reflect a significant lateral rotation of the pelvic elements. Individual Sk. 869 also displays other skeletal pathology in the form of porous lesions of the maxillae and endocranial lesions that are potentially suggestive of a compromised immune system, as well as unusually gracile lower limb bones. Differential diagnosis includes congenital hypogonadism that leads to prolonged growth periods and subsequent gracile skeletal elements, particularly the major long bones (Ortner, 2003). However, the skeletal remains of Sk. 869 do not consistently display elongation nor is the remainder of the skeleton particularly gracile.

Figure 6.10. Left ilium, ischium and pubis (arrow) of Barton Court Farm Sk. 869 (0-1 month) (top). Agenesis of the pubic symphysis (middle) (lateral and medial aspects). Normal neonatal pubis shown in the bottom images (lateral and medial aspects).

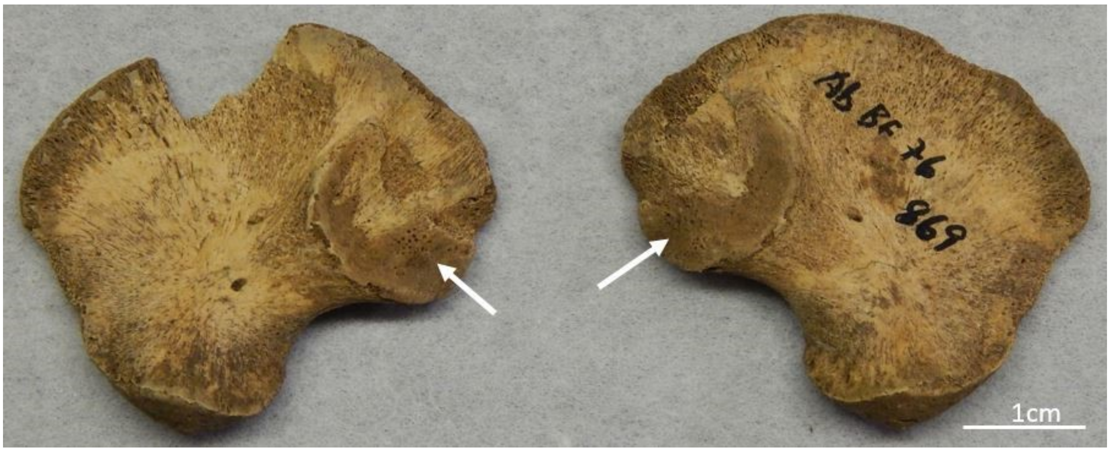


Figure 6.11. Abnormal porosity (arrows) of the sacroiliac joint surface on the ilium (Barton Court Farm Sk. 869, 0-1 month).

A perinatal individual from the Wharram Percy burial population (Sk. NA61, 36-40 weeks) has a complete transverse cleft of the basilar process of the occipital with potential agenesis of the anterior half of the element. Agenesis of the anterior half of the basilar process is considered to be very rare (Bryce, 1915; Kawakubo *et al*., 2013; LeDouble, 1903). The partes lateralis and the occipital squama are normal in appearance (Figure 6.12). Barnes (2012) attributes a bilateral horizontal cleft of the basilar process to a failed cranial border shift. There is no other occipital or vertebral evidence for cranial shifting in this individual, although there is considerable evidence for various cranial and caudal shifting in the rest of the burial population at Wharram Percy (see Chapter 7). Brothwell (1958) describes an adult with agenesis of the basilar process of the occipital. He notes that the sphenoid was unaffected and suggests that the space that would normally be occupied by the basilar process was occupied by a cartilaginous connection (1958, 73). Individual Sk. NA61 also has a porous lesion within the hypophyseal fossa of the postsphenoid that may be associated with soft tissue deformity in this region (Figure 6.13). It is also possible that the basilar process developed from multiple ossification centres

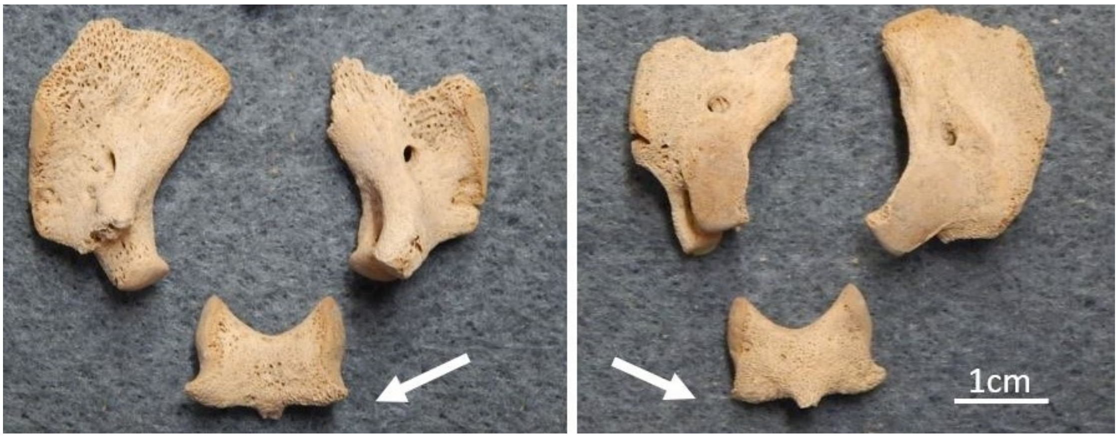


Figure 6.12. Bilateral transverse cleft of basilar process with potential agenesis of the anterior half (arrows). Endocranial surfaces (left) and ectocranial surfaces (right) of the occipital elements. (Wharram Percy Sk. NA61, 36-40 weeks).

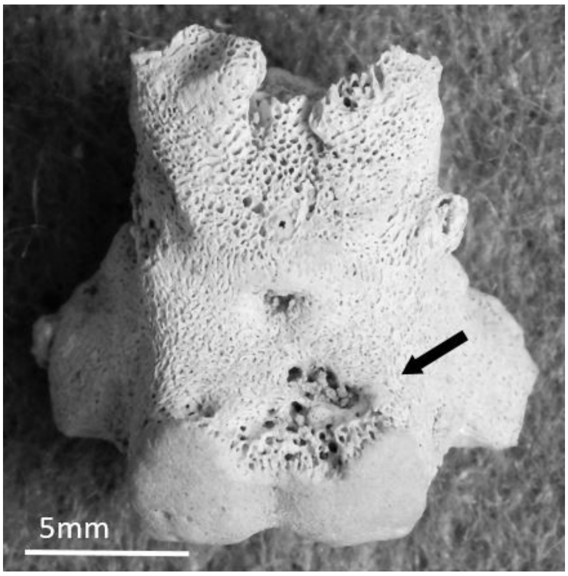


Figure 6.13. Erosive lesion (arrow) in the hypophyseal fossa of Wharram Percy Sk. NA61.

6.4.4 Dysmorphy

One individual among those analysed, a perinate from the Ardreigh burial population (Sk. 1444, 38-40 weeks), has a midline defect in the supra-occipital portion of the squama that is evident on both the ectocranial and endocranial surfaces (Figure 6.14). The endocranial surface of the defect is continuous with the sutural margin of the occipital squama. This suggests that the connective cartilaginous tissue in this region was involved in the formation of the defect.

Figure 6.14. Midline defect (arrow) in the inferior border of the occipital squama (Ardreigh Sk. 1444, 38-40 weeks).

Several other forms of skeletal pathology and variation of the cranial elements that are developmental in origin were observed in the archaeological collections. These include extra-sutural ossicles of the cranial vault, early fusion of sutures, partial clefts and partial agenesis of cranial elements. Eleven individuals had cranial vault ossicles, three of which were unusually situated and relatively large (Table 6.4). Two perinatal individuals (Barton Court Farm Sk. 904, 38-40 weeks and Wharram Percy Sk. NA6A, 34 weeks) have unilateral elongate epipteric ossicles with porous ectocranial surfaces (Figure 6.15) (Barnes 2012, Figure A-1.1). A neonatal individual from the Gussage All Saints burial population (Sk. 132.5, 40-42 weeks) has an unusually large section of the occipital squama missing with a clear sutural edge on the remaining portion. By overlaying the occipital fragments on a more complete squama from the same population, the size of the absent area is demonstrated to be considerable (Figure 6.16). No other cranial fragments with similar sutural edges were present with the remains of this individual. Agenesis of this portion of the occipital squama is an unlikely explanation, however a large inter-parietal ossicle would account for the missing area of squama and the edge morphology of the fragments present.

Table 6.4. Individuals with extra-sutural ossicles of the cranial vault.

Collection	Individual	Age	Description
Barton Court Farm	904	38-40w	Unilateral elongate epipteric ossicle
Çatalhöyük	10390	38-40w	Lambdoid (?) ossicle
Çatalhöyük	10391	38-40w	Lambdoid (?) ossicle
Çatalhöyük	14164	38-40w	Lambdoid (?) ossicle
Gussage All Saints	285.1	0-1m	Lambdoid (?) ossicle
Gussage All Saints	132.5	40-42w	Inter-parietal (?) ossicle
Scheuer	91	6-9m	Small lambdoidal ossicles of the occipital squama and two parietal ossicles within the sagittal suture
Wetwang Slack	162	9-12m	Lambdoid ossicle (left)
Wetwang Slack	NA92	3-6m	Lambdoid (?) ossicle
Wharram Percy	NA6A	34w	Unilateral elongate epipteric ossicle
Wharram Percy	G534	3-6m	Lambdoid (?) ossicle

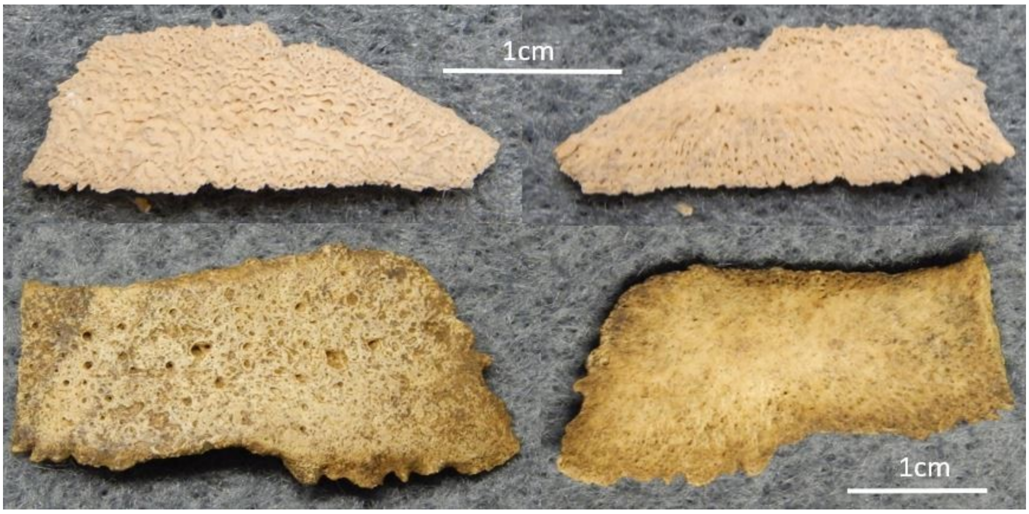


Figure 6.15. Elongate epipteric ossicles. Ectocranial surface (left) and endocranial surface (right). (Barton Court Farm Sk. 904 (38-40 weeks) (top) and Wharram Percy Sk. NA6A, 34 weeks).

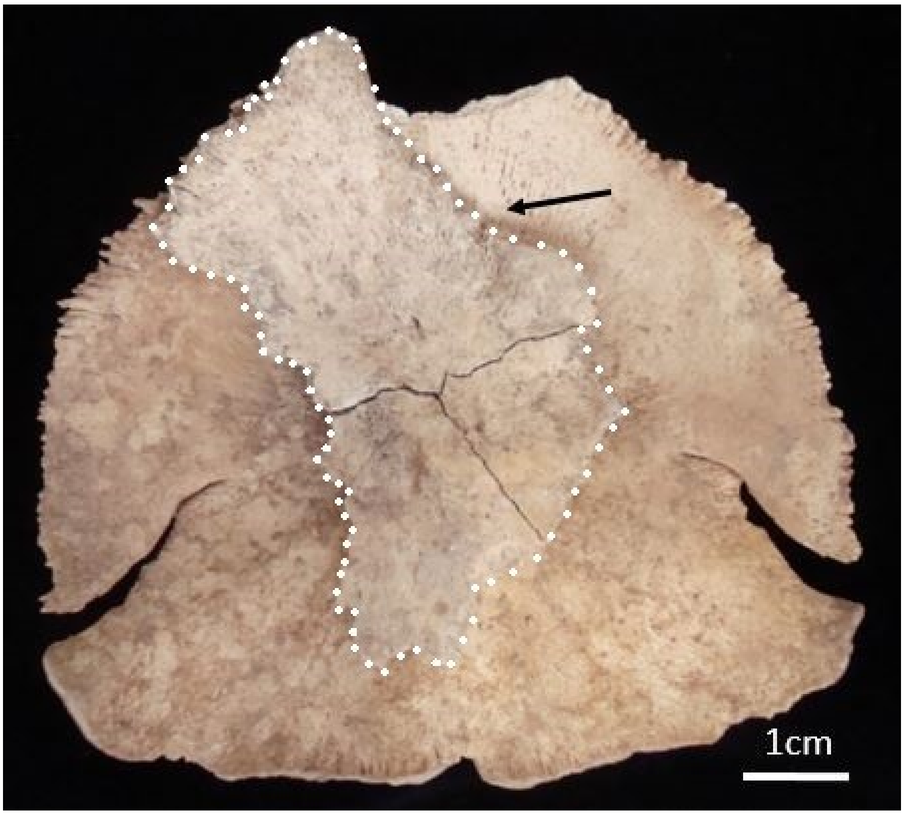


Figure 6.16. Location of a large occipital squama ossicle. The arrow indicates the sutural edge. (Gussage All Saints Sk. 132.5, 40-42 weeks).

An infant held in the Scheuer reference collection (Sk. 91, 6-9 months) has a number of small lambdoidal ossicles of the occipital squama, particularly on the right side as well as a couple within the parietal portion of the sagittal suture (Figure 6.17). Seven other individuals had ossicles that could not be associated with a particular location on the cranial vault (Figure 6.18). These ossicles had porous ectocranial surfaces and irregular margins. It is assumed that they are associated with the lambdoid suture although a more anterior location, such as the pterion is also possible. Their size of approximately 2cm in diameter suggests that they are more likely to have been located at bregma or lambda, or within the inter-parietal sutures. By comparison, smaller ossicles are more commonly located along the sutures (Barnes 2012).

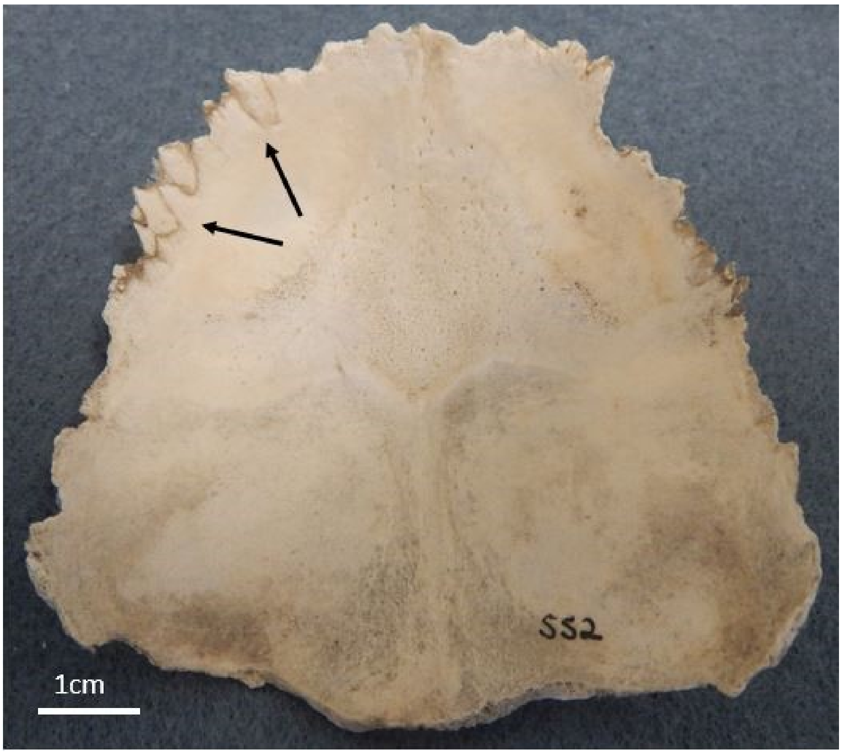


Figure 6.17. Extra-sutural ossicles (arrows) in the lambdoidal suture. (Scheuer Sk. 91, 6-9 months).

Figure 6.18. Extra-sutural ossicles most likely associated with the lambdoidal suture (L-R top: Çatalhöyük Sk. 10391 and 10390, Gussage All Saints Sk. 285.1; L-R bottom: Çatalhöyük Sk. 14164, Wharram Percy Sk. G534 and Sk. NA92).

Three perinatal individuals display unusual morphology of the mendosal suture of the occipital squama. One (Barton Court Farm Sk. 400, 38-40 weeks) has what appears to be a fold in the central portion of the suture (Figure 6.19). This suggests irregular fusion between the supra-occipital and the inter-parietal portions of the occipital squama. The other two individuals (Barton Court Farm

Sk. 916, 38-40 weeks and Wharram Percy Sk. NA129, 36-40 weeks) both show early fusion of the suture from the lateral margins of the squama, leaving a section of the suture open within the squama (Figure 6.20). The mendosal suture should start to fuse from the fourth postnatal month (Redfield, 1970), however these two individuals are considerably younger. Premature fusion of this suture may be indicative of early stage craniosynostosis although there is no evidence of early fusion in the remaining vault elements.

Figure 6.19. Abnormal fusion (arrow) of the mendosal suture of the occipital squama (Barton Court Farm Sk. 400, 38-40 weeks).

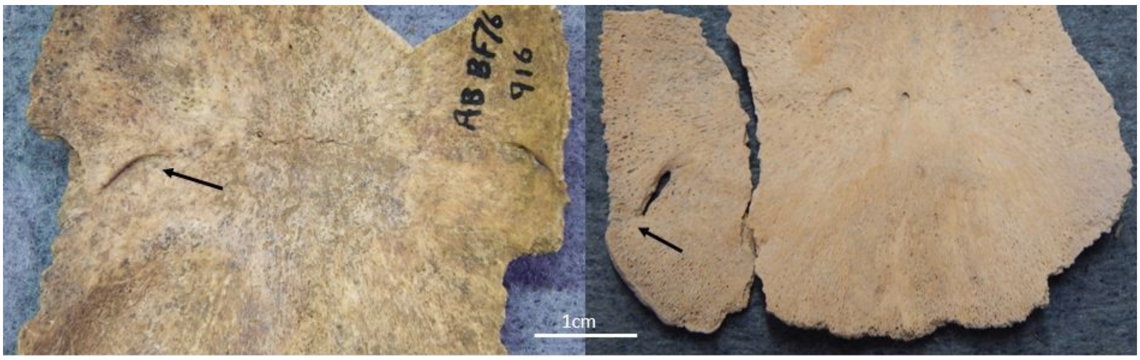


Figure 6.20. Early fusion of the lateral margins of the mendosal suture (arrows) (L-R: Barton Court Farm Sk. 916, 38-40 weeks and Wharram Percy Sk. NA129, 36-40 weeks).

One perinatal individual (Ardreigh Sk. 905, 36-38 weeks) has unusual unilateral dysmorphy of the first and second left ribs. The costal end of the first rib is expanded and the surface that articulates with the costal cartilage is convex longitudinally. The second rib has a broad medial projection on the shaft that would be adjacent to the sternal end of the first rib if these two elements were anatomically positioned (Figure 6.21). The location of this anomaly on the second rib suggests an alteration in the morphology of the first costal cartilage involving an articulation with the second rib. There is no evidence of dysmorphy of the vertebral ends of the first two left ribs.

Figure 6.21. Unilateral dysmorphy (arrows) of the first and second left ribs (Ardreigh Sk. 905, 36-38 weeks).

Two individuals from the Wharram Percy burial population have unusual characteristics of the elbow joint. Individual Sk. G476 (36-40 weeks) displays clear bilateral definition of the insertion site of *m. brachialis* on the antero-medial surface of the proximal ulna (Figure 6.22). The primary function of *m. brachialis* is to flex the forearm (Stone and Stone 2012). The appearance of the proximal ulnae in this individual may indicate either a sustained position of flexed forearms or hyperkinetic activity of the same during the second half of gestation (Jones, 2006; Son-Hing and Thompson, 2014). The tension exerted on the developing bone through contraction of this muscle is likely to produce a noticeable difference in the cortical surface in this region of the ulna. The second individual (Sk. NA161, 34-36 weeks) has bilateral dysmorphy of the distal metaphyseal surface of the humerus in the form of a distally extended central anterior border of the olecranon fossa (Figure 6.23). There is no evident dysmorphy of the proximal ulna in this individual.

Figure 6.22. Bilateral pronounced insertion site of m. brachialis (arrow) (Wharram Percy Sk. G476, 36-40 weeks).

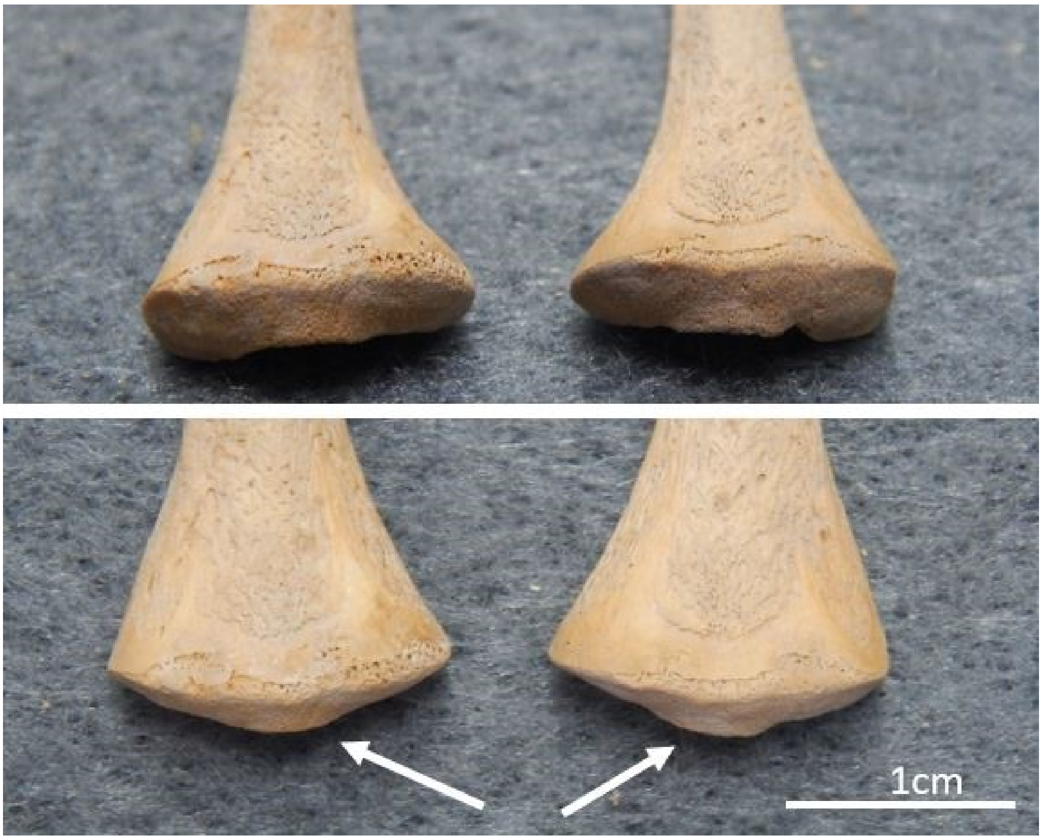


Figure 6.23. Bilateral dysmorphy (arrows) of the distal metaphyseal surface of the humerus (Wharram Percy Sk. NA161, 34-36 weeks).

Four individuals display dysmorphy of the ribs and clavicles (Table 6.5). There is no associated surface pathology in these elements, which suggests that the dysmorphy is developmental in nature and may be a response to individual intrauterine restriction, particularly in the case of the clavicles (Son-Hing and Thompson, 2014). As these four individuals are from different burial populations or different time periods and range in age from perinatal to early infancy, there is no apparent cultural or population specific connection to the shared expressions of dysmorphy. One individual (Scheuer Sk. 83, 40 weeks) displayed a bilateral anomaly of the auricular surface of the ilium (Figure 6.24).

Table 6.5. Morphological anomalies of the pectoral girdle and thorax.

Collection	Sk.	Age	Description	Aetiology
Ardreigh	1431	40-42w	Expansion of sternal end of left rib one	Developmental
Barton Court Farm	UB5	38-40w	Undulation of inferior costal margin, costal neck agenesis (single rib)	Developmental
Gussage All Saints	96	38-40w	Bilateral expanded acromial end of clavicle	Developmental or positional
Wharram Percy	NA170A	1-3m	Undulation of inferior costal margin (mid-thorax)	Developmental

Figure 6.24. Bilateral anomaly of the auricular surface of the ilium (Scheuer Sk. 83, 40 weeks).

6.4.5 Anomalies of the Sphenoid

A range of morphological and developmental variation was observed in the elements of the sphenoid during analysis. These include undulation of the anterior margin of the lesser wings, varying degrees of anterior clinoid bridging, porosity of the greater wings, irregular fusion of elements and dysmorphy of the hypophyseal fossa. The basilar process that articulates with the postsphenoid does not display a similarly wide range of morphological variation, which suggests that the elements of sphenoid are more susceptible to alteration through environmental and developmental factors.

The anterior margin of the lesser wings is usually smooth but in nine individuals it was irregularly undulated (Figure 6.25) (Table 6.6). The anterior margin of the lesser wings articulates with the posterior surface of the frontal orbital plate once ossification is complete (Scheuer and Black 2000). The dysmorphy of the lesser wing margin observed during analysis was not reflected in the adjacent elements. It is suggested that this alteration in the anterior margin is a pathological extension of ossification into the cartilaginous connective tissues and may be related to developmental pathology of the chondrocranium. It is also possible that the appearance of the lesser wings is a reflection of incomplete formation.

Figure 6.25. Undulation of anterior margin in the lesser wings of the sphenoid (arrow) (Scheuer Sk. 161, 0-1 month).

Table 6.6. Individuals with abnormal undulation of the lesser wings of the sphenoid.

Collection	Individual	Age	Description
Ardreigh	905	36-38w	Bilateral
Çatalhöyük	2017	38-40w	Left wing (right wing absent)
Çatalhöyük	10112	38-40w	Bilateral with lateral extension on the right wing
Çatalhöyük	14165	38-40w	Right wing (left wing absent)
Çatalhöyük	22759	38-40w	Bilateral with bilateral lateral extension and inclusion of incomplete foramina
Gussage All Saints	132.9	38-40w	Bilateral, with mediolateral compression of wings
Scheuer	161	0-1m	Bilateral with bilateral lateral extension and bilateral inclusion of foramina
Wetwang Slack	746	38-40w	Bilateral, with mediolateral compression of wings
Wharram Percy	NA142	38-40w	Bilateral, with mediolateral compression of wings

Three individuals displayed irregular fusion and dysmorphy of the sphenoid body that are developmental in origin. Two perinatal individuals (Wharram Percy Sk. NA142, 38-40 weeks and Scheuer Sk. 97, 36-40 weeks) have a dysmorphic presphenoid and one of these has lateral reduction of the lesser wings (Figure 6.26). One perinatal individual from the Çatalhöyük burial population (Sk. 10112, 38-40 weeks) has a sagittal cleft in the postsphenoid (Figure 6.27). The cleft appears to be an expansion of the posterior fissure of the postsphenoid into the central portion of the hypophyseal fossa. There is no corresponding dysmorphy of the basilar process. This individual had several other anomalies of the vertebral elements that may share an aetiology with the dysmorphy of the postsphenoid. These are unilateral mild hypoplasia of the right cervical neural arches (see section 6.4.6) and evidence of persistent notochordal tissue in the third to eighth thoracic centra (see section 6.4.7).

Figure 6.26. Dysmorphic presphenoid with lateral reduction of the lesser wings (top) (Wharram Percy Sk. NA142, 38-40 weeks). Dysmorphic presphenoid with normal lesser wings (bottom) (Scheuer Sk. 97, 36-40 weeks).

Figure 6.27. Sagittal cleft of the postsphenoid (white arrow) that bisects the hyposphyseal fossa (black arrow) (Çatalhöyük Sk. 10112, 38-40 weeks).

Fifteen individuals in the collections analysed have evidence of an anatomical variant of the sphenoid, the carotico-clinoid foramen that is formed by bridging between the anterior and medial clinoid processes (Zdilla *et al*., 2015) (Table 6.7) (Figure 6.28). The foramen can appear bilaterally, but in the majority of the cases observed it was unilateral. Two individuals also have evidence for bridging between the anterior and posterior clinoid processes, forming an inter-clinoid osseous bridge (Erturk *et al*., 2004) (Figure 6.29). These morphological variants involve the internal carotid artery and have significant implications for vascular pathologies and neurovascular surgery (Zdilla *et al*., 2015).

Table 6.7. Individuals with clinoid bridging of the sphenoid.

Collection	Individual	Age	Description
Ardreigh	304	38-40w	Left anterior clinoid process
Ardreigh	898	0-1m	Bilateral anterior clinoid bridge
Ardreigh	905	36-38w	Right middle clinoid process
Ardreigh	1911	0-1m	Left anterior clinoid bridge
Barton Court Farm	678	38-40w	Right middle clinoid process
Barton Court Farm	869	0-1m	Bilateral middle clinoid process
Barton Court Farm	1138	38-40w	Bilateral anterior clinoid bridge
Çatalhöyük	14146	36-38w	Right middle clinoid process
Çatalhöyük	14164	38-40w	Bilateral middle clinoid process
Çatalhöyük	14165	38-40w	Bilateral middle clinoid process
Scheuer	17	38-40w	Left anterior clinoid process, right anterior clinoid bridge
Scheuer	83	40w	Right anterior clinoid bridge
Scheuer	161	0-1m	Right anterior clinoid bridge, right posterior process beyond bridge
Wharram Percy	EE88	40-42w	Bilateral middle clinoid process
Wharram Percy	NA99	36-38w	Left anterior clinoid bridge, right middle clinoid process
Wharram Percy	NA150	3-6m	Bilateral anterior clinoid bridge, left posterior process beyond bridge

Figure 6.28. Bilateral bridging of the anterior and middle clinoid processes (arrows) (Barton Court Farm Sk. 1138, 38-40 weeks).

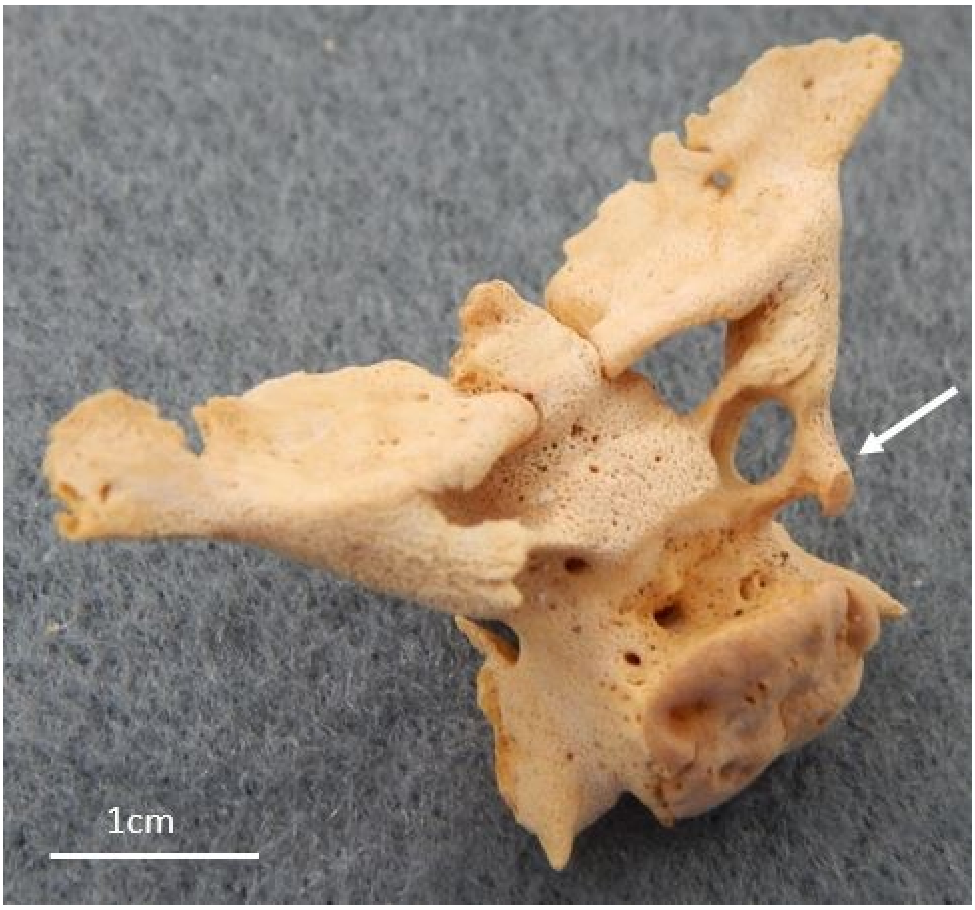


Figure 6.29. Right inter-clinoid process (arrow) with associated anterior clinoid bridge (Scheuer Sk. 161, 0-1 month).

6.4.6 Vertebral Anomalies

Developmental pathology of the vertebral elements including asymmetry and dysmorphy were observed in eighteen individuals (Table 6.8). The majority of individuals analysed in the course of this research displayed minor vertebral asymmetry that falls within the range of normal variation. There are several individuals with atypical morphology that is noteworthy. One perinate from the Çatalhöyük burial population (Sk. 10112, 38-40 weeks) has unilateral mild hypoplasia of the right cervical neural arches that is expected to have resulted in clinical symptoms had the individual survived (Barnes 2012). The mild hypoplasia of the atlas neural arches noted in another individual (Barton Court Farm Sk. UB5, 38-40 weeks) is likely to have been asymptomatic but would have reduced the posterior arch of the atlas if the individual had survived (Barnes 2012).

Table 6.8. Anomalies of the vertebral elements.

Collection	Individual	Age	Description
Çatalhöyük	10112	38-40w	Smaller cervical arches on the right side
	10366.1	34-38w	Posterior sagittal cleft in a single mid-thoracic centrum
Barton Court Farm	UB5	38-40w	Shortened posterior arch of C1
Yewden Villa	31	3-6m	Early development of the anterior bar and enlarged vertebral artery groove in C1 arch
Wharram Percy	G476	36-40w	C6-C7 and two thoracic centra have unequal hemimetameres
	G492	38-40w	Mild dorsal hypoplasia of eight thoracic centra
	NA76	38-40w	Reduced superior articular facet of the left C1 arch corresponding to the occipital condyle
	NA160	0-1m	Mild partial dorsal hypoplasia of a single mid-thoracic centrum
	NA193	0-1m	Enlarged vertebral artery groove in C1 arches
	NA232	0-1m	Dysmorphic posterior synchondrosis of three mid-thoracic arches
	V1	38w	Mild dorsal hypoplasia of three thoracic centra
	V6	2-3m	Early posterior fusion of the lower thoracic arches
Ardreigh	377	0-1m	Enlarged vertebral artery groove in C1 arches
	771	0-1m	Asymmetry of C2 odontoid process, exaggerated facets (pedicles) on sacral arches
	956	0-2m	Asymmetry of superior articular facets of C1
	1444	38-40w	Asymmetry of C2 pedicles and upper thoracic arches, laterally abducted inferior facet on a single right thoracic arch
Scheuer	20	38-40w	Posterior sagittal cleft in a single mid-thoracic centrum
	161	0-1m	Indentation in the left pedicle of C2 and C3 neural arches; altered pathway of vertebral artery

A further five individuals displayed mild forms of asymmetry and dysmorphy of the axial odontoid process, neural arch articular facets, or the posterior synchondrosis of neural arches. Two individuals have small isolated morphological variations; one has a laterally rotated inferior facet on a single right thoracic arch (Ardreigh Sk. 1444, 38-40 weeks) and the other an unusual indentation in the pedicle of the second and third left cervical arches (Scheuer Sk. 161, 0-1 month) (Figure 6.30). The latter may reflect an altered pathway of the vertebral artery in the affected individual.

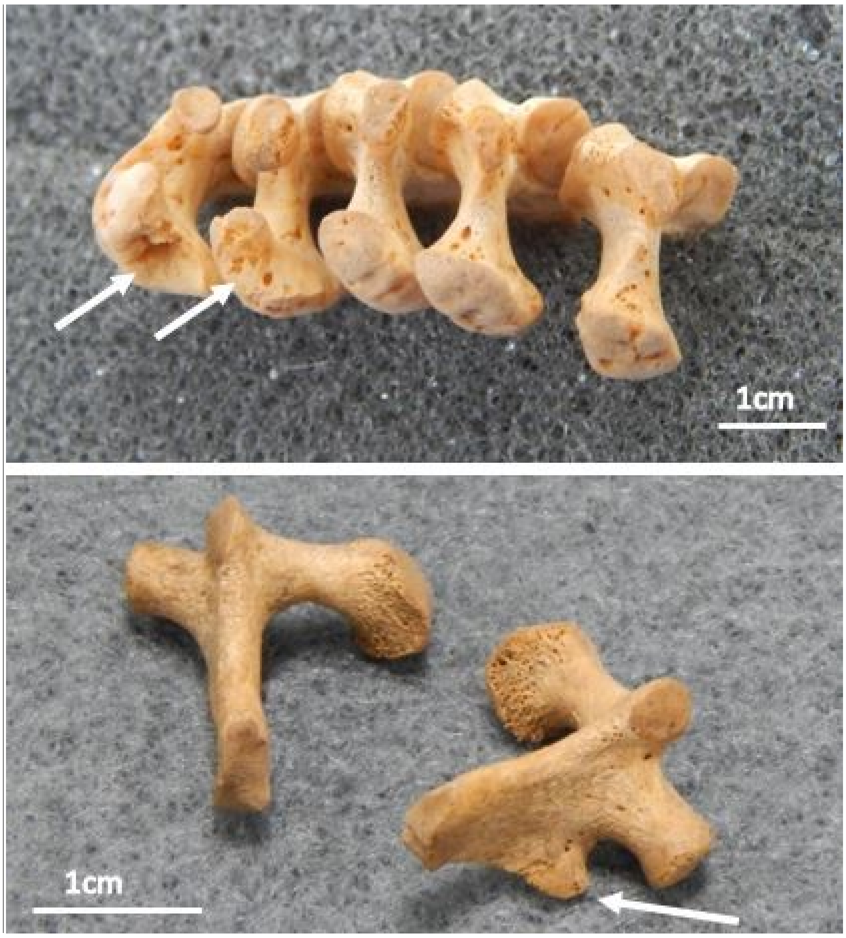


Figure 6.30. An unusual indentation in the pedicle of the second and third cervical neural arches (arrows) (Scheuer Sk. 161, 0-1 month) (top) and a laterally abducted inferior facet on a right thoracic neural arch (arrow) (bottom) (Ardreigh Sk. 1444, 38-40 weeks).

The pathway of the vertebral artery over the posterior arch of the atlas is exaggerated in three individuals (Yewden Sk. 31, Wharram Percy Sk. NA193, and Ardreigh Sk. 377). This is indicated by an enlargement of the superior groove for the artery and the formation of a ridge and lateral process at the posterior margin of the groove. This change in the vertebral element may be a reflection of an increased diameter of the vertebral artery related to volumetric flow and pressure. However this appearance is not necessarily pathological and could represent an asymptomatic variation in physiology.

Dorsal hypoplasia of the vertebral centrum resulting in a ‘pinched’ appearance of the posterior margin, was observed in the thoracic region of three individuals. This form of hypoplasia is usually observed in the lower lumbar vertebrae (Barnes 2012), yet there was no evidence for lumbar dorsal hypoplasia within the populations analysed. The three individuals affected by this developmental pathology were from the Wharram Percy burial population. In the first perinate (Sk. G492, 38-40 weeks), nine consecutive mid-thoracic centra were affected by dorsal hypoplasia (Figure 6.31). In the same population, three mid-thoracic centra were affected in Sk. V1 (38 weeks), and a single mid-thoracic centrum was affected in Sk. NA160 (0-1 month).

Figure 6.31. Dorsal hypoplasia of the vertebral centrum in nine consecutive centra (inside dotted line). The dorsal margin of the centra is inferior in this image. (Wharram Percy Sk. G492, 38-40 weeks).

Two examples of a posterior sagittal cleft in a single mid-thoracic centrum were noted in perinatal individuals (Çatalhöyük Sk. 10366.1, 34-38 weeks and Scheuer Sk. 20, 40 weeks) (Figure 6.32). This form of cleft may be the result of retained notochordal tissue affecting the posterior portion of the developing centrum (Barnes 2012). A single individual in the archaeological collections (Wharram Percy Sk. G476, 36-40 weeks) has dysmorphic cervical and thoracic centra that involves the sixth and seventh cervical centra and two unidentified thoracic centra (Figure 6.33). Only half of the vertebral centra were recovered for this individual, which limits positive identification of specific thoracic vertebrae. There are two possible aetiologies for this dysmorphic expression that arise from errors in the fusion and development of hemimetameres; namely a contralateral or unilateral shift prior to fusion or a mild lateral hypoplasia of the hemimetamere (Barnes 2012). The first option would entail the presence of hemivertebrae. None were curated with the remains of this individual, although this may be a reflection of identification and recovery methods employed in the field. There is no evidence of any associated dysmorphy in the neural arches or ribs of this individual.

Figure 6.32. Posterior sagittal cleft in a mid-thoracic centrum. Scheuer Sk. 20, 40 weeks (left) and Çatalhöyük Sk. 10366.1, 34-38 weeks (right).

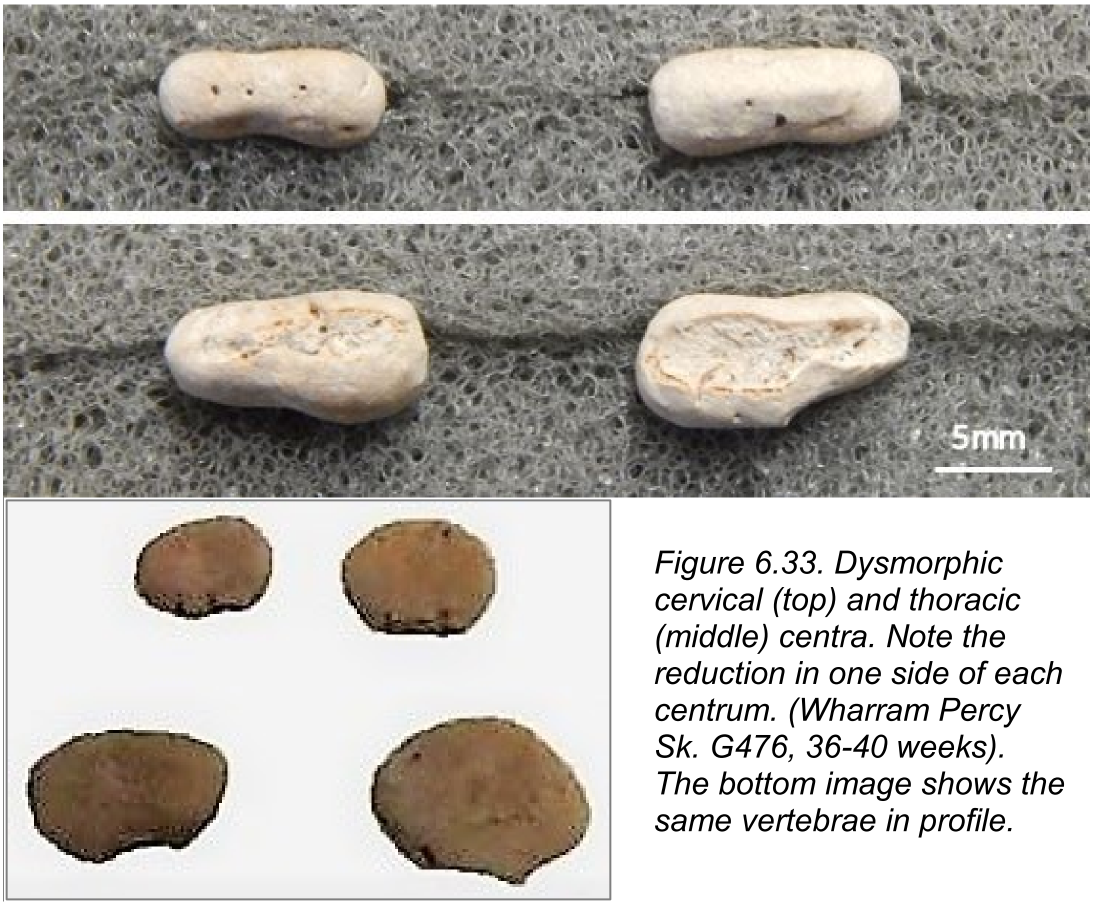


Figure 6.33. Dysmorphic cervical (top) and thoracic (middle) centra. Note the reduction in one side of each centrum. (Wharram Percy Sk. G476, 36-40 weeks). The bottom image shows the same vertebrae in profile.

An infant from the Yewden villa burial population (Sk. 31, 3-6 months) displayed premature development of the anterior bar of the right atlas, a feature that normally develops in early childhood between the age of three and four years (Scheuer and Black 2000). Another example of premature development was observed in an infant from the Wharram Percy burial population. In this infant (Sk.

V6, 2-3 months) the neural arches in the lower thoracic region display evidence of posterior fusion that may have constricted the vertebral foramen. Posterior fusion of the neural arches in this region of the vertebral column usually occurs during the second half of the first postnatal year (Scheuer and Black 2000). Although it could be argued that this individual is older on the basis of posterior neural arch fusion, the remainder of the skeletal remains, including the dentition, provide estimates of around three postnatal months.

6.4.7 Notochordal Variation

Two perinatal individuals from the burial population of Çatalhöyük have an anatomical variation of the thoracic centra (Table 6.9). In individual Sk. 10361 (38-40 weeks) one surface of five centra has a centrally-placed well-defined circular depression (1.5 mm diam.) that is matched on the opposite surface by a protuberance (Figure 6.34). It was not possible to differentiate between the superior and inferior surfaces of the perinatal centrum (Scheuer and Black 2004) in order to determine the orientation of the anomaly. The second individual (Sk. 10112) has six affected thoracic centra with an additional feature in the form of a very small perforating foramina (Figure 6.35).

Table 6.9. Individuals from the Çatalhöyük burial population that exhibit a notochordal anatomical variant of the thoracic centra.

Individual	**Age**	**Description**
10112	38-40w	Raised circular nodule with single central foramen in the centre of the flat surface; affecting T3-T8
10361	38-40w	Well-defined circular depression in the centre of the flat surface; affecting five mid-thoracic centra

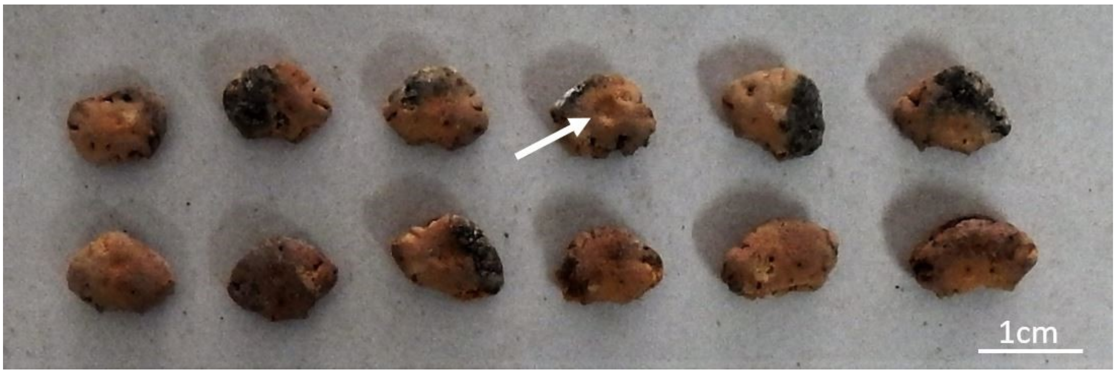


Figure 6.34. Anatomical variation of the thoracic centra (arrow) in a perinatal individual (Çatalhöyük Sk. 10361, 38-40 weeks). Note that only five of the centra are affected.

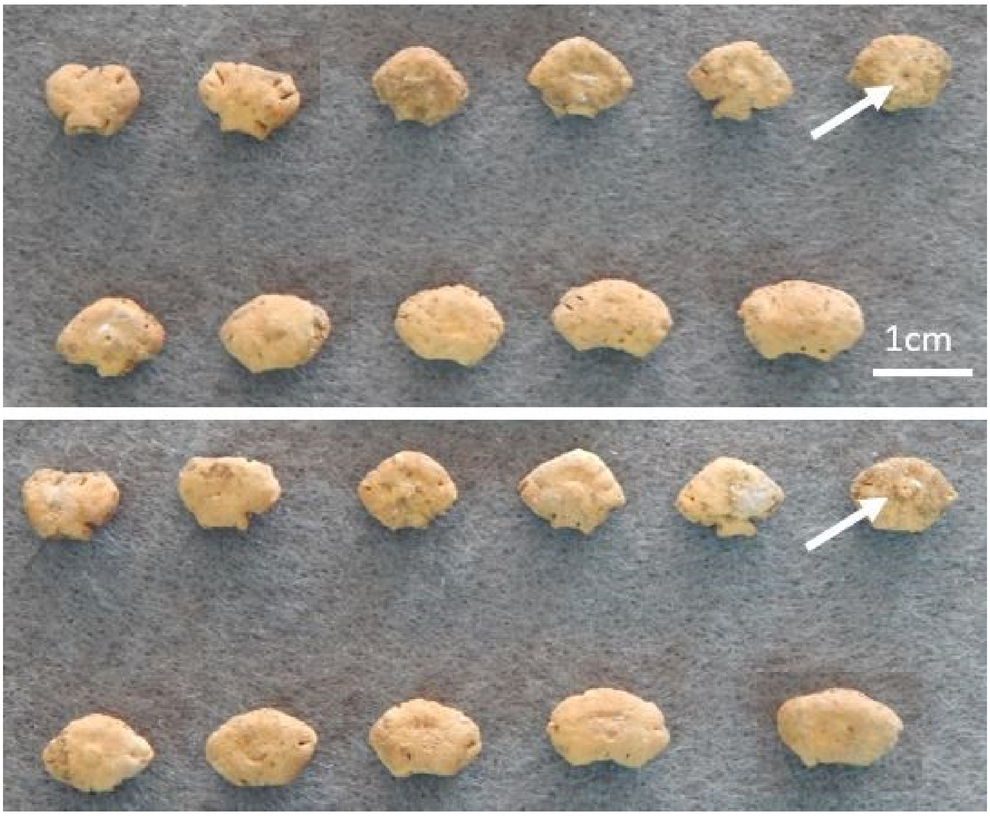


Figure 6.35. Anatomical variation of the thoracic centra with a central foramen (arrow) (Çatalhöyük Sk. 10112, 38-40 weeks).

This anatomical variant of the centrum is interpreted as an impression on the ossifying element left by persistent notochordal tissue, or in the one individual with perforating foramina, a possibly persistent notochord (Christopherson *et al*., 1999; Cotten *et al*., 1995; Taylor, 1972). In the normal development of the vertebral column, the notochordal tissue is resorbed prior to ossification of the centrum and is usually absent at birth (Christopherson *et al*., 1999; Stambough *et al*., 2011). Postma *et al.* (2013) have identified a genetic link to a new syndrome in which one of the characteristics is a persistent notochord. The other characteristics of their syndrome are agenesis of the sacrum and abnormal ossification of the centrum, which were not present in the two affected individuals described above. The precise aetiology of notochordal persistence remains unconfirmed (Christopherson *et al*., 1999; Stambough *et al*., 2011). The presence of notochordal tissue in the vertebrae at birth and persisting into adulthood is usually asymptomatic and is not regarded as pathological (Cotten *et al*., 1995; Taylor 1972; Stambough *et al.* 2011).

6.4.8 Enthesial Alterations

Four individuals exhibit unusual enthesial alterations associated with muscle development (Table 6.10). Two of these individuals are perinatal in age, a strong indication that the visible changes had developed *in utero*. The first perinatal individual, Çatalhöyük Sk. 10388 (38-40 weeks), has asymmetrical alteration of the insertion site of *m. deltoideus* on the lateral humerus that is considerably more pronounced on the left (Figure 6.36). The skeletal remains of Sk. 10388 also have a bilateral symmetrical tubercle located in the region of the medial collateral ligament of the tibia (Figure 6.37). These modified surfaces may indicate that the intrauterine position of this individual could have been restricted involving lateral pressure on the knee and hyperkinetic movement of the left upper limb (Bonneau *et al.*, 2011; Gupta *et al*., 2011; Hall, 2009; Ruano *et al*., 2003). The second perinatal individual (Wharram Percy Sk. V3, 36-40 weeks) with an enthesial alteration has unusually pronounced development of the anterior crest on the left tibia (Figure 6.38). This development may be associated with sustained intrauterine dorsiflexion of the left foot (Stone and Stone 2012), and is an unusual observation within this age category. Among various possible aetiologies, this may be an indication of congenital talipes calcaneovalgus or neural pathology of the left lower limb (Castriota-Scanderbeg and Dallapiccola, 2005).

Table 6.10. Individuals with skeletal changes associated with attachment sites.

Collection	Individual	Age	Description	Involvement
Ardreigh	956	0-2m	Inversion of left radial tuberosity	*M. biceps brachii*
Çatalhöyük	10388	38-40w	Bilateral enthesial alteration of the tibia and left humerus	Medial tibial collateral ligament and *m. deltoideus*
Scheuer	91	6-9m	Development of the left *linea aspera*	Quadriceps involvement
Wharram Percy	V3	36-40w	Pronounced anterior crest of left tibia	*M. tibialis anterior*

Figure 6.36. Asymmetry of m. deltoideus insertion site (arrow) (Çatalhöyük Sk. 10388, 38-40 weeks). Note the exaggerated curvature of the left diaphysis.

Figure 6.37. Bilateral tubercle (arrows) located in the region of the medial collateral ligament of the tibia, anterior view (Çatalhöyük Sk. 10388, 38-40 weeks).

