A Critical Consideration of the Role of Mental Toughness and Pain in the Acute Pain Experiences of Athletes

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This narrative review investigates the relationship between mental toughness (and mental toughness resources) and pain in athletes. Theorists have postulated that mentally tough athletes possess the ability to push through painful periods of training and competition to achieve high levels of performance. Athletes and coaches attribute the capacity to tolerate and even thrive while experiencing pain to be a potential differentiator to performance outcomes, however, few experimental studies examine the predictive value of mental toughness in the context of pain. There are researchers who have examined the resources of mental toughness that could shed light on how mental toughness influences pain experiences in athletes. Therefore, this review examined the relationship between mental toughness as a global construct and the separate mental toughness resources and pain experiences. We identified resources of mental toughness based on previous research and then considered which of these resources had been studied in the context of pain. Optimism, resilience, self-efficacy, and goal attention were identified as key components of mental toughness that were related to pain experiences. The findings of this review indicate a potential area for performance enhancement in the development of applied coaching practices.

Keywords: mental toughness, pain, athletes, performance psychology, individual differences

Pain and sport are intricately interwoven (Buckworth, Dishman, O'Conner, & Tomporowski, 2013). Athletes experience pain in training, in competition, and when injured; consequently the ability to manage pain could represent a critical component of success across a range of sports. The purposes of this narrative literature review are to consider the evidence that mental toughness is associated with specific pain experiences (i.e., pain tolerance, pain threshold, and pain intensity) and then to critically consider whether specific mental toughness resources drive the relationship between mental toughness and pain behavior. Given the lack of direct research on this topic, we initially explore associations between pain and sport, followed by a conceptual overview of mental toughness and wider discussion of the links between mental toughness and pain. This review is predominantly concerned with pain derived from training or competing in sport, not in relation to sporting injury. For clarity, we have therefore considered and classified pain by type and associated sports and training modalities (see table 1). For the purposes of this article, types of pain listed within table 1 will be referred to as 'sport pain'.

[Table 1 near here].

Sport and Pain

Pain has been defined as an unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described regarding such damage (Merskey & Bogduk, 1994). More recently, Moseley (2003) contended that this definition is somewhat simplistic because the experience and outcome of pain involves a complex interaction of multiple physiological, neurological, and psychological systems. Studies using imaging techniques have shown there is no single pain-processing center in the brain, rather, a 'neuromatrix' composed of several cortical areas contributing to pain processing through differing levels of activation (Moseley, 2003). The neuromatrix generates output patterns via information communicated through perceptual, behavioral, and homeostatic systems, suggesting pain to be an output of processing in the neuromatrix rather than simply a direct response of sensory input (Gatchel, Peng, Peters, Fuchs, & Turk, 2007). As such, the sensation of potential noxious stimuli (e.g., contact injury, muscle acidosis) is communicated through peripheral afferent nerves sending nociceptive impulses to the central nervous system for processing (Joyce & Butler, 2016). Whether information is interpreted as harmful is dependent in part on a range of individual differences (Pen & Fisher, 1994) including but not limited to, gene expression, emotions, culture, and gender (Gatchel et al., 2007). Experiences of pain and predicted consequences if the sensory information is ignored are postulated to represent two major factors in behavioral outcomes associated with pain (Joyce & Butler, 2016). The aforementioned emotional contribution to pain processing indicates the prominence of psychological input to pain experience. This component represents a complex interaction that also incorporates personality, cognitive, and behavioral factors (Gatchel et al., 2007). The anticipation or experience of pain stimuli therefore represents a subjective and personal phenomenon that comprises a large psychological component. As a result, responses and outcomes to pain are unique to the individual.