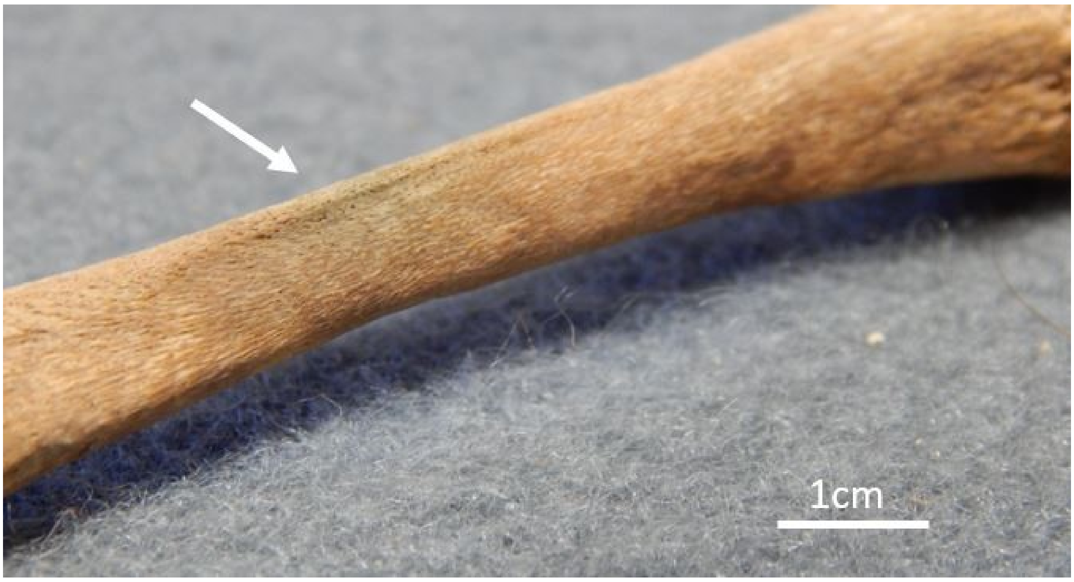


Figure 6.38. Pronounced anterior crest of the tibia (Wharram Percy Sk. V3, 36-40 weeks).

The other two individuals died during early infancy. This suggests that the skeletal changes observed may be related to postnatal muscle activity and development. The youngest of these two (Ardreigh Sk. 956, 0-2 months) has an inverted radial tuberosity on the left radius. This unilateral change in expression may be related to differential use of the arms, although the dominance of one side over the other cannot be distinguished on the morphology of this single anatomical feature. The same does not necessarily apply to the older infant (Scheuer Sk. 91, 3-6 months). The posterior surface of the femora clearly show a significant difference in the *linea aspera* between the sides. The left *linea aspera* is considerably longer and wider than that on the right femur (Figure 6.39). This surface morphology indicates the involvement of the quadriceps muscle group, but only in one lower limb. The quadriceps act as flexors of the leg, and their asymmetrical development in Sk. 91 may be indicative of side preference in early motor movements; that is perhaps this infant had a preference for left leg first in kicking and pushing-off movements.

Figure 6.39. Asymmetry in the development of the linea aspera (arrow) (Scheuer Sk. 91, 3-6 months).

6.5 Periostosis

Several individuals display evidence of periostosis that may be associated with inflammation due to trauma or muscle development and usage (Table 6.11). A perinatal individual from the Wharram Percy burial population (Sk. NA4A, 38-

40 weeks) has unilateral periostosis on the left humerus; on the antero-medial surface of the proximal third and on the posterior surface of the distal third of the diaphysis (Figure 6.40). As there is no evidence of cortical pathology on the right humerus or on the remainder of the left humerus, it is likely that the affected area is a localised periosteal response associated with muscle attachment sites. Given the age of this individual, the response may have occurred as a result of intrauterine restriction of the upper limb involving increased strain on the muscles of the left side, but not the right (Schumacher *et al.*, 2010).

Table 6.11. Individuals with periostosis of the lower limb bones.

Collection	Individual	Age	Description	Aetiology
Ardreigh	1305	3-6m	Lesion on distal anterior left femur	Inflammation of periosteum
	1510	0-2m	Lesions at muscle attachment sites on major long bones	Inflammation of periosteum
Barton Court Farm	246	2-3m	Lesion on diaphysis of left femur and tibia	Inflammation of periosteum
	678	38-40w	Erosive lesion on right tibia	Infection related to sharp trauma?
Çatalhöyük	21676	3m	Lesion on posterior diaphysis of left ulna and radius	Infection related to soft tissue trauma
Scheuer	96	32w	Lesion on anterior surface of femur, bilateral	Inflammation of periosteum
Wharram Percy	NA4A	38-40w	Lesions on anterior and posterior surfaces of left humerus	Inflammation of soft tissue
	NA14A	1-3m	Lesions on posterior proximal tibia in region of *m. soleus*, bilateral	Inflammation of periosteum
	NA43	3-6m	Lesions on diaphysis of femur and tibia, bilateral	Systemic condition
	NA60	1-3m	Lesions on posterior diaphysis of humerus (bilateral) and right ulna	Inflammation of periosteum
	NA160	0-1m	Postero-lateral surface of the proximal left tibia	Congenital trauma involving knee joint

Another individual from Wharram Percy (Sk. NA43, 3-6 months) has periostosis on the diaphyses of both femora and on the left tibia. This symmetrical response is anticipated to have resulted from muscle use in early infancy. As demonstrated in Figure 6.41, the margins of the reactive cortical surface is well integrated into the smooth cortical surfaces and there is a uniformity of appearance throughout the periosteal lesion. This individual also has significant porous lesions on the ectocranial vault surfaces and the orbits that were active at the time of death. These lesions could indicate a systemic condition and will be discussed in the following chapter (see section 7.5.3).

Figure 6.40. Periostosis of the left humerus on the antero-medial proximal surface (left) and on the posterior distal surface (right) (Wharram Percy Sk. NA4A, 38-40 weeks).

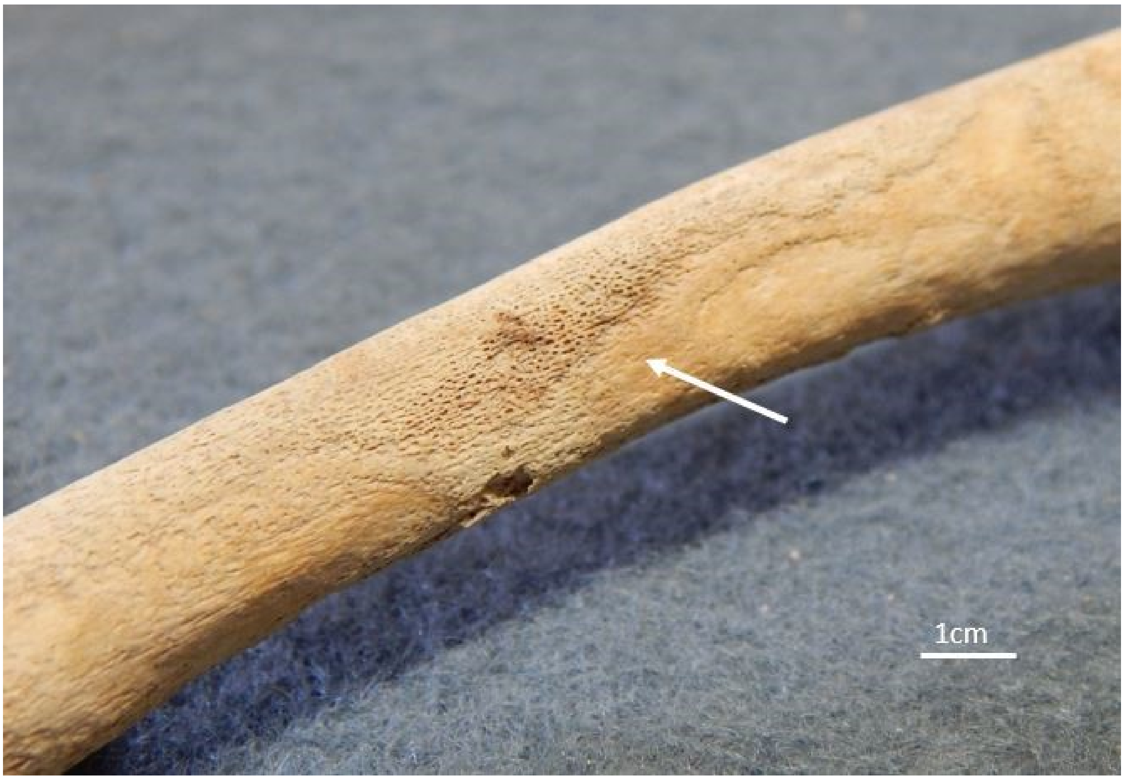


Figure 6.41. A region of periostosis with remodelling of the margins into the smooth cortical surface of the left tibia (Wharram Percy Sk. NA43, 3-6 months).

A largely remodelled periosteal lesion is evident on the postero-lateral surface of the proximal left tibia in a neonate from the Wharram Percy burial population (Sk. NA160, 0-1 month). The lesion consists of a superficial layer over the unaffected cortical surface (Figure 6.42). Ortner suggests that the presence of periosteal reactive bone that overlays but does not affect the cortical surface can be attributed to primary periostosis resulting from trauma or infection (2003).

Figure 6.42. Periosteal lesion associated with trauma in a neonatal individual (Wharram Percy Sk. NA160, 0-1 month). Note the superficial nature of the lesion that does not involve the original cortical surface.

6.5.1 Intrauterine Restriction

A neonatal individual from the Ardreigh burial population (Sk. 1956, 0-1 month) displays evidence that supports a possible case of femoral nerve palsy. The vertebral pathology takes the form of bilateral lesions of woven bone on the internal surface of the lumbar neural arches. The appearance of lesions on the laminae of the lumbar neural arches are an unusual observation in very young individuals. (Figure 6.43). There are also bilateral reactive lesions of woven bone on the surface of the iliac fossa, perforated orbital plates that may be associated with intracranial pressure, and regions of superficial endocranial lesions on the frontals (Figure 6.44). The lumbar lesions may indicate spinal stenosis in the lower vertebral column. Spinal stenosis is usually the result of a degenerative condition but can develop from trauma leading to inflammation. Inflammation of the vertebral connective tissues may cause vessel and nerve damage through compression (Ward 2000), resulting in palsy.

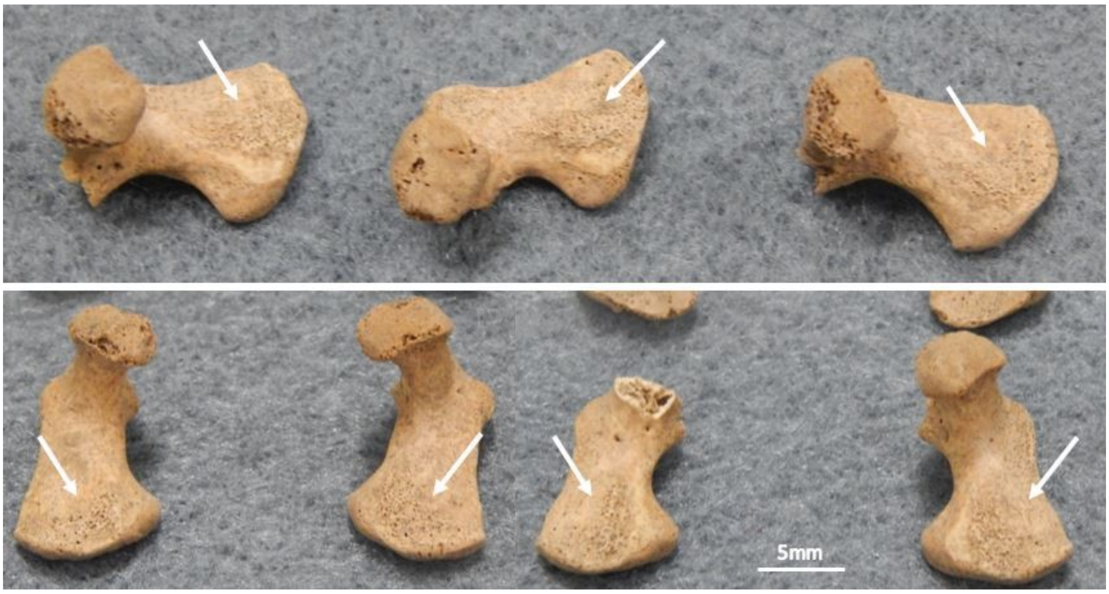


Figure 6.43. Bilateral lesions on the internal laminar surface of the lumbar neural arches (arrows) (Ardreigh Sk. 1956, 0-1 month).

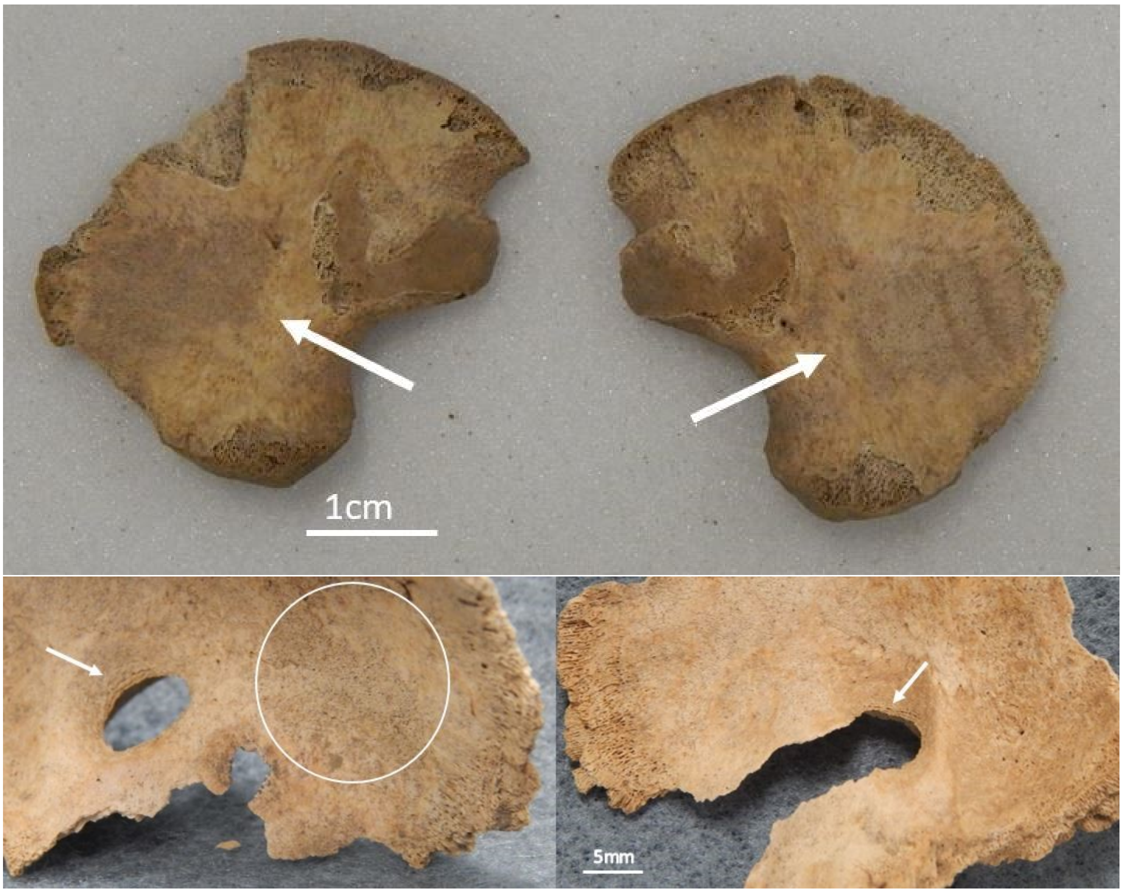


Figure 6.44. Bilateral lesions of the iliac fossa (arrows) (top). Perforated orbital plates (arrows) (bottom images) and a localised endocranial lesion (circled) (Ardreigh Sk. 1956, 0-1 month).

One perinatal individual from the Barton Court Farm burial population (Sk. 619, 38-40 weeks) displays unusual morphology of the superior medial border of the left scapula (Figure 6.45). The right scapula is fragmented and the comparative part of the superior medial border was lost post-mortem. The altered margin morphology in the intact scapula may have a pathological aetiology, however non-pathological congenital variations of the superior border of the scapula include notch-like and foramina-like defects (Keats and Anderson, 2013). Superior border dysmorphy may be developmental or arise following injury or restriction and can include aetiologies such as torticollis, Klippel-Feil syndrome, spina bifida and Sprengel's deformity (Hylton 1997; Kadavkolan *et al*., 2011). This individual also displayed a bilateral dysmorphic posterior border of the pars lateralis of the occipital (Figure 6.45). This anomaly is not directly associated with any particular syndrome (Lachman, 2007) but may represent a non-pathological variant of the immature cranial base. Klippel-Feil syndrome also involves a range of vertebral pathologies (fusion of vertebrae, dysmorphic centra, hemivertebrae, cervical spine abnormalities and spina bifida) (Lachman, 2007), none of which are reflected in the skeletal remains of individual Sk. 619.

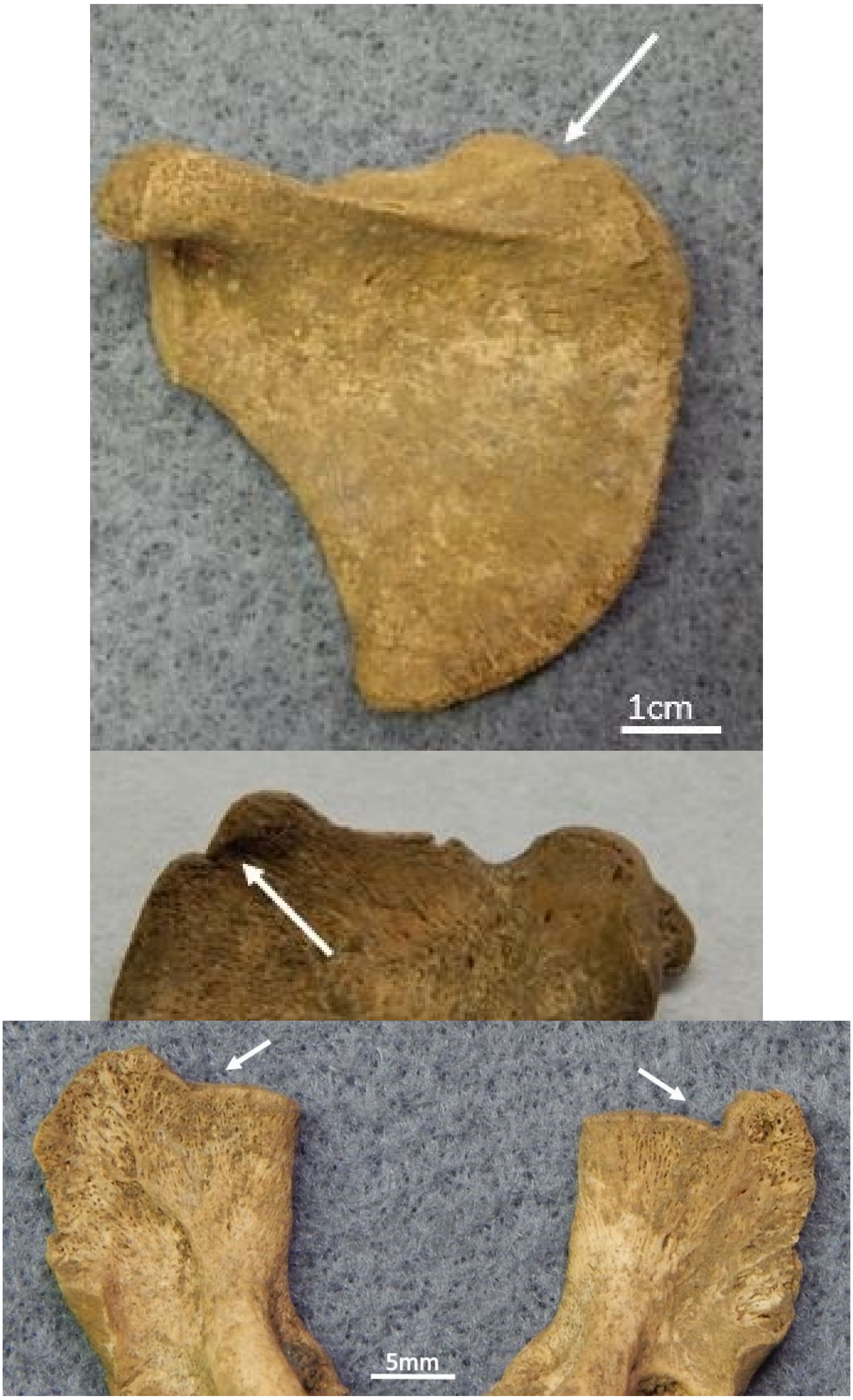


Figure 6.45. Unusual morphology of the superior border of the left scapula (arrows) (Barton Court Farm Sk. 619, 38-40 weeks). Dorsal view (top) and ventral view (middle). Dysmorphic posterior border of the partes lateralis of the occipital in the same individual (bottom).

The skeletal elements of the pelvic girdle were slightly less affected by morphological variation and pathology than those of the pectoral girdle and thorax in the individuals analysed. Only ten individuals were identified with pelvic pathology and dysmorphy compared to sixteen individuals with pectoral and thoracic pathology (see Tables 6.5, 6.13 and 6.15 for pectoral and thoracic cases); this includes a single individual (Wharram Percy Sk. NA69, 36-40 weeks) with skeletal pathology evident in both girdles. Details of the individuals with pathological and non-specific morphological changes of the ilium are provided in Table 6.12.

Table 6.12. General pathology of the ilium.

Collection	Sk.	Age	Description	Aetiology
Ardreigh	45	0-1m	Lesion of woven bone around the nutrient foramen of the iliac fossa in the left ilium	Soft tissue trauma involving localised haemorrhage
	542	36-38w	Reduction of sacroiliac joint on the right ilium	Intrauterine restriction
	1956	0-1m	Bilateral reactive lesions of woven bone on the surface of the iliac fossa	Soft tissue pathology
Barton Court Farm	869	0-1m	Bilateral abnormal porosity of the auricular surface	Pathological change in the sacroiliac joint
	1076	38-40w	Pronounced posterior superior iliac spine	Intrauterine restriction
Yewden Villa	46	14-18m	Dysmorphy of the right auricular surface with an adjacent erosive lesion	Pathological change in the right sacroiliac joint
Wharram Percy	NA64	0-1m	Broad auricular surface of right ilium	Intrauterine restriction
	NA69	36-40w	Elongation of ilia	Growth disturbance
	NA119	6-9m	Bilateral flattened ilia	Developmental (Mays 2007, 186)
	NA149B	0-1m	Bilateral broad auricular surface and pronounced posterior superior iliac spine	Intrauterine restriction

6.5.2 Lesions

Various forms of palaeopathology were observed in the skeletal elements of the pectoral and pelvic girdles and the thorax. The majority were minor alterations in the morphology of these elements that can be reasonably attributed to normal variation. The individuals with pathology that is considered to fall outside of normal variation are discussed in more detail below. It was not possible to ascribe a specific aetiology for several of the cases, however an understanding of the developmental stage and likely external physical impacts on these individuals allows for tentative causes to be suggested (Table 6.13). As discussed above, an unusual cortical surface appearance of developing elements cannot necessarily be associated with a pathological cause. In many cases the developing cortical layer will have the same appearance as some pathological lesions that are observed in older individuals. Examples of periostosis, dysmorphy, asymmetry, agenesis and trauma in the elements of the pectoral girdle and thorax were predominantly observed in the Roman and medieval collections.

Porous lesions of the dorsal surfaces of the scapula are usually associated with an increased susceptibility to haemorrhage from weakened blood vessels supplying the supraspinous and infraspinous muscles and the scapula itself (Ortner *et al*., 2001). This weakened state of the vessels is attributed to a systemic condition arising from a deficiency in ascorbic acid (Vitamin C), which leads to scurvy if untreated (Brickley and Ives, 2006). In affected individuals it is surmised that the use of the scapular muscles is sufficient to result in a vascular response that impacts the bone (Ortner *et al*., 2001). Five individuals within the collections analysed display localised areas of increased porosity in these fossae (Table 6.13).

Table 6.13. Pathology of the elements of the pectoral girdle and thorax.

Collection	Sk.	Age	Description	Aetiology
Ardreigh	385	38-40w	Increased porosity of the infraspinous fossa of the scapula	Inflammation associated with anaemia
Barton Court Farm	917i	1-2m	Woven bone deposits in the infraspinous fossa of the scapula	Muscle use and development
Wharram Percy	EE54	3-6m	Periostosis of the sub-glenoid margin and ventral surface	Inflammation
	NA4A	38-40w	Porous lesions on the posterior surfaces of the scapula (*m. infraspinatus*)	Inflammation of periosteum
	NA60	1-3m	Porous lesions on the posterior surfaces of the scapula (*m. infraspinatus*) and clavicle (*m. pectoralis major*)	Inflammation of periosteum
	NA69	36-40w	Bilateral periostosis of the supraspinal fossa of scapula	Inflammation or intrauterine infection
	V10	6-9m	Increased porosity of the supraspinous fossa of the scapula	Inflammation associated with anaemia
Yewden Villa	3	0-1m	Porous lesion at the superior-lateral margin of the left scapula (*m. infraspinatus*)	Inflammation of periosteum
	42	40-41w	Increased porosity of the infraspinous fossa of the scapula	Inflammation associated with anaemia

One infant (Wharram Percy Sk. V10, 6-9 months) has increased porosity of the supraspinous fossa that is abnormal in its extent and the size of the foramina (Figure 6.46). The extent of the porous lesions on the cranial vault in this individual led Mays (2007) to ascribe an aetiology of chronic anaemia. This aetiology is further supported by the abnormally porous supraspinous fossa of the scapula, which was not noted in Mays' analysis. Two perinates have increased porosity of the infraspinous fossa that is also likely to be associated with anaemia or inflammation (Ardreigh Sk. 385, 38-40 weeks and Yewden Sk. 42, 40-41 weeks). A third infant with bilateral changes to the cortical surface of the infraspinous fossa displays new superficial woven bone deposits rather than areas of abnormal porosity (Barton Court Farm Sk. 917i, 1-2 months) (Figure 6.47). It is possible that the deposition of new bone could have occurred in response to early muscle use in global movements of the upper limbs but may also be related to soft tissue trauma.

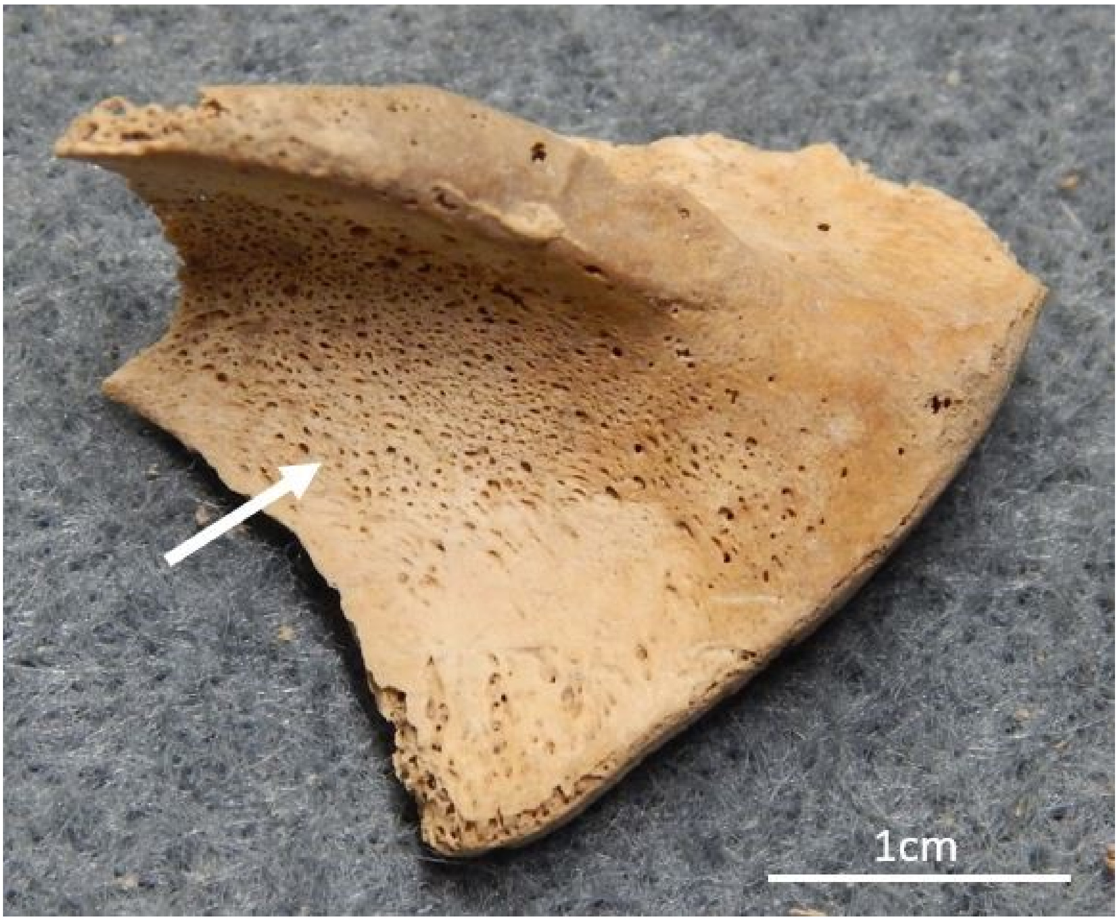


Figure 6.46. Porous lesion (arrow) of the supraspinous fossa of the right scapula (superior view) (Wharram Percy Sk. V10, 6-9 months).

Figure 6.47. Bilateral new periosteal bone deposits (arrow) (Barton Court Farm Sk. 917i, 1-2 months).

Another infant from the Wharram Percy burial population (Sk. EE54, 3-6 months) displays an area of periostosis on the left scapula in the region of the attachment for the long head of *m. triceps*; inferior to the glenoid fossa on the lateral margin and extending onto the ventral surface (Figure 6.48). The right scapula is not present, preventing an assessment of the symmetry of the lesion.

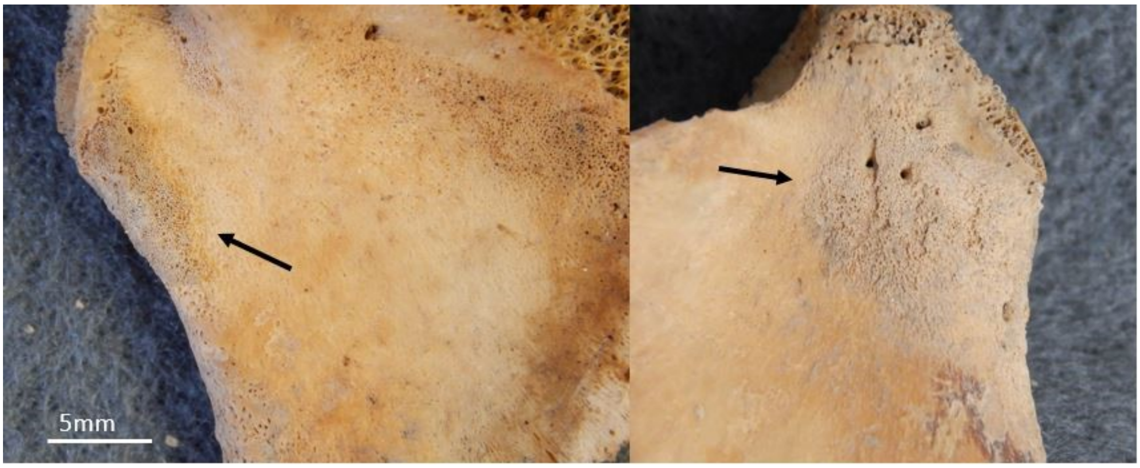


Figure 6.48. Periosteal lesions on the left scapula (arrows) (Wharram Percy Sk. EE54, 3-6 months). Dorsal view (left) and ventral view (right). Note the area of increased porosity in the infraspinous fossa (top right of left image).

Apart from the individuals listed above in Table 6.12, three further individuals have specific skeletal pathology of the ilium that is noteworthy. The cortical surface of the iliac fossa is affected in two neonatal individuals who have areas of periosteal woven bone centrally located within the fossa. Both of these individuals are from the Ardreigh burial population (Sk. 45 and Sk. 1956, both 0-1 month), although the appearance of the lesions is different. The first individual (Sk. 45) has an area of superficial woven bone surrounding the nutrient foramen of the left iliac fossa that appears to be a direct osseous response to localised haemorrhage associated with the blood supply to the ilium. This osseous response may also be related to a soft tissue trauma (Figure 6.49). As the lesion is not bilateral and there was no further evidence of skeletal pathology observed in this individual, a systemic condition is unlikely. A localised trauma is the most plausible aetiology given the skeletal evidence.

In contrast to Sk. 45, the lesions observed in the second individual (Sk. 1956) are bilateral and symmetrical. These lesions display evidence of cortical remodelling and are suggestive of the appearance of an osseous response to inflammation, specifically of the *iliacus* muscle (see Figure 6.44). A possible aetiology for the areas of woven bone within the iliac fossae of Sk. 1956 is an abscess of the iliopsoas muscle group. Han *et al*. (2015) report on a relatively rare case of unilateral iliopsoas abscess in a three week old neonate, while Al-Zaiem *et al*. (2014) detail an even rarer case of bilateral iliopsoas abscess in a four week old neonate. These abscesses form from a pre-existing bacterial presence that is exacerbated through vascular or lymphatic distribution in conjunction with a weakened immune response (Han *et al*. 2015). Although iliopsoas involvement is considered a rare occurrence in this age group, the skeletal evidence supports an aetiology involving soft tissue inflammation rather than a localised haemorrhagic event, and may also have involved localised areas of infection. Alternative aetiologies include appendicitis and necrotising enterocolitis, both of which have been documented in neonatal individuals and can lead to areas of infection and inflammation within the iliac fossa (Remington *et al*., 2011). Neonatal appendicitis normally only affects the right iliac fossa, while necrotising enterocolitis may affect the left iliac fossa but again, usually has a unilateral expression. Given the bilateral and symmetrical expression of the lesions in Sk. 1956, involvement of the muscle bodies within the iliac fossa is a plausible aetiology, potentially more so than an aetiology associated with the abdominal organs.

Figure 6.49. Lesion of woven bone around the nutrient foramen of the iliac fossa (arrow) in the left ilium (Ardreigh Sk. 45, 0-1 month).

The third individual is a child recovered from the Yewden villa site (Sk. 46, 14-18 months). This individual has unilateral dysmorphy of the right auricular surface of the ilium with an associated erosive lesion of the iliac fossa adjacent to the auricular surface (Figure 6.50). Unfortunately the incomplete nature of the skeletal remains limits comparison of further pathology that may have been evident on the sacral elements. The right ilium of this child is also noticeably heavier compared with the left. This difference in weight may be an artefact of taphonomic process or potentially an increase in the cortical thickness of this element. Radiographical analysis was not available to assess cortical changes in the affected element. An irregular shape of the auricular surface may be a non-pathological variation however, the erosive lesion adjacent to the auricular surface of the right ilium is a potential indication of juvenile rheumatoid arthritis (Still's disease) (Ortner, 2003) or juvenile idiopathic arthritis with sacroiliitis (Sheybani *et al*., 2013). It is also possible that the skeletal pathology evident in the right ilium developed following a localised trauma to the right sacroiliac joint.

Figure 6.50. Dysmorphy of the right auricular surface (arrow) with an adjacent erosive lesion (Yewden villa Sk. 46, 14-18 months).

A fourth individual, an infant from the Wharram Percy burial population (EE54, 3-6 months) mentioned above (this section) with periostosis on the left scapula, has been reported as having non-specific bilateral periostosis of the ilia (Mays 2007, 168 and 356). The supposed lesions on the lateral surfaces of the ilia occur in the region of *m. gluteus minimus* (Figure 6.51). The appearance of the lateral surface is more plausibly associated with the development of this muscle rather than bilateral porotic lesions of pathological origin, namely infection (Mays 2007). There is no other evidence of periosteal new bone formation on the elements of this individual. The ilia of several other similarly aged individuals from Wharram Percy and other sites were observed to have the same appearance as the ilia of Sk. EE54 (Figure 6.52 shows the right ilium of three of these individuals). Although it is possible that these individuals exhibit a shared pathological expression of a physiological aetiology, the author is not aware of a condition that is expressed in this way. As these individuals have a common age at death in early infancy, it may be that the surface appearance is either a reflection of the development stage of the ilium or potentially an osseous response associated with the use of the gluteal muscles.

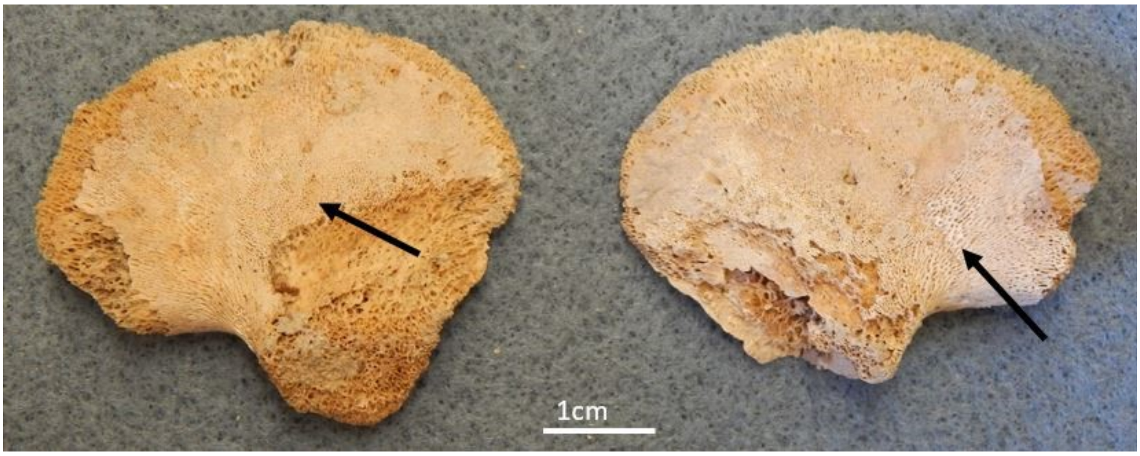


Figure 6.51. Bilateral woven appearance of the lateral surface of the ilia (arrows) (Wharram Percy Sk. EE54, 3-6 months).

Figure 6.52. Comparative lateral surfaces of the ilium showing the same woven surface appearance as Sk. EE54 (Figure 6.49). Left to right: Wharram Percy Sk. EE53, 3-6 months; Wharram Percy Sk. NA60, approx. 3 months; Exeter collection Sk. EXE665ii, approx. 2 months.

An infant from the Çatalhöyük burial population (Sk. 21676, 3 months) displays unusually localised periostosis of the left forearm elements (Figure 6.53). There are large superficial lesions of porous woven bone on the posterior surfaces of the left ulna and radius. The extent of the lesions suggests a significant involvement of the soft tissues and periosteum. This type of localised response is usually observed in cases of primary periostosis associated with inflammation and infection (Ortner 2003), especially where the cortical surface is unaffected. A number of other conditions can be expressed in localised periostosis, such as juvenile chronic arthritis, reactive arthritis, scleroderma, trauma, infection, trauma, and stress injuries (Altman, 2001). Given the age of this infant, the absence of other skeletal pathologies, and the living environment of the Çatalhöyük population, a soft tissue trauma may provide the most plausible aetiology.

Figure 6.53. Periostosis (arrows) of the posterior surfaces of the left radius and ulna (left). Comparison of both radii (top right) and detail of periosteal expansion on the left radius (bottom right) (Çatalhöyük Sk. 21676, 3 months).

Several individuals from the Wetwang Slack burial population have areas of differential cortical staining (Table 6.14). This staining may result from areas of micro-porosity of the cortical surface that are pathological in origin. Alternatively, it may be associated with sediment inclusions in the burial environment. The latter explanation is less likely, especially in cases of bilateral symmetrical staining. Staining associated with attachment locations of muscle and connective tissue may be an indication of soft tissue involvement. Two individuals have unilateral staining that is located in attachment areas; Sk. 34.1 (38-40 weeks) and Sk. 132.5 (40-42 weeks). The first individual (Sk. 34.1) has an area (7mm x 15mm) of staining on the anterior surface of the proximal left tibia that covers the tuberosity for the patellar ligament (Figure 6.54). Radiographs of the tibiae of this individual demonstrate that there is no macroscopically evident expansion of the cortical bone or increased porosity (Figure 6.55). In the second individual (Sk. 132.5) the proximal left humerus is stained in the region of the bicipital groove (Figure 6.56).

There is no similar staining on the right humerus, although both humeri have slight staining of the medial supracondylar surfaces.

Table 6.14. Individuals with differential cortical staining on the long bones.

Collection	**Individual**	**Age**	**Description**
Gussage All Saints	34.1	38-40w	Posterior surface of the distal left femur and anterior surface of the proximal left tibia
	34.2	38-40w	Proximal humerus, bilateral
	96	38-40w	Posterior surface of femoral diaphysis associated with the nutrient foramen and *linea aspera*, bilateral
	130.7	38-40w	Proximal humerus, bilateral
	132.5	40-42w	Bicipital groove of left proximal humerus and medial supracondylar region, bilateral
	132.9	38-40w	Distal femur and proximal tibia, bilateral
	285.1	0-1m	Diaphysis of left humerus and ulna
	293.5	38-40w	Proximal humerus, bilateral
	418	38-40w	Posterior surface of the distal femur and anterior surface of the proximal tibia bilateral
	661	0-1m	Distal left humerus
Wetwang Slack	159	0-1m	Subtrochanteric region of posterior femur, bilateral
	748	40-42w	Subtrochanteric region of posterior femur, bilateral

Figure 6.54. Staining of the left tibia tuberosity (arrow) (Gussage All Saints Sk. 34.1, 38-40 weeks).

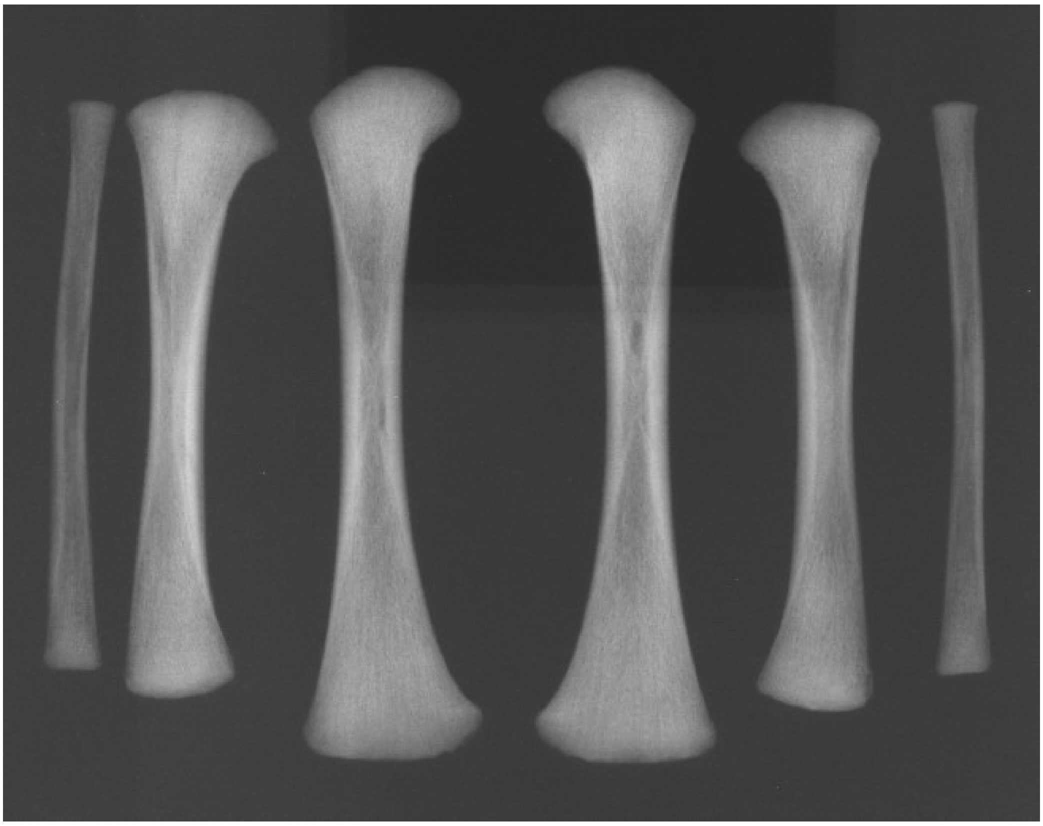


Figure 6.55. Radiograph of the femora and tibiae of Sk. 34.1 showing uniformity of the underlying trabecular structure.

Figure 6.56. Staining in the region of the bicipital groove (arrow) on the left humerus (Gussage All Saints Sk. 132.5, 40-42 weeks).

6.6 Trauma

Despite the limitations of preservation condition in some of the skeletal remains, it was possible to identify several individuals with skeletal trauma. The most apparent forms of perimortem skeletal trauma are sharp force injury with no evidence of healing, and perimortem fracture indicative of collagen presence at the time of impact. Individuals with observed skeletal evidence of perimortem and postmortem trauma are listed below in Table 6.15. Four of these individuals have postmortem changes associated with taphonomic activity including cortical staining, fractures of the dentition and marks left by rodent gnawing. The evidence of postmortem impacts on skeletal remains can potentially provide insight into the burial environment and pre-burial of the remains. The individuals with postmortem skeletal changes are discussed below in the relevant sections. The remainder of the individuals have evidence of skeletal trauma that was sustained prior to death or in the period shortly thereafter.

Table 6.15. Individuals with skeletal trauma.

Collection	Individual	Age	Description
Ardreigh	830	36-40w	Reactive lesions on the occipital squama and partes lateralis and superior atlas facets
	839	0-1m	Gnawing marks on proximal lateral surface of left femur
	924	6-9m	Bilateral avulsion fractures on the lateral surface of three upper ribs
	1302	36-40w	Gnawing marks on distal lateral surface of left humerus
	1444	38-40w	Ectocranial area of reactive bone on the occipital squama
Çatalhöyük	21709	38-40w	Incomplete fracture of the right radius
Scheuer	21	6-9m	Postmortem staining and dental fractures
Wharram Percy	G457	30w	Bilateral mid-shaft cut-mark (?) on anterior surface of tibiae
	NA55	1-3m	Bilateral partial fusion of the atlas to the pars lateralis, erosive lesions on the laminae of the upper cervical neural arches, new bone formation on the endocranial surfaces of the basilar process and pars lateralis
	NA64	0-1m	Depressed fracture of the left parietal with associated reactive bone surface
	NA129	36-40w	Depressed fracture of the left parietal
	V3	36-40w	Mid-shaft fracture of a middle right rib
Yewden Villa	7	38-40w	Cut-marks on anterior surface of distal right tibia
	20	40w	Articular fracture of the sternal end of the left clavicle
	38	36-40w	Bilateral cut-marks on posterior surface of proximal femora
	Bag 5	40w	Cut-marks on anterior surface of distal right tibia

6.6.1 Fracture

Establishing cranial trauma in the skeletal remains of very young individuals is frequently exacerbated by the degree of fragmentation in these elements and insufficient detail about *in situ* body positioning. Detailed examination of cranial fragments and the relationship between fractured surfaces and areas of increased porosity can reveal previously unidentified perimortem trauma. Within the collections analysed, four individuals have evidence of cranial trauma. Five individuals display evidence of perimortem trauma and two of postmortem damage to the long bones of the appendicular skeleton (Table 6.15).

A neonatal individual from Wharram Percy (Sk. NA64, 0-1 month) sustained an elongate depressed fracture (17mm medio-laterally x 10mm antero-posteriorly x 6mm depth) to the left parietal slightly superior to the eminence (Figure 6.57). The area adjacent to the depressed fracture on the ectocranial surface has a marked increase in porosity that is an apparent response to soft tissue trauma. There is an associated incomplete fracture on the endocranial surface with small areas of superficial reactive bone that probably developed in response to localised haemorrhagic events related to the cranial trauma (Figure 6.58). A large dry fracture bisects the depression, but despite its location it is unlikely to be related to the trauma.

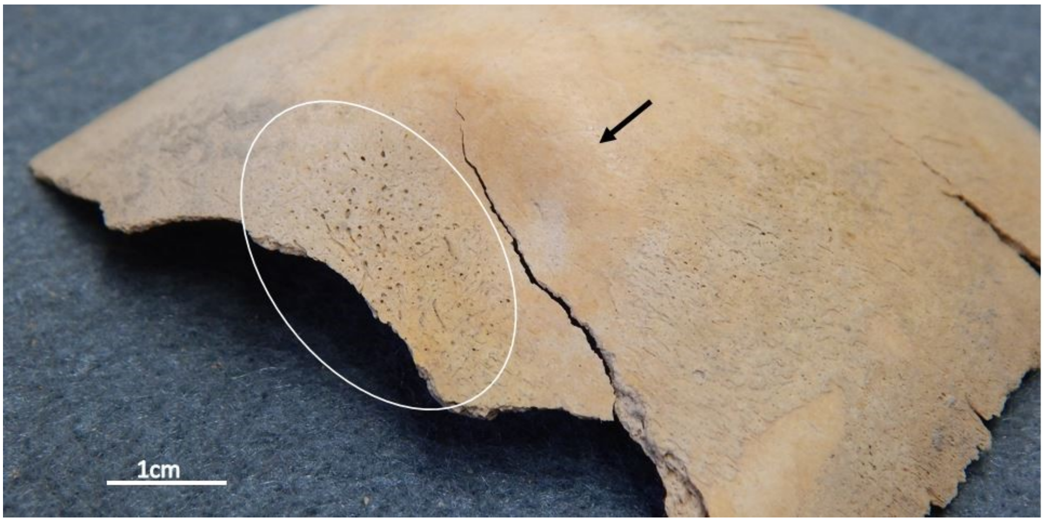


Figure 6.57. Ectocranial surface of depressed fracture (arrow) with associated porous lesion (circle) (Wharram Percy Sk. NA64, 0-1 month).

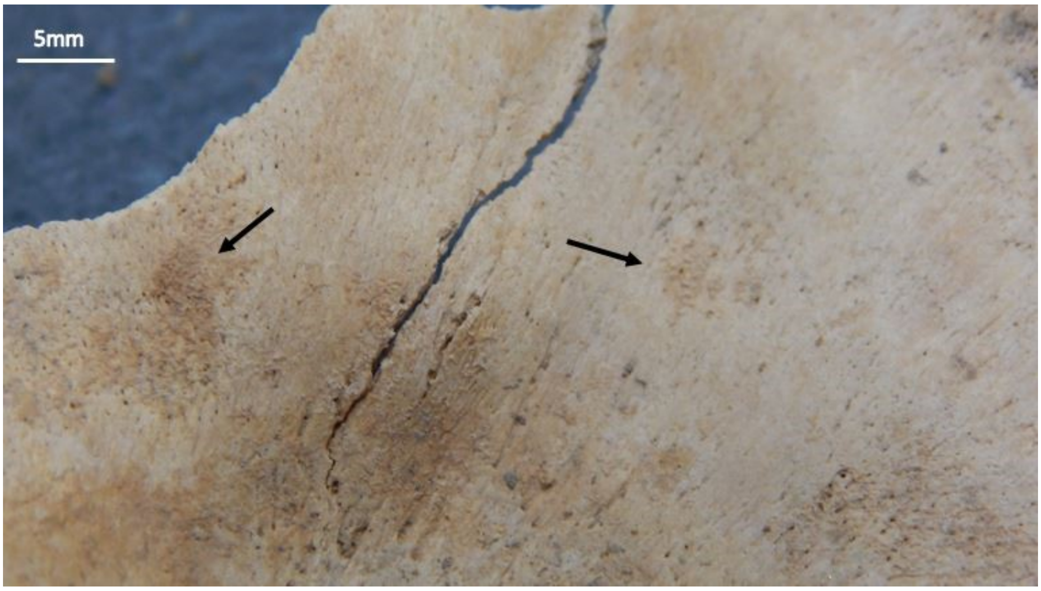


Figure 6.58. Endocranial surface of depressed fracture showing small areas of reactive bone (arrows) on the surfaces surrounding the trauma (Wharram Percy Sk. NA64, 0-1 month).

This individual also displays increased porosity on the endocranial surface of the sphenoid, particularly around the foramen rotundum, and on the frontal process of the maxilla. Porous lesions in the former location can be associated with scurvy (Armelagos *et al*. 2014) and those in the latter location with inflammation (Brickley and Ives 2006). If it is assumed that this individual was prone to inflammatory response, then it follows that a haemorrhage associated with the cranial trauma could have been significant, but not necessarily immediately fatal. The osseous response indicates that this neonate lived for a short period of time following the trauma.

Another individual from Wharram Percy (perinatal Sk. NA129, 36-40 weeks) was identified with a perimortem depressed fracture of the left parietal. The fracture is positioned on the superior plane of the bone, posterior to the bossa and is uniformly circular in form, with a diameter of 3mm (Figure 6.59). There is corresponding endocranial flaking of the fracture margins indicating the presence of bone collagen at the time of injury (Figure 6.60), however there is no macroscopically visible evidence of radiating fractures around the depressed area. No evidence of an osseous response to the fracture on either cranial surface was visible.

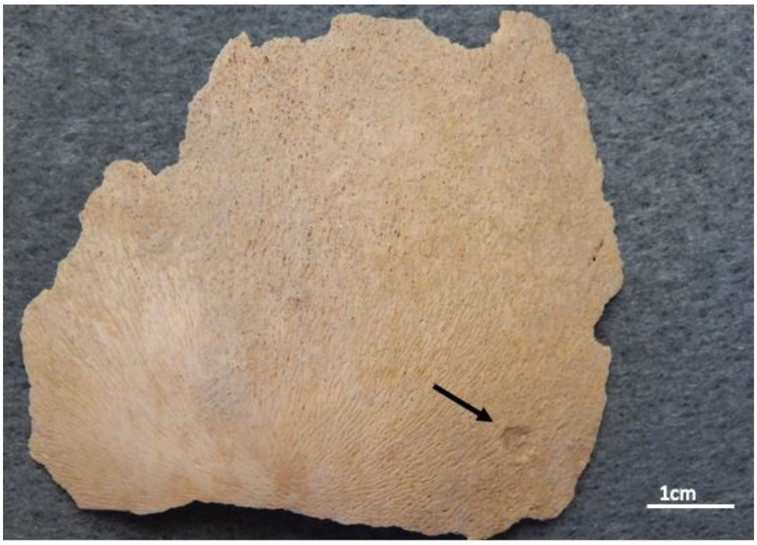


Figure 6.59. Ectocranial surface of small depressed fracture (arrow) (Wharram Percy Sk. NA129, 36-40 weeks). Note there is no evidence of reactive bone associated with the trauma.

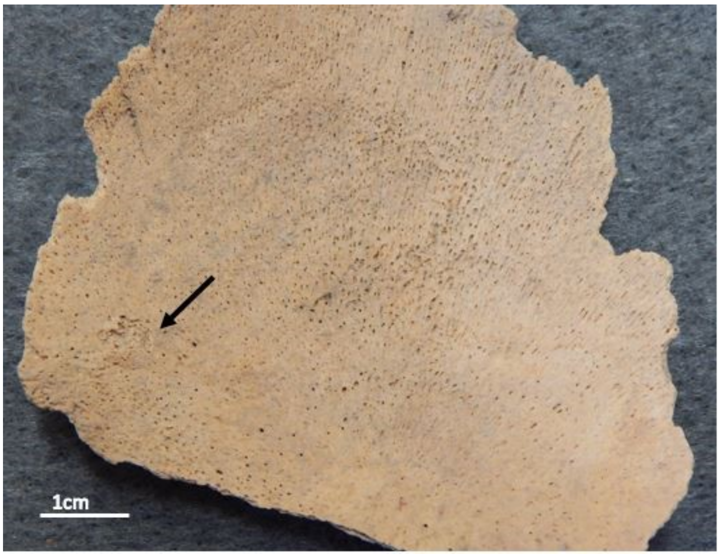


Figure 6.60. Endocranial surface of small depressed fracture (arrow) (Wharram Percy Sk. NA129, 36-40 weeks). Note that the minor flaking of the fracture edges suggests the presence of collagen at the time of impact. There is no evidence of reactive bone associated with the trauma.

An infant in the Ardreigh collection (Sk. 924, 6-9 months) has what appear to be bilateral avulsion fractures on the lateral surface of three upper ribs. Avulsion fractures result when a fragment of bone is pulled off by a muscle at the site of its tendon attachment. Both second ribs and the right third rib are affected and close examination of the remaining ribs and fragments confirmed that there are no other similar features present. The fracture sites have a flattened appearance with partial removal of the cortical layer in the affected areas and an associated tear scar from the fracture site towards the costal head (Figure 6.61). The surface anatomy of the second rib features the origin site for *m. serratus anterior* and the insertion site of *m. serratus posterior superior.* The latter muscle attaches to the second to fifth ribs while *m. serratus anterior* originates on the superior border of the first eight or nine ribs. (Abrahams *et al*., 2008; Stone and Stone, 2012). The lesions observed on the left second rib of Sk. 924 correspond to these sites, while the affected areas on the two right ribs correspond to the origin site of *m. serratus anterior*. There is potential evidence for healing in the relatively smooth appearance of the fracture surfaces. The tear scars are more likely to occur in bone with a collagen component suggesting that the injury was sustained prior to death or shortly afterwards.

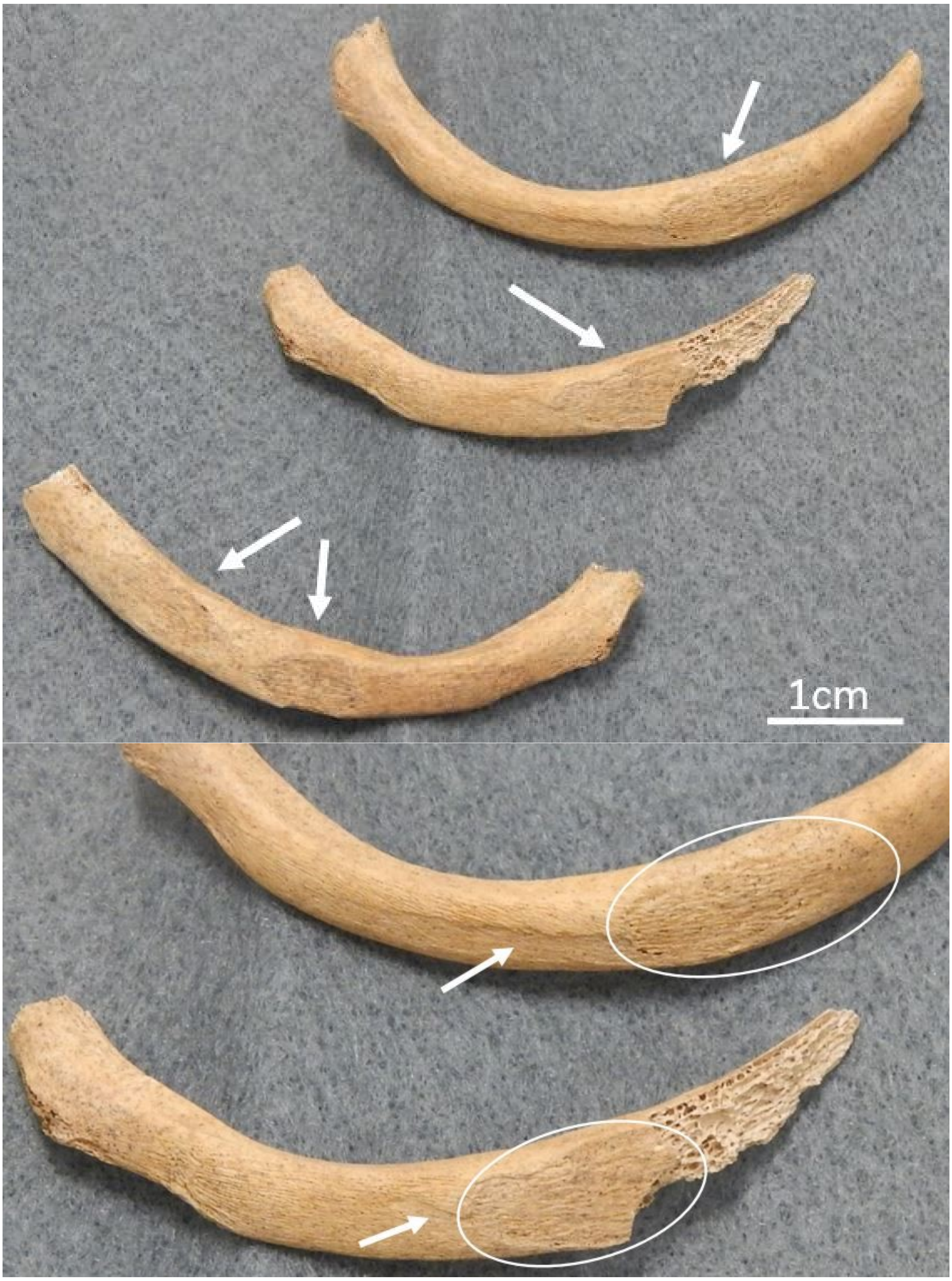


Figure 6.61. (a) Unusual surface morphology of upper ribs (arrows) that is suggestive of avulsion fracture (Ardreigh Sk. 924, 6-9 months). (b) Detail of ribs showing fracture site (circled) and associated periosteal tear (arrows).

A perinatal individual from the Wharram Percy burial population (Sk. V3, 36-40 weeks) sustained an incomplete perimortem mid-shaft right rib fracture with no evidence of healing (Figure 6.62). This individual has several other forms of skeletal pathology involving elements of the pectoral and pelvic girdles that may be associated with various syndromes. The skeletal evidence consists of bilateral elongated and thin clavicles, bilateral and symmetrically dysmorphic scapular spines, bilateral reduction in the scapula width, hypoplastic ischial ramus, and the prominent anterior border of the tibia mentioned above (Figure 6.63). No single syndrome describes all of these skeletal characteristics however, the thin elongated clavicles and dysmorphic scapulae are noted in Chromosome-14 Uniparental Disomy syndrome and the hypoplastic ischial ramus is a feature of ischiadic hypoplasia but can also present as an isolated anomaly (Braegger *et al*., 1991; Castriota-Scanderbeg and Dallapiccola 2005; Lachman, 2007). It is possible that a combination of non-pathological skeletal anomalies are represented in Sk. V3 along with skeletal constituents of other syndromes. It is unlikely that all of the skeletal pathologies developed independently, particularly as there is bilateral and symmetrical expression.

Figure 6.62. Incomplete fracture of an upper right rib (arrow) (Wharram Percy Sk. V3, 36-40 weeks).

Figure 6.63. Unusually elongate and thin clavicles (top), dysmorphic scapular spines (bottom) and hypoplastic ischial ramus (inset) (Wharram Percy Sk. V3, 36-40 weeks).

6.6.1.1 Obstetric

A perinatal individual in the Ardreigh burial population (Sk. 1444, 38-40 weeks) sustained damage in the region of the attachment sites for *m. rectus capitis posterior* and *m. semispinalis capitis* on the occipital squama. The ectocranial surface is stained and slightly raised in this area with minor irregularity of the cortical surface (Figure 6.64). The staining may have been caused by differential mineral uptake from the soils within the burial environment that affected areas of increased micro-porosity on the bone surface. Although the lack of other areas of similar staining on the ectocranial surfaces in this individual suggest muscle involvement as a more likely interpretation.

Figure 6.64. Staining and cortical surface irregularity (arrow) on the occipital squama (Ardreigh Sk. 1444, 38-40 weeks).

The function of *rectus capitis posterior* and *semispinalis capitis* is to extend and rotate the cranium (Stone and Stone 2012). Given the age at death of this individual, the potential ectocranial surface pathology of the occipital squama may indicate a soft tissue trauma occurring during the perinatal period, possibly associated with an obstructed delivery. Recent investigation has demonstrated a physical connection between *m. rectus capitis posterior minor* and the dura mater (Palomeque-del-Cerro *et al*., 2017). This anatomical connection is an indication that any muscle damage in this region may have extended to involve the spinal tissues, and this could potentially be a contributing factor to neonatal death.

More concrete evidence of birth trauma was observed in a perinatal individual from the Ardreigh collection (Sk. 830, 36-40 weeks). This individual has obvious skeletal trauma to the occipital squama and partes lateralis in the form of a pronounced margin of porous woven bone above the inferior margin of the squama on the ectocranial surface and matching excavated regions of porous bone surface on the endocranial surface of the posterior partes lateralis (Figure 6.65). In this case the aetiology can be restricted on the basis of the osseous response to a mechanical injury involving the internal displacement of the occipital squama over the endocranial surface of the partes lateralis. A shearing trauma of the fibrous connective tissues between the occipital squama and the partes lateralis with internal displacement has been described as occipital osteodiastasis. Occipital osteodiastasis is usually experienced during a difficult breech delivery in which compression of the occipital squama leads to its inward displacement (Govaert and deVries 2010; Volpe 2008). In extreme cases of occipital osteodiastasis the displacement will cause significant damage to the soft tissues of the brain and related vascular structures, and is lethal (Volpe 2008).

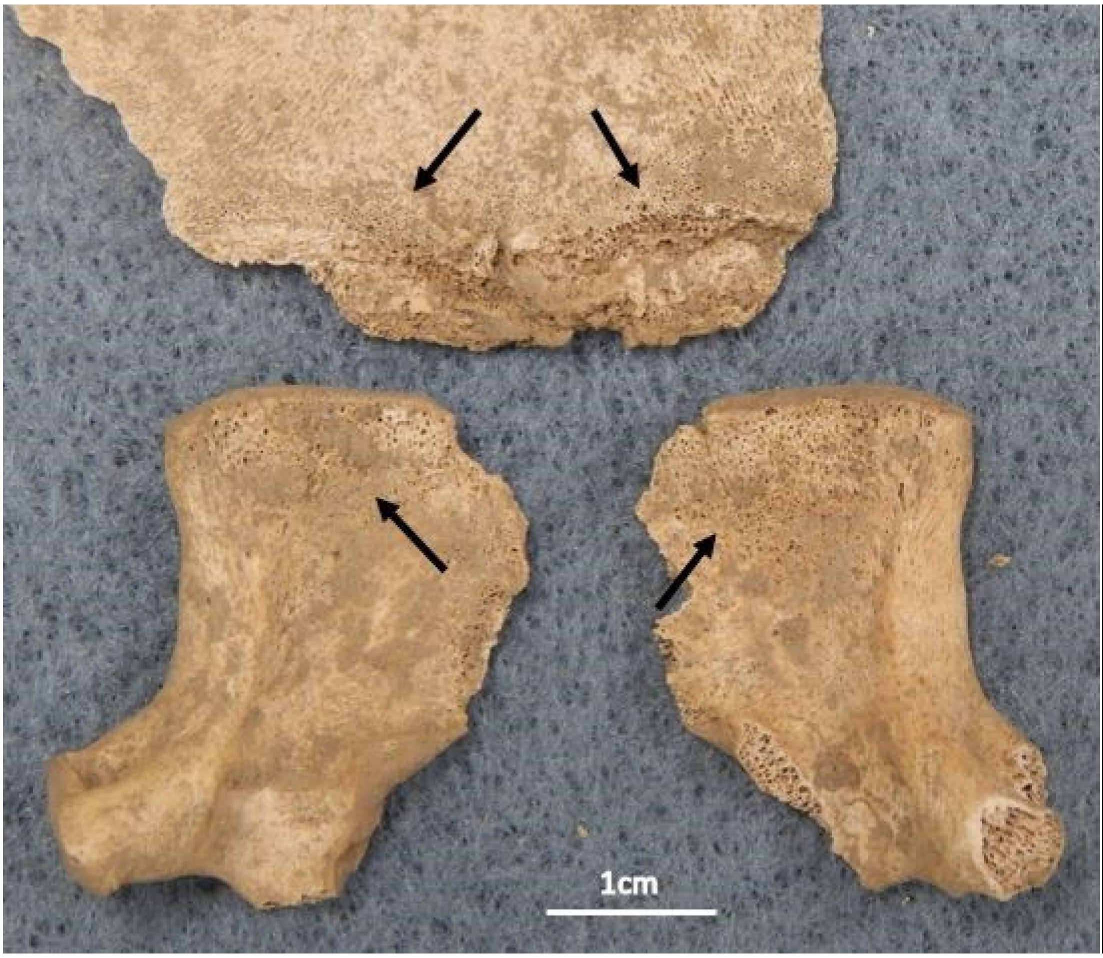


Figure 6.65. Trauma to the endocranial surface of the occipital squama and the endocranial surfaces of the partes lateralis (arrows) attributed to occipital osteodiastasis (Ardreigh Sk. 830, 36-40 weeks).

The osseous response evident in individual Sk. 830 in which displacement of the occipital squama has reduced the foramen magnum, also includes modification to the superior facets of the atlas neural arches with small localised areas of superficial reactive lesions (Figure 6.66). Roche *et al*. (1990) report a rare case of cephalic delivery with occipital osteodiastasis, associated soft tissue trauma and haematoma that resolved without surgical intervention. Their case demonstrates that survival following this form of cranial trauma is possible, provided that the resulting soft tissue damage is minimal. Currarino (2000) describes three forms occipital osteodiastasis: a severe fatal form; a form compatible with survival; and postnatal onset. The first two forms are intrapartum and are associated with trauma sustained during delivery of the head. In the less severe form, affected individuals display intracranial haemorrhage and neurological complications associated with the initial trauma (Dixit *et al*., 2010). Currarino (2002) noted that the displaced occipital squama returned to a near-normal position following the trauma and that evidence of an osseous response in the form of a callus had developed within two weeks. If the trauma evident in individual Sk. 830 was sustained through a difficult delivery, the osseous response on the occipital squama and partes lateralis formed during the postnatal period and that any associated soft tissue trauma was apparently not immediately fatal. Despite evidence for this individual potentially surviving a significant birth trauma, it is plausible that any related soft tissue injuries or haemorrhagic events may have contributed to its death shortly thereafter. To the author's knowledge, this perinatal individual from a medieval context represents the earliest described case of potential occipital osteodiastasis.

Figure 6.66. Small areas of reactive bone (arrow) on the superior facets of the right atlas neural arch (Ardreigh Sk. 830, 36-40 weeks).

Considerable variation in the morphology of the clavicle was observed during analysis, although few examples were considered to be pathological in aetiology. The majority of cases involved asymmetry of the lateral ends and an exaggeration of the lateral curvature of the element. In some individuals the lateral end appeared somewhat expanded, although this is still likely to fall within normal anatomical variation of the element. These examples of slight morphological changes were not associated with any cortical pathology or changes to the muscle attachment sites. In one perinatal individual from the Yewden villa collection (Sk. 20, 40 weeks), the sternal end of the left clavicle has damage to the medial metaphysis that may be associated with the sternoclavicular capsule (Figure 6.67). If associated with a physical trauma rather than a taphonomy, this form of damage in a very young individual is rarely spontaneous and is most commonly associated with trauma sustained during a difficult delivery and resulting in dislocation of the clavicle (Beluffi and Sileo, 2009).

Figure 6.67. Articular fracture of the sternoclavicular capsule (arrow) (Yewden villa Sk. 20, 40 weeks).

As described above, the Ardreigh burial population contained one definite (Sk. 830) and one tentative (Sk. 1444) example of cranial trauma associated with birthing. The trauma observed in these two individuals may indicate a difference of birthing practice within the Ardreigh population, although no specific delivery technique is associated with occipital osteodiastasis. The Yewden villa burial population contained one probable example (Sk. 20) of trauma sustained during delivery, but there was no other evidence of obstetric trauma observed in any of the other very young individuals analysed.

One infant from the Wharram Percy burial population (Sk. NA55, 1-3 months) has several anomalies of the cranial base and cervical vertebrae that are strongly suggestive of injury. There is evidence of bilateral partial fusion of the atlas neural arches to the partes lateralis of the occipital and erosive lesions of the neural arch laminae in C2 to C5 (Figure 6.68). The partially fused neural arch of the atlas and the erosive lesions of the upper cervical vertebrae are potential indications of an injury affecting the connective and soft tissues of the neck with a localised osseous response. Extension of the cranium may contributed to spinous articulation of the cervical vertebrae and possible associated erosion however, flexion of the cranium with sufficient force could result in avulsion fractures associated with the strain on the interspinal ligaments. This individual also has reactive lesions on the endocranial surface of the basilar process and the right pars lateralis of the occipital (Figure 6.69) that suggest localised endocranial haemorrhage in the region of the cranial base. The skeletal pathology of the cranial base and cervical spine described above have not been previously identified. Given the age at death of this individual, the injuries present have several potential aetiologies. The trauma may have developed from intrauterine constraint associated with uterine malformations and compression (Higginbottom *et al*., 1980). The skeletal trauma may also have been sustained in the intrapartum period if related to cranial entrapment or fetal malpresentation, or potentially during the first few postpartum months.

Figure 6.68. Partial fusion of the atlas neural arch (arrows) with the pars lateralis and erosive lesions of the neural arch laminae (arrows) in C2 to C5 (Wharram Percy Sk. NA55, 1-3 months).

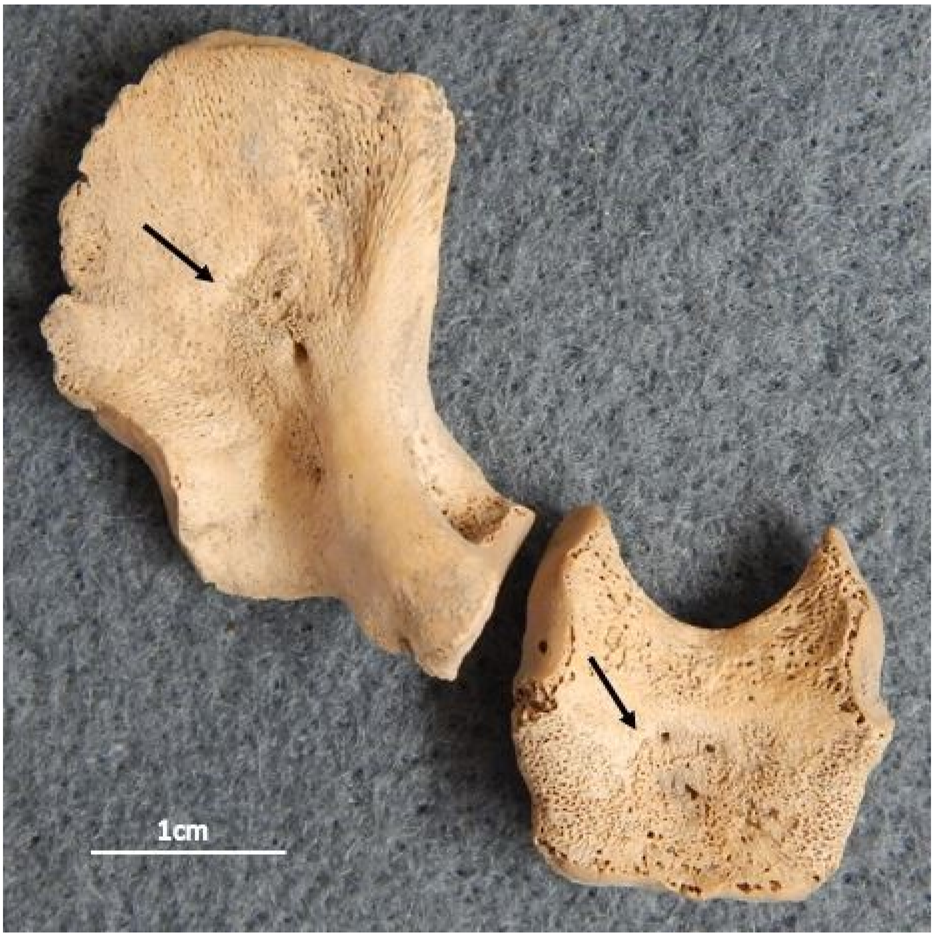


Figure 6.69. Periosteal new bone formation on the endocranial surfaces of the right pars lateralis and the basilar process (arrows) (Wharram Percy Sk. NA55, 1-3 months).

6.6.1.2 Post-mortem

One individual (Çatalhöyük Sk. 21709, 38-40 weeks) sustained an incomplete fracture to the proximal right radius (Figure 6.70). The burial of this perinate clearly shows minimal disturbance to the position of the skeletal remains (Figure 6.71). The position of the right radius supports an aetiology of postmortem trauma. It is proposed that the connective tissues of the wrist and elbow were decomposed sufficiently to enable the separation of the distal radius. Downwards pressure applied to the elbow joint at this stage would contribute to the medial dislocation of the distal half of the pronated radius. The helical non-displaced fracture indicates the presence of collagen in the bone at the time of injury. It is considered that the right radius of Sk. 21709 may have been fractured through a combination of decomposition processes and downward pressure from above the burial. Despite the tightly articulated position of the skeletal remains, there was rodent (European souslik, *Spermophilus citellus*) burrowing in the vicinity of the head that is the probable means of removal of several missing elements of the cranial base, the left side of the cranium and face, and the left humerus.

Figure 6.70. Incomplete fracture of the proximal right radius (arrow). The head of the vertically positioned ulna is adjacent to the fracture. (Çatalhöyük Sk. 21709, 38-40 weeks).

Figure 6.71. In situ remains of Çatalhöyük Sk. 21709 showing tight articulation of the elements and minimal disturbance.

6.6.2 Cut-marks

Three perinatal individuals from the Yewden villa settlement (Sk. 7, Sk. 38 and Sk. Bag 5) and one premature individual from the Wharram Percy burial population (Sk. G457) have evidence of perimortem sharp-force trauma to the major long bones of the lower limbs. The trauma has the appearance of cut-marks, which is an unusual find on the skeletal remains of very young individuals. Potential aetiologies include trauma associated with the manipulation or assisted removal of the full-term fetus. Assisted delivery is usually required in the event of a breech presentation or maternal complications that jeopardise the life of one or both individuals. None of the cut-marks present in these four individuals appear to have been made with the intention to amputate the respective limbs or sections thereof, as might be expected in the event of an embryotomy which was a documented practise in the Roman period (Jackson, 1988). All of the marks are relatively superficial with regard to the bone structure as only one penetrates through the cortical layer to the medullary cavity (Yewden villa Sk. 38), however they are likely to have caused damage to associated muscle groups and vessels. Attempts to manipulate a full-term fetus in breech presentation may have involved the use of various tools including hooks (Jackson, 1988).

One of the individuals appears to have cut-marks on both femora (Yewden villa Sk. 38, 38-40 weeks) (Figure 6.72). Mays *et al.* (2011) and Mays *et al.* (2014) discuss the cut-marks on the right femur, but are not convinced that the marks on the left femur, which suffered more taphonomic cortical erosion, share the same aetiology as those on the right femur. The potential presence of bilateral cut-marks that involve multiple strokes across both proximal femora sheds doubt on the interpretation of embryotomy proposed in these two papers. In the event of a frank breech position, the buttocks and thighs of the full-term fetus would present first. Cutting into the back of the upper thighs would not have facilitated delivery of the legs and would be an unusual form of attempted embryotomy however, it is possible that the marks were made in the process of reducing soft tissue bulk.

In an incomplete breech position the full-term fetus presents with one foot delivered and the other held in a flexed position against the abdomen. Attempts to secure the undelivered ankle using the tools available may have caused matching injuries to the femora as seen in individual Sk. 38. The cut-marks on this individual follow the curvature of the diaphysis, a possible indication that a curved rather than a straight tool was used. Todman (2007) comments that sharp and blunt hooks were used to assist in extracting the full-term fetus during difficult deliveries in the Roman period. It is clear that if the observed skeletal trauma was sustained in this manner, extreme measures were evidently taken with the incentive of preserving the mother's life over that of the perinate. There is no skeletal evidence that suggests the removal of presenting limbs through embryotomy.

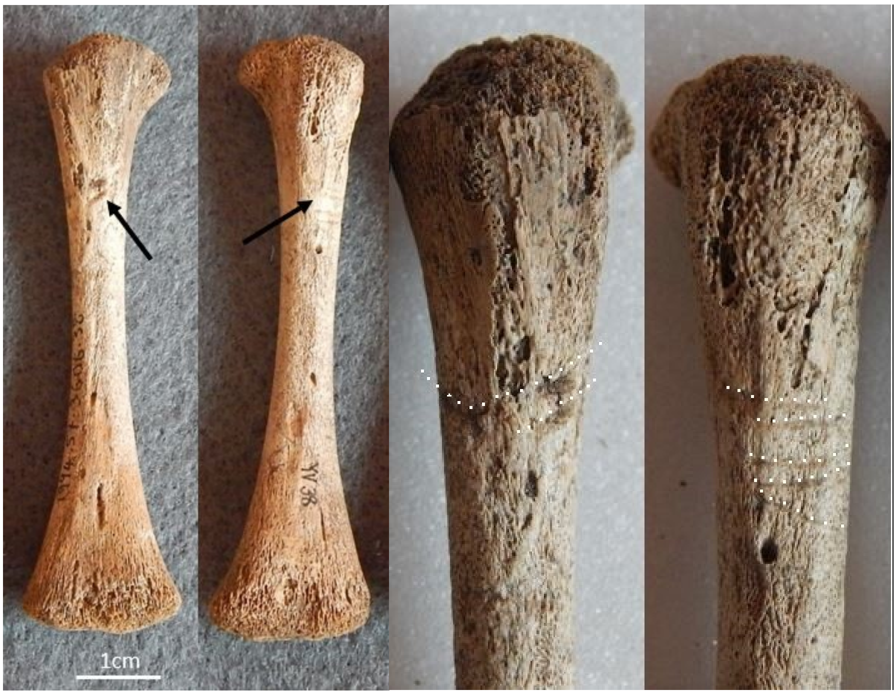


Figure 6.72. Cut-marks on the proximal femora of Yewden villa Sk. 38 (38-40 weeks). Detail on the right.

Two of the perinatal individuals from Yewden villa (Sk. 7, 38-40 weeks and Sk. Bag 5, 37-40 weeks) have unilateral cut-marks on the anterior surface of the distal right tibia. The similarity in appearance and location of these cut-marks is strongly suggestive of a common behaviour as the cause. The cut-marks on Sk. 7 consist of five unevenly spaced marks along the same plane, two of which are overlaid (Figure 6.73). The most superior mark is 5.68 mm long and 0.8 mm deep. Yewden Sk. 7 no longer has a comparative left tibia as this was destroyed for the purposes of ancient DNA analysis (Hassan *et al*. 2014). There are also five cut-marks on the tibia of Sk. Bag 5 (Figure 6.74). The longest measures 5.17 mm long and 0.7 mm deep. The skeletal remains were largely incomplete for this individual, with no other long bones present. Initial analysis of the skeletal remains from Yewden villa does not mention any cut-marks on individuals Sk. 7 or Sk. Bag 5 (Mays *et al*., 2011, 2014).

Figure 6.73. Cut-marks on the distal right tibia of Yewden villa Sk. 7 (38-40 weeks).

Figure 6.74. Cut-marks on the distal right tibia of Yewden villa Sk. Bag 5 (38-40 weeks).

The premature individual from the Wharram Percy burial population (Sk. G457, 30 weeks) was recovered from a multiple burial in which its remains were located between the upper thighs of a female middle adult (Sk. G438, 25-30 years) (Figure 6.75). There is a sharp-force trauma that resembles a mid-shaft cut-mark on the anterior surface of the right tibia (Figure 6.76). There may be a similar trauma to the left tibia, however this element has been reconstructed obstructing further assessment. The female is assumed to be the mother although analysis was unable to confirm this as the perinatal DNA preservation was poor (Mays 2007). The adult suffered from advanced tuberculosis with significant skeletal pathology (Mays 2007). It is more probable that the perinate was placed in this burial position following birth rather than the positioning of the individual's remains resulting from postmortem extrusion (Sayer and Dickinson 2013). The possibility also exists that the individual was removed from the mother after she had died. This alternate explanation may account for the potential cut-mark observed on the tibia.

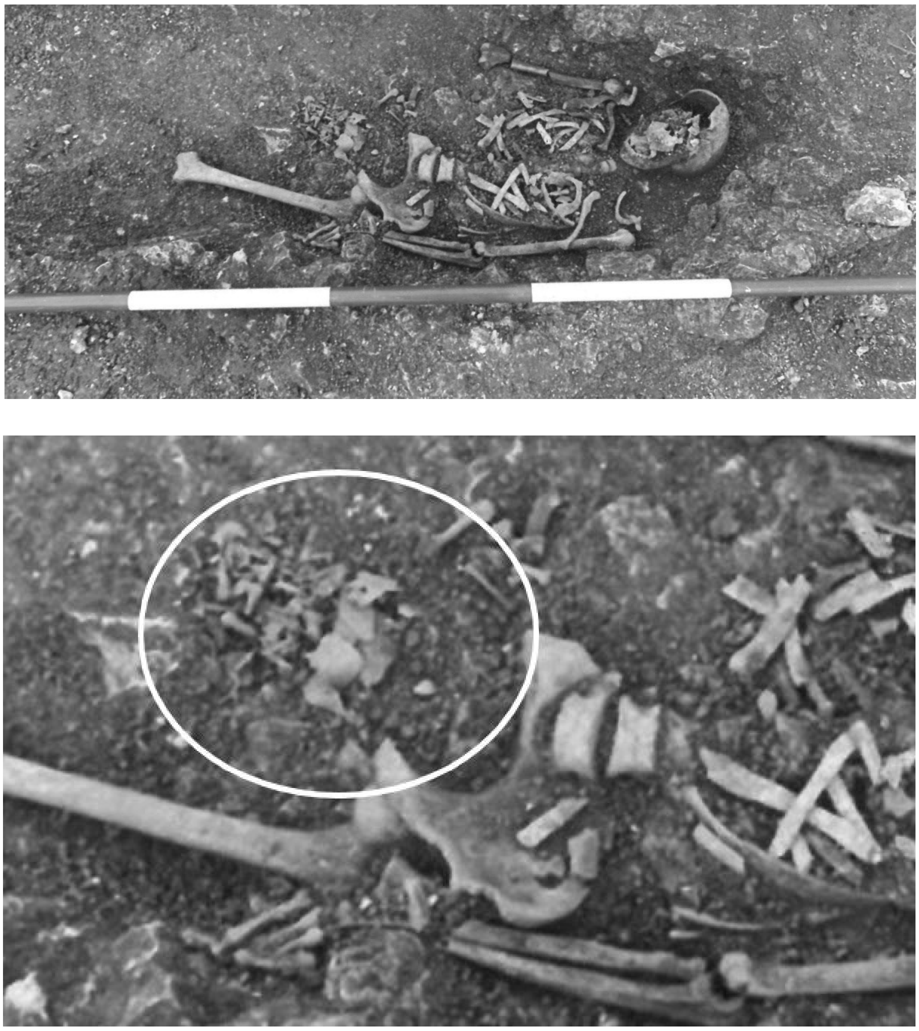


Figure 6.75. In situ burial of adult female (Sk. G438, 25-30 years) (top) with perinatal remains of Sk. G457 (30 weeks) positioned between the upper thighs (bottom).

Figure 6.76. Sharp force trauma (arrow) on the anterior mid-shaft surface of the right tibia (Wharram Percy Sk. G457, 30 weeks).

6.6.3 Taphonomic Alteration

6.6.3.1 Cortical degradation

One individual presents an unusual case among the collections analysed. The skeletal remains of an infant in the Scheuer collection (Sk. 21, approx. 6 months) display differential preservation with indications of destructive salt formation. The affected elements are the maxillae and maxillary incisors and canines, the superior and posterior semi-circular canals of the petrous temporal, the cervical and thoracic neural arches, the vertebral ends of ribs, the manubrium and sternebrae, and potentially the left pubis. The cortical bone of the neural arch laminae is largely absent while the trabecular bone remains intact, although heavily discoloured (Figure 6.77). The pedicles of the thoracic neural arches are unaffected by this loss of cortical bone, which is focussed on the laminae and transverse processes. The semi-circular canals are clearly defined by a white mineralised substance and the surfaces of the temporals, maxillae, mandibulae, sphenoid, and zygomae all have smaller clumps of a light-coloured crystalised substance (Figure 6.78). These crystalised deposits may have developed from the burial environment, however they are not consistently distributed over the remains. It is also possible that they derive from the decomposition of soft tissues within confined skeletal structures such as internal sinuses or canals, or in positions where decomposing tissues may have persisted. The dentition of this infant is discoloured to a dark brown and the dental crowns of the incisors and canines are fractures along the cusp margins (Figure 6.79).

Figure 6.77. Destruction of the cortical surface with intact trabecular bone in the thoracic vertebrae of Scheuer Sk. 21 (6 months).

Figure 6.78. Crystalised deposits (circled) on the sphenoid of Scheuer Sk. 21.

Figure 6.79. Fractured crowns of maxillary incisors and canines (arrows) (Scheuer Sk. 21).

There are several surfaces with superficial residues that may be associated with decomposition and the taphonomic environment. In particular, these deposits are clear on the palate and lateral surfaces of the maxillae, mandibulae, zygomae, temporals, and left pubis (Figure 6.80). The maxillary incisors and canines are split into lingual and labial halves through single coronal fractures and also display minor fractures of the enamel. Differential taphonomic conditions of the skeleton is further supported by the appearance of the cortical bone on the vertebral ends of the ribs, the manubrium and sternebrae (Figure 6.81). Unusually, the long bones of the limbs, ilia and ischia are unaffected by the changes to the axial skeleton described above. This suggests that despite the remains being deposited together, very likely in articulation, some regions of the skeleton experienced different post-depositional impacts. The skeleton also provides evidence of post-mortem activity involving surface cleaning; damage to the iliac fossa of the right ilium and the left supraorbital ridge is evident in the form of groups of scratches (Figure 6.82). Despite a documented cause of death of bronchopulmonary pneumonia, there is little supporting skeletal evidence for this aetiology. It is expected that individuals suffering from a severe, acute condition that contributed to their death would not have survived long enough to develop associated skeletal pathology.

Figure 6.80 Darkened and cracked superficial residue on the surfaces of the maxilla and left pubis (Scheuer Sk. 21).

Figure 6.81. Variably affected cortical bone on some rib heads (arrows), the manubrium and sternebrae (Scheuer Sk. 21).

Figure 6.82. Evidence of surface cleaning in the form of scratches (arrows) marking the cortical bone of the right ilium (left) and left frontal (right) (Scheuer Sk. 21).

However, there is one indication that this infant suffered from a chronic condition. This is the mineralisation of the semi-circular canals of the petrous temporal (Figure 6.83). Labyrinthitis ossificans is a condition in which the semi-circular canals gradually become ossified following a bacterial infection, usually commencing within the first month after the onset of the infection (Gadre *et al*., 2006; Harris 2006; Paparella and Sugiura, 1967). This condition may arise as a complication of several conditions including bacterial meningitis (Mitchell and Dehkharghani 2014), although it is very unlikely that an infant would survive several months following onset of this condition. If infection persists within the vestibular system of the petrous, and ossification is consistent, it is estimated that complete ossification of the canals may take a month or two to reach the stage evident in Sk. 21. Given that this infant died at approximately six postnatal months and assuming a constant progression of ossification, the infection is likely to have been contracted within the first two months of life.

Figure 6.83. Mineralised semi-circular canals (arrow) of the petrous temporal (Scheuer Sk. 21, 6 months). Note the crystalised deposits (circle).

6.6.3.2 Gnaw-marks

Two individuals from the Ardreigh burial population (Sk. 1302, 36-40 weeks and Sk. 839, 0-1 month) have evidence of gnawing. The perinate (Sk. 1302) has five individual parallel marks on the distal lateral surface of the left humerus (Figure 6.84). The second individual (Sk. 839) displays similarly paired marks that are cross-hatched on the lateral surface of the proximal left femur

(Figure 6.85). There appear to be at least five pairs of marks in the same area on the proximal femur. These paired marks are suggestive of rodent gnawing. There is a space of 0.3 mm between the paired marks and each mark is approximately 0.7 mm wide, which is a similar incisor width and spacing to several small species. Many of these were not present in Ireland during the medieval period, however the house mouse (*Mus musculus*) and the wood mouse (*Apodemus sylvaticus*) were (Sheehy and Lawton, 2015). The location of the burials suggests that the more probable of these two species is the wood mouse. Evidence of rodent gnawing on the skeletal remains of very young individuals may indicate burrowing access to a burial, an extended period of time between death and burial, or storage of the remains above ground, which would leave the remains vulnerable to animal activity. A single perinatal individual from the Yewden villa site (Sk. 8, 38-40 weeks) has significant evidence of gnawing activity on the distal left tibia (Figure 6.86). This is not unexpected from a site where there has been continued agricultural activity and the shallow burials were disturbed prior to excavation (Cocks 1921), however surprisingly few skeletal remains were similarly affected.

Figure 6.84. Gnaw-marks (arrow) on the distal lateral surface of the left humerus (Ardreigh Sk. 1302, 36-40 weeks).

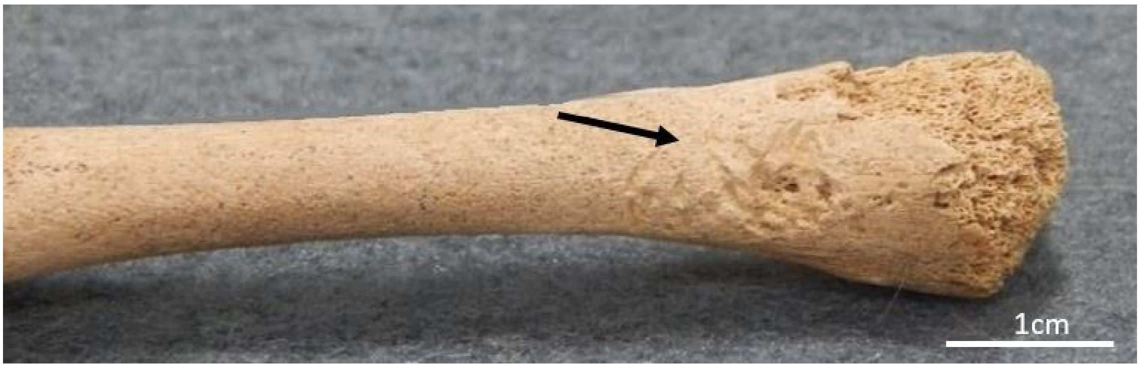


Figure 6.85. Gnaw-marks (arrow) on the proximal left femur (Ardreigh Sk. 839, 0-1 month). Note that the cortical surface has been removed to reveal the inner trabecular bone.

Figure 6.86. Gnaw-marks on the distal left tibia (Yewden villa Sk. 8, 38-40 weeks). The arrow points to one of the paired marks. Note that the gnaw-marks cover the distal half of the diaphysis and the activity has noticeably reduced the diameter and distal end.

6.7 Summary

This chapter has presented the results of detailed analysis with regard to the pathology, variation, and taphonomic impacts observed in the skeletal remains of very young individuals within the study populations. This analysis revealed that the majority of skeletal pathology appears to be an osseous response associated with developmental and traumatic pathology and developmental variations. The pathological expression observed in skeletal elements ranged from relatively subtle forms of morphological alteration to major dysmorphy involving agenesis. The evidence for taphonomic effects on the skeletal remains sheds light on the potential funerary treatments and burial environments of the very young individuals within the past populations studied.

Only a few cases of skeletal trauma were identified in the populations analysed. Two of these were depressed fractures of the cranial vault associated with varying degrees of reactive lesion. The presence of craniolacunia and irregular thinning of the vault elements suggests that developmental anomalies in the dura were present in the populations analysed. One individual suffered a significant birth trauma to the occipital elements that involved damage to the connective tissues between the squama and partes lateralis as well as significant trauma to the underlying soft tissues and vasculature. To the author’s knowledge this is the only described case of probable occipital osteodiastasis from an archaeological context.

The observed intra-population similarities in the pathologies described above indicate that some of the communities studied may have had restricted genetic input, with higher expression of non-metric skeletal traits compared to the other populations studied. Common elements of palaeopathology that are shared across all populations are ectocranial and endocranial lesions, morphological variation of the sphenoid, and non-specific periostosis. The skeletal pathology presented above demonstrates that the youngest individuals in the populations analysed, are likely to have experienced physiological stresses that influenced disturbances to their intrauterine skeletal development and growth during early infancy.

This chapter has provided descriptions of the normal appearance of developing skeletal elements and some of the pathological changes that occur in the very young. Apart from the skeletal evidence of developmental disturbance, several forms of morphological anomalies and anatomical variation have also been identified and described. Two perinatal cases of cranial trauma, both of which have not been previously identified in archaeological remains, and three of postcranial trauma, were positively associated with birth trauma. It was shown that changes in the appearance of cortical and articular surfaces can be suggestive of positional and inflammatory aetiologies. Several individuals sustained perimortem fractures that display various degrees of osseous response, and at least one (Çatalhöyük Sk. 21676) has periosteal reactive bone arising from a soft tissue injury that became infected.

Analysis revealed several skeletal impacts that were population specific. The Çatalhöyük population has notochordal variation that is not present in any of the other populations analysed. While the Yewden villa site was the only location where perimortem trauma in the form of cut-marks was observed on perinatal individuals. Unusual pathologies of the vertebral column that include complete transverse cleft of the basilar process and dorsal hypoplasia of the centra were only observed in the Wharram Percy burial population. As were the two identified cases of depressed fractures of the cranial vault.

It is apparent that without a detailed understanding of the formation, morphological development and macroscopic appearance of the skeletal elements of very young individuals, the presentation and brief discussion of the skeletal pathology observed would not have been possible. This, in conjunction with knowledge of the musculo-skeletal system and the ways in which changes in other systems can affect the developing skeleton, makes it possible for the researcher to identify pathological skeletal changes, differentiate these from the normal range of variation and ascertain possible underlying causes on an individual basis.

Chapter Seven

Maternal Influence and Skeletal Pathology

7.1 Introduction

This chapter considers the evidence of fetal, perinatal, neonatal and infant palaeopathology in response to the maternal condition prior to and during pregnancy. It covers the observed skeletal variants and pathologies that are known to be genetically influenced, as well as pathology that is more likely to be a consequence of the maternal condition than of an independent condition in the very young individual. Associations have long been made in the medical disciplines between the maternal condition and fetal growth and development, however limited research has been undertaken involving the study of skeletal remains to assess these factors in past populations (Gowland 2015). This chapter provides palaeopathological evidence of the close physiological connection between maternal and fetal health through the analysis of the skeletal remains of very young individuals and, where possible, the remains of their mothers. As in the previous chapter on skeletal pathology, the aetiology of noteworthy cases associated with maternal health will be detailed.

7.2 Maternal-Fetal Relationship

The collections analysed included eight mothers with associated babies. Four of these died during pregnancy, three at the end of the third trimester and one in the first two months following delivery (Table 7.1). One of these maternal deaths is an obstetric death associated with complications from a bilateral pelvic fracture, discussed above in Chapter 5. Two further adult females died and were buried at Barton Court Farm during the final stages of pregnancy. These two burials were dated to the Anglo-Saxon period and are not necessarily associated with the remains dated to the Roman settlement that have been analysed for the current research.

The physiological relationship between the mother and the developing fetus has been well documented through reproduction research. Despite the physical separation the mother's body provides between the developing fetus and the external environment, the fetus is not necessarily protected from environmental impacts experienced by the mother. This connection has been observed in the offspring of mothers who have experienced a natural starvation event, illness prior to and during pregnancy, or significant emotional stress (Gluckman and Hanson, 2004; Gowland, 2015; Roseboom *et al*., 2001). Barker (2001) discusses the fetal impacts of maternal undernutrition that include alterations in metabolism, hormone production, and growth rate (Fowden, 1995). Some of these changes in the developing fetus have long-lasting effects on the individual well into adult life (Barker, 2001; Gowland, 2015; Harding, 2001; Roseboom *et al*., 2001).

The pathway of nutrient transfer between the mother and the developing fetus, referred to as the fetal supply line, has multiple stages that render it highly vulnerable to disruption. This is not surprising given the significant impact of failure in any one of the pathways. The starting point of the fetal supply line is the maternal body composition and size prior to pregnancy. The mother's nutrient stores play a vital role from the onset of pregnancy, as do the other parts of the fetal supply line: maternal nutrition during pregnancy, the transport of nutrients to the placenta, and the transfer of nutrients across the placenta to the fetus (Barker 2001; Harding, 2001). The concept of a maternal buffer to negative environmental impacts is no longer an accepted viewpoint (Richardson *et al*., 2014). Depending upon her own development conditions and pre-pregnancy physiological state, the mother will have a varied ability to provide for the developing fetus, which in turn will influence that individual's growth, development and potentially, health and well-being during adulthood (Barker, 2004; Ceesay *et al*., 1997; Gowland 2015; Richardson *et al*. 2014; SACN Report, 2011). The physiology of the mother will determine to what extent she may provide limited protection from external impacts, but there is no absolute barrier to detrimental impacts upon the developing fetus.

Table 7.1. Identified cases of maternal mortality and their respective offspring. (denotes individuals whose maternal association was clear upon excavation but has subsequently been lost during cataloguing).*

Collection	Adult	Age	Fetus/ Neonate	Age	Cause of Death
Ardreigh	1087	18-25y	5698	<36w	Unknown: fetus head first in birth canal
	1371	18-20y	5833	16w	Unknown: fetus within pelvic cavity
	1505	25-29y	5633	0-1m	Complications associated with maternal anaemia
Barton Court Farm (Anglo-Saxon)	271i	unknown	271ii	37-40w	Unknown: *in utero*
	807i	18-25y	807ii	37-40w	Unknown: *in utero*
Çatalhöyük	13162	20-25y	13163	38-40w	Obstetric complications: within pelvic cavity
Wetwang Slack	156	21-25y	* Unknown	full-term	Unknown
	309	20-25y	* Unknown	premature	Unknown: *in utero*
Wharram Percy	G438	25-30y	G457	<36w	Complications associated with maternal tuberculosis: fetus between femora
	NA170	20-25y	NA170A	1-2m	Unknown: shared burial

7.3 Differential Impact

The developing fetus has the ability to adapt physiologically to maternal nutrition. This ability is referred to as developmental plasticity and is associated with the developmental origins of health and disease (Barker, 2001; Gowland, 2015; West-Eberhard, 1989). Barker (2001) describes the differential impact of maternal nutrition on the developing fetus determined by the timing of the impact. Maternal undernutrition has the effect of slowing fetal growth and development regardless of the timing, however the ability of the fetus to regain a normal growth rate is determined by the length of maternal undernutrition and its timing during pregnancy. Fancourt *et al.* (1976) demonstrated that the infants with the longest gestational exposure to maternal undernutrition were those that had postnatal growth failure. By comparison, those infants with shorter exposure to maternal undernutrition during late gestation had the ability to regain a normal growth rate rapidly following improved nutrition (Barker 2001).

The subsequent generation following the Dutch famine displayed intrauterine responses to maternal undernutrition, despite their mothers having suffered no similar deficiencies during pregnancy (Painter *et al*., 2008). These intrauterine responses have a direct impact on future health and wellbeing of the individual during their adulthood (Roseboom *et al*., 2001). Painter *et al*. (2005) demonstrated that the timing of maternal undernutrition determines which organ system is affected in the developing fetus. The offspring of mothers affected by undernutrition during the early stages of pregnancy were more likely to develop cardiovascular disease, obesity and diabetes during adulthood, compared with those whose mothers were affected during the final stages of pregnancy (Painter *et al.*, 2005). The offspring of mothers affected in later pregnancy experienced greater intrauterine growth restriction but did not develop the same conditions during adulthood as those individuals who had been affected in early gestation (Painter *et al*., 2005).

Maternal nutritional supply to the developing fetus is also dependent upon her own developmental state. Research has demonstrated that immature mothers prioritise their own nutritional needs over those of the fetus, however the physiology of mature mothers prioritises the fetal nutrient supply (Barker, 2001; Gluckman and Hanson, 2004; James, 1997). This differential nutrient supply is a form of biological limitation that optimises successful reproductive outcomes through maternal maturity. The fetal supply line is prioritised during maternal undernutrition, supporting fetal development despite the maternal condition. The skeletal evidence of nutritional deficiency in the remains of very young individuals is an indicator that the maternal condition was exceptionally poor (Chávez *et al*., 2000). However, it may also be an indication that the mother was herself immature and that her nutritional needs were prioritised over those of the developing fetus.

Two individuals of similar age at death (Çatalhöyük Sk. 10390 and Sk. 10391) exhibit the same unusual appearance of the basilar process (Figure 7.1) and could represent a potential set of twins. The perinatal individuals were buried in opposite corners of the same space with a domestic building (Space 258, Building 58). Although the burials are spatially separated they share a common stratigraphic activity layer within the space, indicating that they were contemporary burials. Both individuals had age discrepancies between skeletal (38-40 weeks) and dental (30-36 weeks) estimates for age at death.

Figure 7.1. Unusual morphology of the basilar process of the occipital in potential twins (Çatalhöyük Sk. 10390 (left) and Sk. 10391 (right)).

Both of these individuals display porous lesions of the maxilla and have a similarly shaped extra-sutural ossicle in the lambdoid region (Figure 6.18). It is possible that these individuals were born prematurely, based on dental development and that; the larger size of the skeletal elements are an indication that the babies may have been large for their gestational age. The expression of porous lesions of the maxilla suggest that both individuals were potentially affected by an inadequate fetal supply line during gestation. An alternative interpretation of these two burials is that both individuals were born at the end of singleton pregnancies but had experienced a significant period of intrauterine disruption, such as intrauterine infection or severe maternal undernutrition that resulted in delayed dental development.

7.4 Development Disturbance

The underlying causes of intrauterine developmental disturbance may be associated with the maternal condition as discussed above. They may be genetically inherited or influenced by an independent occurrence in the development of the fetus. As most developmental abnormalities occur within the embryonic and early fetal stages of development (Barnes, 2012), the state of maternal health prior to and during pregnancy is an important contributing factor to fetal development. Abnormalities in the embryonic structures that give rise to skeletal elements have the potential to result in significant morphological pathology that is easily identifiable in skeletal remains. In contrast, environmental impacts resulting in disturbances to the growth and development of the fetus are most often associated with soft tissue pathology and systemic conditions. As such, they will not necessarily be reflected in the developing skeletal elements, although more severe soft tissue abnormalities, such as neural tube defects, have the potential to cause significant skeletal pathology.

7.4.1 Genetic

The analysis of cranial skeletal pathology in very young individuals has revealed a few population specific skeletal traits that indicate genetic inheritance. Three of the individuals from the Gussage All Saints burial population (Sk. 34.4, 36-38 weeks, Sk. 132.10b, 38-40 weeks and Sk. 132.9, 40 weeks) have a thin basilar process of the occipital, a morphological difference that was not observed in the other populations. The superior-inferior width was significantly reduced without alteration to the remainder of the element. There is no pathological condition associated with this morphology of the basilar process. It is proposed that the thin basilar process may reflect a difference in overall cranial morphology or more specifically of the parachordal cartilage during development (Barnes 2012). As this morphological variant of the basilar process was rarely observed during analysis, it may be a non-metric trait particular to the Gussage All Saints population.

7.4.1.1 Anomalies of the Jugular Foramen

Jugular foramen bridging is a relatively rare non-metric skeletal trait (Dodo, 1986; Hanihara and Ishida, 2001). The trait consists of an intrajugular process arising from the petrous temporal or the pars lateralis of the occipital. In most cases the processes meet across the jugular foramen effectively dividing the space. Dodo (1986) describes Type I bridging as the dominant form with the intrajugular process of the occipital located above the hypoglossal canal. Type II bridging in which the intrajugular process is located posteriorly to the hypoglossal canal is considered to be an ‘extremely rare’ expression of the trait (Dodo 1986). Bridging of the jugular foramen was observed in only two burial populations, Wharram Percy and Çatalhöyük, with six perinates, one neonate and one infant expressing the trait (Table 7.2). Figure 7.2 shows a neonatal individual (Wharram Percy Sk. NA193, 0-1 month) with jugular foramen bridging on the right side, with occipital and temporal processes that are Type I in form. Four individuals had bilateral intrajugular processes of the occipital and the remainder had processes on the right pars lateralis only. Two of the perinatal individuals in the Wharram Percy burial population have the rare Type II bridging of the jugular foramen (Sk. NA76 and Sk. NA96) (Figure 7.3), while the remainder have Type I, the more common form. Intrajugular bridging is considered to be primarily under genetic control (Kaur *et al*., 2012). A single reproductive individual with the trait would be a sufficient genetic source for the trait to perpetuate within the Wharram Percy population.

Table 7.2. Individuals from Wharram Percy and Çatalhöyük with bridging of the jugular foramen.