Chronic pain has been defined as ‘a state in which pain persists beyond the usual course of an acute disease or healing of an injury**,** or that may or may not be associated with an acute or chronic pathologic process that causes continuous or intermittent pain over months or years’ (West et al., 1998, p. 7). Whereas acute pain has been defined as, ‘the normal, predicted physiological response to a noxious chemical, thermal, or mechanical stimulus and typically is associated with invasive procedures, trauma and disease. It is generally time-limited’ (West et al., 1998, p. 7). Acute pain may become chronic through a combination of increased peripheral and central sensitization that can heighten pain perception (Voscopoulos & Lema, 2010). However, repeated exposure to certain acute stimuli perceived to be painful (e.g., high intensity exertion), could result in an enhanced ability to tolerate pain (Geva &

Defrin, 2013). Sport, exercise, and pain are interwoven (Buckworth et al., 2013), largely due to activation of nociceptive muscle afferents via release of algesic chemicals (e.g., H^+, adenosine, bradykinin) as certain thresholds of exercise intensity are reached, and exceeded (Cook, O'Connor, Eubanks, Smith, & Lee, 1997). Pain may also occur due to muscle damage associated with strenuous resistance training (Pen & Fisher, 1994). There is evidence that despite having similar pain thresholds, athletes have significantly better pain tolerance than healthy non-athlete populations (Geva & Defrin, 2013; Leznicka et al., 2017; Ryan & Kovacic, 1966). Adverse outcomes of pain in athletes may result in the avoidance of performance enhancing training modes (e.g., high intensity interval training or resistance training), withdrawal from competition if pain is anticipated (e.g., a boxer feigning injury to avoid being hurt or knocked out by a powerful opponent), increased injury duration (Sullivan et al., 2002), and affective distress that negatively influences performance and athlete wellbeing (Levy, Polman, Clough, Marchant, & Earle, 2006).

Given the individualized nature of pain experience, acute and chronic pain is commonly measured subjectively via self-report methods (for an in depth discussion of pain rating scales the reader is directed to Hjermstad et al., 2011). Behavioral outcomes can be observed through measuring voluntary responses (e.g., pain tolerance to heat or cold pain; Geva & Defrin, 2013, neuromuscular stimulation; Mileva, Green, & Turner, 2004, or reductions in exercise task performance; Sullivan et al., 2002). Conversely involuntary responses can also be examined, for instance alterations to breathing patterns (Green, Bowtell, & Turner, 2008) or changes to facial expression (Bartlett, Littlewort, Frank, & Lee, 2014). A full discussion of pain assessment is beyond the scope of this review, however, it would appear logical that employing a combination of subjective and objective measures of pain may enable a more comprehensive understanding of both experiences and responses to pain.

Mental Toughness

The link between pain and sports performance has stimulated attempts to identify psychological constructs that predict pain (e.g., pain intensity, pain tolerance, avoidance of anticipated pain). A potentially salient construct that has been implicated in the relationship between pain and sport performance is mental toughness (Jones, Hanton, & Connaughton, 2002). Mental toughness is a psychological construct comprising an assembly of attitudes, values, behaviors, and emotions that permit perseverance in the presence of obstacles, adversity, or pressure (Gucciardi, Gordon, & Dimmock, 2008). Previous researchers have provided evidence that mental toughness represents a unidimensional construct (i.e., Gucciardi, Hanton, Gordon, Mallett, & Temby, 2015), whereas others have shown mental toughness represents a higher-order multidimensional variable comprised of subordinate dimensions (e.g., Guillén & Laborde, 2014). From the dimensional perspective, mental toughness serves as an umbrella term for a range of constructs including but not limited to, hope, self-efficacy, resilience, optimism, and attentional control (Crampton, 2014). According to Gucciardi et al. (2015), mental toughness is unidimensional; however, salient mental toughness resources integrate and aggregate over time, so higher levels of one mental toughness resource are typically associated with higher levels of other mental toughness resources. The authors also suggested the resources associated with mental toughness represent a "resource caravan", providing a collection of personal resources an individual can utilize to drive performance (Gucciardi et al.), such as an ability to maintain performance when experiencing sport pain. Such a conceptualization would suggest that mental toughness is not something that is 'in' an individual or athlete, rather facilitates a process that is experienced. Therefore, in the context of pain, to what extent an individual will remain in the experience of pain is dependent on the individual's mental toughness resource repertoire.