Individual	**Age**	**Intrajugular Process of Occipital**	**Intrajugular Process of Temporal**	**Form**
NA6A (WP)	34w	Bilateral	Left (no right present)	Type I
NA67 (WP)	38w	Right	-	Type I
NA69 (WP)	36-40w	Right	-	Type I
NA76 (WP)	38-40w	Bilateral	-	Type II
NA96 (WP)	40w	Bilateral	Left	Type II
NA193 (WP)	41-44w	Right	Right	Type I
V6 (WP)	2-3m	Bilateral	-	Type I
10368 (C)	38w	Right	-	Type I

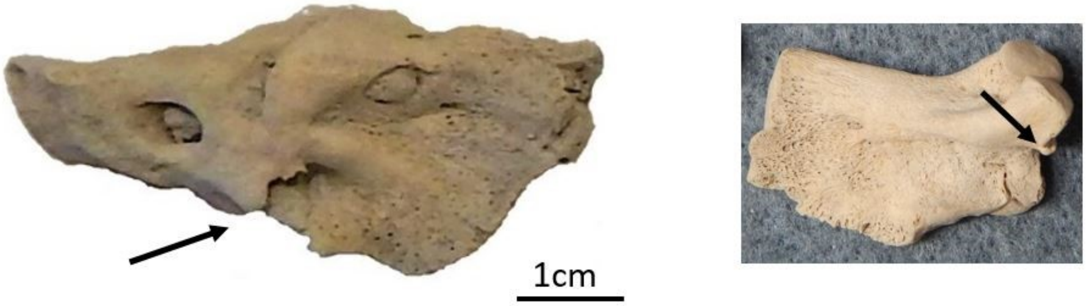


Figure 7.2. Intrajugular processes (arrows) of the temporal (left) and pars lateralis (Wharram Percy Sk. NA193, 0-1 month). This form is Type I that sits above the hypoglossal canal.

Figure 7.3. Bilateral Intrajugular process (arrows) of the jugular foramen of Type II form (posterior to the hypoglossal canal). Wharram Percy Sk. NA76 (left) and Sk. NA96 (right).

7.4.1.2 Vertebral Border Shifting

In addition to the vertebral anomalies described above in Table 6.8, seven individuals displayed evidence of cranial or caudal shifts in the vertebral column, two of whom were adult females associated with very young individuals (Table 7.3). Six of the seven individuals were from the same burial population; Wharram Percy. The two mother-baby pairs share similar vertebral features that are strongly suggestive of shared vertebral shifts. One in particular (Sk. NA170A, 1-2 months) has the same vertebral anomalies as its mother (Sk. NA170, 20-25 years). Both this adult female and infant share cranial shifts at the thoracic-lumbar and lumbar-sacral borders (Figure 7.4).

Table 7.3. Vertebral shifting evident in the Çatalhöyük and Wharram Percy burial populations.

Collection	Individual	Age	Description
Çatalhöyük	13163	38-40w	Caudal shift with supernumerary sacral arches
Wharram Percy	EE54	3-6m	Cranial shift at thoracic-lumbar border: L1 and L2 have thoracic-type facets
	G438	25-30y	Caudal shift at occipital and C1 (assoc. with G457)
	G457	30w	Dysmorphic C2
	NA150	3-6m	Occipitalised C1 (dysmorphic right arch with fusion to pars lateralis), block thoracic centra
	NA170	20-25y	Vertebral shift in L1 and S1 (assoc. with NA170A)
	NA170A	1-2m	Cranial shift in lumbar-sacral and thoracic-lumbar borders: S1 neural arch has lumbar features and L1 and L2 have separate superior and inferior articular facets

The seventh individual is a perinate (Sk. 13163) from the Çatalhöyük burial population that has an additional transitional vertebra at the lumbar-sacral transition (Barnes 2012). Two of the individuals also have block vertebrae (G438, female 25-30 years and NA150, 3-6 months) (Figure 7.5). The remains of the individual Sk. G457 associated with the adult Sk. G438 are too incomplete to ascertain if this individual also had block centra. Individual NA150 also has unilateral partial occipitalisation of the right atlas neural arch with associated changes to the lamina of the right axis neural arch (Figure 7.6). Vertebral developmental pathology in two of the Wharram Percy infants (Sk. EE54 and NA170A) has not been previously identified.

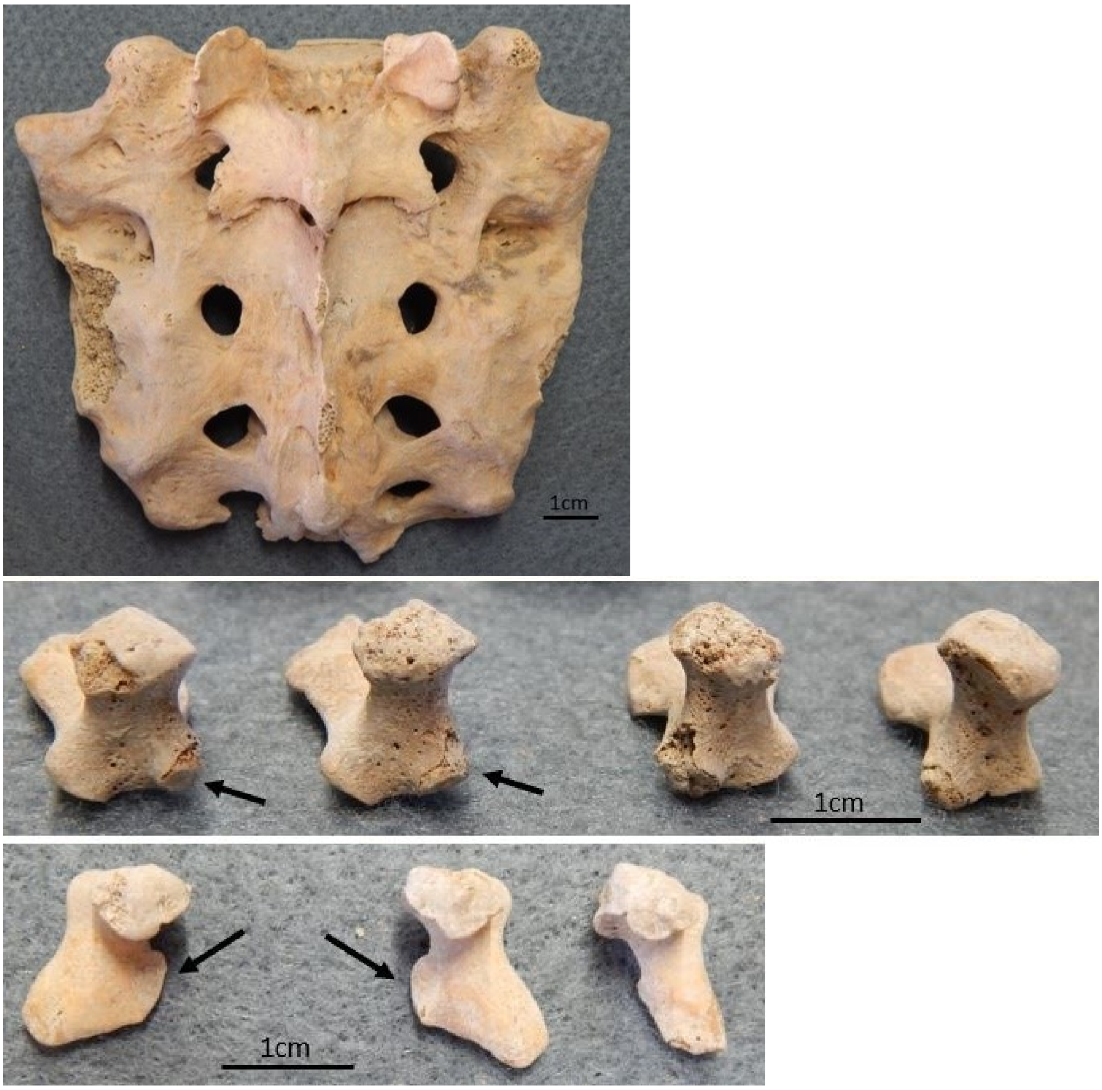


Figure 7.4. Lumbarisation of S1 in Wharram Percy Sk. NA170 (female, 20-25 years) (top) and the same features reflected in the infant NA170A (1-2 months), arrows indicate thoracic pedicles in L1 and L2 (middle), and prominent articular facets in S1 (bottom).

Figure 7.5. Block centra in two individuals from the Wharram Percy burial population. Sk. G438 (20-25 years) (top) and Sk. NA150 (3-6 months) (bottom). Note that there is no reduction in the size of the vertebral bodies of the adult.

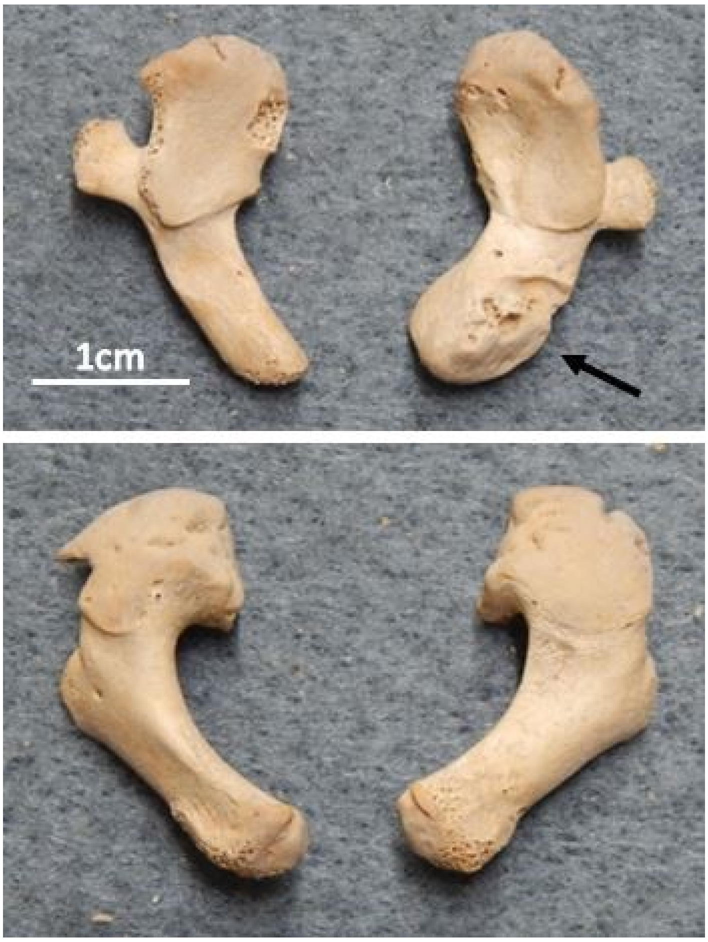


Figure 7.6. Occipitalisation of right atlas neural arch (arrow) (Wharram Percy Sk. NA150, 3-6 months). Note the thickened lamina of the right axis neural arch and partial fusion with the pars lateralis at the neural arch.

7.4.1.3 Supracondylar Process of the Humerus

In the present study, the supracondylar process is regarded as a skeletal non-metric trait and was recorded as either present or absent and unilateral or bilateral. This morphological variant has been associated with the ligament of Struthers although its presence is not always associated with soft and connective tissues (Natsis 2008). Several studies have presented a variable prevalence of the supracondylar process in modern populations, ranging from 1% (Hrdlička, 1923) to 2.7% (Gruber, 1859), however these calculations only considered the feature if the process was larger than 3mm in length (Hrdlička 1923; Terry 1921). When all forms of a supracondylar change (roughness, ridge, or tubercle) are grouped together with the longer process, a much larger percentage of individuals are affected. Hrdlička (1923) considered all forms of a supracondylar change to be homologous, and observed some form of change in 66.3% of his sample (1332 of 2010 individuals).

Anatomical and clinical research of the supracondylar process has predominantly focussed on adults, yet the presence of a supracondylar process in very young individuals is not an unusual observation (Adams, 1934; Finnegan, 1978; Saunders, 1989). As the range of expression is limited in very young individuals, the supracondylar process was considered present if a marked change was evident in the supracondylar region of the distal humerus (Figure 7.7). Of the 309 individuals with humeri in which the diaphysis and distal end are present (Table 7.4), only seven (2.3%) have supracondylar process (Table 7.5).

Figure 7.7. Varied expression of the supracondylar process of the humerus. Barton Court Farm Sk. 915, 40 weeks (top left), Wharram Percy Sk. NA40, 1-2 months (top right), Yewden Villa Sk. 26i, 38-40 weeks (bottom left) and Scheuer Sk. 82, 38-40 weeks (bottom right).

Table 7.4. Number of individuals in the study sample with suitable humeri for assessing presence of the supracondylar process. (six of this total are from Roman contexts)*

Collection	**Single**	**Both**	**Total**
Ardreigh	34	41	75
Barton	15	20	35
Çatalhöyük	17	43	60
Gussage	7	16	23
Scheuer	-	17	17*
Wharram Percy	25	51	76
Yewden	15	8	23
Totals	**113**	**196**	**309**

Table 7.5. Individuals with a supracondylar process of the humerus. (Sk. 82 is from a Roman context).*

<table>
<tr><th>Collection</th><th>Individual</th><th>Age</th><th>Description</th></tr>
<tr><td>Barton Court Farm</td><td>915</td><td>40w</td><td>Left humerus, medial</td></tr>
<tr><td>Scheuer</td><td>82*</td><td>38-40w</td><td>Left humerus, medial</td></tr>
<tr><td rowspan="2">Wharram Percy</td><td>NA40</td><td>1-2m</td><td>Left humerus, medial</td></tr>
<tr><td>NA191</td><td>1-3m</td><td>Left humerus, medial</td></tr>
<tr><td rowspan="3">Yewden Villa</td><td>22</td><td>38-40w</td><td>Right humerus, medial</td></tr>
<tr><td>26i</td><td>38-40w</td><td>Left humerus, medial</td></tr>
<tr><td>30</td><td>40w</td><td>Left humerus, medial</td></tr>
</table>

Two of the collections that represent a burial population have a similar prevalence of the supracondylar process in very young individuals when compared to that of the whole sample; Barton Court Farm (1/35, 2.8%) and Wharram Percy (2/76, 2.6%). The Yewden Villa burial population has a higher prevalence (3/23, 13%). The presence of a supracondylar process in one of the individuals from the Yewden villa burial population (Sk. 26i) has not been previously recorded (Mays *et al*. 2011). The populations with expression of the supracondylar process are Roman and medieval; the individual from the Scheuer collection is from the Roman burial context of St Albans, United Kingdom.

All of the cases of supracondylar processes observed were unilateral, although two individuals only have a single humerus present (Sk. 915 and Sk. NA191). The supracondylar process was observed on the medial margin of the diaphysis in all seven individuals. Mays *et al.* (2011) consider that the appearance of the process in two individuals within the Yewden villa burial population (Sk. 22 and Sk. 30) is an indication of their genetic relatedness, in which case an additional individual with the same trait (Sk. 26i) suggests that at least three of the very young individuals in this burial population may have been genetically related. Following this line of argument, the two infants with the trait in the Wharram Percy burial population may also be possibly genetically related.

7.4.2 Environmental

In two of the very young individuals with associated mothers it is possible to estimate the timing of intrauterine impact based upon the type of skeletal pathology that developed. The postsphenoid of one individual (Wharram Percy Sk. NA170A, 1-2 months) displays significant asymmetry with reduction of the anterior-posterior distance on the left side (Figure 7.8). This region of the cranial base ossifies between 13 and 16 weeks gestation (Noback, 1944). The mother (Sk. NA170, 20-25 years) of this infant had significant bilateral lesions of the maxillary sinus, suggesting a chronic infection (Figure 7.9). The combination of probable compromised maternal health and a developmental anomaly in the infant may indicate that during early gestation, prior to the fourth month, the mother experienced a significant period of ill-health that impacted the development of the sphenoidal region of the chondrocranium in the developing fetus.

Figure 7.8. Asymmetry in the postsphenoid resulting in overall element asymmetry (Wharram Percy Sk. NA170A, 1-2 months).

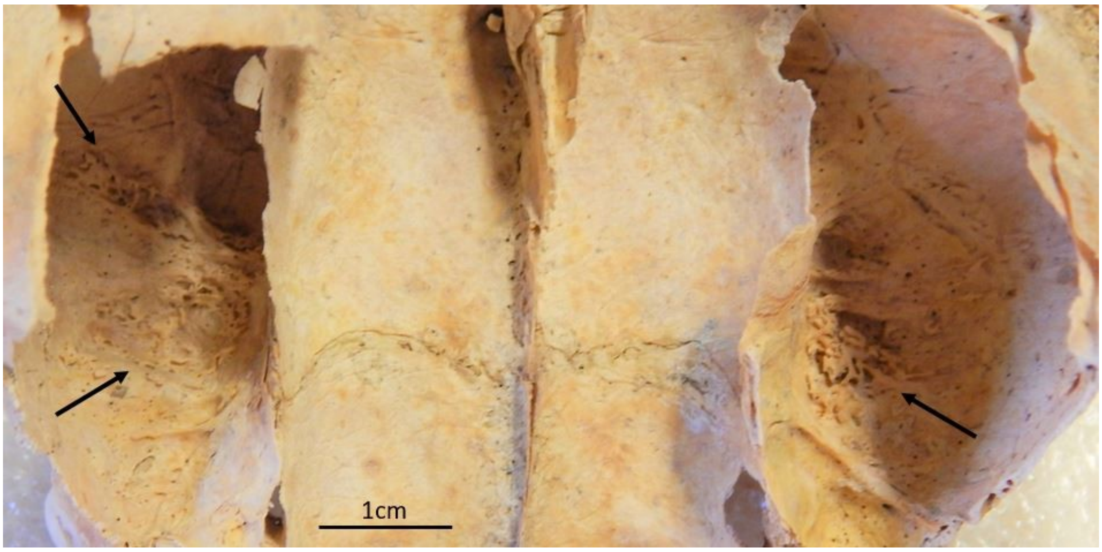


Figure 7.9. Bilateral maxillary sinusitis (arrows) in adult female (Wharram Percy Sk. NA170, 20-25 years).

The second is a neonatal individual from the Ardreigh burial population (Sk. 5633, 0-1 month). This individual's skeletal development was approximately 34-36 weeks, however the dental age at death estimated using crown development was between birth and one postnatal month. No other evidence of skeletal pathology was observed in the remains of this individual. An absence of skeletal pathology associated with the formation and ossification of elements indicates that the delay in skeletal growth must have taken place during the second half of the pregnancy after these elements (humerus, radius, ulna, femur, tibia, fibula, ilium, ischium and scapula) have attained their perinatal morphology (Scheuer and Black 2000). Although it cannot be determined if the causative factors for this intrauterine growth restriction were maternal or fetal in origin, the skeletal remains of the mother (Sk. 1505, 25-29 years) display evidence that her physiological condition was compromised on multiple occasions. The observed maternal skeletal pathology includes bilateral porous lesions of the orbit that indicate nutritional deficiency, anaemia or infection, antemortem mandibular tooth loss with alveolar resorption and carious lesions that suggest poor oral hygiene, and dental enamel hypoplasia. The enamel hypoplasia is an indication that the mother's dental development was disrupted during her childhood as a result of a period of physiological stress.

7.4.2.1 Neural Tube Defects

Some of the most recognisable skeletal defects that arise during embryonic development are neural tube defects. They have a diverse skeletal expression and impact on neonatal survival. In extreme cases with cranial involvement, the skeletal elements are highly modified in form and are not easily identifiable, demonstrating the adaptive capacity of skeletal elements to soft tissue pathology. The pathology collection at the Royal College of Surgeons in London includes the skeletal remains of fetal and perinatal individuals with neural tube defects and other pathological conditions that affect the axial skeleton, as well as those that display normal skeletal development. Detailed examination of the form of skeletal involvement in these individuals revealed that the degree of deformity was directly related to the severity of the condition. Individuals with non-viable pathology displayed the most extreme forms of skeletal dysmorphy while individuals with viable conditions usually displayed minor skeletal pathology. There were no individuals or disarticulated remains identified within the archaeological collections with skeletal pathology of the cranium that could be clearly attributed to neural tube defects. The identification of pathological cranial morphology in conditions such as hydrocephaly may have been possible had reconstruction of fragmentary cranial elements been undertaken.

Depending upon the type of soft tissue pathology, the impact on the surrounding skeletal elements may not be apparent once the remains have been excavated. This is particularly the case for neural tube defects of minor severity such as spina bifida occulta. This condition does not necessarily affect the morphology or surface appearance of the vertebral elements involved, however it is possible to detect the condition in undisturbed articulated remains prior to excavation.

The presence of dysmorphic neural arches in skeletal remains can be an indication of soft tissue pathology such as a neural tube defect. Examination of developmental skeletal remains held within the Royal College of Surgeons collection demonstrated that dysmorphy of the vertebral elements was usually present in individuals with neural tube defects. Although there were a few individuals in which the neural tube defect had not impacted the form of the vertebral elements, the majority of individuals with neural tube defects displayed a range of vertebral and costal pathology from abnormal curvature to severe forms of fusion and dysmorphy as demonstrated in Figure 7.10. A summary of the skeletal pathology observed in this collection is provided below in Table 7.6.

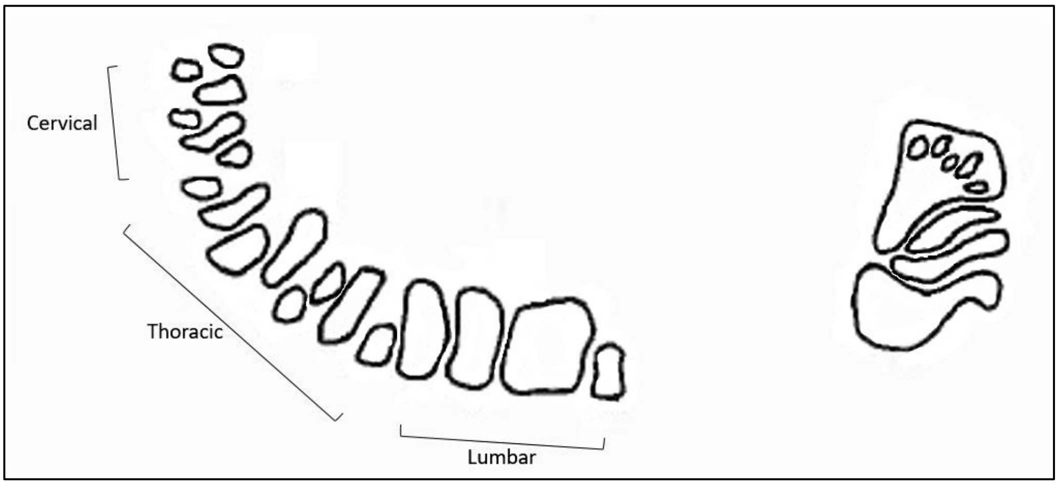


Figure 7.10. Drawing of the vertebral centra from the cervical to the lumbar regions (anterior view) (left) and of the fused mass of thoracic neural arches (posterior view) (right) (R.C.S. Sk. 8432, approx. 20 weeks). This individual is a confirmed case of craniorachischisis totalis. (Illustration by Belinda Tibbetts).

One perinatal individual from the Çatalhöyük burial population (Sk. 10366.1, 34-38 weeks) has comparatively thin neural arches in the lower thoracic and lumbar regions in addition to the posterior sagittal cleft in a mid-thoracic centrum, mentioned above in Chapter 6 (see Figure 6.31). These skeletal anomalies suggest a deviation from normal vertebral development, and although slight, are probable reflections of soft tissue pathology. The Royal College of Surgeons collection contains examples of spina bifida that exhibit similar vertebral changes. The cleft centrum in this perinatal individual is a clear indication of persistent notochordal tissue that has interfered with ossification of the element. In conjunction with the altered appearance of the neural arches in the region of the cleft centrum, a tentative aetiology of spina bifida for Çatalhöyük Sk. 10366.1 is plausible.

Table 7.6. Skeletal pathology observed within the Royal College of Surgeons (London) collection.

Primary Pathology	**Description**	**Fetal**	**Perinatal**	**Neonatal**	**Individuals Affected**
Neural Tube Defects	Anencephaly	51	2	4	57
	Chiari II malformations	13	1	2	16
	Craniorachischisis totalis	11	0	0	11
	Iniencephaly	1	0	1	2
	Rachischisis	4	0	0	4
	Spina bifida	7	1	0	8
	Indeterminate	1	1	1	3
Cranial Abnormality	Cleft palate	0	0	1	1
	Craniolacunia	8	0	0	8
	Craniosynostosis	14	0	1	15
	Encephalocele	3	0	0	3
	Hydrocephaly	11	1	3	15
Other	Dwarfism	1	0	1	2
	Klippel-Feil syndrome	0	0	1	1
	Renal agenesis	1	0	0	1
	Subdural haemorrhage	2	0	1	3
	Scoliosis	1	0	0	1
Indeterminate		20	1	3	24
Total		149	7	19	175

7.4.2.2 Trisomy 21

Three individuals have a particular morphological alteration of the hypophyseal fossa of the sphenoid that is genetically linked. The alteration takes the form of an irregular convex expansion of the anterior wall of the fossa that reduces the volume of the fossa. When compared to a normal sphenoid, the dysmorphy is clearly obstructive to the space occupied by the pituitary gland. Type II dysmorphy of the sella turcica is indicative of Trisomy 21, otherwise known as Down syndrome (Kjær *et al*., 1998; Kjær, 2012; Russel and Kjær, 1999). Two of the individuals with Type II dysmorphy of the sella turcica are perinatal (Barton Court Farm Sk. UB4, 38-40 weeks and Wharram Percy Sk. EE59, 36-40 weeks) and the third individual is a neonate from the Wetwang Slack burial population (Sk. 1160, 0-1 month). The varying degrees of the dysmorphy in these three individuals are shown in Figure 7.11.

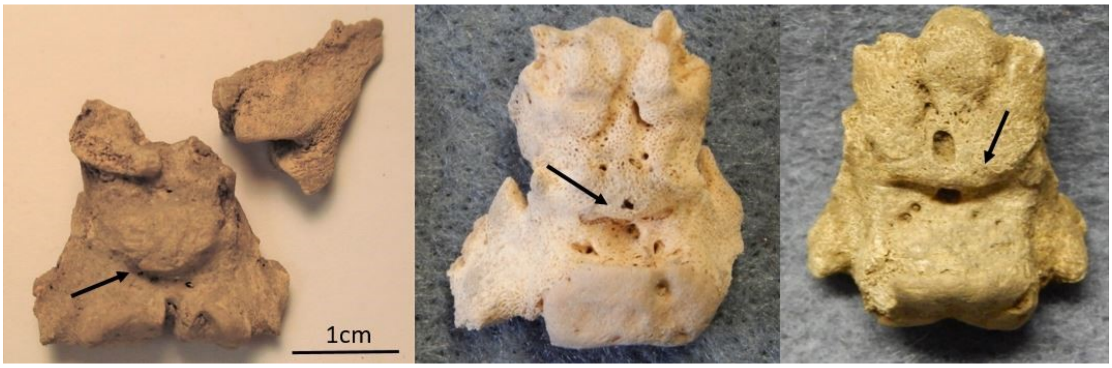


Figure 7.11. Type II dysmorphy (arrows) of the sella turcica indicative of Trisomy 21, Down syndrome (left to right: Wetwang Slack Sk. 1160, 0-1 month; Wharram Percy Sk. EE59, 36-40 weeks; Barton Court Farm Sk. UB4, 38-40 weeks).

The earliest known case of Down syndrome was reported by Rivollat *et al*. (2014) and was recovered from archaeological contexts dated to the 5-6th century AD. The individual is a child aged between five and seven years with various skeletal pathologies that support a diagnosis of Down syndrome, however their diagnosis was limited by the post-excavation loss of both the sella turcica and postcranial skeleton. The earliest of the individuals in the present study with Type II dysmorphy of the sella turcica is the Wetwang Slack neonate that is dated to between the 4th and the 2nd centuries BC (Jay *et al*., 2012) while the youngest is aged between 36-40 weeks and its burial context is medieval (Bayliss *et al*. 2007). The majority of skeletal diagnostic characteristics of Down syndrome are not available for assessment in very young individuals. These include craniometrics, delays in ossification and fusion, hypoplasia of the facial bones and variability in structure, size and eruption of dentition; all of which may be observed in children (Rivollat *et al*., 2014). The partial and fragmentary remains of the three individuals above prevented the identification of any additional developmental defects associated with Down syndrome. To the author's knowledge, these two individuals may represent the earliest date and youngest age of potential Down syndrome from an archaeological context.

Analysis of aDNA for the three individuals described above may potentially provide confirmation of Down syndrome. The post-sphenoid is often recovered with the remains of very young individuals, and Type II dysmorphy of the sella turcica may prove a useful feature for identifying the presence of Down syndrome in burial populations from archaeological contexts. Steele and Stratford (1995) estimate the prevalence of Down syndrome in archaeological populations to be

40-80 individuals per million. This is considerably less than the 1000 individuals affected per million in modern populations (World Health Organization, 2016).

7.5 Metabolic Impacts

Systemic conditions such as rickets and scurvy may develop from underlying metabolic or nutritional deficiencies. Maternal metabolism during pregnancy directly affects the fetal supply line and therefore fetal development and growth. It also has the potential to initiate permanent changes in fetal metabolism (Barker, 2001; Gowland, 2015; Roseboom, 2001). Skeletal evidence of conditions associated with metabolic and nutritional deficiencies in very young individuals is an indication that the maternal condition was significantly compromised prior to and during pregnancy.

7.5.1 Anomalies of the Limbs

Several individuals within the collections analysed exhibit unusual proportions of the major long bones that are likely to be associated with growth disturbance or are perhaps genetic in origin. The affected limbs have an altered appearance in that the diaphyses are either discernibly gracile or short and thickened when compared with other similarly aged individuals within their burial population. These anomalies were not restricted to a single burial population, however it is interesting to note that they were only observed in Roman and medieval populations (Tables 7.7 and 7.8). Thickened diaphyses of the major long bones may indicate a growth disruption that limits longitudinal growth, while allowing increase in the diameter of the diaphysis. The upper limbs appear to be more affected, with the lower limbs affected in only two individuals; both cases involving only the tibia. Two individuals have additional alterations to the plane of the affected element. A perinatal individual (Barton Court Farm Sk. 2, 38-40 weeks) displays exaggerated anterior curvature of the humeri. Another infant from the Wharram Percy burial population (Sk. NA191, 1-3 months) has noticeable thickening and curvature of the left ulna and radius. However, the skeletal pathology of this infant also includes thickened long bone diaphyses and porosity of the metaphyseal zones, ectocranial porotic lesions and thickening of sternal costal ends, which together suggest a systemic aetiology. Ortner and Mays (1998) have previously identified this individual as suffering from rickets.

The skeletal pathology listed above for Individual Sk. NA191 is diagnostic for this condition rickets if several changes occur together. Although unusual in very young individuals aged under four postnatal months, rickets has been documented in neonates whose mothers were vitamin D deficient during pregnancy (Innes *et al*., 2002; Ortner, 2003).

Table 7.7. Individuals with pathological changes to the long bone diaphyses.

Collection	**Individual**	**Age**	**Description**
Ardreigh	377	0-1m	Short and thickened ulnae, radii and tibia
Barton Court Farm	2	38-40w	Short and thickened humeri, anterior curvature
Scheuer	83*	40w	Short and thickened ulnae and radii
Wharram Percy	G470	1-3m	Thickened humeri and ulnae
	NA191	1-3m	Thickened left radius, torsion of left ulna
	V43	0-1m	Short and thickened left humerus
Yewden Villa	20	40w	Thickened left ulna
	26i	38-40w	Thickened tibiae
	45IIii	40w	Thickened right tibia

(Sk. 83 is from a Roman context)*

Three burial populations included individuals with unusually gracile limbs (Table 7.8). This morphology of the larger long bones affected both upper and lower limbs and may reflect altered growth or genetic expression. All but one of these individuals have overall long bone lengths within the normal range for their age group (Schaefer *et al*., 2009). The exception is Barton Court Farm Sk. 103 (38-40 weeks), whose humeri, left ulna, left radius and right femur are the length of those expected in an infant aged between one and two postnatal months. The remaining skeletal elements of this individual are perinatal in age with respect to size and development.

Elongation of long bones has been documented in individuals with reduced or absent testosterone, for example in castrated individuals (Silberberg and Silberberg, 1971). The growth restriction effect of testosterone can also be seen in the smaller and shorter babies of mothers who were given supplementary testosterone during pregnancy (Carlsen *et al*., 2006). The majority of the affected individuals in the collections analysed have normal length diaphyses that are considerably thinner with no apparent pathology of the cortical surfaces. This thinness gives the impression that the limbs are abnormally elongated with respect to the rest of the skeleton. In the case of Barton Court Farm Sk. 103, the long bones have thin diaphyses but are also longer than expected for the respective age group. This individual may be genetically predisposed to longer than normal limb elements. Unfortunately, there have been no contemporary adult remains recovered that can be associated with the Roman remains at Barton Court Farm that might enable a comparison of population stature. Interestingly one of the individuals listed for this site (Sk. 807ii, 38-40 weeks), that was dated to the Anglo-Saxon period, also has gracile limb bones. This could suggest a tentative link between the populations living and burying their dead in this area over an extended period of time.

Table 7.8. Individuals with gracile long bones. (Sk. 807ii is from an Anglo-Saxon burial context).*

Collection	Individual	Age	Description
Ardreigh	1442	38-40w	Gracile limbs (humeri, femora, and right ulna and radius)
	1765	3-6m	Gracile limbs (radius, femur, tibia and fibula)
Barton Court Farm	103	38-40w	Gracile limbs and wide pectoral girdle (humeri, ulna, radius and femur)
	196	38-40w	Gracile limbs (humerus, ulnae, radius, femur and fibula)
	784	38-40w	Gracile limbs (humerus, ulnae, radius and femora)
	807ii*	38-40w	Gracile limbs (humerus and femora)
	885	38-40w	Gracile limbs (humeri, ulnae and radii)
	904	38-40w	Gracile limbs (femur)
Wharram Percy	NA76	38-40w	Gracile limbs (humerus, femora and tibia)

7.5.2 Disrupted Ossification

One individual displays an osseous anomaly of the major long bones that does not affect the overall dimensions of the diaphysis. The infant, from the Iron Age context at Wetwang Slack (Sk. 150, 6-9 months), has unilateral dysmorphy of the left elbow joint involving the distal humerus and proximal ulna (Figure 7.12). There is a significant reduction in the olecranon fossa of the distal humerus. This unusual appearance of the articular surfaces involved in the joint may be a reflection of localised neurological damage associated with intrauterine restriction and possibly leading to palsy of the forearm. The elbow joint dysmorphy is not reflected in the elements of the right upper limb, however there is evidence for a systemic condition affecting bone growth displayed through changes to the cortical bone of the diaphysis of the right tibia.

Figure 7.12. Dysmorphy of the distal left humerus (top) in an infant (Wetwang Slack Sk. 150, 6-9 months). Note the reduced olecranon fossa (outlined by dashed line).

The right tibia of Wetwang Slack Sk. 150 has a postmortem mid-shaft fracture that exposes multiple cortical layers. There are three clearly defined layers of cortical bone with intervening trabecular structure on the lateral side of the diaphysis (Figure 7.13). These layers appear to be coalescing into a single cortical layer at the posterior and anterior margins of the lateral surface. Development of the cortical layer and growth of the long bones normally involves an osteolytic process that prevents the build-up of multiple layers of bone deposition while maintaining overall structure (Ortner, 2003). It is evident that this process was impaired in Sk. 150 and that the deposition of new bone continued without the balance of removal. This cortical appearance may reflect a normal process in the development of the tibial diaphysis, resulting in differential thickening across the diameter of the element that is later remodelled, however no similar cases were identified during the current research.

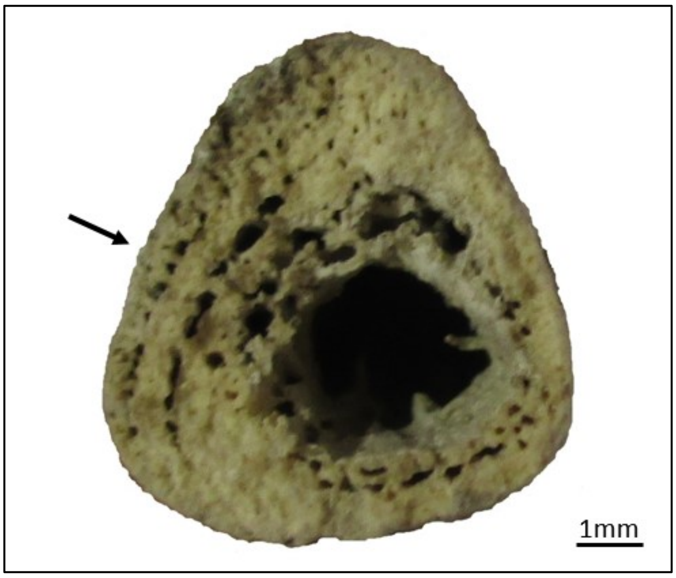


Figure 7.13. Multiple cortical layers (arrow) of the right tibia seen in a mid-shaft transverse view (Wetwang Slack Sk. 150, 6-9 months). Note the normal dimensions of the diaphysis and the presence of trabecular structure between the cortical layers.

7.5.3 Inflammation

Porous lesions are typified by areas of increased cortical porosity that are distinct from the surrounding bone surfaces. The differentiation of porous lesions from normal bone surface porosity is made on the basis of expansion of the existing vascular foramina, and a marked increase in the number of perforations in the cortical surface (Ortner *et al.* 1999). Among the individuals analysed, porous lesions were predominantly located on the ectocranial surfaces of the vault elements, the orbital plate of the frontals and the lateral surfaces of the maxillary frontal process and mandibular ramus (Figure 7.14). Porous lesions were also occasionally observed on the elements of the sphenoid. The appearance and aetiology of endocranial lesions, which can also be porous in nature, will be discussed separately below in section 7.5.4.

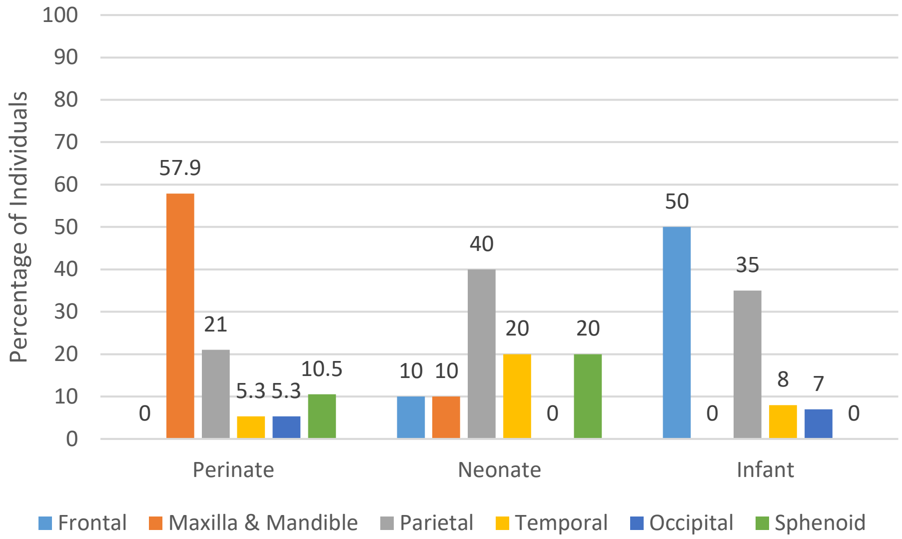


Figure 7.14. Porous lesions of the cranial elements within each age category, excluding endocranial vault lesions.

Porous lesions on the ectocranial surfaces were predominantly found on the parietal and frontal, with fewer individuals exhibiting involvement of the temporal or occipital squamae. Porous lesions on the ectocranial surface of the parietal were usually observed around the margins of the element without involvement of the bossae, which retain a normal cortical surface. However, an extreme case of a lesion with coalescing foramina and increased thickness that covers an area adjacent to the suture and extends across the squama is demonstrated in Figure 7.15. This lesion was active at the time of death. The more common marginal distribution of porotic lesions may be a reflection of diploic communication between the endocranial and ectocranial circulatory systems. Recent studies (Bruner and Sherkat, 2008; Patel, 2009; Rangel de Lázaro *et al*., 2016; Tsutsumi *et al*., 2013) have established the existence of interconnecting networks involving three of the four cranial vascular systems in modern adults; the diploic channels, the middle meningeal vessels and the pericranial vessels (Adeeb *et al*., 2012; Bruner *et al*., 2005; Bruner and Sherkat 2008; Falk, 1986; Hershkovitz *et al*., 1999; Jivraj *et al*., 2009). These vascular systems are anatomically connected and form a single cranial vascular system (Bruner 2015; Rangel de Lázaro *et al*. 2016). The connection between ectocranial and endocranial vascular structures is not usually a consideration in the study of cranial lesions in archaeological specimens, where they are often dealt with as separate pathologies. The current study also considers the expression of ectocranial and endocranial lesions independently in order to assess their relationship with the developing cranial vault and to provide a developmental context for these lesions.

Figure 7.15. Extreme case of porotic lesion on the ectocranial surface of the parietal involving the bossa (Wharram Percy, Sk.NA92, 3-6 months).

An interesting finding in the physiology of the diploic channels is that they appear to be more active with regard to blood flow in sub-adults. The middle meningeal vessels are frequently involved in cranial trauma resulting in epidural haemorrhage, and are usually ligated during neurosurgical procedures to alleviate epidural haematoma. Bruner and Sherkat (2008) note that ligation of the middle meningeal artery in adults undergoing surgical decompression of epidural haemorrhage has no apparent adverse effect. They conclude that the physiological function of the middle meningeal vessels may be more important during early sub-adult development, with possible implications for thermoregulation in younger individuals.

With regard to palaeopathology, ectocranial lesions of the vault and orbit are usually discussed in relation to deficiencies, anaemia, infection and disease, but without reference to any connection with the endocranial surface (Aufderheide and Rodriguez-Martin, 1998; Lewis 2004; Ortner 2003). Earlier authors have suggested a connection between various forms of cranial lesion.

Møller-Christensen (1961) and Mensforth *et al.* (1978) considered the aetiology of endocranial lesions to be inflammatory and associated the lesions with porous lesions of the orbit. While Koganei (1912) and Henschen (1961) agreed that porous lesions of the endocranial surface shared a common aetiology of nutritional deficiency with orbital lesions and ectocranial porous lesions. The relationship between ectocranial and endocranial lesions that was alluded to in earlier research has been confirmed through recent research into the form and function of diploic channels through biomedical imaging (Bruner and Sherkat, 2008; Patel, 2009; Tsutsumi *et al*., 2013).

It is widely accepted that the diploic layer of the cranial vault has the capacity to expand in response to pathological conditions such as anaemia, vitamin deficiencies and infection (Aufderheide and Rodriguez-Martin, 1998; Mensforth *et al*., 1978; Ortner 2003; Williams *et al.* 1975). Ortner (2003) describes the diploic expansion and destruction of the ectocranial cortical layer that leads to a porous appearance of the bone surface. In contrast, Walker *et al.* (2009) argue that anaemia from iron deficiency would effectively inhibit the expansion of the diploic layer and therefore could not be the underlying aetiology for porous lesions with diploic expansion. Instead they suggest that a combination of dietary deficiencies are a likely aetiology for the porous lesions observed in archaeological skeletal remains. Ortner *et al*. (2001) also describe porous lesions that do not involve expansion of the diploic layer and are associated with scurvy in sub-adults. Mays (2013) put forward an alternative aetiology of the combined impact of weaning and cultural practices for these porous lesions. As a result of the similarity in surface appearance, which is likely to be a reflection of the stage of the systemic condition, there remains some confusion regarding the aetiology of porous ectocranial lesions in very young individuals.

A neonatal individual from the Çatalhöyük burial population (Sk. 10495, 0-1 month) has severe porous lesions of the ectocranial surface with visible connections through diploic channels to areas of increased porosity on the endocranial surface. The porous areas of the inner and outer vault surfaces are positioned adjacently rather than directly opposite each other. This distribution of porous areas is an indication of the inter-connecting diploic channels. Figure 7.16 shows the porous lesions on the ectocranial surface of the parietals with interconnecting diploic channels visible along the fractured edges. The lesions in this individual have coalescing foramina, extending from the element margins into the squama, and were active at the time of death.

Figure 7.16. Ectocranial and endocranial porous lesions with interconnecting diploic channels (Çatalhöyük Sk. 10495, 0-1 month).

Another individual from the Çatalhöyük burial population (Sk. 22759, 38-40 weeks) has bilateral ectocranial lesions of the parietals along the posterior half of the sagittal suture, extending over the eminence to the posterior margins (Figure 7.17). Capillary lesions with porous cortical surfaces such as these are highly vascular and are associated with healing rather than an active lesions (Lewis 2004). Schultz (2001) also attributed this appearance in endocranial lesions to healing, with a combined haemorrhagic and inflammatory aetiology. The superior occipital squama in this individual also has a small area that is affected by similar porosity and capillary lesions (Figure 7.18), however the frontals do not have any evidence of ectocranial lesions. The cranial lesions evident in this individual were indicative of healing at the time of death and were most likely associated with inflammation. Given the age at death of 38-40 weeks, the lesions are very probably a reflection of severely compromised health during gestation.

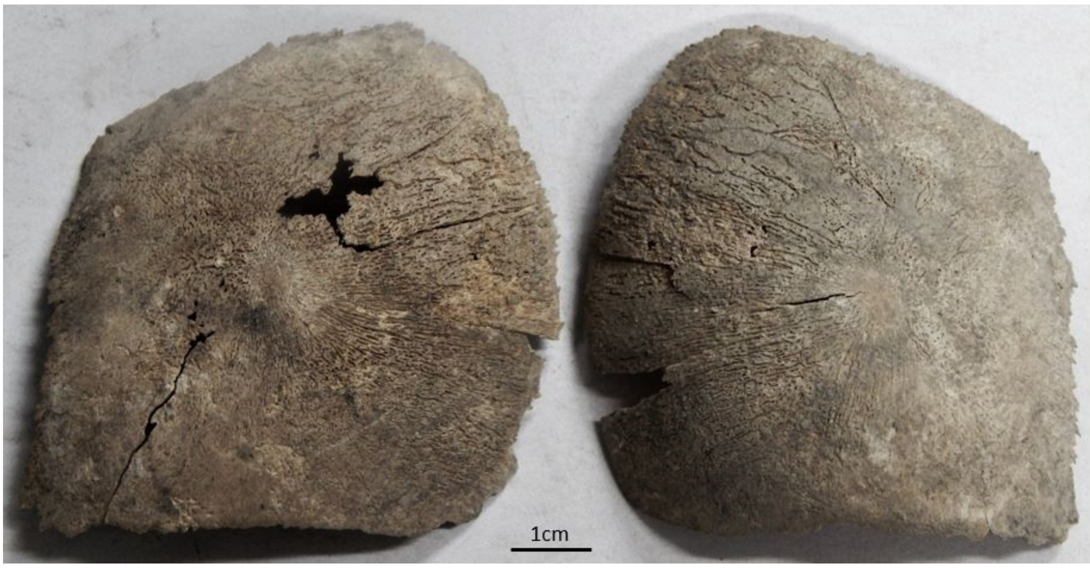


Figure 7.17. Bilateral ectocranial capillary lesions of the parietal with porous cortical surface (Çatalhöyük Sk. 22759, 38-40 weeks).

Figure 7.18. Ectocranial capillary lesions of the occipital squama (Çatalhöyük Sk. 22759, 38-40 weeks).

There is evidence of recovery from a chronic condition in an infant from the Wharram Percy burial population (Sk. EE52, 9-12 months) who displays abnormal porosity of the frontal squama that was inactive at the time of death. Although there is porosity present, the cortical surface is largely remodelled (Figure 7.19). The orbital plates of the frontals also have areas of abnormal porosity with varying degrees of activity. Two distinct porous lesions are present with vascular impressions, indicating healing, and a less distinct area of porosity with coalescing foramina is visible on the orbital roof that was active at the time of death (Figure 7.20). There is no evidence of other porous lesions on the remaining vault elements in this individual.

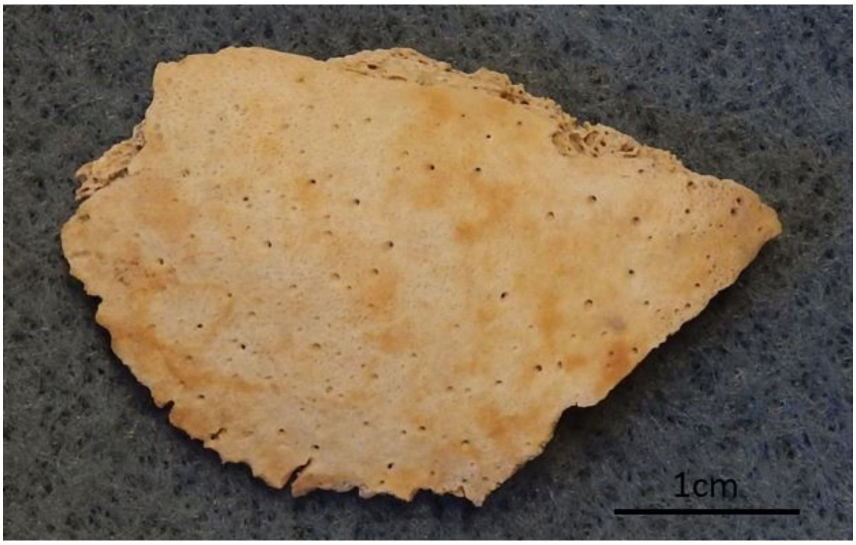


Figure 7.19. Ectocranial porous lesion of the frontal with evidence of healing (Wharram Percy Sk. EE52, 6-9 months).

Figure 7.20. Ectocranial porous lesions on the orbital plate of the frontal with a mixture of healed and active lesions (Wharram Percy Sk. EE52, 6-9 months).

Infantile rickets, otherwise referred to as Möller-Barlow disease, has been identified in two infants from Wharram Percy (Sk. NA92 and Sk. NA194, both 3-6 months) (Mays 2007). Both infants have extensive ectocranial lesions on the frontals, parietals and temporal squamae, with a similar degree of severity (Figure 7.21). The lesions are porous with coalescence of foramina and some cortical thickening, and were active at the time of death.

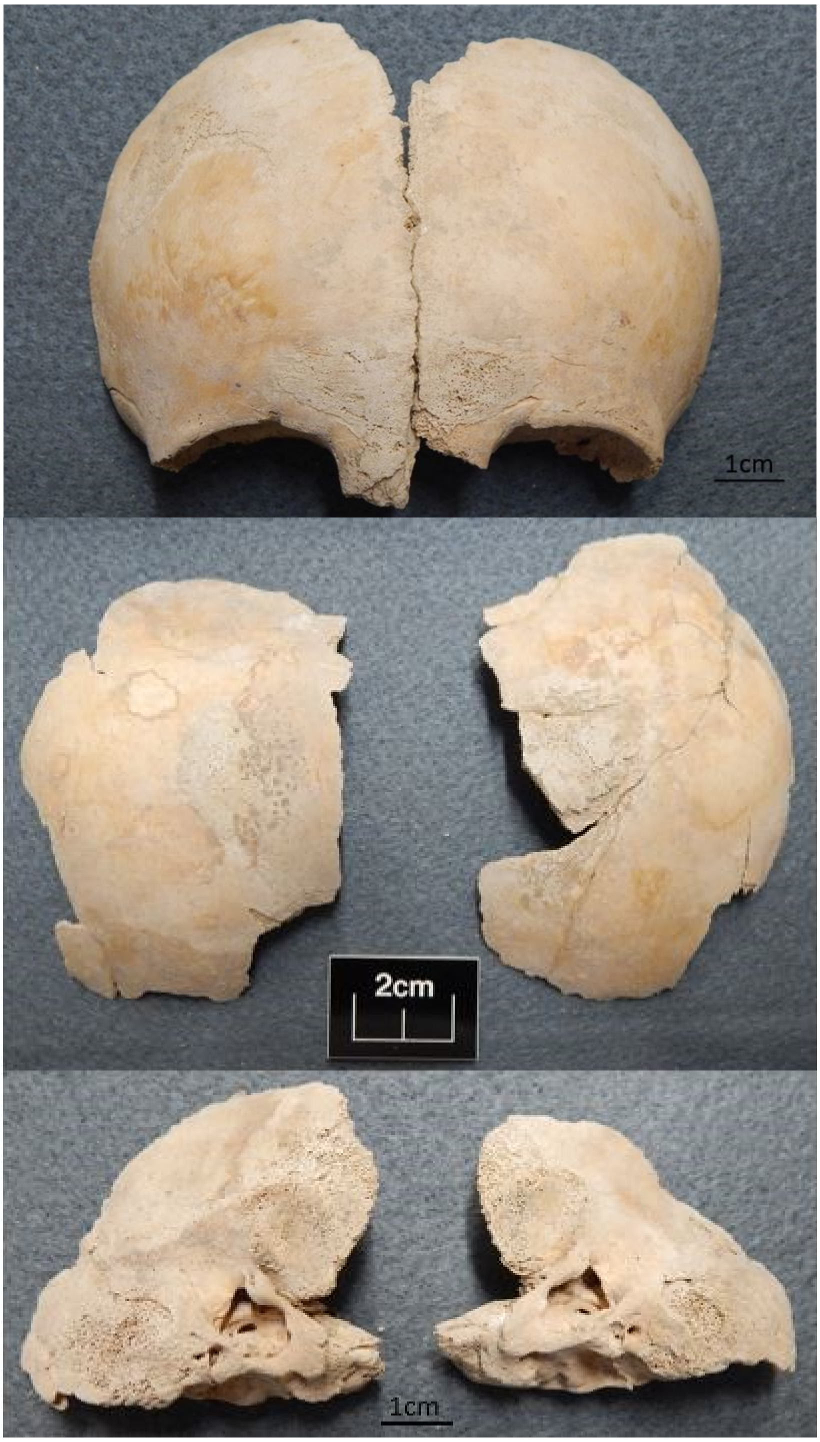


Figure 7.21. Ectocranial porous lesions on the frontals, parietals and temporal squamae (Wharram Percy Sk. NA194, 3-6 months).

Two other individuals in the Wharram Percy collection (Sk. V10 and Sk. NA43, both 3-6 months) display evidence of considerable diploic expansion in conjunction with porous lesions of the vault elements. Both infants have severe porous lesions on the ectocranial surfaces of the parietals that were active at the time of death. These exhibit expansion of the diploic layer, obliteration of the outer table, and coalescence of foramina (Figure 7.22). The porous lesions are typical of those referred to as porotic hyperostosis and are associated with several conditions including anaemia, scurvy, rickets and infectious diseases (Ortner, 2003). In addition to the skeletal pathology identified by Mays (2007) it was observed that Sk. V10 also has increased porosity of the supraspinal fossa of the scapula (shown in Figure 6.45 in the previous chapter), which is also associated with infantile scurvy (Brickley and Ives 2006). Mays (2007) attributed the porous cranial lesions in Sk. V10 to anaemia. Although no similar aetiology was suggested for Sk. NA43 (Mays, 2007), it is very likely that this individual was also anaemic.