Jones et al. (2002) identified twelve key attributes of mentally tough athletes. These attributes are suggested to be essential for success at the elite level (Jones et al., 2002). One of the proposed attributes was ‘pushing back the boundaries of physical and emotional pain, while still maintaining technique and effort under distress (in training and competition)’ (p. 212). Theorists and commentators frequently reference the relationship between mental toughness and pain, despite a relative lack of evidence to substantiate this association. For instance Addison, Kremer, and Bell (1998) suggested an athlete’s ability to tolerate pain whilst avoiding injury is considered by researchers and coaches essential to sports performance and to possibly differentiate performance levels between elite athletes and their sub-elite counterparts. Likewise, it has been suggested pain tolerance (i.e., the maximum intensity of a pain-producing stimulus that a subject is willing to accept in a given situation) represents a marker between successful and unsuccessful endurance athletes, acknowledging that tolerance of sport pain is not simply a function of physical condition (Anshel & Russell, 1994). Elite performers have reported embracing and welcoming painful parts of training and competition, considering this to give them an advantage not simply over counterparts who disliked or avoided those elements of training, but also those who merely “coped” or “tolerated” these elements (Jones, Hanton, & Connaughton, 2007). Alongside claims of a meaningful relationship between mental toughness and pain tolerance, clichés such as “no pain, no gain” have become common place from elite sport through to recreationally active circles. Such a relationship holds important considerations for athlete welfare because there is an obvious risk of serious harm to an athlete’s well-being as a consequence of pushing too hard in training and competition, whether through their own choice or via external factors such as pressure from coaches. It is also not an intention of this review to make a value judgment on the topic of athlete well-being. We are concerned with the relationship between athletic performance and pain experience, where the ability to accept and manage pain may enable an athlete to optimize performance in a positive manner.

Despite the perception that mentally tough athletes can push back the boundaries of pain, it is not clear how mentally tough athletes achieve pain management compared with their low mental toughness counterparts. A possible reason for the lack of understanding of how mental toughness influences pain experiences is the limited volume of empirical data that directly examines the relationship between mental toughness and pain. Notwithstanding the scarcity of research however, there are studies that can help reveal how mental toughness might be related to pain. For instance, there is evidence that related constructs (i.e., resilience, optimism, hope, self-efficacy, goal attention) that are often considered mental toughness resources are related to pain experiences.

Mental Toughness and Pain

As previously stated, several researchers have identified pain related mental toughness attributes associated with a range of sports and competitive levels (Abdelbaky, 2012; Bull, Shambrook, James, & Brooks, 2005; Butt, Weinberg, & Culp, 2010; Connaughton, Wadey, Hanton, & Jones, 2008; Coulter, Mallett, & Gucciardi, 2010; Jaeschke, Sachs, & Dieffenbach, 2016; Jones et al., 2007). However, such studies did not include assessments of subjective pain experiences (i.e., pain intensity, pain tolerance, and pain threshold) or pain outcomes (e.g., pain behavior).

Investigations into the relationship between mental toughness and pain during injury rehabilitation have shown higher levels of mental toughness predict a better ability to cope with pain (Levy et al., 2006) and increased likelihood that intention to rehabilitate from injury translates into rehabilitative action (Gucciardi, 2016). Whilst the pain associated with these studies is not that with sports performance (e.g., muscle acidosis), they lend support to the notion that mental toughness enables individuals to better tolerate pain and engage in active, rather than avoidance behaviors associated with pain. This contention has been supported elsewhere, with the identification of a moderate inverse relationship between mental toughness and pain catastrophizing in a population of cyclists; however, this point should be interpreted with a degree of caution as no subjective pain experiences (i.e., pain tolerance) or pain behavior (i.e., avoidance of pain) were obtained (Jones & Parker, 2018).

Ultra-endurance trail walkers suggested that mental toughness enables the ability to normalize pain, facilitating rational, as opposed to emotional appraisals of physical pain during training and competition (Crust, Swann, & Allen-Collinson, 2016). This normalization was postulated to result in the acceptance of pain as a by-product of the athlete pursuing competitive goals. Mountaineers have been shown to consider mental toughness to be needed to be able to continue when in pain. Also highlighted though was a potential detrimental quality of mental toughness, where individuals may physically push themselves too far, resulting in severe injury (Crust, Nesti, & Bond, 2010). This quality of mental toughness has been identified elsewhere. Results of semi-structured interviews with marathon runners added support for the beneficial effect of mental toughness enabling athletes to push though pain and injury, which was considered part of 'ultra-marathon culture' (Jaeschke et al., 2016). However, scenarios were discussed where despite significant injuries (e.g., severely sprained ankles, dislocated hips, and torn knees) athletes persisted to finish races, once again highlighting the risks of athletes pushing too hard. These studies do indicate how individuals may use mental toughness attributes to enable success in the presence of pain in sporting situations. The caveat being that success and/or longevity in sport is not a guaranteed outcome of possessing the ability to push through intense pain.