Porotic lesions of the orbit are considered to be a response to several conditions, including scurvy developing from a vitamin C deficiency (Brickley and Ives 2006; Ortner, 2003; Ortner *et al.*, 2001; Ortner and Ericksen, 1997; Schultz, 2001). They are described as distinct regions of increased vascular porosity in the roof of the orbit (Brickley and Ives 2006). The cortical surface of the orbit in fetal and perinatal individuals often has a layered appearance perforated by foramina, however this is not considered to be pathological. Despite this, some very young individuals display a marked porosity in this layered region of the orbital surface that may indicate pathological interference with the development of the cortical layer, especially where there is increased vascular porosity in conjunction with porous lesions of the orbital roof.

Juveniles are susceptible to dietary inadequacies during early infancy and childhood through the process of weaning and the possibility of limited food resources. Nutritional deficiency may also be exacerbated through infection leading to iron-deficiency anaemia. Although porous lesions of the orbit are predominantly associated with vitamin C deficiency, when they occur in conjunction with expansion of the diploic layer they are more likely to be associated with anaemia (Armelagos *et al.*, 2014).

Within the burial populations analysed, 12 infants (12/660, 1.8%) had active or resolving porous lesions of the orbital roof, referred to as cribra orbitalia, at the time of death (Table 7.9). The infants identified with porous lesions of the orbit were all aged older than three months.

Figure 7.22. Ectocranial porous lesions on the parietal with diploic expansion in two infants (Wharram Percy Sk. V10 and NA43, both 6-9 months).

Table 7.9. Individuals with porosity of the orbit.

Collection	Individual	Age	Description
Ardreigh	924	6-9m	Porosity only, healed
Wharram Percy	NA43	3-6m	Porosity with coalescence of foramina, active
Wharram Percy	EE52	6-9m	Porosity with coalescence of foramina, mixed healed and active
Wharram Percy	G686	3-6m	Porosity only, healed
Wharram Percy	NA92	3-6m	Coalescing foramina with increased thickness, active
Wharram Percy	NA194	3-6m	Coalescing foramina with increased thickness, active
Wharram Percy	NA203A	3-6m	Coalescing foramina with increased thickness, active
Wharram Percy	V17	3-6m	Porosity only, healed
Wharram Percy	WCO42	3-6m	Porosity only, healed
Wetwang Slack	162	9-12m	Porosity only, active
Wetwang Slack	778	9-12m	Porosity only, healed
Yewden Villa	21	9-12m	Porosity with coalescence of foramina, active

Figure 7.22 shows the porous lesions in three of these infants; Wharram Percy Sk. NA194 and Sk. NA203A, both 3-6 months, and Ardreigh Sk. 924, 6-9 months. The younger infants have active lesions with increased porosity, coalescence of foramina and perforation of the orbital plate, while the older infant shows a largely resolved porous lesion of the orbital roof. Figure 7.24 shows healed lesions in an older infant (Wetwang Slack Sk. 778, 9-12 months). Patches of superficial woven bone and porosity of the orbital roof are clearly visible. Smith-Guzmán (2015) demonstrates the association between the presence of cribra

orbitalia and malaria in the ancient Nile Valley. Although the debate on the aetiology of cribra orbitalia and porotic hyperostosis remains unresolved, there is considerable evidence for multiple contributing factors to the development of these skeletal indicators (McIlvaine, 2015).

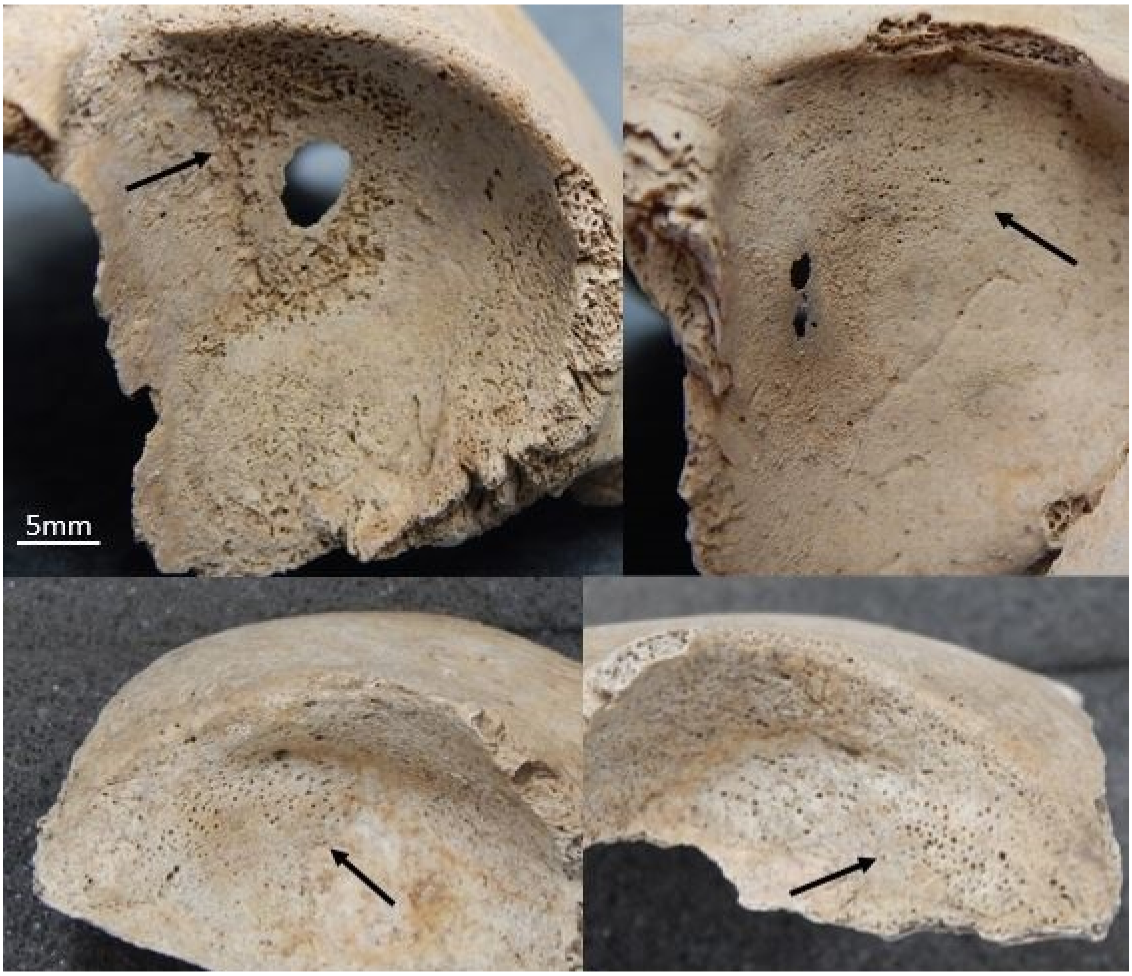


Figure 7.23. Porous lesions of the orbit (arrows). Active lesions are evident in two Wharram Percy infants; Sk. NA194 (top left) and Sk. NA203A (top right), both 3-6 months. The lesions observed in an older infant (Ardreigh Sk. 924, 6-9 months) have a smoother appearance that suggests remodelling (bottom images).

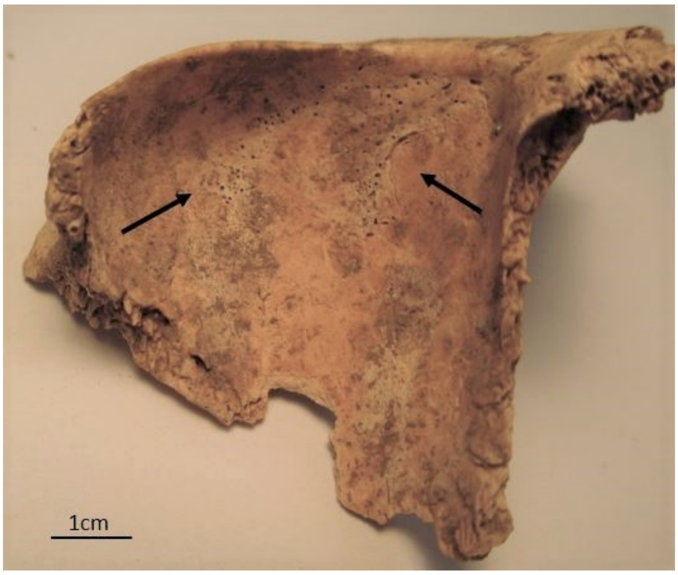


Figure 7.24. Resolving porous lesions (arrows) on the orbital plate of an infant (Wetwang Slack Sk. 778, 9-12 months).

It is suggested that increased areas of porosity and new bone formation on the greater wing of the sphenoid, particularly surrounding the foramen rotundum as shown in Figure 7.25, are another indicator for scurvy (Geber and Murphy, 2012; Ortner *et al*., 1999; Ortner and Ericksen, 1997). Armelagos *et al*. (2014) state that porous lesions found on the sphenoid, maxilla and mandible are indicative of scurvy, and Ortner (2003) associates porosity of the lateral surface of the greater wing of the sphenoid, external surfaces of the temporal and lateral margin of the frontal with scurvy. Brickley and Ives (2006) also discuss the involvement of the sphenoid in infantile scurvy. They suggest that spicules of periosteal new bone formation over the lesser wings support an aetiology of scurvy when they occur with other skeletal lesions. A neonatal individual from the Wharram Percy burial population (Sk. NA193, 0-1 month) exhibits porous lesions of the sphenoid that are clearly overlying the cortical surface (Figure 7.26). There is no evident alteration or expansion of the diploic layer or cortical bone giving the lesions a superficial appearance.

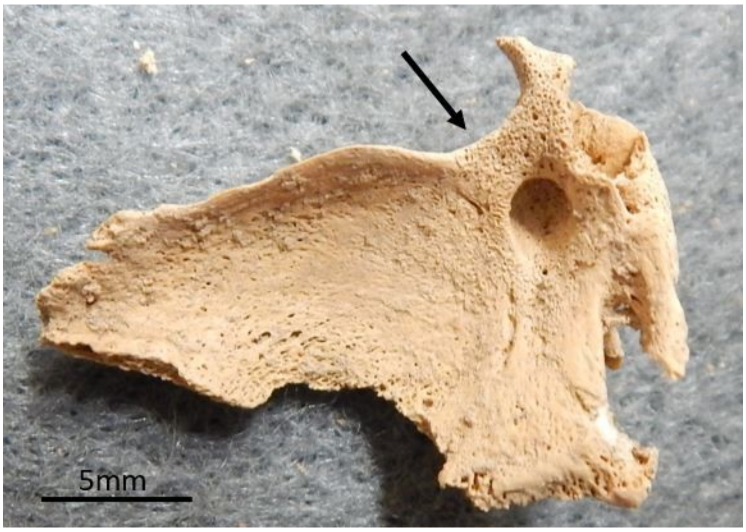


Figure 7.25. Abnormal porosity (arrow) surrounding the foramen rotundum of the left greater wing of the sphenoid (Wharram Percy Sk. NA61, 36-40 weeks).

Figure 7.26. Superficial spicules of new bone (arrows) on the lesser wings and presphenoid (Wharram Percy Sk. NA193, 0-1 month).

Porous lesions of the maxilla were observed on the frontal process in twelve perinatal and four neonatal individuals (Table 7.10). Figure 7.27 shows the typical appearance of these porous lesions in two individuals (Çatalhöyük Sk. 10361 and Barton Court Farm Sk. 916, both 38-40 weeks). Increased porosity of the frontal process of the maxilla has previously been identified as a response to inflammation and bleeding in the overlying soft tissues (Brickley and Ives 2006); a symptom of vitamin C deficiency. They suggest that irritation of the facial muscles through breastfeeding, with associated soft tissue damage, may be sufficient to cause this response. It is also possible that a cultural behaviour involving rubbing of the gums could have been a contributing factor. One perinatal individual (Wetwang Slack Sk. 1163, 38-40 weeks) that had porous lesions of the maxillary frontal process also had extensive porosity of the mandibular ramus with development of a plaque of reactive bone (Figure 7.28).

Table 7.10. Individuals with porous lesions of the maxilla.

Collection	Individual	Age	Description
Barton Court Farm	869	0-1m	Porosity with coalescence of foramina, active
Barton Court Farm	916	38-40w	Porosity with coalescence of foramina, active
Çatalhöyük	2772	38-40w	Porosity with coalescence of foramina, healed
Çatalhöyük	10361	38-40w	Porosity with coalescence of foramina, active
Çatalhöyük	10366.1	34-38w	Porosity with coalescence of foramina, active
Çatalhöyük	10368	38w	Porosity with coalescence of foramina, active
Çatalhöyük	10390	38-40w	Porosity with coalescence of foramina, active
Çatalhöyük	10391	40w	Porosity with coalescence of foramina, active
Çatalhöyük	10495	0-1m	Porosity with coalescence of foramina, healed
Çatalhöyük	22759	38-40w	Porosity with coalescence of foramina, active
Wharram Percy	NA4A	38-40w	Porosity with coalescence of foramina, active
Wharram Percy	NA142	38-40w	Porosity with coalescence of foramina, healed
Wetwang Slack	159	0-1m	Porosity with coalescence of foramina, active
Wetwang Slack	1163	38-40w	Porosity with coalescence of foramina, active
Wetwang Slack	3332	0-1m	Porosity with coalescence of foramina, active
Wetwang Slack	7388	38-40w	Porosity with coalescence of foramina, healed

Figure 7.27. Abnormal porosity of the maxillary frontal process in perinatal individuals (Barton Court Farm Sk. 916 (left) and Çatalhöyük Sk. 10361 (right), both 38-40 weeks).

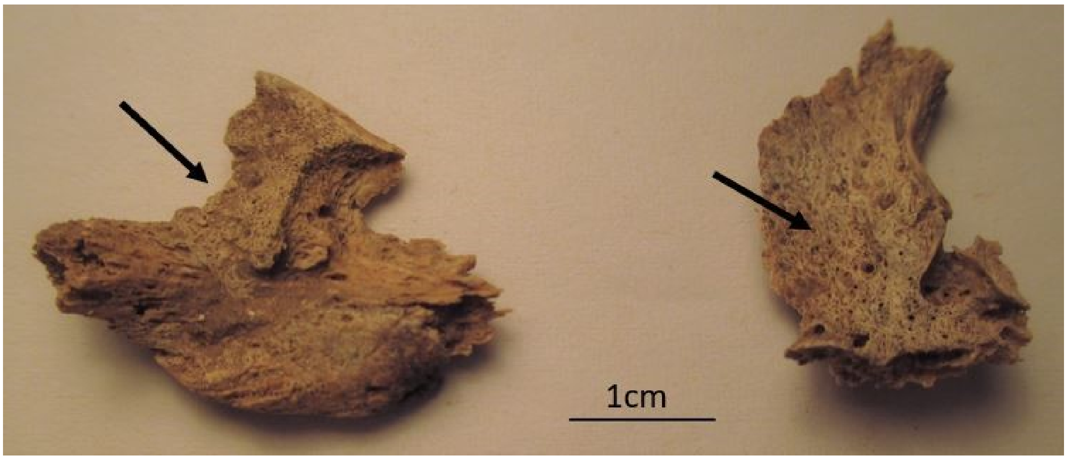


Figure 7.28. Abnormal porosity of the maxillary frontal process and coronoid process of the mandible (Wetwang Slack Sk. 1163, 38-40 weeks).

Walker *et al*. (2009) propose that vitamin B12 deficiency (dietary sources are meat, dairy and fish), scurvy, or chronic infection may be underlying factors in the aetiology of porotic lesions of the vault and orbits. They argue that anaemia developed through iron-deficiency is an unlikely aetiology for the porotic lesions of the cranium observed in archaeological collections, claiming support from physiological research that demonstrates that iron-deficiency anaemia inhibits the diploic expansion commonly seen in conjunction with porotic lesions (Walker *et al*., 2009). Consideration of co-morbidity, multiple conditions occurring simultaneously, should also inform interpretations of skeletal pathology (Brickley and Ives, 2006). It is to be anticipated that an individual with a significant systemic condition may also have a compromised immune system. This may result in the expression of skeletal pathology with multiple aetiologies as demonstrated by

Stuart-Macadam (1989) in the case of anaemia co-occurring with scurvy, or by Schattmann *et al*. (2016) for scurvy and rickets.

Regardless of the specific aetiology behind the porous lesions observed, the age of the individuals analysed is a strong indication that for the majority of affected individuals the onset of any systemic deficiency or infection occurred during gestation. This timing would allow sufficient development of lesions in response to compromised maternal health during later pregnancy. Although possible, it is less likely that each of the individuals with porous lesions suffered from independent systemic conditions during their intrauterine development.

Several individuals were observed to have anomalous vascularity that affected the cortical layers but was unrelated to porous lesions (Table 7.11). The hyper-vascular appearance is typified by an expansion in the diameter of existing vessels and a marked increase in the number of vessels perforating the skeletal element. Increased vascularity of this kind was most often observed in the hypophyseal fossa of the postsphenoid and the intracranial surface of the basilar process of the occipital. Scheuer and Black (2004) note that the intracranial surface of the basilar process has multiple nutrient foramina unlike the postsphenoid that usually has only a single nutrient foramen in the hypophyseal fossa. Increases in the diameter and number of vessels indicates a change in vasculature in close association with the ossifying elements.

Table 7.11. Individuals with hyper-vascularity not associated with porotic lesions.

Collection	Individual	Age	Affected Element
Ardreigh	1492	34-38w	Basilar process of the occipital
Barton Court Farm	885	38-40w	Basilar process of the occipital
	1076	38-40w	Hypophyseal fossa of the sphenoid
Çatalhöyük	10361	38-40w	Basilar process of the occipital
Wharram Percy	NA4A	38-40w	Basilar process of the occipital
	NA76	38-40w	Hypophyseal fossa of the sphenoid
	NA82	36-38w	Hypophyseal fossa of the sphenoid
	NA96	40w	Basilar process of the occipital

Five individuals had increased vascular changes to the intracranial surface of the basilar process (Figure 7.29) and three had hyper-vascular hypophyseal fossae (Figure 7.30). The hyper-vascular appearance of these two fossae may be pathological and suggests a shifting position of the superficial blood vessels, resulting in greater inclusion within the ossifying elements.

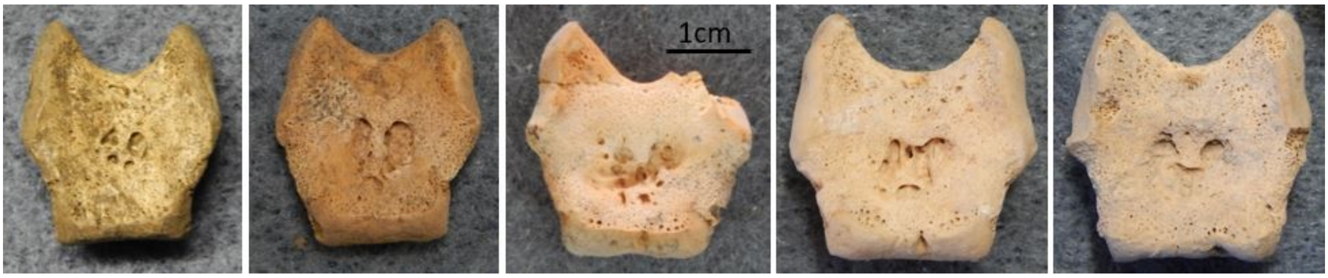


Figure 7.29. Increased vascularity of the superior surface of the occipital basilar process in perinatal individuals (left to right: Barton Court Farm Sk. 885, Ardreigh Sk. 1492, Çatalhöyük Sk. 10361, Wharram Percy Sk. NA4A and NA96).

Figure 7.30. Increased vascularity of the hypophyseal fossa in the postsphenoid (Wharram Percy Sk. NA76, 38-40 weeks and Sk. NA82, 36-38 weeks).

7.5.4 Endocranial Lesions

Lesions involving the endocranial surfaces of the frontals, parietals and occipital squama are frequently observed in the skeletal remains of very young individuals recovered from archaeological contexts. In very young individuals the differentiation of pathological endocranial lesions from normal ossification of the cranial elements involved appears to be associated with age rather than form, in that the presence of lesions at birth may be considered normal (Lewis, 2004), but endocranial lesions present during later infancy and early childhood are considered to be pathological (Lewis, 2004; Mensforth *et al*., 1978; Schultz, 1989). This interpretation of aetiology appears to be centred on the assumption that a pathological origin of endocranial lesions is unlikely to occur prior to birth and that the lesions reflect the immature state of ossification in the affected elements.

Lewis (2000) also suggests that the endocranial lesions observed in very young individuals are not pathological but connected with the development of the endocranial cortical layer. Intracranial haemorrhage is proposed as a possible aetiology for the endocranial lesions present in older individuals, yet it is recognised that prenatal individuals can also experience intracranial haemorrhage (Lewis 2000; Tiller *et al*., 2013). Schultz (2001) examined the histopathology of endocranial lesions and attributed their expression to haemorrhage or inflammation, or a combination of the two. While Lewis (2004) concluded that all of the lesions observed in individuals aged between birth and six months (12/79, 15.2%) in her study population, were either porous or fibre bone deposit and attributed the porous endocranial lesions to non-pathological cortical development. The same lesions observed in older infants were considered to be associated with inflammation and haemorrhage.

Lewis (2004) considered multiple aetiologies that may contribute to the formation of endocranial lesions, such as meningitis, infectious disease, subdural haemorrhage and vitamin deficiency, but did not include individuals under the age of 40 weeks in her study, which removes the possibility of identifying possible intrauterine aetiologies. A further limitation is the single age grouping that includes all individuals between 40 gestation weeks and six postnatal months. This is a considerable constraint for determining any association between endocranial lesions and early periods of rapid cranial ossification. It also removes the possibility of differentiating pathological lesions in this age group from normal developmental appearance of endocranial cortical surfaces.

Endocranial lesions of the vault are usually symmetrical with variation of form within the lesion, indicating a close association with the cranial vascular structures. The distribution and frequency of endocranial lesions on the vault elements by age category is given in Figure 7.31. Each individual is represented once, demonstrating that the greatest number of individuals in each age category had endocranial lesions on multiple elements. In fetal, perinatal and neonatal individuals with only one element affected by endocranial lesions, the frontal is the most commonly involved element. This is not the case for very young individuals with endocranial lesions on a single element. In these older individuals the occipital squama was most commonly involved. The following brief discussion of endocranial lesions is arranged by skeletal element.

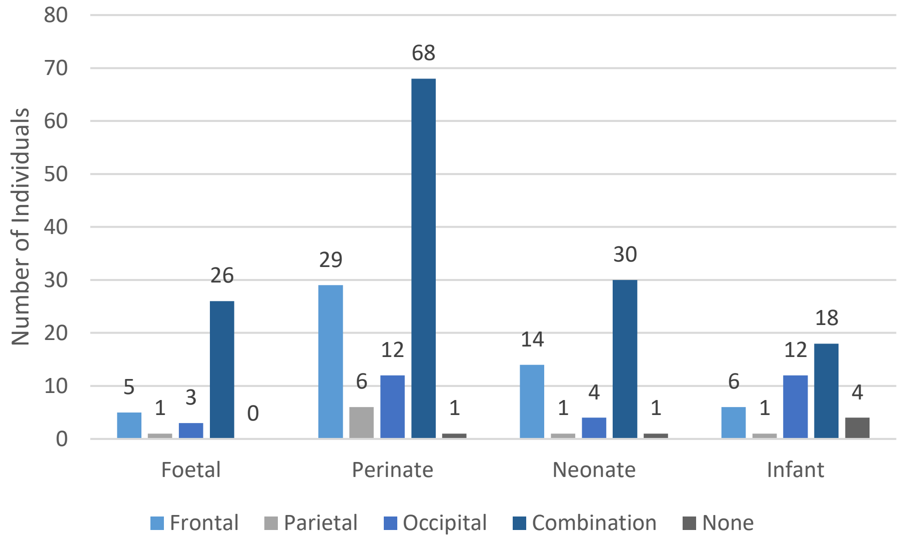


Figure 7.31. Endocranial lesions of the cranial vault by age category. The Combination category represents at least two elements with active lesions in the same individual.

7.5.4.1 Frontal

Endocranial lesions of the frontal were observed centrally on the vault surface of the element or adjacent to the angle of the orbital plate. Although they commonly extend superiorly towards the medial and lateral borders of the frontal, they rarely extend to the orbital plate. The lesions are predominantly porous with vascular impressions that are diploic in origin. Broad areas of the endocranial vault surface are frequently affected, however the lesions have an inconsistent appearance over the affected area (Figure 7.32).

Figure 7.32. Endocranial surface of the frontals demonstrating porous lesions with vascular impressions (Scheuer Sk. 5 (top) and Sk. 161, both 0-1 month).

The thickness of the vault is not necessarily altered by the presence of endocranial lesions, rather the inner surface is altered without thinning or the addition of superficial plaque-like layers. It is suggested that alteration of the endocranial surface along the medial margins of the vault may indicate zones of diffuse venous drainage into the superior sagittal sinus. The vascular pathways that may be involved in the haemorrhagic events associated with endocranial lesions of the frontal include the superior cerebral vessels and the frontal branch of the middle meningeal artery (Gupta *et al*., 2008; Moore *et al*., 2014; Ogeng'o *et al*., 2015; Snell, 2010). Occasionally, the anterior meningeal artery that arises from the ethmoidal artery may be involved where lesions are present on the orbital plate. The difference in diploic vascularity between the smooth surfaces and lesion area is demonstrated in Figure 7.33 in which it can be seen that the areas of the frontal vault usually affected by endocranial lesions are also the areas with the greatest underlying blood supply. The association of endocranial lesions with diploic vascular supply suggests that the lesions may develop in response to pooling of blood through small scale diploic haemorrhagic events.

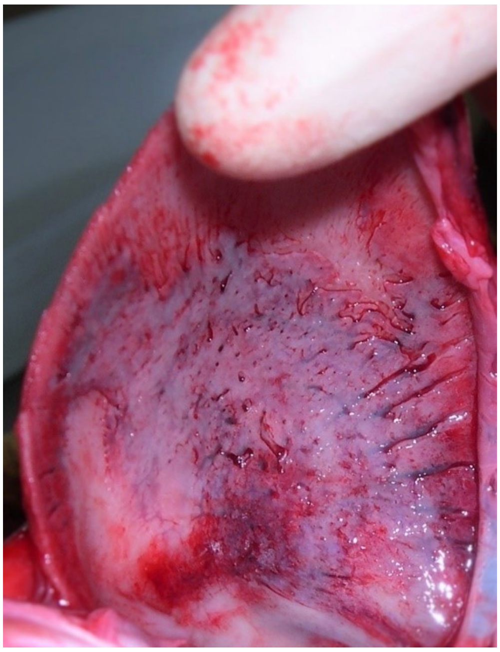


Figure 7.33. Endocranial surface of the frontal demonstrating diploic distribution of blood supply (darker areas) (Clinical B, 40 weeks).

A perinatal individual from the Yewden villa burial population (Sk. 29, 40 weeks) displays an endocranial plaque of new bone on the right frontal (Figure 7.34). The lesion is located on the endocranial surface of the orbital plate, an unusual location and one that is indicative of haemorrhage. This individual also displays porous lesions of the orbits that suggest a systemic condition related to nutritional deficiency, however the incomplete nature of the skeletal remains limits further interpretation of the observed skeletal pathology. The perinatal age at death of this individual in conjunction with the observed skeletal pathology indicates that the fetal supply line was compromised in later pregnancy, with the most probable aetiology being maternal undernutrition.

Figure 7.34. Endocranial lesion (arrow) on the posterior surface of the orbital plate in a neonatal individual (Yewden Sk. 29, 40 weeks).

7.5.4.2 Parietal

Endocranial lesions of the parietals are similar in form to those of the frontals, although they are more regular in appearance. The lesions are predominantly remodelled woven bone laid down in a radiating pattern that mirrors the underlying osseous organisation of the developing element. Occasionally vascular impressions of the middle meningeal arteries are visible on the lesion surface. The distribution of endocranial lesions on the parietal are primarily central and extend towards the frontal margin. The cortical surface surrounding the endocranial lesions is normally smooth, with clearly identifiable impressions of the middle meningeal arteries. As in the frontals, areas of altered cortical surface display increased vascular supply indicating a difference in osteoblastic activity across the vault surface. The developing parietal has a single arterial supply via the middle meningeal arteries with venous drainage via the superior sagittal sinus.

A comparison of endocranial parietal lesions between individuals of different ages suggests that the initial response occurs along the frontal margin

(Figure 7.35). This area is subsequently incorporated into the developing cortical layer while the central area of the element develops a radiating pattern with vascular impressions (Figure 7.36). This distribution is also evident in the clinical cases. An individual of approximately 26 weeks (Clinical C) has no evidence of an altered endocranial surface, while a perinatal individual (Clinical A, 40 weeks) displays the central radiating distribution of lesion often noted in archaeological specimens (Figure 7.37).

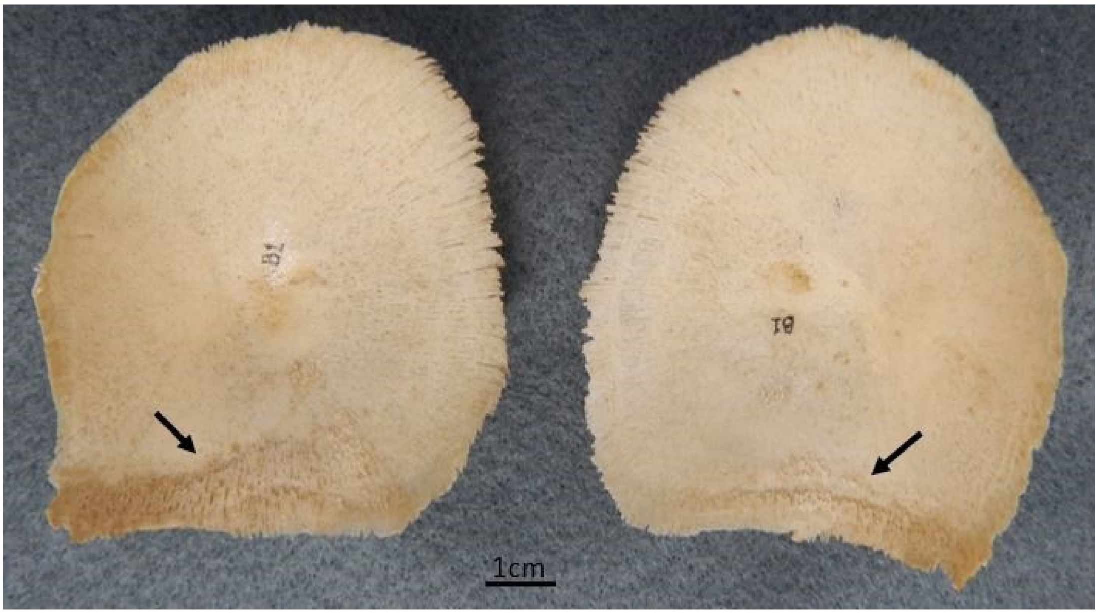


Figure 7.35. Endocranial surface of the parietals demonstrating distribution of superficial lesions along frontal margins (arrows) (Scheuer Sk. 96, 32 weeks).

Figure 7.36. Endocranial surface of the parietals demonstrating the radiating pattern of new bone deposition (Scheuer Sk. 5, 0-1 month).

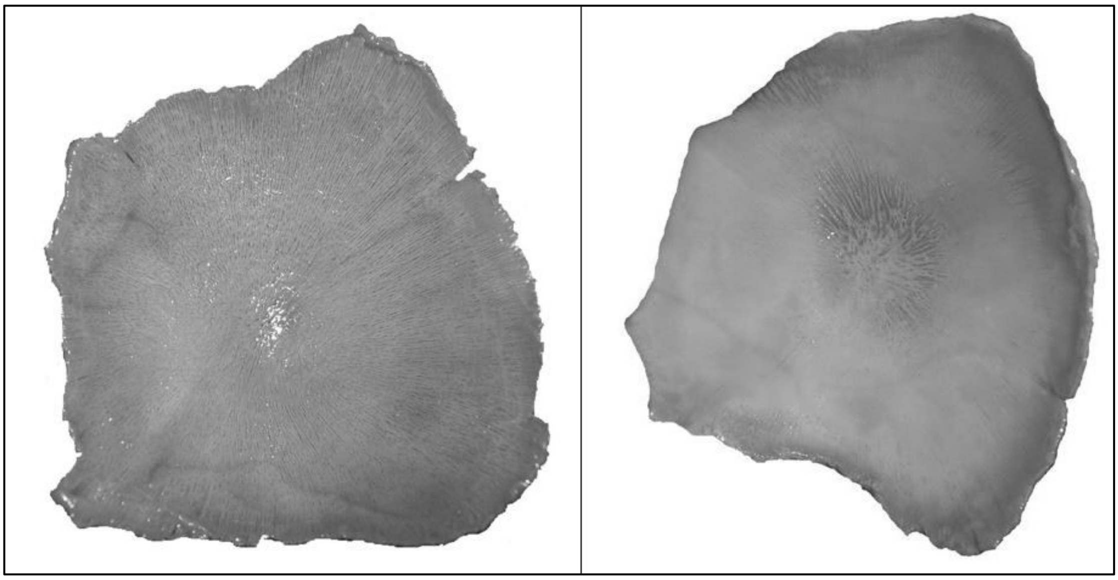


Figure 7.37. The different appearance of endocranial surfaces of different developmental ages (Clinical C, approx. 26 weeks (left) and Clinical A, 40 weeks (right).

7.5.4.3 Occipital Squama

Endocranial lesions are frequently encountered on the cruciate eminence, transverse sinus, occipital sinus and within the cerebellar and cerebral fossae of the occipital squama (Lewis 2000, 2004). The lesions are predominantly porous with occasional fine vascular impressions. They appear as plaque-like lesions on the cortical surface or as areas of increased porosity that disrupt the cortical surface (Figure 7.38). In extreme cases the thickness of the squama is reduced and perforation occurs. This was observed in a perinatal individual (Çatalhöyük Sk. 2199, 38-40 weeks) that displays severe porous endocranial lesions affecting the superior sagittal and occipital sinuses. Thinning of the vault in the cerebral fossae has resulted in bilateral perforation (Figure 7.39).

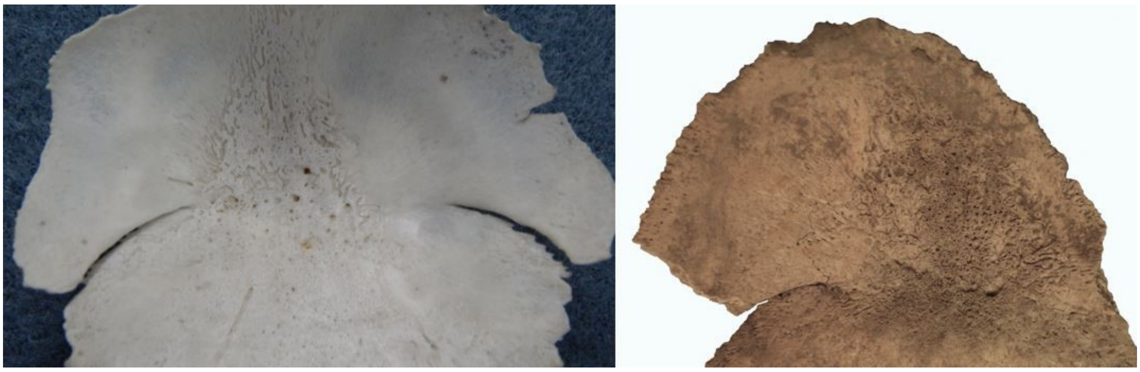


Figure 7.38. New bone deposit with porosity and vascular impressions on the occipital squama (Scheuer Sk. 5 (left) and Wetwang Slack Sk. 7389 (right), both 0-1 month).

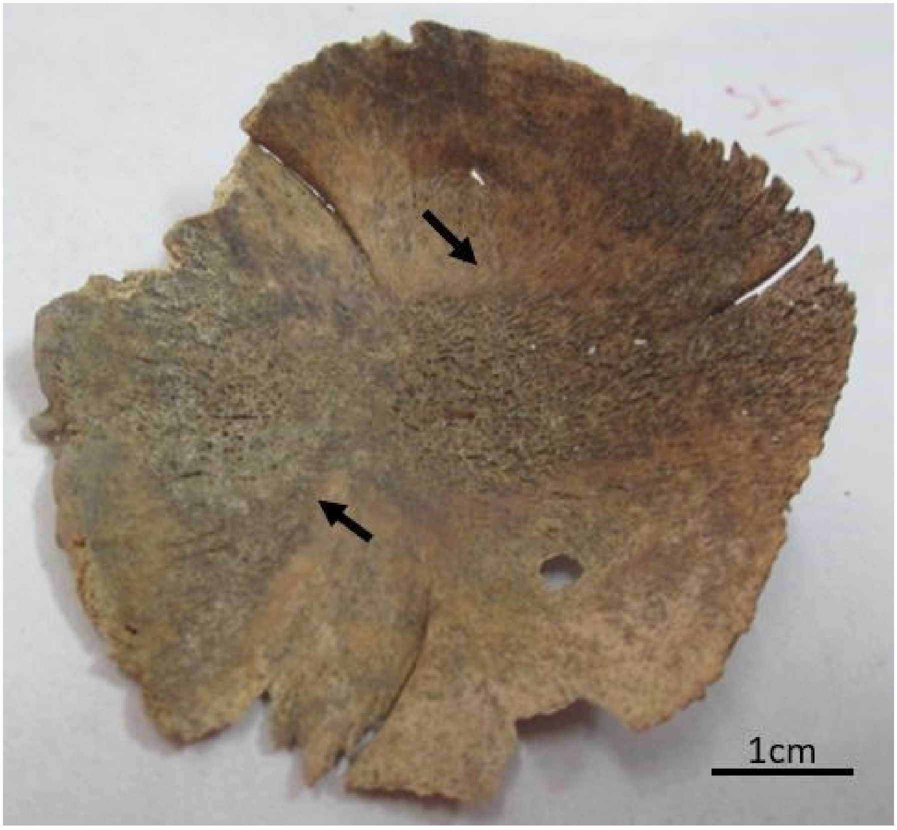


Figure 7.39. Endocranial porous lesions (arrows) on the occipital squama. Note the distribution in relation to pathways of venous drainage. There is bilateral thinning and perforation of the cerebral fossae (Çatalhöyük Sk. 2199, 38-40 weeks).

The distribution of endocranial lesions on the occipital squama follows the pathways of venous drainage. Arterial supply to the dura in the occipital region is via the meningeal branches from the vertebral artery and the occipital artery which occur predominantly within the cerebral and cerebellar fossae. All venous sinuses of the vault converge at the torcula; the confluence situated at the internal occipital protuberance. From this point blood travels through the transverse and sigmoid sinuses leaving the cranium through the jugular foramina.

The occipital squama of a perinatal individual (Clinical C, 26 weeks) that does not display endocranial deposits, but clearly demonstrates the underlying structure of the developing squama is shown in Figure 7.40. Increased density around the cruciate eminence and the location of the superior sagittal sinus is evident. The location of endocranial lesions in these areas of increased vault thickness suggests that they may be connected with normal expansion of the endocranial cortical layer. This distribution coincides with major vascular structures in this region of the cranium, indicating that haemorrhage may be a contributing factor to the development of endocranial lesions on the occipital squama.

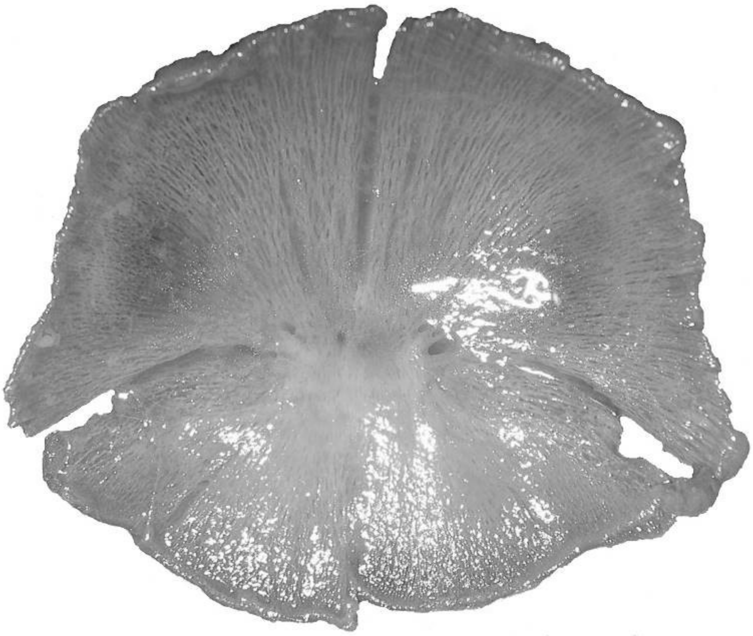


Figure 7.40. Underlying structure of the developing occipital squama (Clinical C, approx. 26 weeks).

7.5.4.4 Aetiology

Four forms of endocranial lesions have been described by Lewis (2004), and several aetiologies have been proposed for these forms of endocranial lesions (Lewis, 2004; Schultz, 2001). A summary of these details is provided in Table 7.12.

Table 7.12. Classification of endocranial lesions and aetiologies.

Form	Description	Aetiology (Schultz 2001)	Aetiology (Lewis 2004)
Porous Lesion	Expansion of vessels	Haemorrhage	Anaemia
Fibre Lesion	Irregular woven appearance, periosteal	Active meningeal haemorrhage	Unknown
Hair-on-End Lesion	Expansion of the diploic layer with disruption of the cortical surface	Inflammation (ossified soft tissues)	Haemorrhage, Vascular pressure fluctuations, Trauma
Capillary Lesion	Vascular impressions involving the cortical layer	Vascular in origin (healing)	Unknown

Hypoxia

Fetal hypoxia is a condition that can develop through placental insufficiency and maternal conditions such as pre-eclampsia (Hutter *et al*., 2010). It is also a characteristic feature of labour that is experienced by the full-term fetus during uterine contractions (Gibb, 2008). Although these brief periods of hypoxia do not normally have an adverse effect on the fetus, the impact is considerably magnified for fetuses that have experienced restricted intrauterine growth (Scheimberg and Cohen *et al*., 2013). Kingdom and Kaufmann (1997) identified a connection between fetal hypoxia and subdural haemorrhage, and Scheimberg and Cohen *et al*. (2013) confirmed an association between intrauterine hypoxia and both intradural and subdural haemorrhage. They observed more cases of subdural haemorrhage in individuals aged less than one postnatal month than in older infants, and connected the presence of subdural haemorrhage in these fetal individuals with intrauterine hypoxia.

An assessment of occurrence and form of subdural haemorrhage in asymptomatic neonates was undertaken by Rooks *et al*. (2008). They concluded that subdural haemorrhage was commonly observed in neonatal individuals and was associated with delivery. The mode of delivery was not found to be a contributing factor for subdural haemorrhage. This suggests that the haemorrhagic event occurred prior to delivery and may be the result of increased cranial pressure experienced whilst the baby is engaged, or intrauterine pressure changes, rather than the mechanical impacts of modern assisted delivery.

Kelly *et al*. (2014) also investigated the relationship between subdural haemorrhage and hypoxia but did not find any correlation between the two. They concluded that subdural haemorrhage was common in fetal and perinatal individuals and had usually resolved by three months with no long-term negative outcomes. Their results support an interpretation of endocranial lesions in older infants as being pathological, but more importantly, indicate that the timing of subdural haemorrhage in fetal and perinatal individuals allows sufficient time for an osseous response of the endocranial surfaces in contact with the haematoma to develop.

The research presented above highlights the improvement of neonatal outcome following subdural haemorrhage with medical intervention and support. It also provides evidence that intrauterine subdural haemorrhage is correlated with intrauterine hypoxia in the majority of cases. Fetal growth and health is an important contributing factor to an individual surviving periods of hypoxia. Individuals that have experienced restricted intrauterine growth through maternal undernutrition are more vulnerable to periods of intrauterine hypoxia and are more likely to experience haemorrhagic events (Scheimberg and Cohen *et al*., 2013). The consequences of which include a higher probability of perinatal and neonatal mortality.

Sepsis

Neonatal sepsis has various causes that include bacterial and viral infection as well as parasitic and fungal agents (Cortese *et al*., 2016). Neonatal sepsis usually involves multiple systems and a significant compounding factor is a compromised immunological response. Early onset sepsis occurs within the first postnatal week and is commonly ascribed to the transfer of bacteria from the mother to the fetus, either through ascending infection or direct contact during delivery (Cortese *et al*., 2016). As well as multiple concurrent system failures, neonatal seizures are a noted feature of neonatal sepsis and are associated with severe neurological impairment and mortality (Anand and Nair, 2014).

Interleukin-6 (IL6) is a cellular compound that stabilises ossification processes under normal conditions by limiting bone resorption. During an inflammatory response, IL6 control over osteoclastic activity is not maintained (Yoshitake *et al*. 2008) and can result in disproportionate bone resorption. Elevated levels of IL6 in fetal or neonatal individuals is indicative of an immune response to infection, neonatal sepsis, or trauma (Chiesa *et al*. 2015). The irregular appearance and surface area of endocranial lesions suggests that there is sporadic ossification across the lesion area, which may be a reflection of interrupted osteoblastic activity in the cortical layer through cellular changes involving IL6. Increased diploic blood supply to the developing vault elements, demonstrated above in Figure 7.33, may be indirectly associated with porous endocranial lesions, and could provide evidence of diploic haemorrhage in these highly vascular zones.

Three of the individuals in the clinical cases (A, B and D) had developed intrauterine infections, one of which had developed into pneumonia (Table 7.13). The infections were acquired through trans-placental or trans-membranous movement of causative agents and were contributing factors to the death of these individuals. Four of the five individuals were affected by a compromised fetal supply line through immaturity of the placenta, obstruction of the umbilical cord, or thrombotic vasculopathy. Individual B did not have any apparent disruption in growth or development, but was severely compromised by an intrauterine infection and the associated development of pneumonia. All of the clinical cases were otherwise normal in development and growth for their gestational age.

Table 7.13. Clinical cases included in the current research, with associated pathology confirmed through autopsy.

Individual	**Age**	**Pathology**	**Timing of Death**
A	40w	Immature placenta, amniotic fluid infection	Intrauterine (stillborn)
B	40w	Ascending fluid infection, congenital pneumonia	Intrapartum (during delivery)
C	26w+	Chronic intermittent umbilical cord obstruction	Intrauterine (stillborn)
D	41w+	Amniotic fluid infection, fetal thrombotic vasculopathy	Intrauterine (stillborn)
E	37w	Placental villous immaturity	Intrauterine (stillborn)

Vitamin Deficiency

Previously identified as haemorrhagic disease of the newborn (Dam *et al*., 1952), a deficiency of vitamin K will lead to neonatal death without immediate medical intervention (Greer, 2010; Shearer, 2009). Vitamin K is obtained through ingestion of green vegetables and dairy products and is also produced by gut flora (Nimavat and Sherman, 2016), however very little vitamin K crosses the placenta to the developing fetus (Greer, 2010). McNinch *et al*. (1983) demonstrated that vitamin K deficiency in neonatal individuals causes haemorrhage through clotting insufficiency. Their study highlighted that individuals could present with haemorrhage within 24 hours of birth, and that haemorrhage associated with vitamin K deficiency can occur during the weeks following birth (McNinch *et al.*, 1983). Shearer (2009) comments on the high neonatal mortality (up to 26%) in affected individuals who received delayed treatment and of the permanent neurological damage sustained in surviving infants. A deficiency in vitamin C is associated with compromised vascular structures, contributing to sub-periosteal haemorrhagic events (Brickley and Ives 2010). Intracranial haemorrhage associated with fetal hypoxia, and possibly exacerbated by vitamin deficiencies, has the potential to contribute to the intrauterine formation of the endocranial lesions that are observed in the skeletal remains of very young individuals.

Fetal and Neonatal Alloimmune Thrombocytopenia

Tiller *et al*. (2013) report on the prenatal onset of intracranial haemorrhage in individuals with fetal and neonatal alloimmune thrombocytopenia (FNAIT), an immunological response of the fetus to maternal antibodies. FNAIT presents as subdural haemorrhage with slow bleeds that are fatal if undetected. Tiller *et al*. (2013) observed that intracranial haemorrhage occurred prior to 28 weeks gestation in the majority of cases (23/43, 54%) and resulted in mortality within four days of birth in 15 individuals (35%). Although the majority of individuals in their study group survived (28/43, 53%), only five of these did not experience adverse effects (Tiller *et al*. 2013). FNAIT has a recurrence risk in subsequent pregnancies of 79% (Tiller *et al*. 2013) and the impacts on the fetus can be avoided in subsequent pregnancies if maternal intervention is provided prior to five months gestation.

Although the frequency of FNAIT in Caucasian populations is estimated to be approximately 1/600 live births, which is considerably less than Rh haemolytic disease (1/2200 live births, without treatment; Kumar and Regan, 2005), it carries a significantly increased risk for each subsequent pregnancy (Bussel *et al*., 1997; Kamphuis *et al*., 2010; Tiller *et al*., 2013). The implication of recurrent conditions for fetal and neonatal mortality within smaller populations is significant, and should be a consideration when assessing burial populations with apparently high mortality in these age categories in tandem with evidence for a relatively limited gene pool.

It has been demonstrated that the intracranial blood flow of fetal and perinatal individuals is lower than that of adults and that very young individuals are also susceptible to negative intracranial pressure (Bertolizio *et al*. 2011). The combination of low blood flow and negative intracranial pressure provides an ideal environment for the development of slow haemorrhage into the subdural space. Independent of the aetiology of haemorrhagic events in fetal and perinatal individuals, their unique physiology is undoubtedly an underlying factor in the development of the endocranial lesions and cortical surface appearances described above.

7.6 Summary

This chapter has presented skeletal evidence for fetal response to the maternal condition. Although only ten maternal mortalities were identified in the populations analysed, including two from Anglo-Saxon burial contexts, information regarding the maternal condition of many more individuals was obtained through detailed analysis of the skeletal remains of very young individuals. The physiological relationship between the mother and fetus and the effects of a compromised fetal supply line were demonstrated through the skeletal pathology expressed in very young individuals. Developmental plasticity, the differential impact of the maternal condition on fetal growth and development, which is contingent upon the stage of pregnancy, gives rise to different expressions of skeletal pathology. It also affects the ability and degree to which the fetus can recover. Maternal constraint was shown to be a contributing factor to the success of the fetal supply line, especially with regard to maternal age at pregnancy and the maternal condition.

Several individuals exhibit intrajugular bridging of the occipital and temporal that have relatively low prevalence in modern populations. A relatively high proportion of vertebral border shifting was observed in the individuals from the Wharram Percy population compared to the other populations. It was also demonstrated that the presence of a supracondylar process of the humerus was predominantly observed in Roman populations, but was also present in the Wharram Percy population. These traits highlight the diverse nature of genetically associated traits across contemporaneous populations.

Despite the considerable evidence of neural tube defects within the Royal College of Surgeons collection, only a single perinatal individual was identified with skeletal pathology that is suggestive of spina bifida. One individual from the Wharram Percy burial population exhibits agenesis of the basilar process, a particularly unusual form of bilateral transverse basilar cleft. A specific dysmorphy of the sphenoid indicates the presence of Trisomy 21 in three of the individuals analysed. The individuals from Wetwang Slack and Wharram Percy represent the earliest in date and youngest individuals with this condition that have been identified from archaeological contexts. This particular dysmorphy may provide a potentially useful diagnostic feature for future analysis of Trisomy 21 in archaeological remains.

There was evidence for metabolic and nutritional deficiency within the observed skeletal pathology, the majority of which points to a compromised maternal condition that affected intrauterine development. Several individuals had gracile or thickened long bone diaphyses that may be associated with intrauterine growth disturbance. An extreme example of metabolic disturbance affecting bone remodelling was observed in the multiple cortical layers of the tibia of an infant.

Multiple porous lesions were observed on the cranial and postcranial elements. Contributing factors to the development of the observed lesions include compromised maternal physiological condition as the affected individuals are considered too young to have developed a similar degree of skeletal pathology during the postnatal period. Conditions such as maternal anaemia, infection and nutritional deficiency are possible aetiologies that could have a significant impact upon the fetal supply line. Lesions associated with nutritional deficiency were observed in younger perinatal and neonatal individuals. While lesions associated with rickets and anaemia were observed in young infants aged between three and six postnatal months.

Nine individuals displayed anomalous hyper-vascularity that reflect changes to the vascular supply of the affected cranial and postcranial elements (see Table 7.11). Numerous individuals (n=242, see Figure 7.31) have endocranial lesions of the vault elements and orbits. These are likely to have an intrauterine haemorrhagic or inflammatory aetiology, although some of the individuals affected may have developed lesions during the postnatal period. These lesions are a strong indication for compromised health in the mother where perinatal individuals are affected. They also suggest adverse conditions for the affected neonatal individuals and infants. Several individuals with cranial lesions display evidence for remodelling that is suggestive of healing. Despite this evidence for recovery, the development of the lesions is indicative of chronic systemic conditions and many of the lesions observed were active at the time of death.

The possibility of fetal hypoxia and genetic conditions linked to haemorrhage, such as FNAIT, were discussed in relation to the predisposition of individuals to fetal and neonatal intracranial haemorrhage. The compounding factors of an insufficient fetal supply line, maternal undernutrition, reduced fetal immunological responses, hypoxia and intrauterine infection will inevitably result in fetal or neonatal death through multiple system failures without medical intervention and support. They will also result in developmental delays and growth restriction, which is identifiable through detailed skeletal analysis.

Gowland (2015) comments on the applicability of interpreting skeletal remains through the filter of the developmental origins of disease in order to assess the maternal condition. The evidence provided above through the skeletal analysis of very young individuals demonstrates that it is possible to access significant and considerable detail regarding the possible maternal condition prior to and during pregnancy when only the skeletal remains of very young individuals are available. The skeletal pathology of the very young individuals from the study populations provides information about their individual development and postnatal wellbeing and the health of their mothers, which in turn enhances our understanding of the experiences of their respective communities.

Chapter Eight

Population Stress

> "…stress is a hybrid phenomenon, the product of both biological and cultural forces rendered visible by the technology and language of biomedical science…"
>
> (Jackson 2013, 16)

> "Stress can be defined as a physiological change caused by strain on an organism from environmental, nutritional, and other pressures…"
>
> (Reitsema and McIlvaine 2014, 181)

8.1 Introduction

Population stress is a broad term that includes the myriad of environmental and physiological impacts that have detrimental effects on a group of people, or that act as catalysts for physiological adaptation. The skeleton has the ability to respond to various physiological stressors such as deficiency, disease, and activity. Evidence of these skeletal responses is often macroscopically visible in the skeletal remains of older individuals and forms the basis for palaeopathological analysis. The current research has used the skeletal pathology of very young individuals as a proxy for examining physiological responses to stress in reproductive females. This approach also enables the consideration of more general environmental stresses within the wider population at each location.

The funerary treatment afforded to the youngest individuals in each population, and in some cases their mothers, is a form of cultural buffering in response to maternal, fetal, perinatal, neonatal and infant mortality, and reveals socio-cultural attitudes to the identity of very young individuals (Sayer and Dickinson, 2013). Cultural buffering is also tangible through the evidence of treatment and support provided to individuals who were incapacitated due to injury or illness, or mothers who experienced a difficult delivery. This chapter considers the evidence for individual pathology and living environment presented in the previous three chapters in terms of what this information can reveal about the stress experienced in each population analysed. The role of the mother in sustaining the fetus throughout pregnancy and the scope for intrauterine recovery, will be considered in conjunction with the potential of positive outcome for those individuals with significant skeletal pathology. It will also place this evidence within the concept of cultural buffering to examine the behaviours of the living communities.

8.2 Skeletal Indicators of Stress

Temple and Goodman (2014) maintain that the skeletal indicators identified through osteological analysis are closely associated with stress and disease, and can provide a record of some of the more severe physiological impacts experienced by an individual. The focus of analysing indicators for stress should remain on the individual's skeletal pathology, with cautious application to the wider community only in cases where the extent of pathology and bioarchaeological context supports such interpretations. This approach enables an evaluation of physiological stress within a population based upon the skeletal evidence observed within the associated burial population, assuming that some forms of physiological stress will have an osteological impact.

Skeletal indicators associated with physiological stress include those that are a reflection of interrupted growth and developmental disturbance, such as Harris lines that develop at the growth plates of long bones and dental enamel hypoplasias (Goodman and Armelagos, 1989). Other forms of skeletal pathology that reflect physiological stress include the porous lesions of cribra orbitalia and porotic hyperostosis, non-specific periostosis, pathology of the dentition such as carious lesions, abscess and periodontal disease, and lesions associated with systemic conditions and infectious diseases such as scurvy, rickets and tuberculosis (Ortner, 2003; Redfern *et al.*, 2015). The majority of these forms of skeletal pathology have been noted in the preceding three chapters and discussed in terms of individual impact.

More general indicators of stress can be identified through discrepancies in growth and development across the skeleton, such as dental development that is significantly in advance of postcranial development. These less specific indicators can reveal chronic conditions in which the growth and development of an individual are differentially impacted by restraints on normal physiology. Chronic malnutrition is one example of a systemic condition that will result in this type of developmental discrepancy. Of course, causative agents do not necessarily occur in isolation and skeletal pathology may reflect multiple concurrent conditions, particularly if the pathology indicates a chronic or recurrent state.

Geber (2014) demonstrated considerable evidence of skeletal pathology associated with physiological stress in children affected by the Great Irish Famine (AD1845-1852), including Harris lines, growth retardation, enamel hypoplasia and cribra orbitalia. Although the study included individuals aged less than one postnatal month at death, the results only include individuals aged older than six months. This precludes any interpretation of maternal health through the skeletal pathology of neonatal individuals. Physiological stressors such as metabolic disturbance, infection, malnutrition and starvation are all probable contributors to the skeletal pathology observed in the individuals analysed by Geber. He also considered the social disruption and associated psychological stress experienced by children to be a significant contributing factor to the physiological stress evidenced in skeletal lesions.

Aside from infectious and systemic conditions, the presence of trauma in skeletal remains is a direct reflection of physiological stress sustained through injury. The type of trauma and the location on the skeleton can be indicative of specific behaviours. For example, fractures of the forearm may suggest a defensive posture, and fracture patterns can denote the force of impact such as sharp or compression and the direction of the force applied (Merbs, 1989). Skeletal trauma provides information about the prevalence of injury within a population and possible causative behaviours or activities. The state of healing evident at the time of death not only provides insight into an individual's capacity for recovery from a significant injury but may also reveal evidence of treatment and support received by the affected individual.

In considering the osteological paradox, Wood *et al.* (1992) proposed that lesions exhibiting healing at the time of death are an indication that the individual was less susceptible to the condition than others who died with active lesions or prior to the formation of lesions. The presence of skeletal lesions on the skeletal remains of very young individuals, and in particular, their state of activity at the time of death, may provide a reflection of the individual's ability to outlive the causative condition(s) (DeWitte, 2014). There are also many acute conditions that will result in death prior to skeletal impact. In this respect, the absence of skeletal pathology in very young individuals is most plausibly explained by aetiologies that have a rapid onset and significantly compromise the individual's survival (Goodman and Armelagos, 1989).

Studies of maternal and neonatal health in developing countries have demonstrated the very great impact of intrauterine or congenital infection leading to the rapid onset of severe conditions such as pneumonia and sepsis (Duke, 2005). Fetal pneumonia is acquired through aspiration of amniotic fluid containing bacterial infection, and neonatal pneumonia may derive from either intrauterine infection or intrapartum contact with bacterial agents (Duke, 2005). In a survey of global child mortality in 2013, Liu *et al*. (2015) found that 44% of deaths (2.761 million) in children aged under five years occurred in the neonatal period. The top three causes of neonatal mortality were preterm complications (0.965 million), pneumonia (0.935 million) and intrapartum complications (0.662 million) (Liu *et al*., 2015).

8.3 Maternal Physiological Stress and Fetal Response

It has been demonstrated that intrauterine exposure to physiological stress through the maternal condition, has the potential to affect neonatal immune response and thereby increase mortality risk (Rodney and Mulligan 2014). If an individual so affected survived infancy it is anticipated that if the early life impacts of maternal stress were significant, they will be reflected in the skeletal remains. The impacts of maternal health on the developing fetus are best captured through the skeletons of very young individuals in the perinatal and neonatal periods. These youngest individuals offer the most reliable source of information, as older infants and children whose development may have been affected by the maternal condition are also affected by various independent causative factors during infancy and childhood.

The connection between maternal and infant health was demonstrated by Goodman and Armelagos (1989) through bone growth and remodelling. They highlight that a compromised maternal condition, particularly during pregnancy and lactation, will have a comparative impact on the fetus. Maternal physiological stress prior to pregnancy has also been associated with low neonatal birth weight and a significant reduction in maternal and neonatal methylation levels, affecting cell differentiation and metabolic processes (Rodney and Mulligan, 2014). Cao-Lei *et al*. (2014) demonstrated the long-term effects of DNA methylation in the offspring of mothers who were pregnant during a significant natural disaster. They found that methylation was strongly correlated with objective prenatal maternal stress and particularly impacted immune and metabolic functions (Cao-Lei *et al*. 2014). In an earlier study Charil *et al.* (2010) attributed permanent changes in the brain development of individuals in the same cohort with the intrauterine timing of prenatal maternal stress.

Elevated $\delta^{15}N$ levels in neonatal and infant skeletal remains are commonly associated with breastfeeding (Richards *et al*., 2002), however Kinaston *et al.* (2009) offer an alternative explanation for elevated $\delta^{15}N$ levels that occur in perinatal individuals. They suggest that intrauterine stress associated with the maternal condition and with infection can also lead to elevated $\delta^{15}N$ levels. By considering the broader context and population pathology, multiple contributing factors can be indicated to inform the interpretation of elevated $\delta^{15}N$ levels in very young individuals. This is particularly so for perinatal or neonatal individuals who are unlikely to have developed $\delta^{15}N$ changes related to the effects of breastfeeding.

Piperata *et al*. (2014) demonstrated that individuals under the age of five years had the highest risk of developing anaemia, although their study did not consider smaller age groupings within the first five years, such as neonates. They highlight the multiple potential causative agents of anaemia which include iron deficiency, Vitamin C, Vitamin B9 and Vitamin B12 deficiencies, infections, intestinal parasites and other substances associated with absorption of haemopoietic nutrients (Piperata *et al*. 2014). Assuming an adequate nutrient supply and lack of blood related disorders, very young individuals should have enough iron stores at birth to last four to six weeks (Piperata, 2014). With the acknowledged higher risk of external factors leading to anaemia in this age group, a limited store may not be sufficient to combat environmental insults. Cultural factors such as preferential resource allocation may also impact an infant's susceptibility to developing anaemia (Piperata, 2014).

The presence of significant porous lesions in perinatal and neonatal individuals indicates disruption of the fetal supply line and the probability of a compromised maternal condition. In very young individuals it is apparent that the onset of the causative agent occurred during gestation. Other than a compromised fetal supply line affecting intrauterine growth, the presence of infection will also pose a considerable risk to neonatal survival. The 2013 UK neonatal and infant mortality data reveal that one in 200 full-term pregnancies (0.47%, n=3284) result in stillbirth, which is approximately eleven babies per day. Of these stillbirths, 53% have no identified cause of death. Research into unexplained late-term intrauterine death has demonstrated that in one third of prenatal deaths occurring in the final month of gestation no specific cause of death could be identified during autopsy (Craven and Ward, 2002; Frøen *et al.*, 2001; Loo, 2013).

For the remainder, 737 died from asphyxia, anoxia or trauma (antepartum and intrapartum), 513 from complications associated with congenital abnormalities, and 25 from infection (Office for National Statistics UK, 2016). Neonatal deaths in the same cohort (n=3338) were caused by the following in descending order: immaturity related conditions (n=1913); congenital abnormalities (n=856); asphyxia/anoxia/trauma (n=315); and infection (n=84). These statistics are a reminder that the risks of limited oxygen supply, intrauterine and intrapartum trauma, organ immaturity, infection and congenital abnormalities are significant contributors to fetal and neonatal mortality in an environment with advanced medical intervention and support.

As discussed above in Chapter 7 (section 7.5.4.4), a maternal condition that is affected by undernutrition and deficiency throughout pregnancy will predispose the fetus to restricted intrauterine growth and place it at greater risk of hypoxia and associated subdural haemorrhage. Ascending and intrapartum infections place the fetus or neonate at risk of developing rapid onset conditions such as fetal pneumonia or neonatal sepsis. These two conditions are treated with immediate intervention in order to prevent systemic failure and improve the chances of survival. Three individuals within the clinical cases analysed for the current research succumbed to complications associated with intrauterine infections. Two of the individuals (A, 40 weeks and D, 41+ weeks) were stillborn and their death was attributed to amniotic fluid infection. The third individual (B, 40 weeks) had an ascending fluid infection with congenital pneumonia and was an intrapartum death.

The analysis of mortality profiles for very young individuals often reveals a peak in the age-at-death distribution around birth. Although there is demonstrable fetal, perinatal and neonatal mortality, Sayer and Dickinson (2013) highlight that maternal deaths associated with childbirth can occur within the first six weeks following birth. Given this understanding of postnatal mortality, it is likely that a proportion of the neonates and young infants identified through the current analysis succumbed to complications of their birth. The modern understanding of gestation places a ‘term’ pregnancy between 37 and 42 weeks (Spong, 2013). The age category of ‘term’ is further divided into smaller age ranges, each with its inherent mortality risks that are closely associated with the development of organ systems. Within these smaller groupings, it is acknowledged that survival is considerably reduced for individuals born closer to 38 weeks than 40 weeks gestation (Clark and Fleischman, 2011). It is recognised that one limitation of the current research is the broad age range of the perinatal and neonatal categories. In assigning the analysed individuals to an age category, some will undoubtedly have been older perinatal individuals rather than neonates. Recent advances have employed micro computed tomography (micro-CT) to attempt to differentiate between live born and stillborn individuals using perinatal skeletal remains (Booth *et al*., 2016), however the current research did not have the scope to include this type of analysis.

The growth and nutritional characteristics of the newborn at birth are determined by a complex interaction of maternal factors, including pre-pregnancy nutritional and health status, macro- and micronutrient status during pregnancy, and others such as age, parity, birth/pregnancy interval, and environmental or other exposures. (Christian *et al.* 2015). Zhang *et al.* (2016) demonstrated growth deficits in older individuals were directly related to physiological impacts experienced during gestation and within the first two postnatal years. A joint study into childhood malnutrition in 2011 reported that 165 million children aged under five years experienced stunted growth and 18% (29.7 million) had iron-deficiency anaemia (UNICEF *et al*., 2013). Nearly three million annual neonatal deaths now account for an estimated 44% of all under-five deaths globally (Darmstadt *et al*., 2014). Darmstadt and colleagues go on to summarise the changes over the last decade of targeted support for improving neonatal and maternal outcomes. Their synopsis highlights the exceptionally slow improvement for neonates in comparison to older infants and children, and identifies socio-cultural response to perinatal mortality as one of the most significant barriers to change.

Darmstadt (2015) note that although there have been some advances in maternal and neonatal outcomes, there has been "little to no progress in addressing stillbirths" since the implementation of the Millennium Development Goals (MDG). There has also been an increase in maternal and child mortality in regions of social unrest, as well as increased preterm and neonatal mortality (Darmstadt, 2015). Interestingly Darmstadt's assessment of progress made since the implementation of the MDG includes an "increased recognition of the importance of maternal mental health" for improved neonatal outcomes. With regard to the reduction of preventable stillbirths in countries of low to middle income, the most effective obstacles occur at the highest organisation levels giving rise to a lack of support through political prioritisation, policy and funding.

The evidence clearly identifies maternal health as having significant impacts on the development and health of the fetus. These impacts may be compounded in the case of repeated short interval pregnancies in which the maternal condition may not sufficiently recover before each subsequent pregnancy. Such reproductive conditions will lead to increased mortality affecting mothers and very young individuals (Martin *et al*., 1988). The living conditions and nutritional resources in each of the communities also have a considerable influence over the risk of very young individuals developing systemic conditions and their capacity to recover from the same. Apart from the direct physiological impacts of the maternal condition upon the fetus, it is apparent that the broader socio-cultural roles of mother, kin groups and the wider community are also fundamental determinants of health and survivorship of the very young.

The burials of very young individuals are a tangible reminder of the negative outcomes of pregnancy and childbirth. The burials of pregnant females, or mother-fetus double burials highlight the maternal risk of pregnancy and childbirth, which although assumed, is less visible in archaeological remains. Ten females buried with associated very young individuals were encountered during the analysis for the current research; six died while pregnant or during delivery (see Chapter 7, Table 7.1). It is interesting to note that despite the geographical and temporal differences between the burial populations analysed, all ten cases of identified maternal mortality were of females aged between eighteen and thirty years. In a study of southern Indian populations, the highest risk of maternal mortality was found to be in females aged between fifteen and nineteen resulting in 40.2 % of deaths (Marai Bhat, 2002), followed by females aged between twenty and thirty years (Bhatia, 1993; Stoodley, 1999). It is possible that a proportion of females in these higher risk age groups within archaeological burial populations are victims of maternal mortality.

As mentioned in Chapter 5, two of the perinatal individuals associated with maternal mortalities are likely to have been intrauterine deaths as a consequence of maternal death (Çatalhöyük Sk. 13163, 38-40 weeks and the perinate associated with Wetwang Slack adult Sk. 156, 20-25 years). In the case of Wetwang Slack Sk. 156, the perinate is represented by long bone fragments and the right neural arch of S1. The remainder of this individual's remains have been disassociated following excavation, although it is possible that the initial interpretation of a double burial is incorrect and that the few perinatal skeletal remains recorded with the adult female originated from the burial fill. The fetal and perinatal deaths associated with maternal death within the collections analysed include four deaths during early or mid-term pregnancy and five deaths at the end of the pregnancy. The infant (Sk. NA170A) buried with the young adult female (Sk. NA170) in the Wharram Percy burial population has been established as very likely her baby on the grounds that they both share vertebral shifts in the lower spine that are uncommon within the remainder of the burial population, and are a probable indication of a genetic relationship between the two individuals.

8.3.1 Neolithic Sample

The Neolithic population of Çatalhöyük was successful in terms of continuous occupation for nearly one thousand years. Yet, the sample of the burial population includes at least 18 individuals who were born prematurely and died prior to 36 weeks gestation. This suggests that for the mothers of these premature individuals, maternal physiological stress prior to and throughout their shortened pregnancies was significant enough to compromise the viability of the pregnancy. It has been previously concluded that the population at Çatalhöyük experienced normal growth and development (Larsen *et al.*, 2015). This is true for the older individuals in the burial population, however, individuals under the age of six months were not included in their analysis and so this interpretation is only applicable to individuals who survived the first six postnatal months and may have had fewer physiological impacts.

The Çatalhöyük burial sample included twelve individuals with age estimation disparities of at least one month (Chapter 5, Table 5.3). These disparities are indicative of restricted growth and failure to recover during early childhood. This skeletal evidence provides information on the maternal condition prior to and during pregnancy as well as the physiological health of the individuals that survived into infancy. There are multiple possible aetiologies that may result in delayed growth including a compromised fetal supply line during gestation and additional physiological stresses during the postnatal period and infancy.

For the majority of older individuals within the burial population, it appears that environmental stressors did not impact significantly on their capacity to attain normal body size and stature (Hillson *et al*., 2013). There is also very little evidence for dental pathology in younger individuals, with carious lesions occurring predominantly in the heavily worn dentition of adult individuals (Hillson *et al*., 2013). Given that the population at this location was predominantly reliant upon seasonal resources, it is probable that the maternal condition would have been impacted by environmental conditions and resources. It follows that disparities in growth displayed in the skeletal remains of very young individuals may be a reflection of maternal physiological responses to environmental stress. When assessing intra-skeletal age estimation discrepancies, the contribution of genetically influenced factors towards skeletal growth in young individuals should be considered. It is also likely that the intrauterine growth and development of some individuals was affected by individual cases of maternal, or small scale population physiological stress related to environmental conditions and resources. Socio-cultural behaviours are also likely to have played a significant role in conditioning access during periods of limited resources.

Periostosis associated with systemic conditions was identified in a subsample of the burial population at Çatalhöyük; 7% of adults (12/166) and 8% of sub-adults (17/213) (Sadvari and Larsen 2013). Aside from systemic conditions, periostosis was also associated with injury and localised infection. Only one infant was identified during the current research with evidence of inflammation and infection associated with an injury to the left forearm (Çatalhöyük Sk. 21676, 3 months). The details of this skeletal pathology are described above in Chapter 6 (Section 6.5.2).

Six perinatal individuals and one neonate display porous lesions of the maxilla that developed prior to birth (see Table 7.11). Healing is evident in only two of these individuals; one perinate and the neonate. The lesions present in the remainder of the perinates were active at the time of death. Other perinatal and neonatal individuals within the burial population had active porous lesions of the cranial vault at the time of death that are indicative of a compromised fetal supply line resulting in an intrauterine systemic response in the fetus. The severity of these porous lesions evident in neonatal individuals strongly suggests that the onset of the causative agents occurred during gestation.

Eight perinatal individuals display evidence of vertebral and notochordal anomalies. It has been demonstrated that a compromised maternal condition immediately prior to and during the first month of pregnancy is a contributing factor towards the development of neural tube related defects (Greene *et al.* 2011). Given the other evidence for developmental and growth disturbance in perinatal individuals that is associated with maternal condition, it is not improbable that embryogenesis was similarly impacted in the individuals with these anomalies.

One of the most interesting cases of combined mortality is the adult female (Sk. 13162, 25-35 years) and her perinate (Sk. 13163, 38-40 weeks) (Figure 8.1). There is no skeletal pathology evident in the remains of the perinate that suggests any form of compromised fetal supply line. The mother, however did sustain significant skeletal trauma in the form of scapular and pelvic fractures, both of which were healing at the time of death (see Chapter 5, Section 5.5.1.2). As stated above, the age of the perinate and degree of fracture remodelling suggest that the injuries were sustained in a single event, approximately one month prior to death. Although the mode of injury cannot be determined, the fracture locations suggest either substantial direct impacts to both the scapula and pelvis or a combination of forceful abduction of the left upper limb and impact to the pelvis. One plausible scenario among many in which the mode of injury could have been sustained involves a fall from height with unsuccessful interruption using the left upper limb. There is also the possibility of interpersonal violence, although there are no defensive injuries or evidence of other healed skeletal trauma.

Regardless of the mode of injury, the mother clearly survived the traumatic event, although there is no certainty that the perinate did. The healing pelvic fractures are very likely to have affected the mobility of the pelvis required during delivery. Irregularities in the surface of the pubic symphysis and reactive bone evident on the medial surfaces of the pubis, in conjunction with possible connective tissue injuries, provide strong support for labour dystocia. The mother would have been exposed to considerable risk of infection, haemorrhage and undoubtedly exhaustion if labour had started. If the perinate had survived the injury it would also have been at increased risk of infection, hypoxia and haemorrhage during obstructed labour.

Figure 8.1. Burial of the earliest confirmed case of obstetric dystocia from the Neolithic settlement of Çatalhöyük, Sk. 13162 (25-35 years) with the remains of Sk. 13163 (38-40 weeks) visible within the abdominal cavity. The cranium and mandible of the adult was retrieved following burial. (J. Quinlan).

The burial of Sk. 13162 and her perinate dates to the late period of Neolithic occupation at Çatalhöyük (6400-6000BC) (Hillson *et al*., 2013). Lieverse *et al.* (2015) report on a case of obstructed labour from the southern Siberian site of Lokomotiv. The Lokomotiv example also dates to the Early Neolithic, but is more recent (6000-5000BC) than the example from Çatalhöyük. The interpretation of obstructed labour in the Lokomotiv case is based upon the location of the fetal remains in relation to that of the female, particularly the location of fetal postcranial elements between the female's femora and fetal cranial remains within the abdominal and pelvic regions of the female. No apparent skeletal pathology associated with obstructed labour was documented in either the adult or fetal remains in the Lokomotiv case. In light of the significant skeletal pathology in the remains of Sk. 13162 and the abdominal location and perinatal age of Sk. 13163, the author proposes that this double burial can confidently be considered to replace the Lokomotiv case as the earliest confirmed case of labour dystocia.

8.3.2 Iron Age Sample

Adult pathology within the Iron Age burial populations includes degenerative joint disease, fractures, lesions associated with infection and evidence of interpersonal violence (see Chapter 5, Section 5.5.2.2 and 5.5.3.2 for details). The skeletal pathology of older individuals highlights the physiological impact of life within these communities, and the evidence for interpersonal violence provides information about possible exposure to social unrest. Further support for widespread population stress is the shorter than average adult stature within the Gussage All Saints burial population. Although genetic influence over stature is acknowledged, the shorter stature of these adults may indicate environmental stress during childhood that prevented the attainment of optimum stature.

The adult dental pathology observed in the Iron Age burial populations showed a significant increase in type and prevalence compared to the Neolithic population. It included dental carious lesions and abscesses, calculus, dental enamel hypoplasia and antemortem tooth loss. There is evidence that the Wetwang Slack females who died while pregnant suffered physiological stress during their childhood; Sk. 309 was affected between the ages of two and four years, and Sk. 156 between the ages of five and seven years. In both individuals linear enamel hypoplasia is present on the permanent dentition that was forming during these childhood years (Hillson, 1996; King *et al*., 2002; Malville, 1997).

Two cases of maternal mortality were identified within the Iron Age burial populations analysed for the current research. Both of these were adult females in the burial population of Wetwang Slack who died during the second half of their pregnancies (Sk. 156, 25-35 years and Sk. 309, 35-45 years). Both were buried with a baby *in utero*, although this association was lost following excavation. A photograph of burial 309 was taken prior to lifting, and clearly shows the skeletal remains of a fetus within the abdominal and pelvic cavities of the female (Figure 8.2). This adult female died during the middle of her pregnancy of unidentified cause(s). Both of the females buried whilst pregnant also display skeletal pathology of the pelvis. The female (Sk. 156) has a fracture of the right ilium that may have affected the survival of the perinate (see Chapter 5, Section 5.5.2.2). The second female (Sk. 309) has mal-alignment of the sacroiliac joints, asymmetry of the lower limbs and patellar articular surfaces, which indicates that her mobility during life was affected, and may have had implications for the viability of her pregnancy.

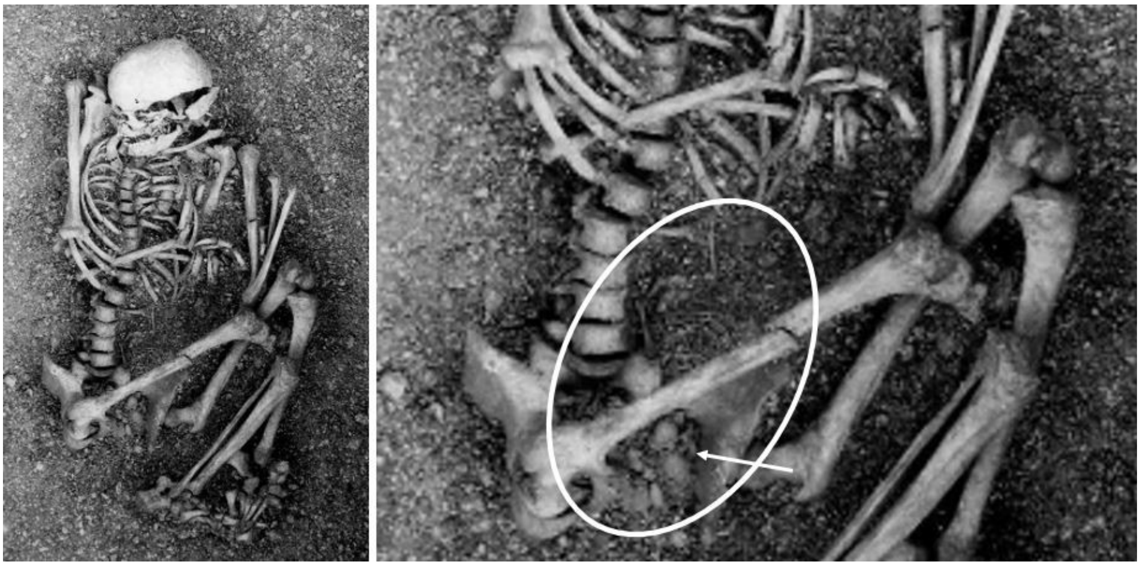


Figure 8.2. Burial of a pregnant female at Wetwang Slack (Sk. 309, 35-45 years). The fetal remains are circled. Note the temporals and other fetal cranial elements within the pelvic cavity.

Of the very young individuals buried at the two Iron Age sites analysed, none were estimated to be younger than 34 weeks gestation and the majority were aged between 38 and 42 weeks. Within the Wetwang Slack burial population, only five infants survived past the first postnatal month, but these infants died before they were one year old. It is acknowledged that individuals who survived infancy and were afforded the same funerary treatment will be represented in the older age categories of the burial population. As discussed in Chapter 5, the mortality profiles of very young individuals do not appear significantly different from natural mortality profiles.

Four of the perinatal and neonatal individuals from the Wetwang Slack burial population have porous lesions of the maxilla, which is associated with nutritional deficiency. The lesions in one of the perinatal individuals (Sk. 7388) displays evidence of healing at the time of death. This is a clear indication that the physiological stress was a discrete event that occurred during gestation, and from which the fetus recovered prior to birth. The aetiology of porous lesions in perinatal and neonatal individuals is very likely the result of a compromised maternal condition. In Sk. 7388, the state of lesion activity demonstrates that the fetal supply line, and probably the maternal condition, was compromised during the third trimester of pregnancy but had recovered prior to the end of the pregnancy.

In contrast to Sk. 7388, the three remaining affected individuals (Sk. 1163, 38-40 weeks; Sk. 159, 0-1 month; and Sk. 3332, 0-1 month) had active lesions at the time of death. This indicates that the fetal supply line was compromised towards the end of the gestation; none of the individuals display evidence of recovery. It is likely that the maternal condition may also have been compromised during this period. As discussed above in Chapter 7, the maternal condition would need to be severely compromised for this type of pathology to occur in perinatal and neonatal individuals. The physiological and immunological state of very young individuals affected in this manner will have had a significantly negative effect upon obstetric outcome and survival.

Several of the burials at Gussage All Saints contained more than one very young individual of similar age at death. The burial contexts indicate that the individuals in burials 34, 132, 139, and 285 were deposited in a single layer and were contemporary burials. This is strong support for an interpretation of multiple contemporary mortalities within this community. There is no skeletal pathology present in these very young individuals that might indicate possible cause of death, however this absence suggests an acute onset and rapid death in the perinatal period.

8.3.3 Roman Sample

There were very few child and adult remains recovered from the Yewden settlement, and those that were recovered, represent a non-normative treatment of the dead (Cocks 1921). The skeletal remains of the older individuals at Yewden display very little pathology. A single adult female provides evidence of generally good oral health with little evidence of periodontal disease, minor calculus, a single carious lesion and antemortem tooth loss. Unfortunately, there were no contemporary older individuals recovered from the settlement site at Barton Court

Farm. As such, it is not possible to comment on the population pathology with reference to specific skeletal remains from this site.

The occurrence of non-metric skeletal traits such as the supracondylar process of the humerus (7/309, 2.3%) in the Roman burial populations analysed, could be an indication that there may have been a limited gene pool in some of the populations analysed. This would predispose individuals within these populations to higher risk from genetically linked conditions, which may have had a significant impact on the mortality of very young individuals. The importance of a limited gene pool lies not only in the skeletal traits associated with genetic inheritance, but also with the myriad of genetic conditions that can involve soft tissue physiology and affect morbidity. Perhaps the most relevant group of genetically linked conditions are those that are associated with the vascular system, such as haemorrhagic conditions, which do not necessarily affect the developing skeleton.

A single neonatal individual (Sk. 869) from the Barton Court Farm burial population has a developmental abnormality in the form of agenesis of the pubic symphysis. As discussed above in Chapter 6 (Section 6.4.3) this skeletal abnormality is associated with exstrophy of the bladder and would have exposed the individual to considerable risk from infection and soft tissue trauma during the perinatal period and afterwards. It is concluded that the complications associated with this pathology would likely have been significant contributing factors to the death of this individual.

The skeletal remains recovered from both sites provide evidence of disruption to the fetal supply line and compromised maternal condition during pregnancy. Examples of unilateral and bilateral changes to the diaphyses of long bones suggest that fetal metabolism may also have been affected. This apparent disruption of longitudinal growth, perhaps associated with restricted intrauterine growth, is evident in very young individuals with thickened or gracile diaphyses of major long bones. There is also evidence of systemic deficiency conditions in the remains of very young individuals from both Roman sites. These include an older infant (Yewden Sk. 21, 9-12 months) with porous lesions of the ectocranial surface and orbits that were active at the time of death. Several perinatal and neonatal individuals have porous lesions of the scapula and maxilla that were active at the time of death. This advanced state of skeletal impact indicates that the onset of the causative agents occurred during gestation, in turn implicating a compromised maternal condition.

8.3.4 Medieval Sample

The adult skeletal pathology within both of the medieval burial populations (see Chapter 5, Sections 5.5.6.2 and 5.5.7.2 for details) included dental pathology such as carious lesions, calculus, dental abscess, antemortem tooth loss and periodontal disease. Dental enamel hypoplasia was predominantly observed in the permanent teeth of older individuals, but at Ardreigh there was a lower prevalence in adults older than 35 years. This may be an indication of changes in physiological stresses over successive generations. The location of linear enamel hypoplasia on the crowns of permanent teeth indicates that the physiological stress occurred when the affected individuals were aged between two and five years.

The adult males in the burial populations were more susceptible to growth disturbance in childhood that affected their attainment of optimal adult stature. This may be a reflection of restricted intrauterine growth and limited catch-up during childhood and adolescence. Other forms of skeletal pathology present in adult individuals were predominantly characteristic of degenerative conditions that are associated with ageing and physical activity, such as degenerative joint disease, and metabolic conditions such as rickets and scurvy. There is an apparent increase in the presence of diseases associated with close animal contact, in particular tuberculosis, that were not identified in the burial populations from earlier temporal periods. With respect to the skeletal stress indicators for metabolic and developmental disruption, it appears that the females and sub-adults in the burial population of medieval Ardreigh were more affected than males, (Troy, 2010).

Skeletal trauma is evident in the adult remains from both of the medieval sites. There are examples of cranial trauma and postcranial fractures, both of which display different stages of healing at the time of death. Troy (2010) noted that the cranial trauma and postcranial fractures were predominantly healed at the time of death in adult males, but the sharp force trauma observed in adult females did not display evidence of healing at the time of death. There is evidence of treatment through trepanation on adult individuals in both of the medieval burial populations. Skeletal trauma in the form of fractures that was observed in younger individuals displays evidence of healing at the time of death, however, there is no support for treatment that involved reduction of the fracture (Troy 2010). Avulsion fractures, evidence of joint dislocation, and fractures of the epiphyseal plates were observed in the skeletal remains of younger individuals in the medieval burial populations.

Examples of possible restriction of intrauterine growth in the form of disrupted longitudinal growth is evident in the diaphyses of the major long bones of very young individuals within the Ardreigh burial population. The same skeletal anomalies were present in very young individuals from the Roman burial populations (discussed above in Section 8.3.3). It is interesting to note that noticeably thickened or gracile long bones were only observed in individuals from the Roman and medieval burial populations. There were no similar skeletal anomalies present in the very young individuals from the Iron Age or Neolithic burial populations.

Four very young individuals from the Ardreigh burial population displayed significantly delayed skeletal development in comparison with dental development that may indicate intrauterine growth restriction. Delayed growth appears to have persisted into early childhood in some individuals, with no apparent recovery of normal growth during the first six postnatal months. There were premature individuals within the Ardreigh and Wharram Percy burial populations. This included eight and eleven, respectively, under the age of 36 weeks gestation and 27 in each population between the ages of 36 and 40 weeks gestation. Some of these very young individuals have porous lesions that are suggestive of anaemia (Ardreigh Sk. 385, 37-40 weeks), inflammation (Wharram Percy Sk. NA4A, 38-40 weeks) or intrauterine infection (Wharram Percy Sk. NA69, 36-40 weeks). Three infants from the Wharram Percy burial population who died before six postnatal months display skeletal pathology that is consistent with rickets (Sk. NA92, 3-6 months, Sk. NA191, 1-3 months, and Sk. NA194, 3-6 months).

The five females who have been identified as victims of maternal mortality within the medieval burial populations all display significant skeletal pathology that is indicative of a compromised physiological condition (Table 8.1). One example is the female Sk. 1505 who had active bilateral porous lesions of the orbit at the time of death, indicating possible systemic anaemia. Both of the females from the Wharram Percy burial population (Sk. G438 and Sk. NA170) had active tubercular lesions at the time of death. An active infection of maternal tuberculosis is positively associated with stillbirth and premature labour (Mittal *et al.*, 2014) and is the most plausible causative agent for the combined maternal and fetal mortality in these cases. The burial of one of the mothers (Wharram Percy Sk. G438) associated with a very pre-term fetus (Sk. G457) is shown in Figure 8.3. Complications related to the early onset of labour may also have contributed to the death of all five mothers.

Table 8.1. Skeletal pathology of the adult females identified as victims of maternal mortality within the medieval burial populations.

Collection	**Adult Female**	**Age**	**Associated Offspring**	**Age**	**Maternal skeletal pathology**
Ardreigh	1087	18-25y	5698	<36w	Dental calculus, carious lesions, periodontal disease, dental enamel hypoplasia, axial and appendicular degenerative joint disease
	1371	18-20y	5833	16w	Dental calculus, carious lesions, porotic hyperostosis
	1505	25-29y	5633	36-40w	Dental calculus, carious lesions, antemortem tooth loss, periodontal disease, bilateral cribra orbitalia, dental enamel hypoplasia
Wharram Percy	G438	25-30y	G457	<36w	Carious lesions, tubercular lesions of the vertebral column
	NA170	20-25y	NA170A	1-2m	Bilateral periostosis of the maxillary sinus, tubercular lesions on lower vertebral column

Figure 8.3. Burial of an adult female (Wharram Percy Sk. G438, 25-30 years). Note the presence of perinatal remains (Sk. G457, <36 weeks) indicated by the arrow.

8.3.5 Modern Comparison

The individuals from the clinical cases have been discussed above in Section 7.5.4.4. These cases demonstrate the significance of a compromised maternal condition for pregnancy outcome. A disrupted fetal supply line directly impacted the survival of four of the individuals (A, C, D and E), while the death of the fifth (Individual B) was attributed to an ascending infection that was transmitted across the amniotic membranes and developed into congenital pneumonia. Although ascending infection is physiologically related to the maternal condition, it may not be reflected in the health of the mother during pregnancy. As the author did not have access to the medical records of the mothers, it is not possible to positively associate the causative agents identified through perinatal autopsy with the maternal condition prior to and during pregnancy.

8.4 Cultural Buffering and Community Response

The interpretation of archaeological burials has undoubtedly drawn significant direction from historical literature. The cultural behaviours and beliefs of past populations as commented on by the classical authors, have provided a basis for early interpretations of past cultures and any associated archaeological remains. These interpretations have been corrected and expanded through the use of modern analytical tools and research approaches.

The socio-cultural systems of past populations are reflected in the treatment they afforded their dead. Responses of the living to mortality are shaped by numerous personal, circumstantial and cultural factors. Extenuating conditions, such as those experienced during periods of conflict or epidemics, will alter these responses (Cannon and Cook 2015). In populations where the majority of the dead are disposed of in an identifiable and consistent manner, it should be possible to observe changes in cultural response through changes in burial practices. It is important, however to consider that variation in funerary practices is also driven by the inevitable processes of cultural change. The archaeological remains of funerary practices provide information on both normative and non-normative behaviours. This is particularly the case for populations that appear to have used a common location for disposing of the dead. The obvious limitation to interpreting this information is the assumption that all dead were disposed of in a manner that resulted in archaeological evidence, which is unlikely to have been the case for all past populations.

Apart from the practicality of disposing of the dead, Sayer and Dickinson (2013) highlight the importance of funerary behaviours as culturally mediated means of acknowledging the identity and loss of individuals. The agency that very young individual have to affect the living is visible through the bioarchaeological analysis of their remains. Their social agency persists after death and influences the behaviour of the living who undertake the appropriate funerary practices. The archaeological examples of maternal mortality during pregnancy provide a tangible sense of the cultural responses to fetal, perinatal, neonatal, infant and maternal mortality in past populations. Lewis (2007) notes the rarity of recovering females buried in this condition, however, this may also be an artefact of missed identification of fetal remains during excavation. All ten females identified during the current research as victims of maternal mortalities, whether the timing of death was in the antepartum period or the weeks following birth, were buried in association with their babies. Aspects of the individual and cultural responses to maternal and very young mortality in past populations can be determined through detailed analysis of the skeletal remains of very young individuals and their bioarchaeological context.

Insight into the personal and social experiences of very young mortality and associated culturally accepted responses is accessible through modern ethnographic research. Scheper-Hughes (1992) found that personal responses to weakened and listless neonates within a poor Brazilian community are predominantly governed by publically sanctioned behaviours and expectations. These responses are mediated through cultural buffering in the form of a common perception that neonatal survival is dependent upon the will of the neonate to live and that of God. This cultural buffering effectively removes the weight of deciding whether or not to sustain a neonate within a very resource poor environment from the mother and family.

The controlled access to breastfeeding may be another form of cultural buffering to protect limited maternal physiological resources. The physiological state of breastfeeding mothers plays a significant role in the availability of breastmilk, which may be of limited supply in under-nourished mothers. It has been demonstrated that a decline in breastmilk consumption among the infants of under-nourished mothers, occurred by the age of two to three postnatal months, and was a significant contributing factor to the development of early childhood malnutrition and delayed growth (Chávez *et al*., 2000). It is likely that differences in weaning age had a direct impact upon the immune response of infants and their ability to cope with physiological stresses associated with the living environment. Immature immune systems may not have been able to cope with the introduction of supplementary foods, particularly when coinciding with dental eruption and the use of teething aids, which may also have posed an increased risk of infection in young infants. The use of wet nurses, who were able to continue the supply of breastmilk if the mother stopped breastfeeding the infant, would have provided the infant with supplementary immunity while its own immune system developed.

8.4.1 The Issue of Infanticide

The archaeological study of the burials and skeletal remains of very young individuals was initially overshadowed by a classical history lens of interpretation (Gowland *et al*., 2014). Early interpretations considered many of the very young individuals to have been buried with little care and these individuals were often referred to as 'disposed of' rather than buried. The suggestion of infanticide was a dominant focus in the interpretation of multiple burials of very young individuals, particularly at Romano-British settlements (Mays, 1993; Mays and Faerman, 2001; Mays *et al*., 2011), and although plausible, it is only one of several possible contributing factors to the mortality profiles of archaeological sites worldwide (Millett and Gowland, 2015).

Aengst (2014) considers infanticide as a means of 'reproductive disruption' in a modern population in the Indian Himalayas where her research examined the wider complex social and cultural aspects of infanticide associated with unmarried females, and the maternal impacts of infanticide. A dominant feature of modern case studies is the public silence surrounding the practice (Aengst, 2014; Briggs, 2007). In contrast to the socio-cultural responses to the practice of infanticide and the reluctance for open public discourse within modern western cultures, the interpretation of multiple perinatal burials associated with an archaeological settlement nearly always considers the role of infanticide and occasionally presumes the very young individuals recovered from these locations to be its discarded victims (for example, Mays and Eyers, 2011).

Given the socially concealed nature of infanticide, it is remarkable that its victims should be buried in locations that appear to have been primarily associated with the burial of very young individuals and openly acknowledged as such. It is considerably more probable that perinatal and neonatal burials in disparate locations away from formal cemeteries and settlement areas are victims of infanticide. Interpretations of burials involving infanticide are not considered for very young individuals buried within formal cemeteries (Gowland *et al*., 2014), and rarely for those buried at other public locations (Sharples 1991). There is no supporting bioarchaeological evidence for the widespread practice of infanticide in Romano-British populations (Gowland *et al*. 2014), and the evidence from other past populations has yet to provide strong support for the practice of infanticide.

8.4.2 Neolithic Sample

Detailed excavation and analysis of the Çatalhöyük settlement has revealed much about the behaviours and culture of the Neolithic inhabitants. The practice of burying the dead in intramural, predominantly domestic, spaces is one key feature at this site. The skeletal evidence indicates that the burial of older individuals was delayed for a period during which the soft tissues reduced in volume and the body was manipulated into the tightly flexed positions observed in the majority of burials. The treatment of very young individuals appears to have differed from that of older individuals in that they are not usually found in such tightly flexed positions. This may simply be a reflection of their smaller size requiring less manipulation prior to burial. They are however routinely buried within baskets or wrapped in woven mats. Simple objects such as shells and beads are found with some burials. The inclusion of these objects does not appear to have been common for all burials of very young individuals, however the majority contained areas of organic material that may have been items such as pouches made from animal skin. Similar organic material has been observed in the burials of adults and interpreted as the remains of hide pouches (Haddow *et al.*, 2016b).

The use of coiled basketry and woven mats in the burials of very young individuals suggests a possible personal response to their deaths. There is substantial evidence of wear on some of the well-preserved baskets that have been recovered indicating that the baskets were already in use within the domestic sphere. Although the process of making a new basket or mat for use in a burial is not a lengthy one, the re-use of coiled basketry, specific to perinatal burials (Willeke and Ryan, 2012), suggests that the importance lay not solely in the basket as an object but extended to its own significance within wider material culture. The inclusion of objects in the burials of very young individuals may reflect personal behaviours in response to mortality within this population. As such, these actions could be interpreted as culturally visible forms of buffering that contributed to mitigating the social consequences inherent in the death of very young individuals.

The burial of individuals under the platforms of domestic spaces highlights that a central cultural response to dead individuals was to physically incorporate them into the domestic spaces of the living. This recognisable end result of funerary behaviours was preceded by processing the dead, extended storage of remains prior to burial, and determination of an appropriate time for burial. Placing burials within the platforms and under floor surfaces of domestic spaces involved the excavation of a burial pit, deposition of the body, sealing the burial and re-plastering, all of which would have resulted in significant disruption of domestic activities. This highlights the socio-cultural complexity and importance of this funerary practice.

Aside from the use of organic objects to contain the remains of very young individuals, the location of their burials also appears to have been an important feature of the funerary treatment. Perinatal individuals were repeatedly placed in the same location over subsequent building phases. For example, the basket burial of Sk. 21678 (32 weeks) was placed in exactly the same position as Sk. 19494 (38-40 weeks) in the next structural phase of building 77. There is no evidence that the burials were marked, indicating that burial location within domestic spaces was culturally governed.

Analysis of the skeletal remains also revealed evidence in support of treatment. The injuries sustained by the adult female (Sk. 13162) mentioned above, would have caused significant pain and in conjunction with her state of advanced pregnancy limited her mobility during the following weeks. It is probable that this female received support in the form of assisted mobility and the provision of nutritional requirements where she could not manage for herself. Only one infant (Sk. 21676, 3 months) has significant skeletal pathology that is suggestive of inflammation and infection associated with a soft tissue injury (discussed in Chapter 6, Section 6.5.2). The osseous response in this individual indicates that the infant survived the trauma. Although systemic complications such as septicaemia may have contributed to this individual's death, the fact that the infant survived for a few weeks suggests some form of treatment of the wound and at the very least, continued breastfeeding and care.

Hillson *et al*. (2013) comment on the evidence for a patrilocal society in which the males remained in their original community and the women moved between communities in the region of the Konya plain. The psychological and physiological impacts of moving to a new living environment may have been substantial for females who were displaced to a new community. This type of socio-cultural system enables the movement of individuals between living environments that may have had differing sources or degrees of environmental stress. If the argument for female movement between communities is accepted, it follows that the pathology evident in the skeletal remains of adult females, and by extension their offspring, may in fact be a reflection of life experience at a site other than the one in which they were buried. The evidence for behaviours associated with very young and maternal mortality in conjunction with changing social circumstances suggest that cultural buffering played an important role in the public response to increasing environmental stress. This is particularly so in the final stages of occupation at Çatalhöyük, a period of changing activity patterns and the gradual decline of the Neolithic settlement (Hillson *et al*. 2013; Hodder, 2006).

8.4.3 Iron Age Sample

The burials from the two Iron Age sites are the reflection of different funerary behaviours. At the smaller site of Gussage All Saints, the burials were recovered within the settlement area. While at Wetwang Slack, a much larger number of burials were recovered from a separate burial ground that extended away from the settlement area (see Chapter 3 for details). At both sites there is minimal disturbance as a result of subsequent burials. The majority of burials at Wetwang Slack were clearly identifiable by their surrounding ditched enclosures, and although the burials of very young individuals were routinely inserted in to these burial enclosures they did not disturb the earlier burials. There is no evidence that the burials within the Gussage All Saints settlement enclosure were marked, however their close association with ditches, pits and structures may have been sufficient to identify the location of burials. The identification of grave location appears to have been an important consideration for both communities. The limited evidence for burial disturbance may also indicate a degree of socio-cultural control over burial placement.

As mentioned in Chapter 5, there is some support for the burial of individuals in kin or family groups within the Wetwang Slack cemetery. An association with a specific kin group could result in the insertion of very young individuals into the existing burials of older individuals. The burial of these youngest individuals within an area that also contains older individuals strongly suggests that they were recognised by the living community as meeting the criteria for burial in these locations. This recognition could have been kin-based, perhaps a reflection of the manner or timing of their death, or countless other unknown criteria. The underlying significance is that very young individuals were buried with older individuals in each community. This in itself is a mode of cultural buffering that maintains the connection between the very young individuals and their community by spatially grouping them with other deceased members of the population.

Some of the Gussage All Saints individuals were buried with items associated with domestic activities and personal adornment such as a red deer antler tip (possibly used as a puncturing tool), bronze brooches, and spindle whorls. The skeletal remains of one neonate (Sk. 661, 0-1 month) has staining on some of the ectocranial surfaces that suggest the use of shroud pins and other objects of copper alloy. As the cranial remains of this individual were highly fragmented, the areas of staining were marked on a replica cast cranium of similar age (Figure 8.4).

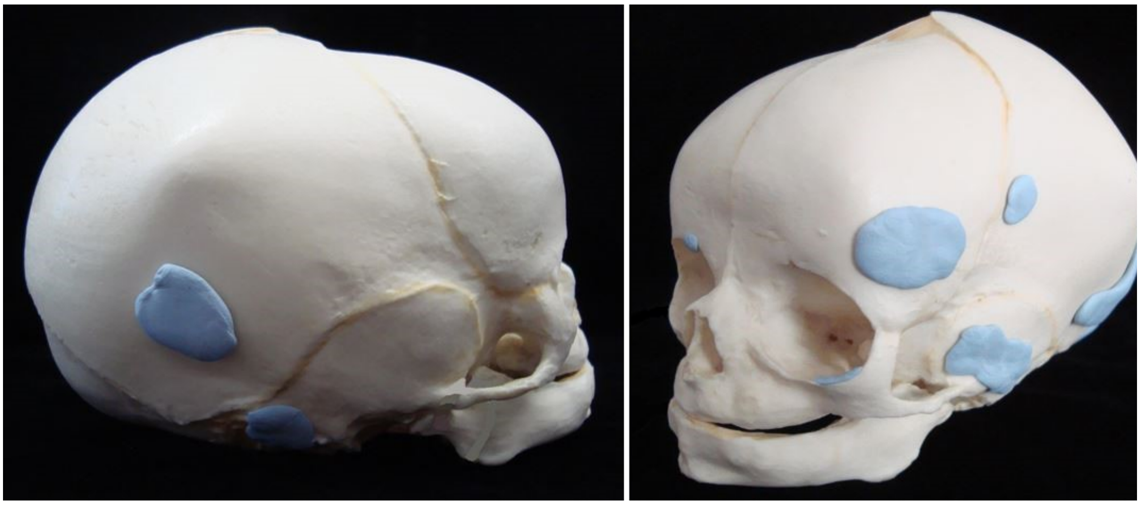


Figure 8.4. Location of staining on the cranium of Sk. 661 (0-1 month), attributed to copper alloy objects.

There is no evidence of skeletal pathology among the remains of very young individuals that might indicate the need for intervention or supportive treatment. Analysis of the skeletal remains of older individuals within the burial populations may reveal evidence that treatment or support was provided. The pregnant female with the fractured ilium (Sk. 156) may have required support following her injury, particularly assistance with mobility. The asymmetry of the sacro-iliac joints in the other pregnant female (Sk. 309) is unlikely to have caused a considerable impairment during life, but may have affected her gait and mobility.

The extensive pathology of adult male (Sk. 285, 20-22 years) highlights the presence of interpersonal violence experienced within the Gussage All Saints community. The injuries appear to have been inflicted with minimal retaliation from the victim and the body was buried in a prone position. These details strongly suggest that the burial of this individual did not follow normative funerary practices for the community. Although this example may have been an isolated occurrence, there is also further evidence of social disruption in the form of a satellite settlement on the other side of the valley that mirrors that of the main settlement. The case of interpersonal violence and the presence of the satellite settlement both occur in the final stages of the settlement, and may potentially have been associated with its decline.

More general information regarding the environmental stress of the populations at the Iron Age sites is available through examination of stable isotope analysis. It has been demonstrated that the Wetwang Slack infants had a limited breastmilk intake with dietary supplementation from a very early age in the form of animal milk or cereal foods. This conclusion was proposed to explain the relatively low stable isotope values of nitrogen and carbon compared to those expected in the skeletal remains of exclusively breastfed infants (Jay *et al*. 2008). An extrapolation of this interpretation is that the low isotopic levels are an indication that maternal capacity for breastfeeding at Wetwang Slack was diminished. The skeletal analysis undertaken as part of the current research suggests that the earlier introduction of supplementary foods and subsequent weaning may have taken place between three and six postnatal months. This early introduction of supplementary foods can be interpreted as a form of cultural buffering in response to the physiological capacity of mothers within the population to sustain exclusive breastfeeding. It is also a strong indication that the population at Wetwang Slack was experiencing limited access to sufficient nutritional resources when these individuals were born.

8.4.4 Roman Sample

Roman culture dictated that inhumation burials were placed within recognised cemeteries located outside the limits of urban centres and settlement sites, and that individuals who died during their first year were permitted to be buried within the domestic environment, usually under floors (Rawson, 1987). All of the very young individuals recovered from the Roman settlement sites died during their first year, and the majority were very young individuals. This evidence provides support for a culturally sanctioned practice of burying individuals older than one year in the common cemetery.

The majority of the very young individuals buried at the Roman sites were located in one area. The clustered distribution of these burials is the result of a repeated pattern of behaviours. Hassan *et al*. (2014) demonstrated that of the twelve Yewden villa babies from which aDNA was successfully amplified, none shared the same mother. This indicates that the clustering of very young individuals was not necessarily associated with family groups, but could have reflected other factors. The lack of genetic relatedness among the very young individuals at Yewden villa sheds further doubt on the interpretation that they were multiple victims of infanticide. It does however, support the presence of a birthing centre with an expected proportion of very young mortality; any maternal mortalities are more likely to have been buried in a formal cemetery.

Aside from the location of burials, the age at death of these individuals does not fit the expected mortality profile for the victims of infanticide. The ages at death ranged from 26 to 44 weeks, although the majority died between 34 and 44 weeks. This indicates that not all pregnancies went to full term and that of those that did, not all babies survived for very long. Although there was no comment on the means of death in the original site report, subsequent analysis of the skeletal remains considered the mortality profile at Yewden to be evidence for the practice of infanticide (Mays *et al*. 2011). In the initial site report Cocks (1921) commented on the disturbed appearance of many of the burials associated with the Yewden villa settlement site. He suggested that the burials had taken place in secrecy and in the dark on the basis that there were no surviving grave markers and that subsequent burials overlaid or intersected earlier ones. The disturbed nature of burials, even within organised cemeteries of extended coffin burials, is a common occurrence and in no way indicates that the very young individuals buried at Yewden villa were the victims of infanticide. Cocks' description of the burials also notes that some of the bodies were placed in an extended position although the majority were tightly flexed as if they had been wrapped or contained within textile (Cocks 1921).

Both of the Roman sites included in the current research reveal aspects of complex funerary behaviours, such as the incorporation of animal crania with burials of very young individuals. This suggests that cultural changes may have been taking place that involved the interplay of pre-Roman and Roman funerary practices, reflecting the complexity of the belief systems within these populations. Millett and Gowland (2015) suggest that the burial of very young individuals conformed to an age-specific funerary behaviour. The absence of a large number of perinatal individuals within formal burial grounds associated with Roman settlements has been considered as evidence that the socially accepted funerary behaviour for these individuals resulted in their burial within other, predominantly domestic, contexts and in close proximity to occupied buildings (Gowland, 2001; Millett and Gowland, 2015; Moore, 2009; Pearce, 2013). This reflects the Iron Age behaviour discussed above, of burying very young individuals within domestic contexts on settlement sites.