Review Strategy

The decision to conduct a narrative review over other options (e.g., systematic review) was due to the limited number of research studies in this area, and the narrative review allows an exploration of the potential relationship between mental toughness and pain experience in athletes. This type of review strategy has been adopted elsewhere for similar reasons within the mental toughness literature (Gucciardi, Hanton, & Fleming, 2017). A search of electronic databases was conducted employing the search terms (“mental toughness” AND “pain” OR “physical endurance” OR “behavioral perseverance” OR “perceived physical demand” OR “coping”) using a range of databases (EBSCO, Web of Science, Scopus, Google Scholar). Seven papers were identified that infer a relationship between mental toughness and pain, where measures of mental toughness and pain or pain associated variables (e.g., physical exertion) were included.

We are aware that despite suggestions mental toughness is related to pain experiences (i.e., Jones et al., 2002) there is no published research that has measured the relationship between mental toughness and subjective pain (i.e., pain tolerance, pain intensity, pain threshold). For example, the authors of the seven studies identified in the literature search measured analogous constructs (e.g., physical exertion and behavioral perseverance) and did not gather data on whether the participants experienced pain (i.e., pain intensity). Therefore, these studies do not assess the magnitude and direction of any relationship between mental toughness and subjective pain. Based on our previous published research in mental toughness and pain, we are aware of more than 60 published works that make reference to a relationship between mental toughness and pain, despite the fact that to our knowledge it is yet to be empirically examined and has only been inferred. This issue is further reinforced by the fact that related terms such as ‘sport’ and ‘athlete’, were investigated but not found to warrant inclusion in the final search terminology, as they did not retrieve any research over and above the included search terms. This highlights the widespread misunderstanding that a relationship between mental toughness and pain does exist in both the general population and specifically amongst athletes. We are also aware of literature that considers mental toughness resources in the context of pain and based on this awareness another goal is to highlight the potential mechanisms that explain why people high in mental toughness might report different pain experiences to those lower in mental toughness.

Mental Toughness and Sport Pain

Researchers have used proxies of pain (i.e., physical exertion) to assess associations between pain and mental toughness in a performance context. This collection of studies represents the seven studies identified in the literature search (Bell, Hardy, & Beattie, 2013; Christensen, Brewer, & Hutchinson, 2018; Clough, Earle, & Sewell, 2002; Crust & Clough, 2005; Giles et al., 2018; Gucciardi, Peeling, Ducker, & Dawson, 2016; Jones, 2019). While these studies are revealing, it is important to note that physical exertion and pain are distinct experiences. Although pain is typically tied to a noxious stimulus like physical exertion, readers should not infer that physical exertion necessarily caused pain in all participants. For some, physical exertion could have been effortful but not painful. Therefore, caution is advised when interpreting the claim that mental toughness is related to pain experiences when pain experiences (i.e., pain threshold, pain intensity, and pain tolerance) are not measured. Various psychological attributes including mental toughness, were examined in a population of athletes in relation to ultra-marathon performance (Christensen et al., 2018). Mental toughness was found to be the only significant predictor when controlling for demographic and training variables. The authors suggested successful athletes might perceive pain as ‘good’, providing useful information as opposed to negative perceptions of ‘bad’ pain, which may amplify factors such as the unpleasantness of pain. This contention supports a postulation that positive constructs (such as mental toughness) hold stronger associations with success in physically and emotionally challenging tasks than maladaptive constructs such as pain catastrophizing.