The placement of two Anglo-Saxon burials within the disused complex at Barton Court Farm is particularly interesting in that the burials both contained pregnant females. These burials may simply represent a convenient location for burying the dead. There is no support that the females buried during the Anglo-Saxon period, and the population that occupied the site during the Roman period were connected by anything other than burial location. The persistence of an association between the location and burials of very young individuals, and possibly maternal mortalities, may indicate continuity in cultural behaviour at settlement sites within this region.

Carroll (2011) demonstrated that the archaeological evidence for infant mortality within the Roman culture is not necessarily in support of the historical sources or modern interpretations of lack of mourning and little regard for the deceased if they were very young individuals. The Roman attitude towards very young mortality has been frequently generalised and applied uncritically. For example, Cicero's often quoted text, "… when a little child dies the event should be borne with equanimity, nay, if it be only an infant in the cradle, that there is no reason for regret" (*Tusculanes*, 1.39), is always provided without context (see Gowland *et al*., 2014). These lines are taken from a disputation on the stoic philosophy, in particular the philosophical arguments behind accepting the actions of Nature. In contrast to the response dictated by the stoic philosophy, the personal letters that Cicero wrote in this same period as the *Tusculanes* reveal that he was distraught by the death of his daughter. In order to cope with his own devastating grief he states that he read everything available on abating grief and wrote prolifically, in the end producing a book on the matter (Letters to Atticus, 12.14-44).

Cicero had personal experience of maternal and very young mortality. His daughter was a victim of maternal mortality, falling ill and dying within one month of delivering her second son, who survived; her first son had died within a year of birth. In a personal letter dated shortly after his daughter's death, Cicero comments on the provisions he had made for his surviving grandson in his will (Letters to Atticus, 12.18A). The baby had been born in January and would have been less than two months old at this point in time. Despite the very young age of the infant, his grandfather who was a well-known and respected aristocratic lawyer, orator and author, formally recognised the baby's legal rights and inheritance.

The Roman practice of delaying naming of a newborn until it had survived the first week may have been a form of cultural buffering in response to high mortality in this age group (Wilson and Daly, 1994). There was also a prejudice among early medical opinion regarding the viability of the baby as dependent upon the length of gestation. Although this has obvious associations with the development of the fetus, it was commonly believed that a baby born at seven months although weaker was more likely to survive than one born at eight months (Cilliers, 2004). This seemingly illogical understanding provided a form of cultural buffering for perinatal mortality. A widely held perception that neonatal survival was a consequence of the timing of birth removed responsibility and blame from the mother and birthing assistants if the baby was stillborn or died following birth (Hanson, 1987). This type of cultural buffering is likely to have provided some relief during the grieving period and enabled wider social acceptance of the neonate's death.

As discussed above in Section 6.6.2, some of the skeletal remains from the Yewden villa site display evidence of trauma associated with difficult delivery in the form of cut-marks. This has previously been interpreted as potential evidence for embryotomy (Mays *et al*., 2011), a process that amputates presenting limbs or parts thereof in order to remove a fetus that cannot otherwise be extracted without endangering the mother's life. It is suggested in this thesis, that rather than being evidence of embryotomy, these cut-marks are explained more convincingly by the attempted manipulation of limbs to assist in the delivery of a mal-presented baby. This distinction is particularly important as there is no evidence that attempts were made to amputate or reduce the affected limbs. There is other evidence for difficult delivery at this site in the form of a fractured sternal end of a neonatal clavicle. The presence of this specific trauma in neonatal individuals is associated with trauma sustained during a difficult delivery involving dislocation of the clavicle (Beluffi and Sileo, 2009). It should be remembered that the very young individuals from Yewden villa represent the unsuccessful outcomes of pregnancy. Given the evidence for skilled assistance during delivery, it is likely that there were far more successful deliveries at Yewden villa during the Roman occupation of the site.

The impacts on the health of communities living in southern England that were exposed to the Romanisation of the region are evident in the skeletal remains of these individuals. It has been demonstrated that there was an increase in metabolic disease and carious lesions in adults following the Roman conquest (Redfern *et al*., 2012). There is also evidence of a change in infant feeding practices, particularly the weaning diet between the Iron Age and Roman periods.

Redfern *et al*. (2012) concluded that apart from the evidence observed in adult skeletal remains, "the cultural, social and economic transformation … directly impacted the lives of children".

The two Anglo-Saxon adult females buried at Barton Court Farm (see Section 7.2) provide evidence of continuity in the socio-cultural aspects of the populations living in the region across time. Although these burials cannot be temporally associated with the remainder of the burial population, their presence does suggest an ongoing connection with the location. Considered separately, the act of burying two women who died whilst pregnant in a location not associated with a contemporary cemetery may reflect a deviant funerary practice that denied these individuals burial with the remainder of their community. Alternatively, the burial of two victims of maternal mortality in a location associated with the burial of very young individuals may not have been simply coincidental.

8.4.5 Medieval Sample

Both of the medieval burial populations were recovered from cemeteries that appear to have served the immediate community and probably those of the surrounding areas. Each cemetery was associated with a church that was the focus of socio-cultural attitudes towards death and funerary treatment. Individuals were buried in an extended position within coffins or wrapped in burial shrouds. Fragments of woven textile were recovered with the remains of an infant from the Wharram Percy burial population (Sk. NA85, 2-3 months) (Figure 8.5). These fragments are likely to have originated from an item of clothing or a simple burial shroud. The excavations of the Wharram Percy cemetery revealed that there may have been a preferred section of cemetery reserved for the burial of very young individuals (Mays, 2007), although the excavations of the cemetery area are incomplete.

Figure 8.5. Fragments of textile recovered with the skeletal remains of an infant (Wharram Percy Sk. NA85, 2-3 months).

The mortality profile of very young individuals within the Wharram Percy burial population is considered to be a representation of the natural mortality expected for a medieval rural population (Mays, 2007). The range and extent of skeletal pathology evident in the remains of the youngest individuals from this site suggest that very young mortalities at this site were influenced by harsher living conditions and apparent widespread chronic physiological stress. The skeletal pathology evident in the very young individuals from the medieval burial populations highlights the risks associated with childbirth, such as labour dystocia and maternal death. The cranial trauma of a neonatal individual identified as occipital osteodiastasis (Ardreigh Sk. 830) is a clear indication that assistance during delivery was provided by skilled individuals who were able to manoeuvre and successfully deliver a breech presentation.

The cultural practice of delaying marriage until females were older (Gilchrist, 2012) is an indirect form of cultural buffering that is likely to have reduced maternal mortality and may have improved neonatal survival. However, some of the medieval attitudes towards breastfeeding are likely to have had a negative effect on neonatal survival. It was commonly believed that colostrum was harmful to a newborn and should be replaced by a purge; common purges were almond oil, honey, butter, sugared wine, salty water and gruel (Fildes, 1987). Given the modern understanding about the various properties of colostrum and its benefits for the newborn, it is likely that many of the preferred substitutions may in fact have been harmful.

The infants from Wharram Percy were breastfed for a prolonged period with the early addition of plant-based supplementary foods such as cereal gruel (Jay *et al*., 2008). Richards *et al*. (2002) found that the $\delta^{15}N$ values in infant skeletal remains from Wharram Percy approach adult levels after the age of two years. This was interpreted as evidence in support of weaning prior to this age. Given the more recent findings of alternative contributing factors to an elevated $\delta^{15}N$ level, the evidence from Wharram Percy young children may indicate that by the age of two years the majority of individuals had an improved immune response to physiological impacts in comparison with younger individuals. Following an investigation of sub-adults from medieval Irish contexts, Novak *et al*. (2016) highlighted the importance of considering concurrent factors, such as infectious diseases and malnutrition, as contributing factors to elevated $\delta^{15}N$ values in infants. Although the very young individuals from the medieval burial populations appear to display a wider range of skeletal pathology associated with physiological stress and limited gene pools, those that survived early infancy appear to have been less susceptible to any later impacts of environmental stress.

8.5 Summary

This chapter has considered the evidence for maternal physiological stress and fetal response. Consideration of the archaeological contexts of the burial populations enabled aspects of cultural buffering in response to maternal and very young mortality within each population to be revealed. Of the ten adult females identified as victims of maternal mortality among the burial populations analysed, all display significant skeletal pathology that provides detailed information on their physiological state prior to and during pregnancy.

The skeletal pathology of the burial populations demonstrates the presence of several causative agents for physiological stress, such as undernutrition or malnutrition, exposure to infectious disease, and social disruption. The prevalence of dental enamel hypoplasia within the burial populations strongly suggests that the living communities of the respective burial populations were exposed to considerable environmental stress (Larsen, 2010).

With regard to the interpretation of the number of very young individuals represented in the burial populations, and on the balance of the skeletal pathology, it is clear that these individuals were very likely to have been the victims of natural mortality associated with this age group. In particular, the Yewden villa individuals that have previously been identified as victims of infanticide (Mays and Eyers, 2011) are more likely to follow a natural mortality distribution in which the youngest individuals are more at risk in the periods immediately prior to and following birth, an interpretation supported by Gowland and Chamberlain (2002).

Regardless of the cultural context, very young mortalities will impact living communities in terms of a reduction in potential human resources. Although still predominantly intangible, socio-cultural differences within living populations are visible in the funerary treatment afforded to very young mortalities. This indirect agency can be demonstrated to extend to the burial of adult females identified as maternal mortalities, highlighting the role of very young individuals' agency in determining the treatment of the mother and reinforcing the social recognition of the very young individual's identity. There is direct evidence for the populations dated to the historical period, that very young mortalities also had a significant emotional impact on those affected. As stated by Sayer and Dickinson (2013), "the inclusion of an infant or fetus in the grave of a woman was a visually powerful statement".

Community response to neonates and infants that survived birth is evidenced in the funerary treatment afforded to those that died shortly thereafter. During the medieval period, the feeding of infants was apparently managed through a prescribed system of supplementary foods in conjunction with breastfeeding. Medical authors writing between AD1540 and AD1792 advised on the age by which breastfeeding should have ceased, ranging from six to 36 months, however records show that infants were commonly weaned, or had commenced weaning, around the end of the first year (Fildes 1987). The target audience for these publications were predominantly from middle and upper social classes, who routinely employed wet nurses for their infants (Fildes, 1987). The lifestyle of poorer communities both within urban and rural settlements is likely to have placed limitations on the length of time that a mother could breastfeed her infant, in terms of her physiological ability and the need to contribute to the agricultural activities of the community. This would result in the earlier introduction of supplementary foods. The economic burden of maintaining a wet nurse may also have limited the length of time that maternal breastfeeding was financially sustainable. This information suggests that the majority of infants in poorer families were likely to have been weaned at much earlier ages or had supplementary foods introduced at an early age.

The isotopic analysis of carbon and nitrogen in bone collagen performed on infants within the Iron Age Wetwang Slack burial population has revealed that the values of both elements were not high enough to confirm exclusive breastfeeding (Jay *et al*., 2008). The infants of Wetwang Slack appear to have had supplementary foods of animal milk or cereal foods in conjunction with breastmilk from a very early age (Jay *et al*., 2008). In contrast, the infants of medieval Wharram Percy had a longer period of breastfeeding into the second year, but it is likely that other foods were introduced to supplement breastmilk from approximately six months (Mays, 2007; Fildes, 1987). Jay *et al*. (2008) found that the supplementary foods for infants within the Wharram Percy population did not include animal milk, but were most likely to be cereal based. It is not surprising that weaning is now considered to be a significant contributor to increased physiological stress in infants (Mays, 2007).

The study of very young individuals affords us a temporally-reduced reflection of the osteological paradox of palaeopathology. One in which the fetus is more susceptible to physiological insults than its mother, but is artificially sustained through any periods of stress by the ‘life-support’ provided by the mother, even in cases of significantly compromised maternal or fetal condition. This unique situation of life sustained through continued gestation allows the skeleton to be affected, and in some cases to begin to remodel following recovery. In this way the bioarchaeology of very young individuals has the potential to ‘witness’ the sustained life of critically weakened individuals.

Chapter Nine

Discussion

9.1 Introduction

The primary aim of the current research was to consider the aetiology of skeletal pathology evident in the remains of very young individuals and the possible connections with the maternal condition prior to and during gestation. As presented in Chapters 6 and 7, the skeletal remains analysed displayed a considerable range of skeletal pathology that for the majority of cases, can be potentially associated with the maternal condition. The secondary goal was to determine if the discernible information of the physiological condition of very young individuals, and potentially their mothers, could provide more general information regarding the living population. It is acknowledged that results relating to the maternal condition and population stress cannot be extrapolated beyond the specific populations studied. The current research was intentionally critical of the published interpretations of community responses to very young mortalities in past populations. It employed a bioarchaeological approach that incorporated an examination of the funerary practices associated with the remains of very young individuals to reach new interpretations of the socio-cultural responses to their deaths for each of the populations studied.

The findings of this research have extended the current understanding of the history of specific skeletal pathologies and trends in the range of pathology in past populations. The research presented above has demonstrated the impacts of maternal health and stress upon the developing fetus in past populations, and on very young mortalities within these communities. The results support the hypothesis of a close relationship between the survival of very young individuals and the maternal condition. Within the context of single populations, the results strongly suggest that the skeletal pathology of very young individuals reflects the level of physiological stress within the living population. This research presents a unique contribution to the study of juvenile palaeopathology and the bioarchaeology of very young individuals that is founded in empirical evidence and supported by recent studies of developmental and infant pathology.

9.1.1 Limitations of the Research

The current research has several inherent limitations that are directly related to the research material and the current state of knowledge in the field of juvenile palaeopathology. The primary limitation is that aetiologies cannot necessarily be suggested for the observed skeletal pathology in very young individuals. This information is predominantly reliant on advances in the field of developmental pathology, however detailed clinical reports of specific perinatal pathology provide aetiological confirmation for a few of the cases of individual pathology associated with obstetric trauma and congenital conditions, as well as the more severe forms of developmental pathology. For the remainder of the individuals for whom a suggested aetiology is provided, this was determined through the comparison of multiple factors including developmental stage, and detailed descriptions of pathological processes and the expression of confirmed cases in older individuals.

Another limiting factor in the interpretation of juvenile palaeopathology is that it is not always possible to distinguish between the causative agents of a condition that are present in the developing very young individual, independently of the mother, and those that are present in the mother and affect her offspring. For example, the skeletal expression of nutritional deficiency in a very young individual may derive from either individual. It cannot be associated positively with the maternal condition unless her skeletal remains also display skeletal pathology attributed to anaemia, indicating that both individuals were affected by the condition during pregnancy.

There are relatively few palaeopathology studies of large assemblies of very young individuals compared to those with a focus on the skeletal remains of older sub-adults and adults, although this situation is changing. A smaller volume of published palaeopathology research on very young individuals, and in particular of those individuals who were victims of prenatal and early postnatal mortality, has led to a very limited number of detailed comparative cases to assist in the identification and interpretation of pathology observed in new cases. This limitation is partially compensated by the availability of detailed reference publications of skeletal pathology in very young individuals. Barnes (2012) offers descriptions of major developmental pathologies of the skeleton and Scheuer and Black (2000, 2004) include details of the variations and anomalies that have been noted in developing skeletal elements. Despite these resources, there remains a need for a skeletal pathology text focusing on very young individuals in order to improve the consistency of suggested aetiologies and the identification of pathological conditions in the remains of preterm and very young individuals.

To counter the limited reference material of confirmed skeletal pathology in very young individuals, clinical research and case reports were used as a source of comparative skeletal pathology. In some instances this involved considering the skeletal impacts of soft tissue pathology and the development of skeletal pathology in the absence of medical intervention. For the few skeletal remains that have associated documentation, any reference to pathological conditions was very rudimentary and not particularly useful.

The state of the remains themselves was also a limitation to a thorough skeletal analysis. The majority of very young individuals recovered from archaeological contexts were fragmentary and a significant proportion of the individuals analysed were incomplete. This reduced the amount of information available through osteological analysis. The ability to identify fragments to element and region of element greatly enhanced the capacity for assessing the presence and form of skeletal pathology within highly fragmented and incomplete skeletal remains.

9.2 Palaeopathology

The developing body is extremely sensitive to changes in its environment. This sensitivity is exaggerated during gestation and early infancy when growth rates are high. It has been demonstrated that changes in the maternal condition and other forms of environmental stress have the potential to impact the skeleton during development and growth. These impacts are sometimes detectable on the skeletal remains of very young individuals, which is of particular importance, as any skeletal pathology present in fetal and perinatal remains is a reflection of a brief period of time during the human life cycle, defined by the period of gestation. There is significant potential to narrow the timing of onset for observed skeletal pathologies to a specific gestational period using the form of pathology, the elements affected and the degree of skeletal response.

The research was approached without a fixed expectation of the type or degree of skeletal pathology that might be observed. The initial approach to the skeletal analysis was to determine if skeletal pathology could be discerned in the remains of very young individuals and if so, what forms could be identified. The results presented above demonstrate that skeletal pathology can be identified and differentiated from the normal range of appearance in the developing skeletal elements of very young individuals. Two thirds of the individuals analysed (453/671, 68%) for the current research display skeletal pathology. The ages at death of these individuals ranged from 16 weeks gestation to 12 postnatal months, although the majority died in the perinatal period (297/671, 44%). Of the individuals with skeletal pathology, the degree of pathological expression observed ranged from subtle changes to major dysmorphy, advanced lesions and trauma. All of the burial populations analysed contained individuals with endocranial lesions of the vault elements, morphological variation of the sphenoid and non-specific periostosis.

Aetiologies can be suggested for juvenile skeletal pathology based upon an understanding of soft tissue pathology, as is the case for skeletal pathology observed in the remains of older individuals. It was not possible to confidently associate all cases of observed skeletal pathology with the death of these individuals, however it has been proposed that the skeletal pathology was predominantly associated with systemic or developmental conditions. It is acknowledged that the incomplete nature of some of the skeletal remains may have prevented the identification of existing pathology, yet it was possible to identify some specific congenital conditions through the pathology of single elements. For the 32% of individuals analysed (218/671) that did not display evidence of skeletal pathology, the factors that contributed to their early death remain unknown. This group of very young individuals is likely to contain those that died of acute conditions or conditions that did not affect the skeleton.

Although individuals whose age at death is estimated to be approximately 38 weeks of gestation are considered as perinatal in the current research, it should be considered that in modern practice, premature death can be indicated at this age (Clark and Fleischman, 2011; Sengupta *et al.*, 2013). This increases the likelihood that these individuals may have been stillborn or died from complications associated with prematurity. Both neonates and mothers are susceptible to succumbing to complications within the first two postpartum months (Sayer and Dickinson, 2013), highlighting that a proportion of neonatal individuals within the burial populations analysed may have had a low probability of survival at birth.

9.2.1 Form and Distribution

The current research used different, complementary information drawn from the skeletal remains of very young remains to augment that drawn from the adult remains. This allowed the researcher to assess more reliably the health status/burden of the past populations analysed. A wealth of information regarding the physiological condition of the developing individual, its mother, and the potential health of the wider community in which they lived, may be revealed through the study of juvenile skeletal remains. The skeletal remains of the individuals analysed during the current research revealed that some of the burial populations may have been relatively genetically closed with the repeated expression of skeletal traits over time. Several developmental anomalies were identified, while others appear to be outside the range of normal morphological variation but could not be further clarified.

The form of skeletal pathology and the severity can inform the possible aetiology of the pathology and the timing of onset. Diagnostic criteria for the skeletal pathology observed in older sub-adult and adult remains can be applied to the skeletal remains of very young individuals, however the appearance of the developing elements must be taken into consideration. Osseous responses are limited in the form they can take by the processes involved in the development and maintenance of skeletal elements. An example of this is the disruption of metabolic processes through various forms of deficiency. The physiological responses to deficiency can lead to structural changes in bone surfaces. This is often observed in individuals with an inflammatory response in which abnormally increased vascularity results in porous lesions; these are typified by expansion and coalescence of foramina and an increase in the number of perforations in the cortical surface. The age at death of an individual with porous lesions confirms that the underlying condition existed for a significant period of time prior to death.

Hence the presence of porous lesions in a perinatal or fetal individual indicate a compromised physiological condition during gestation.

Another example of how the age at death of a young individual can support different causative agents for the same aetiology is the appearance of muscle attachment sites on the major long bones. If these areas of the cortical surface are pronounced, it indicates a more advanced state of development and activity of the associated muscle groups compared to less distinguished attachment sites. Enthesial alterations of unilateral asymmetry that are unexpected for the developmental age of the individual are also suggestive of changes in muscle activity and of possible intrauterine restriction. The appearance of significantly reduced muscle attachment sites in one or more limbs could indicate neurological involvement such as localised palsy. There is potential to differentiate between possible contributing factors of palsy such as intrauterine restriction or trauma sustained during delivery by considering the age at death of the individual and the degree of pathology associated with palsy. For instance, significant skeletal pathology of palsy in the form of asymmetrical development of major limb bones that is present in a perinatal individual would have developed during gestation and therefore could not be associated with birth trauma. By comparison, pathological characteristics of palsy that are present in a young infant might be associated with a range of possible aetiologies including intrauterine development and trauma sustained during delivery and infancy.

As discussed in Section 7.5.4, endocranial lesions of the cranial vault elements have often been observed in the skeletal remains of fetal, perinatal, neonatal and infant individuals from archaeological contexts. Different forms of these lesions have previously been described and attributed to various aetiologies (Lewis, 2004; Schulz, 2001). It is suggested here that some of these different forms of endocranial lesion represent various stages of a single process in response to inflammation and subdural haemorrhage. It can reasonably be expected that if all forms of endocranial lesion represented normal stages in the development of the elements involved, there would be a consistent change in appearance with age in otherwise healthy individuals. Endocranial lesions are associated with vascular aetiologies and their distribution often mirrors the location of the bossae and thicker areas of vault. As such, it is suggested that localised instances of inflammation and minor haemorrhage play a role in the normal morphological development of the vault elements by increasing the thickness of the endocranial layer. This localised pathology appears to be benign in healthy individuals, which may be due to the baby being supported by the uterine environment. Clinical findings of asymptomatic fetal and neonatal individuals with evidence of subdural haemorrhage in which the haematoma resolves over time with no lasting ill effects (Kelly *et al*., 2014; Rooks *et al*., 2008) provide support for this skeletal pathology being a process in the normal development of the cranial vault elements.

It is apparent that the endocranial lesions observed in the skeletal remains of very young individuals do not consistently follow an age-related scale. Individuals of the same age display varied forms and degrees of endocranial lesion (see Figures 4.1, 4.2 and 4.3). One possible interpretation of this variation is that for the individuals with largely remodelled or minor endocranial lesions located at the bossae or cruciate eminence, the lesions were not a major contributing factor to the individual's death, but are a reflection of normal endocranial development. In those individuals who died with active endocranial lesions, their physiological condition may have been otherwise compromised, which in turn would have affected the development and remodelling of the endocranial lesions. Chronic systemic deficiency, restricted intrauterine growth, hypoxia, and intrauterine infection, all of which have exacerbating effects on haemorrhagic and inflammatory responses, may have been underlying factors in very young individuals with endocranial lesions. In some individuals the endocranial lesions display evidence of remodelling indicative of healing. This suggests that the physiological condition of these individuals had improved prior to their deaths. Despite this evidence for recovery in some individuals, the majority of endocranial lesions were active at the time of death with no evidence of remodelling.

Three individuals (Wetwang Slack Sk. 1160, Wharram Percy Sk. EE59 and Barton Court Farm Sk. UB4) among the individuals analysed were identified with a specific dysmorphy of the sella turcica that is indicative of Trisomy 21, also known as Down syndrome. These three individuals include the earliest case and the youngest individual identified from an archaeological context (see Section 7.4.2.2). The significance of these individuals not only possibly extends the known history of this chromosomal syndrome, it also offers a diagnostic skeletal feature for identifying further cases among skeletal remains.

All populations analysed included cases of genetically linked anomalies of the vertebral column and other non-metric skeletal traits. This demonstrates that these skeletal features can be identified in the remains of very young individuals despite the immaturity of the elements involved. Variation in the prevalence and type of skeletal anomaly between populations could indicate that some of the populations, such as Wharram Percy (intrajugular process and vertebral border shifting) and Barton Court Farm (gracile long bones) had a relatively restricted gene pool that enabled the amplification of specific traits within a population.

Only a few cases of skeletal trauma in very young individuals were identified in the populations analysed. These included two individuals with depressed fractures of the cranial vault (Wharram Percy Sk. NA64 and Sk. NA129), two with rib fractures (Ardreigh Sk. 924 and Wharram Percy Sk. V3), and seven with trauma associated with obstetric complications (see Section 6.6). The identified skeletal trauma display various degrees of osseous response indicating antemortem, perimortem and postmortem timing of injury. This provides information on the potential support provided to the affected individuals who survived for a period following the sustained trauma.

9.3 Maternal Condition

The detailed analysis of juvenile skeletal remains revealed considerable information about the maternal physiological condition during gestation. For the ten identified maternal-offspring pairs only two of the very young individuals display skeletal pathology that could be associated with the mother's physiological state during pregnancy. In both of these cases it is possible to estimate the timing of intrauterine impact based upon the type of skeletal pathology that developed in the young individual (see Section 7.4.2). In contrast, all of the adults in the maternal-offspring pairs displayed significant skeletal pathology that identifies a compromised physiological state prior to and during pregnancy in these females.

The skeletal remains of several other perinatal and neonatal individuals display particular skeletal pathology that provides insight into the maternal experience of labour. Trauma sustained by very young individuals as a result of obstructed labour points to several cases of breech presentation. The maternal outcome of these pregnancies is unknown, however even if the skeletal remains of the mother were identified it does not necessarily follow that they would display skeletal trauma associated with obstructed labour. Only one case of maternal mortality could be associated with obstructed labour based on the skeletal pathology of the mother (Çatalhöyük Sk. 13162). This case, in which the skeletal trauma sustained by the mother is very likely to have prevented vaginal delivery, was identified during analysis and is described above (see Sections 5.5.1.2 and 8.3.1).

9.3.1 Generational Impact

Research into the developmental origins of health and disease considers the epigenetic influence over the inheritance of altered genetic expression with the intention of improving health during adulthood (Gowland *et al*., 2014). Studies on the impacts of maternal health have suggested that the current focus on maximising maternal health prior to and during pregnancy would be more beneficial if directed towards improving childhood health, particularly for females (Roseboom and Painter, 2014). This shift in focus may be better able to counter negative pregnancy outcomes and the later life impacts on adult health of compromised pregnancies. The premise being that the mother’s childhood health has a greater impact on the lifelong health of the developing fetus than her health during pregnancy.

The skeletal remains of very young individuals are a unique resource and have the potential to provide significant information regarding health in past populations. The increasing interest in epigenetics may provide a means of extending the interpretation of skeletal pathology in very young individuals beyond the direct temporal connection with maternal health to the childhood health of contemporary adults. Epigenetic research suggests that the physiological condition of a female child will influence the health of her future offspring (Gowland *et al*., 2014; Sletner *et al*., 2014). Given that the analysis of fetal, perinatal, neonatal and infant skeletal remains can provide information about the mother’s physiological condition in the period preceding pregnancy and during gestation, it is perhaps less surprising that this source of information may also reveal aspects of the health of the wider community for several decades prior to the individual’s birth.

It should be remembered that although the skeletal pathology observed in the remains of very young individuals is a valuable resource, the remains of similarly aged individuals that do not display any evidence of skeletal pathology also provide useful indicators. A lack of skeletal pathology in very young individuals may indicate that the physiological conditions of the mother and developing fetus were not sufficiently compromised to affect the developing skeleton. This may be observed in individuals who have died of acute conditions. It is possible that neither the mother nor the fetus had a compromised physiological condition. In this case it is likely that the baby died from an unknown cause, a situation that continues today and which modern medicine has been unable to prevent (UNICEF *et al*., 2013).

9.4 Population Stress

By considering the palaeopathology evident in the skeletal remains of very young individuals it is possible to assess the general state of the past populations into which they were born. The skeletal pathology described above in Chapters 6 and 7 is substantial both in range and prevalence within the burial populations analysed. Many of the affected individuals display congenital pathology, a significant proportion of which is associated with a compromised physiological state.

The remains of older sub-adults and adults within the burial populations display skeletal pathologies indicative of systemic deficiencies. These pathologies include porous lesions of the cranial elements and long bone deformity, with proposed aetiologies of scurvy, rickets, dietary deficiency and infection. Infectious diseases in the form of tuberculosis or leprosy were confirmed in six individuals from Ardreigh and ten from Wharram Percy, both medieval burial populations, but were not identified in the skeletal remains from the other burial populations analysed. The expression of skeletal pathology attributed to tuberculosis in a few individuals is a strong indication that the infection was present in a much larger proportion of the living population (Resnick and Niwayama, 1995), but was not necessarily active at the time of death, or had not developed to a stage of infection that impacted the skeleton. As the majority of systemic conditions associated with skeletal pathology normally require a longer period of active infection or deficiency before the skeleton will be affected, it is very likely that specific infectious diseases or chronic deficiency were endemic in the living populations.

The prevalence of dental enamel hypoplasia in the adult individuals from the burial populations highlights that the majority of these individuals experienced periods of significant physiological stress during their early childhood. Other forms of dental pathology including carious lesions, abscess and antemortem tooth loss provide information on the diet and general oral hygiene of the living populations.

Non-specific periostosis, skeletal trauma, degenerative joint disease and activity related skeletal pathology were also observed in the skeletal remains of older sub-adult and adult individuals. These skeletal pathologies displayed a spectrum of osseous response with many cases of evident healing and inactive lesions. By comparison, there were few examples of healing and inactive lesions in the skeletal remains of very young individuals. This is primarily a reflection of their young age at death and their greater susceptibility to immunological impacts. The osteological and inferred evidence for the treatment of injuries indicates that medical intervention was a contributing factor in the number of individuals displaying healed skeletal trauma. It is presumed that the majority of skeletal trauma present in the burial populations was sustained through non-violent means, however there is also evidence for interpersonal violence in some of the burial populations, for example the multiple injuries sustained by an adult male in the Gussage All Saints burial population (Sk. 285).

The intrauterine development of porous lesions implicates the maternal and/or fetal physiological state. The maternal condition is more likely to have been the primary contributing factor in the development of porous lesions in very young individuals in populations where the skeletal evidence supports compromised health in older individuals. The infant’s physiological condition can more confidently be isolated as the underlying cause when the characteristics of the skeletal pathology indicate that the onset occurred during early infancy rather than prenatally. It is not necessarily possible to differentiate between a maternal or fetal aetiology for the porous lesions observed in the skeletal remains of those individuals who did not survive long past birth.

The majority of individuals represented in the burial populations display evidence of physiological stress through various forms of skeletal pathology. All life stages from prenatal to mature adult are affected. The skeletal evidence presented in the chapters above demonstrates that each living community, represented by the burials recovered from archaeological contexts, experienced considerable environmental stress. This seemingly broad impact of physiological stress was likely to have been long-term with intermittent periods of increased susceptibility during each generation. There is evidence that adults in some of the populations experienced interpersonal violence although there is also evidence for medical knowledge and treatment in most of the populations analysed. It has been demonstrated that the skeletal pathology observed in very young individuals provides information regarding the compromised physiological state of the developing fetus and of the mother. It also highlights the level of physiological stress within the living population that contained the majority of mothers who were not victims of maternal mortality.

9.5 Cultural Response to Mortality in the Very Young

The cultural responses of past populations to very young mortalities are reflected in the funerary treatment afforded to these individuals, although this information is restricted by the survival of burials in the archaeological record. As with any form of funerary practice, it is expected that a degree of personalisation would have been involved in past behaviours. These personal responses may be captured in the variation of burial characteristics within a burial population that is defined by a dominant funerary treatment. It follows that considerable detail regarding the community and individual responses to mortality is potentially available through the analysis of burial remains within their cultural contexts.

The presence of pregnant females and very young individuals in a burial population is an indication that they had a recognised connection with the living population and were subsequently included in the communal burial ground following their deaths. This form of inclusive funerary treatment with the remainder of the burial population also suggests that, for the majority, the circumstance of their deaths did not perceptively alter their burial treatment. Two different responses to funerary treatment with regard to very young individuals were noted in the burial populations analysed. The most striking of these is a separate burial location apart from the remainder of the burial population, as evident at both of the Roman villa sites; Barton Court Farm and Yewden. The very young individuals in the burial population of Çatalhöyük were buried along with other individuals of all ages across the site in the normative practice of intramural burial. At Çatalhöyük it is the pre-deposition treatment of very young individuals that differed substantially from the remainder of the burial population; specifically the body position within the burial.

The very young individuals recovered from Iron Age and Roman contexts in Britain are also the result of more complex behaviours than simply burying the dead. Scott (1991, 117) proposes that unusual deposits of faunal and human remains along with objects such as leather shoes and building debris in wells on settlement sites may reflect complex ritual activities, and have mistakenly been previously interpreted as evidence for interpersonal violence and disposal of unwanted items as backfill (Branigan, 1972; Cocks, 1921; Eyers and Jewsbury, 2011; Miles, 1986). The human remains recovered from a well within the settlement area at Yewden villa may have been part of a ritual deposit or perhaps the circumstances of their deaths may have required a different funerary treatment from the remainder of the burial population.

The proximity of very young individuals to areas associated with agricultural activity within Roman settlement sites, such as malting floors and furnaces, has been interpreted as a connection between the selection of burial location for very young individuals and cultural perceptions of fertility (Scott, 1991). The majority of very young individuals recovered from within the settlement areas of the Roman sites of Yewden villa and Barton Court Farm were located in the same areas as furnaces. The similarities in the burial treatment and location of these individuals at the two Roman period settlement sites and at contemporary settlements across Britain, as well as other characteristics of these sites such as ritual deposits, are a strong indication that there was a shared pattern of culturally sanctioned behaviour between populations. The archaeological peculiarities of each settlement are therefore more likely to be reflections of community specific behaviour than of the wider culture.

The Roman burials at Barton Court Farm and Yewden villa contained very young individuals between the ages of <28 weeks gestation and 12 postnatal months. At the Iron Age settlement of Gussage All Saints the burial population did not include individuals aged between one month and 18 years or between 25 and 35 years. This under-representation of certain ages is likely to be a reflection of the selection processes behind funerary treatment and burial location, however possible changes in the demographic profile of the living population could also influence the age distribution of a burial population.

The mortality risks for individuals during the perinatal and neonatal periods are significant enough to result in the number of very young individuals represented in the burial populations analysed. It is proposed here that the majority of perinatal and neonatal individuals identified in the burial populations analysed were victims of natural mortality. This interpretation is supported by the palaeopathological and contextual evidence presented in the chapters above. Although it has been previously suggested that some past communities, for example the inhabitants of Yewden villa, may have had socially sanctioned controls over population growth that involved practices such as infanticide, there is insufficient evidence in support of these conclusions (Gowland and Chamberlain, 2002; Mays and Eyers, 2011).

There is little dispute that very young mortalities have an impact on social groups from small family units to large populations. A reduction in potential human resources will affect the economic and possibly functional stability of a population. The response of the living population to the treatment of very young individuals after death provides insight into the cultural, social and individual attitudes towards mortality in this age group (Sayer and Dickinson, 2013). In effect, the very young individual continues to have agency within its community. This influence apparently extends to females who died while pregnant, in that their burials also tend to display differences to the burials of non-pregnant females.

Even in the more organised and inclusive burial grounds of the medieval populations, very young individuals are predominantly buried within particular areas of the cemetery. Although juveniles in the Wharram Percy burial population were recovered from all areas of the cemetery, the area adjacent to the north wall of the church contained more burials of individuals aged under two years (Mays, 2007). Coincidentally, it was estimated that the majority of infants had been weaned by this age (Richards *et al*., 2002). This may be an indication that age at death, or transition between social roles, was an influencing factor in burial location within the communities using the cemetery.

9.5.1 Supporting Mothers

The detailed information obtained through the analysis of the very young and maternal skeletal remains can potentially provide insight into the support of pregnant and breastfeeding females within their community. This involves considering the skeletal remains through a bioarchaeological lens with respect to behaviours that can be indirectly associated with the remains and their contextual setting.

Assessing a burial population for evidence of very young mortality and maternal health assumes that all victims of fetal, perinatal, neonatal and infant mortality within a past population were recovered with the remainder of the burial population. This is somewhat unlikely, as a proportion of these individuals probably remain unrecovered or were disposed of by other means. A more plausible assumption is that a representative proportion of these very young individuals were recovered with the burial population. At all of the sites analysed the majority of the very young individuals were perinatal or older, with only a few having died in the second or early third trimester. This indicates that the majority of pregnancies represented in the burial populations were carried to term, or just before term. Aside from any skeletal pathology displayed in these remains, the evidence that they were carried to near term indicates that the physiological state of the mothers was sufficient to sustain a pregnancy through gestation. It can therefore be concluded that the mothers were not so unhealthy that they couldn't sustain a pregnancy, however the majority of mothers did have compromised health during their pregnancies as demonstrated by the skeletal pathology associated with maternal condition that was observed in their babies' remains. This skeletal pathology indicates that the mothers' physiological condition was compromised to an extent that affected the developing fetus. This indirectly implies that mothers received support in order to sustain pregnancy. Possible forms of community support might have included preferential access to dietary resources and the differential treatment of pregnant females within a community in direct response to their pregnant state.

Alternatively, some of the pregnant females within the populations studied may have been individuals who were relatively resilient to physiological stress and managed to carry their pregnancies to term despite the presence of chronic conditions. The impact on the baby in this situation is likely to have been considerable, with survival significantly reduced as a result of compromised neonatal health.

This consideration of the wider contexts of very young and maternal mortality within the populations analysed suggests that a significant proportion of each living population was affected by compromised health and possibly limited dietary resources. It is proposed that within these populations, the mothers experienced environmental stress that did not necessarily lead to preterm delivery, but that did impact the health and survival of neonates and infants.

The form and extent of juvenile skeletal pathology also provide information on the probable contributing factors, timing and duration of physiological stress experienced by the mothers during gestation, as considered above in Chapter 7. With regard to assessing the maternal skeletal remains for evidence of support provided during their pregnancies, it is clear that the cases described in Chapter 8 display skeletal pathology that included healing fractures, systemic deficiency, degenerative joint disease, poor oral health, infection and infectious disease, and impaired mobility. These are not inconsiderable forms of skeletal pathology and indicate significant physiological impact for the individuals affected. Given that most of these females carried pregnancies to term while affected by the various conditions listed above, and also that conditions resulting in skeletal pathology do not necessarily exist in isolation, it is likely that support was provided to these individuals during pregnancy, if only to improve the mother's health.

Despite advances in medical knowledge and the ability to detect and treat conditions that affect the health and survival of mothers and offspring, there is still significant mortality of very young individuals that cannot be attributed to any specific aetiology (UNICEF *et al*., 2013). It has been demonstrated that cultural behaviours and beliefs can be both beneficial and harmful to mother and offspring, highlighting that the balance of survival does not solely lie in advanced medical knowledge. In populations with access to advanced medical care and intervention there have been significant decreases in perinatal and maternal mortality (UNICEF *et al*., 2013), but it must also be noted that many of these cases require immediate emergency response in the peripartum period. Evidently, this form of support is not available to mothers giving birth outside of hospitals and specialist facilities.

Stone (2016) proposes that some of the complications affecting neonatal survival and the maternal experience of birth have been influenced by a shift in cultural beliefs since the 19th century; specifically the changes in perception of the process of birth and the female pelvic structure. This period also saw a change in the preferred birthing environment in western societies. Birth had traditionally taken place within the domestic environment, but the hospital became the primary location for delivery, presumably in order to address the perceived risks of birth. Stone's paper challenges the increased risk that cephalo-pelvic disproportion has for feto-maternal mortality and also that biomedical control over birth reduces obstetric risk. Her opinions highlight the potential for modern assumptions to inadvertently inform interpretations of maternal and very young mortalities in past populations for whom the socio-cultural attitudes towards birth and its associated mortalities are likely to have been different. A patent example of these socio-cultural differences is the variation in funerary treatment for the victims of very young and maternal mortality.

9.5.2 Supporting Neonates and Infants

Cultural control over the infant diet, the introduction of supplementary foods, and the timing of weaning may have been necessary in populations with limited or an unreliable supply of resources. Increased physiological and socio-cultural demands on mothers may have reduced their capacity to continue breastfeeding, leading to the earlier introduction of supplementary foods and weaning. Within smaller agricultural communities any other females who could have provided support through breastfeeding infants may possibly have shared the same limitations as the mothers. It is also probable that cultural attitudes towards the feeding and weaning of infants were influenced by other factors that had little relevance to the physical state of the mother or the infant, such as a belief system.

Analysis of nitrogen and carbon stable isotopes performed on the infant remains indicated that the infants from one of the medieval populations, Wharram Percy, received supplementary cereal based foods in conjunction with breastmilk from approximately six months (Mays, 2007). Although early supplementary foods were incorporated into the infant diet, they continued to be breastfed until around two years of age (Mays 2007; Fildes, 1987). The infants from the Iron Age site of Wetwang Slack did not display similar indications for long-term breastfeeding. Isotopic analysis revealed that supplementary foods of animal milk and cereals were introduced at a very early age (Jay *et al*., 2008). This is supported by the skeletal pathology present in individuals that suggests weaning took place between three and six postnatal months. Weaning is a recognised contributing factor to physiological stress in infants (Mays, 2007). The early introduction of supplementary foods and reduction in breastfeeding, in conjunction with the underdeveloped immune system of very young individuals, will undoubtedly have a significant impact on survival (Chávez *et al*., 2000).

Apart from nutritional support during infancy, there is also evidence that several communities provided support through the care and treatment of infants. This evidence is reflected in the various skeletal pathology observed in the remains of very young individuals. The type of skeletal pathology and the state of lesion activity at the time of death can provide indirect evidence of treatment and support for the affected individuals, as presented in the few examples below. As detailed in Sections 6.5 and 6.6 a number of individuals survived for a period after sustaining trauma, allowing for an osseous response to develop. The youngest of these individuals was the perinatal case of occipital osteodiastasis from the Ardreigh burial population (Sk. 830). The trauma involved the formation of lesions in response to haemorrhage and connective tissue trauma, and although this individual survived for a short period following birth, the injuries sustained would have been difficult to assess and treat as they are predominantly endocranial. One of the individuals with a cranial vault fracture is likely to have only survived for a short period after the trauma was sustained as the osseous response is relatively limited. There is little that could have been done to improve the condition of this individual, who would have experienced intracranial haemorrhage and possibly seizures.

The skeletal pathology observed in three older individuals, two from the medieval burial populations and the third from the Çatalhöyük burial population, provide more substantial support for treatment. The individual from Çatalhöyük (Sk. 21676, 3 months) has an osseous response attributed to soft tissue injury and inflammation. The consistent appearance and evidence of remodelling suggests that the wound was repeatedly treated, allowing for soft tissue healing (see Figure 6.51). The remodelling evident on the fracture surfaces of the avulsion rib fractures in an older infant (Sk. 924, 6-9 months) from the Ardreigh burial population indicates that the individual was likely cared for in the period following the injury (see Figure 6.59). The trauma sustained would not necessarily incapacitate the infant, although it is likely that the muscle involvement indicated would have affected the use of the upper limbs. The third case of probable care is demonstrated in an older infant (Sk. V10, 6-9 months) from the Wharram Percy burial population that has extensive ectocranial and scapular porous lesions attributed to anaemia (see Figures 6.43 and 7.21). These lesions were active at the time of death, but there is also evidence of healing and inactive lesions that indicate past recovery. This combination of skeletal pathology reflects a short life of less than twelve months during which there was a pattern of multiple periods of compromised health followed by recovery.

Intervention in the form of treatment and supportive care is fundamental to increasing the likelihood of very young individuals surviving and recovering from episodes of severe physiological stress. It follows that the skeletal pathology observed in the remains of very young individuals is often evidence in itself that some form of external support has been provided. The ability to survive successive events of compromised health points to the continued provision of care from others who were involved in the physical welfare of the youngest individuals within the respective communities.

9.6 Maternal Health and Population Stress

The contextual information for each of the burial populations was provided in Chapter 3. This information included aspects of the living environment and experience within the associated past communities. Insight into the site specific cultures was enabled by the detailed excavations at each location, recovering substantial material culture that can be connected with particular activities and behaviours. These detailed contexts are a direct connection with the living populations that created them and offer a means of assessing a range of environmental stressors specific to each of the past communities. The skeletal pathology observed in the burial populations is a reflection of some of the same environmental stresses experienced by the living population. By using a bioarchaeological approach to the interpretation of skeletal pathology, the assessment of population stress can be approached through contextual and pathological analysis to develop the most probable conclusions for each population.

9.6.1 Çatalhöyük

The burial population at Çatalhöyük contained a number of adult individuals who had been unable to recover from growth delays experienced during childhood and adolescence leading to significantly shorter stature compared with adults from other contemporary populations in the area. Adult skeletal pathology in the form of periosteal lesions associated with infection and injury, and evidence of systemic conditions such as deficiency provide insight into the physiological stress experienced by the older individuals within the burial population. Degenerative joint disease associated with activity increased in prevalence with age, indicating that the majority of adults were involved in strenuous or repetitive physical activity. The single case of confirmed maternal mortality displayed significant skeletal trauma in the form of postcranial fractures to the scapulae and pelvis with healing evident at the time of death. The skeletal pathology in the remains of older individuals in the Çatalhöyük burial population indicates that a proportion of the community experienced compromised health during their development which led to reduced adult stature, while there is evidence for a more widespread physiological impact from physical activity, systemic deficiency and infection.

Nineteen of the very young individuals in the Çatalhöyük burial population had significant disparities in their age at death estimations for skeletal and dental development. These differences are sufficient to imply that the maternal condition during pregnancy was a contributing factor towards restricted intrauterine growth. The presence of vertebral anomalies associated with neural tube defects and anomalous notochordal variation in eight very young individuals are likely to have been underlying factors in their early death. This is particularly the case for preterm delivery at approximately 34 week's gestation for one such individual (Çatalhöyük Sk. 10366.1). Eighteen other individuals were born before term between 26 and 36 weeks gestation, and 45 died at around 38 weeks gestation. It is acknowledged that these marginally older individuals could still have been born slightly prematurely, affecting the likelihood of their survival.

Skeletal pathology indicative of anaemia or infection was observed in the remains of nine individuals aged between 36 weeks and one postnatal month. This expression of skeletal pathology in very young individuals provides information on the maternal physiological state during pregnancy and the potential presence of intrauterine infection. It also suggests that there may have been cultural or resource related limitations that affected maternal nutrition and health during pregnancy. These conditions could arise from insufficient maternal nutrition resulting from resource-poor environments such as periods of famine, or the intentional differential treatment of pregnant females with regard to nutritional resources. Insufficient nutrition may also have affected individuals experiencing chronic infection, females who fell pregnant during adolescence, and those with a short interval between pregnancies.

Regardless of the aetiologies behind the cases of very young mortalities within the Çatalhöyük burial population, the burials of these very young individuals provide details of their treatment following death. The vast majority of burials retain the remains of woven plant textiles in the form of mats and baskets. There is also evidence of organic lining material, the use of pigments (Haddow *et al.*, 2016b), and the inclusion of items of personal adornment such as strings of shell beads, shells, and in one case tracheal rings of a goose. These all point to personal variations in a ritualised cultural behaviour. Another variation in the funerary treatment of very young individuals is suggested by the lightly flexed body position of their burials compared with the tightly flexed body positions that are common in the burials of children and older individuals. This different treatment of very young individuals appears to have also been applied to the identified victim of maternal mortality.

9.6.2 Gussage All Saints

The adults within the burial population of Gussage All Saints display skeletal pathology that indicates they suffered from a range of chronic systemic conditions. There is also considerable evidence of degenerative conditions and trauma associated with activity and interpersonal violence. The degenerative pathology includes eburnation, vertebral collapse and degenerative joint changes in the hands, knees and feet. These pathological changes were observed in individuals that are not particularly advanced in age, which suggests that repetitive physical activity was an exacerbating factor in their development. The evidence of healed fractures among the skeletal trauma in the adult remains demonstrates that despite a relatively high occurrence of serious injury the affected individuals had access to treatment and support through recovery. The estimated statures of the adults within the burial population are relatively short, which may indicate that the adult population failed to attain optimum stature. The range of adult skeletal pathology associated with chronic systemic conditions, in conjunction with shorter adult stature, suggests that the adults within the Gussage All Saints burial population experienced compromised health during their childhood.

The majority of very young individuals (32/35) recovered from the settlement site died towards the end of gestation, during the perinatal period. The skeletal remains of these very young individuals display limited skeletal pathology, however there is a relatively high prevalence (20/35) of endocranial lesions. This is likely to be an indication of compromised physiology in the affected individuals and in particular, a reflection of the maternal condition during pregnancy. Further evidence that the very young individuals in the burial population at Gussage All Saints experienced physiological stress during gestation lies in the premature delivery of an individual (Sk. 34.4) at approximately 36 weeks gestation and the abnormal porosity of cranial elements associated with anaemia in a perinatal individual (Sk. 132.9).

The contextual evidence indicates that the population of Gussage All Saints experienced significant changes that may have resulted in social disruption. These involved the creation of a satellite settlement and reinforcing existing structures within the settlement. A distinct increase in cereal processing and textile production also occurred towards the end of occupation, which could suggest population growth or the development of external influences such as taxation. On considering the skeletal pathology of compromised development, deficiency and degenerative conditions as well as the structural and production changes reflected in the contextual material, it becomes apparent that the population of Gussage All Saints were subjected to significant environmental stress.

It is acknowledged that this interpretation makes assumptions about the socio-cultural context of the population at Gussage All Saints. It is possible that the instances of interpersonal violence were socially sanctioned and that the apparent reinforcement of existing structures and the development of a satellite settlement across the valley were not necessarily in response to social unrest. The community of Gussage All Saints however, was situated within a landscape of agricultural intensification and multiple contemporary settlements, and the bioarchaeological evidence supports an interpretation of a population that experienced significant physiological stress over an extended period of time.

9.6.3 Wetwang Slack

The adults recovered from the Wetwang Slack cemetery do not display a significantly different range in stature to other comparative populations, unlike those in the Gussage All Saints burial population. This suggests that the majority of adults were able to attain optimum stature despite any potential growth delays they may have experienced during childhood or adolescence. Adult skeletal pathology included degenerative joint disease that affected the vertebral column and major limb joints as well as the hands and feet. There were also a number of examples of ante-mortem fracture, the majority of which had healed successfully. Postcranial fractures of the upper body included a few cases that could be potentially identified as defensive injuries (fracture of the forearm) or interpersonal violence (cranial depressed and sharp force fractures), and a few individuals had developed osteomyelitis following a significant skeletal trauma. These injuries demonstrate the risk of considerable injury among the Wetwang Slack population. They also highlight that although treatment was available it was unable to address significant infections.

Aside from skeletal pathology, the adult remains exhibited an array of dental pathology that included dental enamel hypoplasia and periodontal disease. The presence of enamel hypoplasia indicates that a proportion of the adults in the burial population experienced physiological stress during the period in which the crowns of the affected teeth were forming between the ages of two and five years. These two indicators for childhood stress suggest that adults were variably affected by physiological stress during periods of sub-adult growth and that the majority were able to recover and survive into adulthood.

The majority of very young individuals (31/36) in the burial population died within the perinatal and neonatal periods demonstrating that pregnancies were predominantly carried to term; only one individual (Sk. 7154) was delivered significantly prematurely at approximately 35 weeks gestation. Although mothers were able to sustain a pregnancy throughout gestation, the neonates may have been exposed to significant mortality risk as a result of compromised intrauterine development. This is apparent in the very young individuals with skeletal pathology attributed to infection and anaemia. Only a small number of infants (3/36) in the burial population died in the second half of the first year. This may be an indication that the mortality risk was significantly reduced after early infancy. The age at death of the very young individuals in the burial population supports an interpretation of high mortality in the perinatal period, marked improvement in survival rates after the first postnatal month and a slight increase in mortality during the second six postnatal months. This slight increase in infant mortality between six and twelve months may be associated with the introduction of supplementary foods and related impacts on the developing immune system.

Several congenital anomalies were observed in the burial population of Wetwang Slack that indicate the population had a relatively closed gene pool with repetition of skeletal traits such as persistence of the metopic suture, extra-sutural ossicles and vertebral border shifting over several generations and across all age groups. The skeletal pathology of the very young individuals suggests that their mothers, and possibly a larger proportion of the population, experienced physiological stress during the period of their gestation. The presence of childhood indicators of physiological stress in adult skeletal remains along with evidence of trauma, infection and deficiency point to an adult population that was exposed to various forms of environmental stress within an apparently consistent socio-cultural context. The juvenile skeletal pathology provides a similar picture of maternal health within the Wetwang Slack community. It suggests that the majority of very young individuals (26/36) experienced some form of physiological impact during gestation, most likely as a result of compromised maternal health.

9.6.4 Barton Court Farm

The Roman burial population of Barton Court Farm only contained the skeletal remains of very young individuals. Despite the absence of older individuals it has been demonstrated that the remains of very young individuals can provide insight into maternal and population health. Of the skeletal remains recovered, the majority (44/55) had died in the perinatal period, several individuals (7/55) died during the first postnatal month and a few (4/55) during later infancy. Only a single individual (Sk. 1169) was born prematurely at less than 36 weeks gestation. This mortality distribution indicates that the maternal condition during pregnancy was sufficient to support both the mother and developing baby to term, or that those not carried to term were disposed of in some other location or by other means.

The skeletal pathology of perinatal and neonatal individuals within the Barton Court Farm burial population includes a high prevalence of endocranial lesions as well as active porous lesions of the maxilla that are suggestive of systemic deficiency. These two forms of skeletal pathology reflect the physiological condition of the affected individuals prior to their death and by association, the maternal condition during gestation. The skeletal remains at Barton Court Farm indicate that the majority of individuals experienced significant physiological stress that had a skeletal impact. The maternal physiological condition is likely to have been compromised during gestation, although not to an extent that resulted in premature delivery.

The presence of significant developmental pathology is likely to have been a contributing factor to the early death of affected individuals. There is additional evidence that some individuals experienced intrauterine growth restriction that impacted the development of normal long bone proportions. The combination of rare developmental pathology, intrauterine growth restriction, and systemic deficiency provide substantial evidence that maternal health prior to pregnancy was compromised, affecting embryonic and early fetal development. That these mothers then sustained the developing fetus through gestation is a strong indication that they received support throughout their pregnancies. Although this support would have improved their overall physiological condition, the juvenile skeletal pathology indicates that improvement in the maternal condition during pregnancy was limited.

9.6.5 Yewden Villa

The three adults recovered from the Yewden villa settlement site were part of a non-normative deposit. Although these adults are unlikely to constitute a representative sample of the living adult population, it is probable that they were members of the Yewden population. Their exclusion from a community cemetery indicates that they were considered differently from the rest of the living population with regard to funerary treatment. Only one pathological lesion was observed in the adult remains; a localised area of periostosis on the tibial diaphysis with evidence of healing. The minimal skeletal pathology observed in these adults indicates that they may have been less susceptible to the skeletal impacts of physiological stress, that their exposure to physiological stress was less in comparison to the adults within the other populations analysed, or that if physiologically compromised they died before the skeleton was affected.

In contrast, the skeletal remains of very young individuals display a range of pathology that is attributed to anaemia, infection, delayed development and perimortem trauma. Half of the very young individuals (28/56) had active endocranial lesions at the time of death. Active porous lesions of the cranial vault and orbits associated with anaemia and nutritional deficiency were present in the skeletal remains of perinatal and neonatal individuals. As stated above, the presence of active porous lesions in newborn individuals is an indication that they experienced significant physiological stress during the last few months of gestation. In slightly older neonates, this stress may have been exacerbated by numerous environmental factors such as infection. The compromised health of these very young individuals points to a similar physiological condition in their mothers, with infection and limited nutritional resources being the most probable contributing factors towards compromised health in both the very young individual and the mother. The premature delivery of four individuals between 26 and 36 weeks gestation, as well as the high prevalence (29/53) of perinatal and neonatal skeletal pathology associated with compromised health, indicates that the mothers of the babies buried at Yewden villa had experienced considerable physiological stress during their pregnancies.

Three of the very young individuals in the Yewden villa burial population have skeletal evidence of perimortem trauma in the form of cut-marks. As discussed above in Section 6.2.2, the probable aetiology and interpretation of this perimortem trauma may be associated with labour dystocia and attempts to assist in the delivery of the babies. There is no medically plausible explanation for cut-marks to have been sustained in the postnatal period. Although embryotomy has previously been suggested by Mays *et al*. (2014), this interpretation is highly unlikely as the cut-marks do not display any evidence of an intention to dismember or remove the lower limbs or portions thereof. Further evidence for assisted delivery was apparent in the multiple skeletal pathologies observed in another neonatal individual (Sk. 20). The proposed aetiology in this case is traction of the presenting limb leading to fracture and localised inflammation.

The skeletal pathology of very young individuals provides substantial supporting evidence that maternal health was compromised during pregnancy to the extent that seven individuals were delivered prematurely. The majority (42/56) were carried to term but their survival was affected by their own compromised physiological condition and the circumstances of their delivery. Although it appears that the perinatal and maternal health of the individuals represented in the burial population of Yewden villa was severely compromised by several factors, it is probable that at this location there was also specialist obstetric support available. It is possible that a number of the assisted deliveries were successful and that those that were not are represented in the skeletal remains buried on site.

9.6.6 Ardreigh

Analysis of adult stature in the Ardreigh burial population revealed that males appear to have been more affected by growth disturbance than females; more males (54/321, 17%) attained a shorter stature than the lowest stature for males (167cm) in comparative populations. This implies that the Ardreigh males did not recover from childhood growth delays they may have experienced. As the adult females do not appear to have been similarly affected, they may not have been exposed to the same growth delays or physiological stressors as males during their childhood and adolescence.

The relatively high prevalence (36%, 195/537) of dental enamel hypoplasia in adults demonstrates that individuals of both sexes experienced significant physiological stress during childhood. Skeletal pathology indicative of systemic deficiency, anaemia and infectious disease is present in the individuals of all age groups in the burial population. This strongly suggests that the general population experienced considerable periods of undernutrition and infection. As these forms of physiological stress were sufficient to affect the skeleton, it is likely that there was an endemic environment of malnutrition and poor health within the medieval population of Ardreigh.

As the lifestyle of the Ardreigh population was predominantly agricultural it is not unexpected that a considerable proportion of the burial population were affected by degenerative joint disease and skeletal pathology attributed to strenuous physical activity. Nor is the relatively high prevalence (12%, 102/882) of fracture unusual. The frequency of cranial trauma is significantly higher in the remains of adult males (78%, 14/18) compared to adult females (22%, 4/18). This suggests possible differences in activities and associated risk of injury between males and females in the living population. It is informative that the examples of sharp force cranial trauma display little evidence of healing in contrast to blunt force cranial trauma and postcranial fractures. These differences in the degree of healing may reflect the severity of injury sustained and also offer tentative support for the provision of treatment that was occasionally successful.

Several (4/86) young individuals displayed age at death disparities between skeletal and dental estimates that suggest they experienced restricted growth during gestation or early infancy. A number of very young individuals (12/57) in the Ardreigh burial population had been delivered prematurely between 16 and 38 weeks gestation, however the majority of pregnancies (45/57) were carried to term. The skeletal pathology observed in the remains of very young individuals indicates that they were also affected by systemic deficiencies and infection. Endocranial lesions indicating delayed cortical development were observed in the majority of perinatal and neonatal individuals (13/56) and ectocranial lesions associated with anaemia were also evident in two individuals within these age categories. These pathologies imply that these very young individuals were physiologically compromised during gestation and early infancy. This in turn points to consideration of the maternal physiological condition prior to and during gestation and into the postnatal period. Mortality in very young individuals who already display skeletal pathology associated with compromised development and health could suggest that the mothers were unable to sustain an adequate supply of breastmilk for those babies that survived birth.

The presence of a significant cranial birth trauma (occipital osteodiastasis, Sk. 830) within the neonatal individuals provides evidence that at least one female in the living population delivered a breech presentation. This reveals that knowledgeable support was provided to the mother through the delivery. Unfortunately, the injuries sustained by the baby involved intracranial haemorrhage and soft tissue damage, and would have greatly reduced its chances of survival. Although it is very likely that full-term fetuses in the breech position were safely delivered in past populations, there is no other example that has been identified from the skeletal remains of very young individuals alone. The skeletal remains also include examples of congenital anomalies such as vertebral border shifting and dental gemination. These indicate the probable relatedness of the affected individuals within the burial population at Ardreigh.

The individuals represented in the burial population display significant skeletal pathologies that demonstrate the living population at Ardreigh experienced considerable physiological stress affecting all age groups. The adult males appear to have been less able to recover from these insults, although it is likely that they were more exposed to serious injury and physiological stress than the females in the population. Despite the apparent impacts on the health of the Ardreigh population, the majority of individuals appear to have survived into adulthood.

9.6.7 Wharram Percy

It appears that the adult males of the Wharram Percy burial population may have been more susceptible to growth disruption during childhood and adolescence, as they have a slightly lower average stature (168cm) than males from comparative populations (171-172cm). The females do not appear to have been similarly affected, as is the case in the Ardreigh burial population. The skeletal pathology of older individuals indicates that strenuous physical activity including weight-bearing was regularly undertaken. These forms of skeletal pathology are frequently observed in predominantly agricultural populations.

The dental pathology indicates that approximately one third (32%, 69/214) of the adult burial population were affected by physiological stress during early childhood leading to enamel hypoplasia. The adult skeletal remains also provide evidence of infectious disease, anaemia, infection, and conditions associated with vitamin deficiency such as scurvy and rickets. Degenerative joint disease and minor cases of diffuse idiopathic skeletal hyperostosis were also present in the adult remains. Skeletal sharp and blunt force cranial trauma and postcranial fractures were relatively frequent among the burial population (20%, 72/360) (Mays, 2007). Interestingly, the majority of cranial and postcranial fractures display minimal displacement with evidence of healing. A clear indication of the skilled treatment available is a case of trepanation that displays significant healing around the margins of the lesion.

There is a relatively high proportion of vertebral border shifting in the individuals from the Wharram Percy population (28%, 51/182,) (Mays, 2007) compared with the other populations analysed. Three very young individuals also displayed vertebral border shifting as well as more significant vertebral pathology including clefts, dorsal hypoplasia of the vertebral centra and the relatively rare complete transverse cleft and partial agenesis of the basilar process. The latter two forms were only observed in the Wharram Percy burial population. Varying degrees of intra-jugular bridging were observed in the skeletal remains of several very young individuals in the Wharram Percy burial population. This trait is relatively rare in modern populations and was only present in the Wharram Percy burial population and in a single individual in the Çatalhöyük burial population.

Thirteen individuals were born prematurely prior to 37 weeks gestation. Of the remainder of the very young individuals in the burial population, 36 died in the perinatal and neonatal periods. The majority of very young individuals (46/83) have endocranial lesions and 19 display skeletal pathology indicative of anaemia, infection and systemic deficiency. The presence of infectious disease in the adult population implies that younger individuals in the community would also have been affected. One of the maternal mortalities in this burial population exhibits extensive skeletal lesions attributed to tuberculosis. The infection is likely to have been a contributing factor in the death of mother and baby during the pregnancy. Apart from the considerable array of skeletal pathology in the Wharram Percy burial population, there were also three very young individuals that have skeletal anomalies suggestive of congenital syndromes; one of these was identified as Trisomy 21. These three individuals were not previously identified as having significant skeletal pathology.

The medieval population of Wharram Percy demonstrably experienced considerable physiological stress. The evidence for successful treatment of fractures provides insight into the support available within the community. However, the prevalence of skeletal trauma indicative of infectious and deficiency conditions suggests that some of the causative factors were endemic within the general population. The number of pregnancies that were carried to term provides evidence that pregnant females were supported through their pregnancies. Unfortunately, the maternal condition and the negative impacts on the developing fetus resulted in considerable perinatal and neonatal mortality in the Wharram Percy population.

9.7 Reference Collections

Reference collections provide an important resource for the confirmation of aetiology and for the comparative critical analysis of skeletal pathology. The main limitation in using medical reference collections to provide a standard for describing skeletal pathology is the significant distance between past and modern expressions of pathological conditions. This is primarily the result of advances in anatomical knowledge and medical treatment. These advances have significantly altered the range and form of skeletal expression in modern populations that benefit from this knowledge.

Creating the opportunity to critically analyse the skeletal pathology observed in very young individuals with a practising perinatal pathologist was a deliberate and fundamental approach of the current research. It enabled the comparison between archaeological specimens and modern examples with known medical history and confirmed perimortem circumstances. This collaboration also initiated informed discussions and preliminary investigation regarding the possible aetiologies for observed skeletal pathologies that are not documented in modern individuals.

A crucial outcome of collaborating with a perinatal pathologist is the potential to correct past interpretations of skeletal pathology in very young individuals. For example, the various forms of endocranial lesions were considered in terms of non-pathological and pathological aetiologies. Clinical investigation was undertaken by the perinatal pathologist to further assess the possible contributing factors, leading to the differentiation between pathological lesions and adhesions of the dura. Early collaboration with the perinatal pathologist provided clarification of potential causative factors in the development and appearance of skeletal pathology in very young individuals; a knowledge base that was used throughout the current research. This combined medical and palaeopathological approach to skeletal pathology in the very young allows elements of conjecture to be qualified, which in turn considerably advances the scope of juvenile palaeopathology.

The pathology and developmental collections at the Royal College of Surgeons in London proved to be an important resource in the development of criteria for identifying skeletal pathology in very young individuals, particularly that of the cranium and vertebral column. These collections provided examples across the range in appearance of pathological conditions that can impact the cranial vault elements as well as those of the axial and appendicular skeleton. It was anticipated that the archaeological samples could include individuals with such pathologies and so study of the RCS collections allowed the researcher to become familiar with their form and associated aetiologies. It also confirmed that some known skeletal pathologies were not necessarily reflected in the morphology of the elements involved. For example, confirmed cases of spina bifida aperta did not necessarily result in changes to the shape or appearance of individual vertebral centra and neural arches. Such cases would only be identifiable in archaeological contexts prior to excavation when the articulated remains are undisturbed. In some other more extreme skeletal pathologies associated with non-viable conditions the skeletal elements were significantly modified from their normal form and would not be recognisable unless the researcher was already familiar with the possible pathological changes.

9.8 Summary

The research presented above demonstrates the considerable contribution that fetal, perinatal, neonatal and infant palaeopathology can make towards understanding maternal health and population stress in past populations. The results of this research complement the existing knowledge of juvenile skeletal pathology and past maternal experiences of pregnancy. They also challenge preconceptions of very young mortalities, maternal health and population stress in past populations.

The analysis of palaeopathology of the very young individuals within distinct past populations from different time periods, geographical and environmental contexts, enabled the determination of detailed personal and population specific experiences of very young and maternal mortalities and physiological stress. It revealed the regular occurrence of sustained gestation under conditions of significant physiological stress and captured a very specific window in the life course of both the mother and the very young individual.

With regard to the juvenile skeletal pathology observed within the burial populations, there is considerable evidence that the majority of very young individuals experienced a compromised physiological state prior to their death. Other than indicating aspects of the affected individual’s physiological condition, the presence of multiple very young individuals, particularly the significantly premature babies, with active lesions at the time of death also provides information on the living population. On consideration of the likely presence of acute conditions that did not impact the skeleton and the evident skeletal pathology, the very young individuals within each of the burial populations appear to have been victims of natural mortality associated with the conditions of their gestation and living environments.

The differences in skeletal pathology between the burial populations analysed suggests that there were changes in the prevalence and type of skeletal pathology over time and between populations. These differences are likely to have been the result of genetic variation, environmental conditions, and exposure to physiological stress. The skeletal pathology of very young individuals supports an interpretation that all of the burial populations analysed represented living communities that were under considerable physiological stress.

The presence of skeletal pathology that indicates compromised health in very young individuals and the adult females identified as their mothers, does not necessarily exclude the impact of cultural behaviours that may have limited maternal access to resources. It is unlikely that multiple discrete populations from different temporal periods and environments that followed different cultural and belief systems, would all restrict maternal access to support and resources. Given the similarities in skeletal pathology across the burial populations analysed, it would appear that the communities represented by the burial populations were exposed to long-term environmental stress that affected the survival and health of individuals of all ages, particularly the very young.

The burial of very young individuals within the same contexts as the remainder of the burial population, apart from the Roman samples, points to a social recognition that these youngest individuals were considered as part of the community. It should follow that the analysis of their remains is given equal attention as that of the older individuals within burial populations. This is particularly important in light of the significant contributions offered by the analysis of fetal, perinatal, neonatal and infant palaeopathology.

Chapter Ten

Conclusions

10.1 Concluding Remarks

This research has demonstrated that the skeletal pathology of very young individuals can be differentiated from normal appearance through macroscopic examination. It has been shown that palaeopathology of very young individuals can provide evidence for a compromised maternal physiological condition during pregnancy. The results of the bioarchaeological analysis of the skeletal remains of very young individuals revealed considerable information about population stress experienced in each of the past populations studied. An assessment of the particular physiological stresses was possible because each burial population derived from a distinct living population. Consideration of the skeletal remains in their contexts provided evidence of the varying socio-cultural responses of the respective past communities to fetal, perinatal, neonatal and infant mortality.

This research demonstrated that half of the very young individuals analysed displayed skeletal pathology indicative of physiological stress and disrupted development. These individuals experienced a range of physiological stresses including restricted intrauterine growth, systemic deficiencies, infection and trauma, which were all significant contributing factors to their early death. Analysis of the maternal mortalities in the burial populations revealed considerable information regarding the physiological state of each of these mothers prior to their death, and in some cases the underlying causes of death, as well as the cultural responses to maternal death.

This research supports previous studies in juvenile palaeopathology through presenting a new interpretation of endocranial lesions, detailed descriptions of a wide range of pathology in the developing skeleton, new approaches to the identification of known conditions and considerable insights into past experiences of pregnancy and labour, maternal health, mortality in the very young and population stress.

The primary conclusions of this thesis are that the analysis of palaeopathology in very young individuals:

- Contributes substantial information regarding the physiological condition of the mother prior to and during pregnancy;
- Reveals specific details of the intrauterine development and growth of very young individuals;
- Exposes aspects of population stress within relatively closed communities;
- Reveals external support for individuals who survived birth;
- Supports the identification of genetic relatedness on the basis of skeletal characteristics;
- Extends the known history of particular pathological conditions and trauma;
- Provides insight into the skilled support of mothers during labour and the management of obstructed delivery; and
- Does not support infanticide as a common practise within the past communities studied.

The research established that the bioarchaeological analysis of very young individuals and their burials also provides evidence of cultural buffering, evident through the community responses to fetal, perinatal, neonatal and infant mortality, and enables personal responses to be identified within the more general funerary treatment of other individuals. The investigation into the palaeopathology of very young individuals and maternal mortality in past populations facilitated an estimation of the severity and form of physiological stress within each of the study populations. The examples of delayed skeletal development in comparison to dental development in several very young individuals points to compromised intrauterine growth and development and potentially, the level of physiological stress experienced by the mother during pregnancy.

The burial populations contain skeletal evidence of the relatively difficult lifestyles of the respective past communities involving substantial physical activity resulting in degenerative skeletal conditions, poor nutrition and infection associated with limited resources and living conditions. The skeletal pathology displayed in the burial populations demonstrates the presence of chronic systemic conditions within the populations analysed. For the majority of the past populations analysed, the impact on childhood and adolescent growth was insufficient to noticeably reduce adult stature. However, both of the medieval burial populations displayed a reduced male adult stature in comparison with the females in the same population and relative to other contemporary populations. The presence of dental enamel hypoplasia in the permanent dentition highlights the degree of physiological stress experienced by the affected individuals during childhood and points to low grade physiological stress as a constant within the past populations studied.

With respect to the cultural response to the deaths of very young individuals, this study demonstrated that the youngest individuals in all of the past populations were considered as part of the community, regardless of the age at which they died. These very young individuals received funerary treatments that were considered appropriate for their position in each society. There is also clear evidence for personal variation in the funerary treatment of very young individuals. This can be seen in the inclusion and use of pigments, items of personal adornment, shells, and textiles that all suggest complex personal responses to the funerary treatment of very young individuals. The burial placement of very young individuals in close proximity to older individuals within the burial population is suggestive of an intentional maintenance of community associations after death. The complex belief systems and cultural responses to mortality of mothers and the very young are also reflected in the burial location chosen. For example, both Roman villa populations placed the burials of very young individuals burials in close association with furnaces and malting floors, indicating a shared cultural behaviour relating to the funerary treatment of very young individuals.

The research identified that half of the very young individuals analysed experienced significant physiological stress during gestation. This implicates the status of maternal health and by extension the support available for pregnant individuals. The premature delivery of fetuses also highlights the severity of compromised maternal health during gestation. That the majority of pregnancies were carried to term or near-term provides indirect evidence that each community supported pregnant individuals through pregnancy where possible. This is confirmed by the perinatal and neonatal skeletal pathology that displays evidence of remodelling indicating improvement in the individual's physiological condition prior to death.

The skeletal pathology indicative of physiological stress during gestation, infancy and beyond demonstrates that the populations analysed experienced significant and ongoing stress affecting their health and mortality risk. The skeletal remains of older individuals support the endemic presence of infectious disease and chronic deficiency in the past populations studied. The absence of skeletal pathology in some of the very young individuals does not necessarily equate to an absence of physiological stress. These individuals are likely to have died from conditions with a rapid onset leading to an early death. The risk of perinatal mortality in modern medical settings remains significant. Multiple aetiologies that do not affect the developing skeleton can be implicated in perinatal mortality, including complications from immaturity, soft tissue abnormalities and trauma, asphyxia, anoxia and infection.

This research investigated the appearance and prevalence of endocranial lesions from a bioarchaeological perspective. As a result, it proposes an alternative aetiology for the presence of endocranial lesions in very young individuals. Specifically, the implication of connections between the endocranial and ectocranial vascular systems and the impact upon these of compromised physiology during later gestation. The aetiology is likely to have taken the form of intrauterine inflammatory and/or haemorrhagic events that had minimal impact upon the developing fetus as a result of the supportive intrauterine environment. It is proposed that the formation of endocranial lesions is a normal process in the development of the cranial vault elements that should not affect the survival of the developing fetus. However, the impact is significantly different in cases where the physiological conditions of the mother or very young individual are compromised.

An unexpected result of the research was the identification of period specific skeletal pathology in the form of unusually thickened or gracile major long bones in very young individuals. These were only observed in the Roman and medieval burial populations. Interpreted as evidence of disrupted longitudinal growth or a metabolic condition, this skeletal pathology suggests that the affected populations may have experienced resource limitation or chronic physiological stress. It also highlights a potentially relatively closed genetic contribution in the likelihood of an inherited metabolic condition.

This is the first study to describe one of the earliest confirmed case of obstetric dystocia, dating to between 6400BC and 6000BC. The pubic and scapular fractures sustained by an adult female (Çatalhöyük Sk. 13162) had not been previously identified, although it was apparent that she had died at the end of her pregnancy. The skeletal remains of the full-term fetus are contained completely within the abdominal cavity of the mother with the head positioned low within the pelvis. Given the extent of the osseous response of the healing pubic fractures and the probable extent of scar tissue, it is unlikely that the full-term fetus could have been delivered naturally. Although there is no definitive cause of death for both of these individuals, it is highly probable that both individuals died as result of complications arising from obstetric dystocia.

Skeletal evidence for occipital osteodiastasis in a neonatal individual was identified through osteological analysis. The affected neonate (Sk. 830) was from the medieval burial population of Ardreigh, and may represent the earliest known case. The cranial trauma associated with occipital osteodiastasis is sustained as a result of head entrapment during a breech delivery. Although there would have been considerable trauma involving subdural haemorrhage, the neonate survived the delivery long enough for an osseous response to develop on the damaged cranial elements. The neonatal skeletal pathology in this case also provides evidence that there was at least one individual present who was able to successfully manoeuvre and deliver a breech presentation.

The research is the first to propose the presence of Trisomy 21 on the basis of skeletal pathology of the sphenoid in very young individuals from archaeological contexts. Three individuals display varying degrees of Type II dysmorphy of the sella turcica, which is indicative of Trisomy 21 in living individuals. Two of these three individuals represent the youngest and the earliest identified cases of Trisomy 21 from archaeological contexts. Wharram Percy Sk. EE59 is the youngest in age at approximately 36-40 weeks and the earliest in date is a neonate (Sk. 1160) from the Wetwang Slack burial population, dating to between the fourth and second centuries BC. The third individual is a perinate (Sk. UB4) from the Barton Court Farm burial population.

This study identified two individuals with significant skeletal hypoplasias. The first is a neonate (Sk. 869) from the Barton Court Farm burial population that displays hypoplasia of the left pubis with agenesis of the pubic symphysis and thickening of the superior pubic ramus. This particular form of pubic hypoplasia is usually associated with bladder exstrophy and lateral rotation of the pelvic elements. This neonate displays other forms of skeletal pathology suggestive of lower limb neural pathology and systemic deficiency that may be related to the pelvic deformity.

The second individual is a perinate (Sk. NA61) from the Wharram Percy burial population that displays a complete transverse cleft of the basilar process with agenesis of the anterior half. This is a rare expression of basilar cleft and is of particular note in that it is both complete and symmetrical. It is interesting that this individual was part of the only burial population that displayed an unusually high occurrence of vertebral anomalies.

The research is the first to propose an aetiology of retained notochordal tissue in the thoracic centra of perinatal individuals from the Çatalhöyük burial population (Sk. 10112 and Sk. 10361). This morphology is not necessarily pathological in adults, however the notochordal tissue is normally resorbed prior to ossification of the centra. Its persistence could be an indication of disrupted ossification during the early gestation of the affected individuals.

Three individuals with developmental anomalies of the dura were identified during the osteological analysis (Çatalhöyük Sk. 2199 and Sk. 10368, and Wharram Percy Sk. NA194). All three displayed unusual thinning and transparency of the cranial vault and one (Çatalhöyük Sk. 10368) has associated bilateral perforation of the orbital plate. Although thinning and transparency of the cranial vault elements in itself is not necessarily pathological in premature individuals, its persistence in older individuals is noteworthy.

It was anticipated that the identification of shared genetic skeletal traits should be possible in the skeletal remains of very young individuals, although it was acknowledged that this may be hampered by the immature developmental state of the elements involved. The results demonstrate that several genetically linked non-metric skeletal traits were easily recognised including intrajugular bridging, the supracondylar process of the humerus, vertebral border shifting, extra-sutural ossicles and super-numerary vertebrae. The considerably smaller scale, particularly neural arches, and the pre-fusion appearance of the affected skeletal elements did not pose a significant obstacle to the identification of these skeletal traits. This result opens up a new avenue for investigating genetic relatedness of very young individuals to other individuals within a burial population. DNA analysis of living individuals has the potential to identify possible sequences associated with the expression of these traits.

The most remarkable outcome of this research is the volume and variety of skeletal pathology that is displayed in the remains of very young individuals. The analysis of the palaeopathology of very young individuals in the past populations enabled documentation of the considerable detail available regarding the sustained lives of these individuals, the majority of which appear to have been in a critically weakened physiological state prior to their deaths. Two thirds of the very young individuals analysed displayed skeletal pathology and the majority died in the perinatal and neonatal periods. This may indicate that there was a relatively low probability of survival at birth in the past populations studied. The most likely contributing factors to mortality in the perinatal period are prematurity and conditions affecting the developing fetus such as systemic deficiency or infection.

The level of detail that can be confidently determined for personal experiences of pregnancy and labour was unexpected. The vast majority of pregnancies appear to have been carried to term. This revealed that maternal stress was insufficient to prematurely terminate the pregnancy, but still had a significant impact upon the health and survival of the neonates. The considerable evidence for compromised maternal health as revealed through the analysis of palaeopathology in very young individuals, in conjunction with the ability to sustain a pregnancy, highlights that the majority of mothers are likely to have survived, even if their offspring did not.

The five maternal mortalities in the medieval burial populations all displayed significant skeletal pathology associated with a compromised physiological condition. Although suspected cases of maternal mortality were identified prior to undertaking the skeletal analysis, it was hypothesised that the likelihood of finding skeletal pathology directly related to their death whilst pregnant was minimal. The presence of skeletal pathology associated with infectious disease in conjunction with premature labour highlights the state of compromised health among the living populations. It also provides an indication of potential causative agents of mortality in very young individuals that do not display skeletal pathology.

The research revealed that obstetric support was available for pregnant individuals in past populations. The perinatal and neonatal skeletal pathology is evidence of its provision to women in labour at some of the sites analysed; Ardreigh, Yewden villa, and Wharram Percy. This support was in the form of assistance in the delivery of obstructed labour. The skeletal pathology of perinatal and neonatal individuals indicates that all cases of assisted delivery were in the event of obstruction with the baby in a breech position. It is apparent that specialist equipment was used to manipulate the lower limbs of the babies to enable delivery at one of the sites, Yewden villa. The focus of this support during labour was the survival of the mother, and secondarily the safe delivery of the baby. There is no evidence for abdominal section to remove fetuses or for embryotomy at any of the sites studied. Apart from the information regarding the support for labouring women, it is clear that the techniques employed were routine and are likely to have more often resulted in successful deliveries than not.

The evidence of support is not limited to obstetric care but extended to all individuals within the population. There is ample evidence in the skeletal remains of healed, predominantly aligned fractures, the successful repeated treatment of a cranial trauma through trepanation (Wharram Percy Sk. G715), a successful healed amputation within the disarticulated adult remains in the Ardreigh burial population, and a healing periosteal lesion of the forearm in an infant (Çatalhöyük Sk. 21676).

Overall, this research has established that there is a wealth of identifiable skeletal pathology that is accessible through the bioarchaeological analysis of the remains of very young individuals. This in turn provides a means of determining causative factors for skeletal pathology at an individual and population level. The results revealed that for some individuals, maternal physiological stress was significant enough to compromise the viability of pregnancy, evidenced by the premature babies included in the burial populations. However, for the majority of very young individuals, compromised maternal physiological condition affected intrauterine development and growth but sustained pregnancy to term. Unfortunately for the affected very young individuals, their intrauterine experience of physiological stress greatly increased the risk of perinatal and neonatal mortality.

It has been shown that in all of the past populations studied, maternal health during pregnancy was compromised for the majority of pregnancies represented by the fetal, neonatal and infant skeletal remains in the respective burial populations. The extent of compromised maternal health has been demonstrated to be a reflection of physiological stress in the general population at each location. Contrary to past interpretations, the bioarchaeological analysis of very young individuals has revealed that these youngest members of the population were recognised as part of each community and provided a funerary treatment according to their age and the complex socio-cultural belief systems of their community.

10.2 Future Research and Recommendations

This research has highlighted the significant potential for advancing multiple fields of inquiry through the analysis of juvenile palaeopathology. It has emphasised the need for detailed analysis of palaeopathology in very young individuals to be promoted through all aspects of the disciplines of biological anthropology and osteoarchaeology, particularly with a focus on training at a tertiary level. The forging of inter-disciplinary collaborations and the incorporation of external skill sets proved fundamental to undertaking the research presented above. It highlighted the importance of working with practising perinatal and paediatric pathologists to prevent the somewhat circular discourse that currently exists around juvenile palaeopathology and its interpretations. Other than the significant contributions to be gained from the dissemination of the research results, a crucially important outcome is the need for increased awareness among colleagues of the potential of palaeopathology in very young individuals and the benefits to be gained from inter-disciplinary collaboration.

The research was unfortunately hampered by the previous partial destruction of skeletal remains of very young individuals that displayed significant pathology in the remaining elements. It should be stressed that as part of professional conduct in this field of research, destructive analysis should only be permitted if the skeletal remains have already been examined by an osteologist experienced in analysing the skeletal remains of very young individuals.

Analysis of aDNA in very young individuals with particular skeletal pathologies, such as Type II dysmorphy of the sella turcica associated with

Trisomy 21, would facilitate the study of relatedness and potentially identify the alleles responsible for particular phenotypes. Further investigation involving bone mineral analysis, for example stable nitrogen isotopes, of individuals with significant skeletal pathology associated with physiological stress has the potential to provide detailed information on stress indicators in very young individuals.

A tenet of palaeopathological research is that it must yield information that is useful to modern populations. The findings of the research with regard to maternal health and population stress are significant, particularly in light of the recent Millennial Development Goals (United Nations), the Every Newborn Action Plan (ENAP) (WHO and UNICEF) and the Strategies Toward Ending Preventable Maternal Mortality (EPMM) (WHO). The insight into maternal health and physiological stress in past populations, and their impact on past mortality of very young individuals, is highly applicable to the development and implementation of policy and practise relating to neonatal, infant and maternal care in developing nations. It is also directly applicable to the improvement of maternal health and neonatal survival in lower socio-economic environments within developed nations. Aside from these practical applications of the research, the detailed description of palaeopathology in very young individuals will better inform our understanding of developmental disturbance and its implications for neonatal survival. It will enable further investigation into maternal health and by extension, population stability in past communities. Furthermore, the incorporation of juvenile palaeopathology analyses will improve the accuracy of interpretations relating to past populations. To these ends, it is apparent that the continued investigation and description of skeletal pathology in very young individuals from past populations must be undertaken.

Appendices

Appendix 1a – Skeletal Measurements

Skeletal measurements of juvenile skeletal remains. All measurements recorded in millimetres unless otherwise stated.

Skeletal Element	Measurement	Abbreviation
Atlas	Length of neural arch	ATL
Axis	Length of neural arch	AXL
Occipital *pars lateralis*	Maximum length	PLL
	Maximum width	PLW
Occipital *pars basilaris*	Sagittal length	PBSL
	Maximum length	PBL
	Maximum width	PBW
Temporal *pars petrosa*	Length	PPL
	Width	PPW
Sphenoid body	Length	SL
	Width	SW
Sphenoid lesser wing	Length	LWL
	Width	LWW
Sphenoid greater wing	Length	GWL
	Width	GWW
Frontal	Chord length	FCL
	Chord width	FCW
	Arc length	FAL
	Arc width	FAW
Zygomatic	Length	ZL
	Oblique height	ZOH
Rib one	Length	RIL
Clavicle	Length	CL
Scapula	Length	SCL
	Width	SCW
	Spine length	SCSL

Appendix 1a continued...

Skeletal Element	Measurement	Abbreviation
Humerus	Length	HL
	Distal width	HDW
Radius	Length	RL
Ulna	Length	UL
Metacarpal one	Length	MCL
Ilium	Length	ILL
	Width	ILW
Ischium	Length	ISL
	Width	ISW
Pubis	Length	PL
Femur	Length	FEL
	Distal width	FDW
Tibia	Length	TL
Fibula	Length	FIL
Metatarsal one	Length	MTL
Lesion	Area (mm^3)	LesA
	Depth	LesD

Appendix 1b – Measurement Descriptions

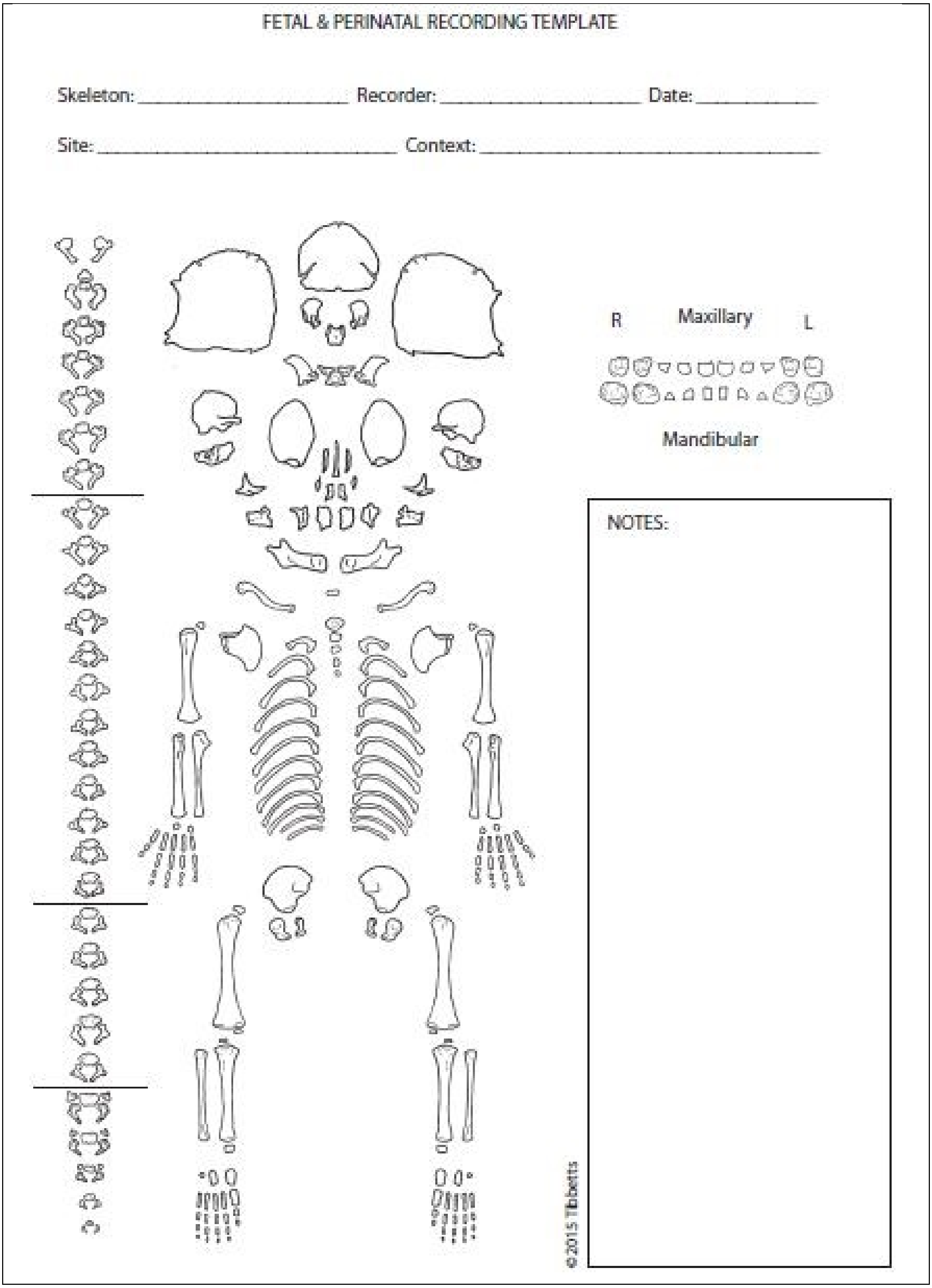
Description of skeletal measurements (taken as greatest distance) listed in Appendix 1.

Measurement	Description
ATL	Length of the vertebral arch of the atlas
AXL	Length of the vertebral arch of the axis
PLL	Between the anterior and posterior inter-occipital synchondroses
PLW	Between the medial and lateral margins of the posterior inter-occipital synchondrosis
PBSL	In the sagittal plane between the foramen magnum and the spheno-occipital synchondrosis
PBL	Between the posterior edge of the lateral condyle and the spheno-occipital synchondrosis
PBW	In the line of the lateral tubercles
PPL	Between the apex of the petrous and the superior posterior end
PPW	In a vertical plane on the posterior surface of the bone across the arcuate eminence
SL	In the midline, between the inter-sphenoid and the spheno-occipital synchondroses
SW	In the transverse plane through the middle of the hypophyseal fossa
LWL	From the lateral tip to the midline of the inter-sphenoid synchondrosis
LWW	From the medial margin of the anterior crest, crossing the optic canal
GWL	Between the medial pterygoid plate and the lateral tip of the wing
GWW	Between the sphenoidal spine and the anterior end of the medial pterygoid plate.
FCL	From the middle of the superior margin of the orbit across the frontal eminence to the superior peak
FCW *	Transversally at the level of the frontal eminence
FAL	The same as FCL taken along the curvature of the bone using a tape measure
FAW	The same as FCW taken along the curvature of the bone using a tape measure
ZL	Between the tip of the maxillary process and the tip of the temporal process
ZOH	Between the tip of the maxillary process and the tip of the frontal process

Appendix 1b continued...

Measurement	Description
RIL	Between the articular tuberosity of the head and the sternal end
CL	Between the sternal and acromial ends
SCL	Between the medial and inferior angles of the scapula
SCW	Between the margin of the glenoid fossa and the medial end of the spine
SCSL	Between the medial end of the spine and the tip of the acromion
HL	Length of the diaphysis
HDW	Medio-lateral width of the distal end of the diaphysis
RL	Length of the diaphysis
UL	Length of the diaphysis
MCL	Length of the diaphysis
ILL	Between the anterior superior spine and posterior superior spine
ILW	Between the mid-point of the iliac crest and the extremity of the acetabular surface
ISL	Between the tip of the ischial ramus and the posterior superior end of the ischial tuberosity
ISW	In the line of the ischial tuberosity
PL	Between the symphyseal end of the bone and the iliac articulation
FEL	Length of the diaphysis
FDW	Medio-lateral width of the distal end of the diaphysis
TL	Length of the diaphysis
FIL	Length of the diaphysis
MTL	Length of the diaphysis
LesA	Surface area affected by lesion
LesD	Depth of lesion

Appendix 2 – Fetal and Perinatal Recording Template



Appendix 3 – Fetal and Perinatal Inventory

PERINATE INVENTORY Skeleton: ____________ Site: ________________________

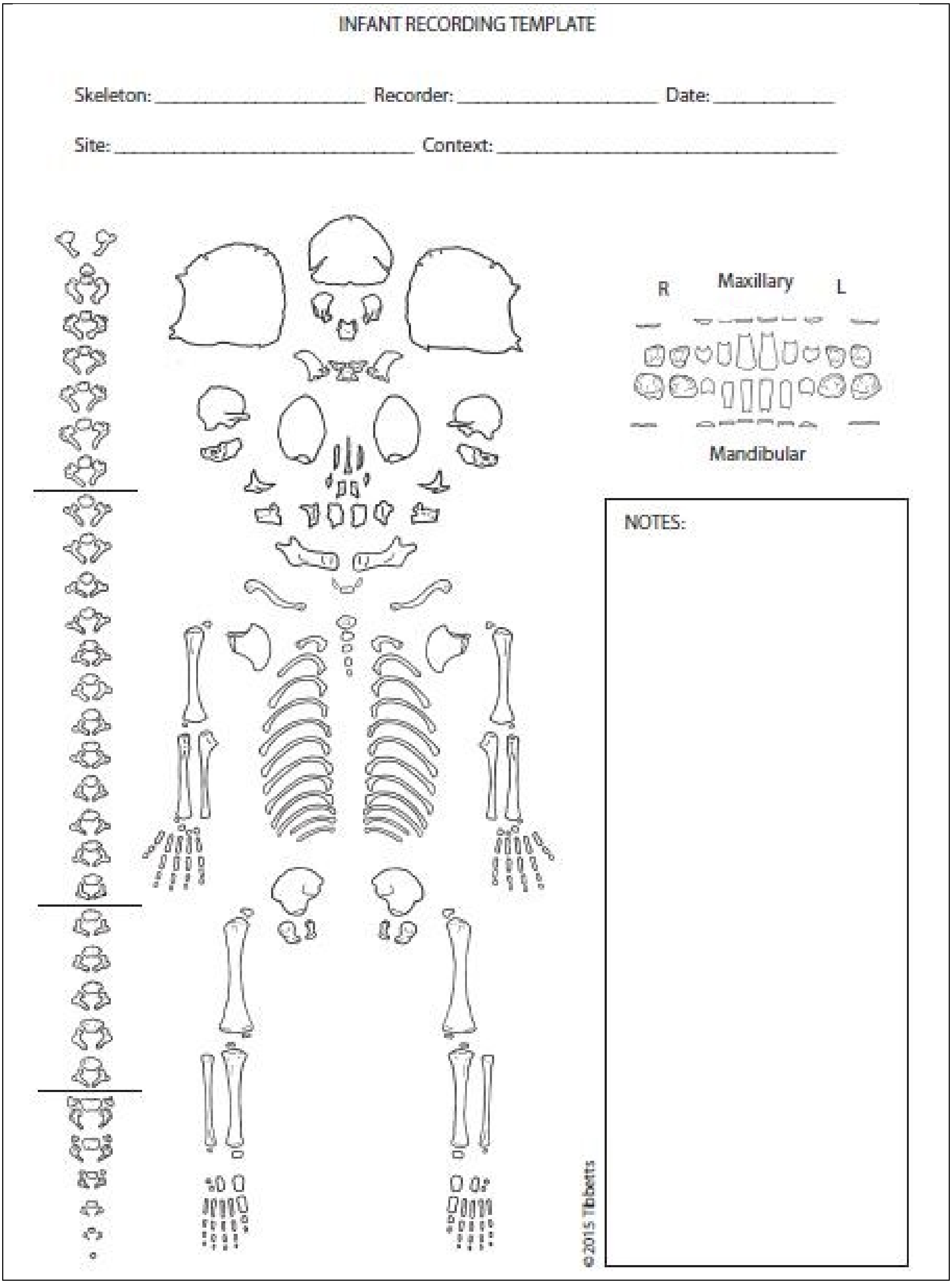
Context: __________________________ Recorder: ___________________ Date: _________

L=left, R=right, U=unsided, indet=indeterminate ©2014 Tibbetts

	L	R	U				L	R	U		L	R	U
Frontal						**Ribs**				**Humerus**			
vault						heads/#				Proximal epiphysis			
orbit						sternal ends/#				P1/3			
Parietal						shaft fragments/#				M1/3			
Occipital						1st Rib				D1/3			
pars squama						2nd Rib				**Radius**			
pars lateralis						3rd Rib				P1/3			
pars basilaris						4th Rib				M1/3			
Temporal						5th Rib				D1/3			
pars squama						6th Rib				**Ulna**			
pars petrosa						7th Rib				P1/3			
pars tympanica (ring)						8th Rib				M1/3			
auditory ossicles						9th Rib				D1/3			
Sphenoid						10th Rib				**Capitate**			
presphenoid						11th Rib				**Hamate**			
lesser wing						12th Rib				**Metacarpals**			
postsphenoid										1st			
greater wing						**Vertebrae**	**L**	**Cent**	**R**	2nd			
Maxilla						indet. vertebral elements				3rd			
alveolar region						**Cervical** 1 (Atlas)		-		4th			
Palatine						C2 (Axis)				5th			
Zygomatic						Dens	-		-	indet.			
Nasal						C3				**Manual Phalanges**			
Vomer						C4				proximal			
Lacrimal						C5				intermediate			
Ethmoid						C6				distal			
Nasal Concha						C7				indet.			
Mandible						Cervical indet.				**Femur**			
Hyoid body						**Thoracic** 1				Proximal epiphysis			
Unident. fragments #/gms						T2				P1/3			
						T3				M1/3			
DENTITION	**CI**	**LI**	**C**	**M1**	**M2**	T4				D1/3			
Maxillary						T5				Distal epiphysis			
Mandibular						T6				**Tibia**			
PECTORAL GIRDLE						T7				Proximal epiphysis			
Sternum						T8				P1/3			
manubrium						T9				M1/3			
sternebrae/#						T10				D1/3			
Scapula						T11				Distal epiphysis			
Clavicle						T12				**Fibula**			
PELVIC GIRDLE						Thoracic indet.				P1/3			
Ossa Coxae						**Lumbar** 1				M1/3			
ilium						L2				D1/3			
auricular surface						L3				**Calcaneus**			
ischium						L4				**Talus**			
pubis						L5				**Cuboid**			
Sacral Elements	L Ala	L Arch	Cent	R Arch	R Ala	Lumbar indet.				**Metatarsals**			
S1										1st			
S2						**Pedal Phalanges**				2nd			
S3						proximal				3rd			
S4						intermediate				4th			
S5						distal				5th			
indet.						indet.				indet.			

COMMENTS:

Appendix 4 – Infant Recording Template



INFANT RECORDING TEMPLATE

Skeleton: ____________ Recorder: ____________ Date: ________

Site: ________________ Context: ________________

NOTES:

Appendix 5 – Infant Inventory

INFANT (birth – 1yr) INVENTORY Skeleton: ____________ Site: ___________________

Context: ____________________________ Recorder: ____________________ Date: __________

L=left, R=right, U=unsided, indet=indeterminate ©2014 [illegible]

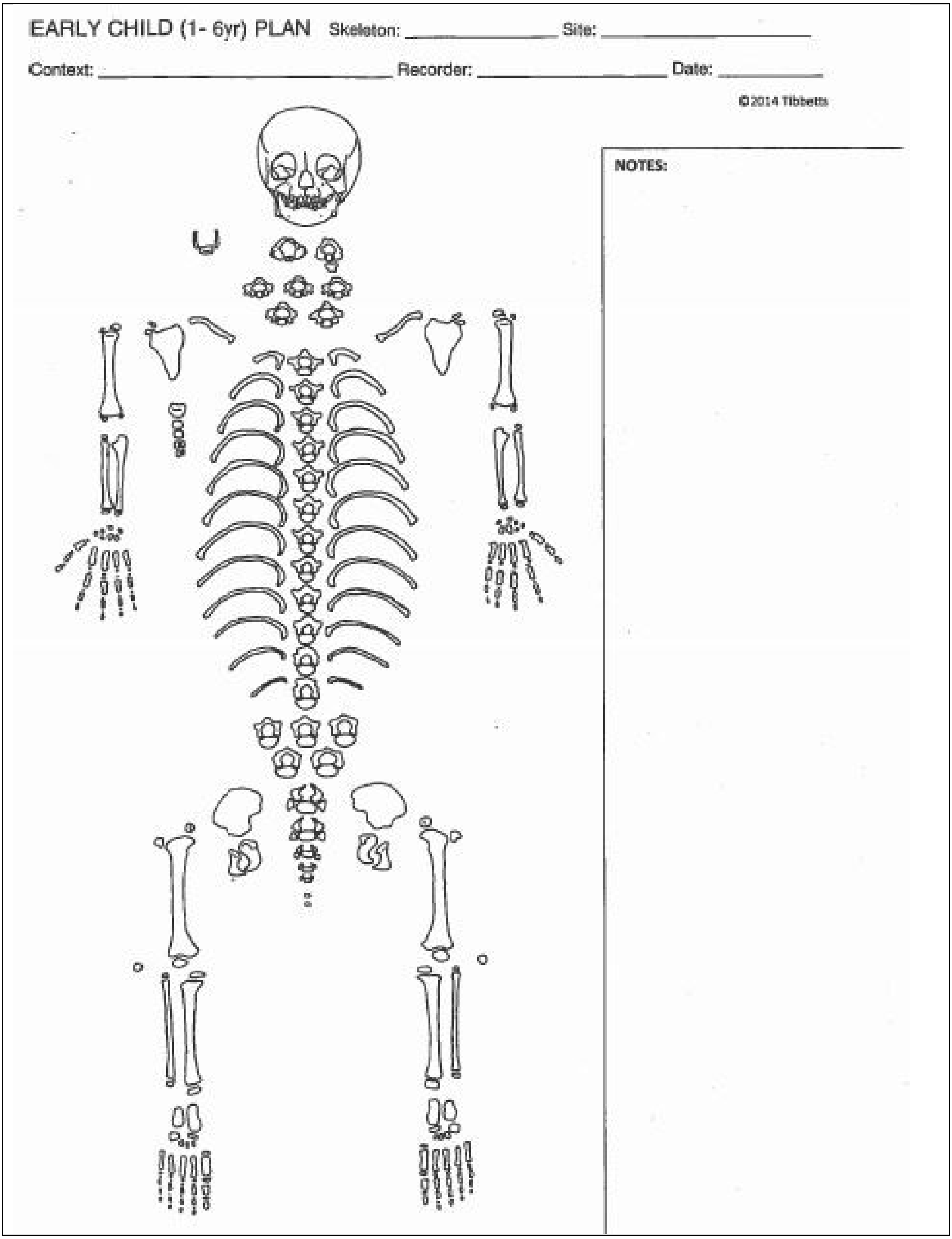
	L	R	U		
Frontal					
vault					
orbit					
Parietal					
Occipital					
pars squama					
pars lateralis					
pars basilaris					
Temporal					
pars squama					
pars petrosa					
pars tympanica (ring)					
auditory ossicles					
Sphenoid					
presphenoid					
lesser wing					
postsphenoid					
greater wing					
Maxilla					
alveolar region					
Palatine					
Zygomatic					
Nasal					
Vomer					
Lacrimal					
Ethmoid					
Nasal Concha					
Mandible					
Hyoid					
Unident. fragments #/gms					
DENTITION	CI	LI	C	M1	M2
Maxillary					
Mandibular					
PECTORAL GIRDLE					
Sternum					
manubrium					
sternebrae/#					
Scapula					
Clavicle					
PELVIC GIRDLE					
Ossa Coxae					
ilium					
auricular surface					
ischium					
pubis					
Sacral Elements	L Ala	L Arch	Cent	R Arch	R Ala
S1					
S2					
S3					
S4					
S5					
indet.					

	L	R	U
Ribs			
heads/#			
sternal ends/#			
shaft fragments/#			
1st Rib			
2nd Rib			
3rd Rib			
4th Rib			
5th Rib			
6th Rib			
7th Rib			
8th Rib			
9th Rib			
10th Rib			
11th Rib			
12th Rib			
Vertebrae	L	Cent	R
indet. vertebral elements			
Cervical 1 (Atlas)		-	
C2 (Axis)			
Dens	-		-
C3			
C4			
C5			
C6			
C7			
Cervical indet.			
Thoracic 1			
T2			
T3			
T4			
T5			
T6			
T7			
T8			
T9			
T10			
T11			
T12			
Thoracic indet.			
Lumbar 1			
L2			
L3			
L4			
L5			
Lumbar indet.			
Coccyx 1			
Pedal Phalanges			
proximal			
intermediate			
distal			
indet.			

	L	R	U
Humerus			
Proximal epiphysis			
Diaphysis			
Distal epiphysis			
Radius			
Diaphysis			
Distal epiphysis			
Ulna			
Diaphysis			
Capitate			
Hamate			
Triquetral			
Metacarpals			
1st			
2nd			
3rd			
4th			
5th			
indet.			
Manual Phalanges			
proximal			
intermediate			
distal			
indet.			
Femur			
Proximal epiphysis			
Diaphysis			
Distal epiphysis			
Tibia			
Proximal epiphysis			
Diaphysis			
Distal epiphysis			
Fibula			
Diaphysis			
Distal epiphysis			
Calcaneus			
Talus			
Cuboid			
Lateral Cuneiform			
Metatarsals			
1st			
2nd			
3rd			
4th			
5th			
indet.			

COMMENTS:

Appendix 6 – Early Child Recording Template



EARLY CHILD (1- 6yr) PLAN Skeleton: ______________ Site: ____________________

Context: ____________________________ Recorder: __________________ Date: __________

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NOTES:

Appendix 7 – Early Child Inventory

EARLY CHILD (1- 6yr) INVENTORY Skeleton: ____________ Site: ____________

Context: ______________________________ Recorder: ____________________ Date: _________

ELEMENT	L	R	U	ELEMENT	L	R	U	ELEMENT	L	Body	R		
Frontal				Ribs				Hyoid					
Parietal				heads/#				Vertebrae	L	Cent	R		
Occipital				sternal ends/#				indet. verts					
Temporal				shaft frags/#				Cervical					
petrous				1st				C1 (Atlas)					
Sphenoid				2nd				C2 (Axis)					
Zygomatic				3rd				Dens	-		-		
Nasal				4th				C3					
Palatine				5th				C4					
Vomer				6th				C5					
Conchae				7th				C6					
Ethmoid				8th				C7					
Lacrimal				9th				C index					
Maxilla				10th				Thoracic 1					
Mandible				11th				T2					
Unident. cranial frags #/gms				12th				T3					
Manubrium				Ilium				T4					
Sternebrae #				Ischium				T5					
Scapula				Pubis				T6					
Coracoid				Femur				T7					
Clavicle				Prox epiph #				T8					
Humerus				Diaphysis				T9					
Prox epiph #				Dist epiph				T10					
Diaphysis				Patella				T11					
Dist epiph #				Tibia				T12					
Radius				Prox epiph				T index					
Prox epiph				Diaphysis				Lumbar 1					
Diaphysis				Dist epiph				L2					
Dist epiph				Fibula				L3					
Ulna				Prox epiph				L4					
Diaphysis				Diaphysis				L5					
Dist epiph				Dist epiph				L index					
									L			R	
								Sacrum	Ala	Arch	C	Arch	Ala
Capitate				Calcaneus				S1					
Hamate				Talus				S2					
Triquetral				Cuboid				S3					
Lunate				Lat Cuneiform				S4					
Trapezium				Med Cuneiform				S5					
Scaphoid				Int Cuneiform				S index					
Trapezoid				Navicular				Coccyx	Co1	Co2			
MC1				MT1									
MC2				MT2				Deciduous Teeth	CI	LI	C	M1	M2
MC3				MT3				Maxillary					
MC4				MT4				Mandibular					
MC5				MT5				Permanent Teeth	CI	LI	C	PM2	PM1
MC index				MT index				Maxillary					
Manual Phalanges				Pedal Phalanges				Mandibular					
proximal				proximal					M1	M2			
intermed				intermed				Maxillary					
distal				distal				Mandibular					

COMMENTS:

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