The relationship between mental toughness and increasing intensities of cycle ergometry has been shown to result in differences in perceived physical demand (Clough et al., 2002). At 30% VO_{2max}, no meaningful differences in perceived physical demand between 'low' and 'high' mental toughness groups were evident. An increased perceived physical demand was observed at 50% VO_{2max} in the low, as opposed to high mental toughness group. At a work rate of 70% VO_{2max}, the low mental toughness group reported significantly higher perceived physical demand, where it can be postulated there was an increased presence of sport pain through higher physical exertion. However, this is speculative as the authors failed to collect any measures associated with pain (i.e., subjective pain experiences, pain behavior). It could be that mental toughness influences pain threshold (i.e., the minimum intensity of a stimulus that is perceived as painful). For example, at 50% VO_{2max} the lower mental toughness group could have appraised bodily sensations as pain whereas the high mental toughness group could have appraised the physiological experience as exertion or tightness. As exercise ceased before participants reached exhaustion, it remains unclear whether differences in perceived physical demand would result in changes to exercise tolerance at higher work rates. It may be possible however to draw inferences regarding the above points from the results of Cook et al. (1997). Their research supports that of Clough et al. (2002), where the authors observed pain threshold to occur at ~50% peak power output and peak VO_2. The authors also reported the variability of pain threshold, which ranged from 24% - 72% of relative peak power output. The participants all stated that they ceased exercise due to leg muscle fatigue, not leg pain. Although these results suggest that sport pain in the form of physical exertion would not be the limiting factor to this type of exercise, the wide variability in pain threshold does show that coping would have been different between participants. Whilst this may not have affected exercise performance within the task, it may have implications for whether individuals who have to cope with more pain would choose to partake regularly in sports or training that carry such demands.

An isometric weight-holding task was employed to examine associations between mental toughness and physical endurance (Crust & Clough, 2005). Increased task performance was associated with higher levels of mental toughness, suggested to provide a buffer enabling participants to be better able to block out pain. This assertion should be evaluated with caution, however, as pain was not measured. Employing a much larger sample size with similar population characteristics, Jones (2019) replicated Crust and Clough's 2005 study but did not support their findings. Jones concluded further replicative research and different research designs are required before any relationship between mental toughness and physical endurance, and in turn pain tolerance might be inferred.

Bell et al. (2013) investigated an intervention designed to increase mental toughness by comparing changes in multistage 20m shuttle-run test performance (MST) between intervention and control groups. Neither mental toughness nor MST performance was different between groups at pre-test, however, significant increases in both variables in the experimental group following the intervention were observed, compared with no significant changes in the control group. The MST was used as it would potentially provide exposure to a form of sport pain (i.e., metabolic acidosis) through physical adversity (Bell et al.). Gucciardi et al. (2016) also implemented the MST, investigating whether the findings of Bell et al. could be generalized to a more naturalistic field based setting in a population of male Australian football players. Mental toughness was found to provide an additional 5.4% in MST performance above that of previously identified predictors of aerobic capacity (age, height, playing experience, and body mass). The authors posited their findings to support the theoretical proposition that behavioral perseverance is a signature of mentally tough athletes.

Giles et al. (2018) looked to develop these two studies by including objective measures of aerobic capacity (VO_{2max}), and assessing the association between mental toughness and behavioral perseverance with participants performing the MST in a nonfatigued and fatigued state. Performing the MST under fatigued conditions attempted to examine the core premise that individuals high in mental toughness are able to 'push through the pain barrier' at a time when their bodies are signaling them to stop. After controlling for aerobic capacity, Giles et al. supported previous findings, showing a positive association between mental toughness and behavioral perseverance in the non-prior-fatigued state. The findings did not however hold under conditions of prior fatigue, leading the authors to suggest other elements of mental toughness such as self-referenced goals may become more important under such conditions. This contention suggests that as the demands of the task increase (e.g., exertional effort), specific components of mental toughness need to be active if the effect of mental toughness is to support performance. If an athlete does not have a self-referenced goal when completing a task such as the MST, motivation may be constrained which could result in sub-maximal effort. It has been suggested that psychological factors may explain between 39-63% of variance in MST (Gucciardi et al., 2016). It is possible that as the demands of such tasks vary (e.g., prior fatigue or not), demands on mental toughness change, challenging individuals differently depending on the qualities of their unique mental toughness profile.

Regardless of the absence of direct pain measurement per se, these studies provide initial support for the existence of a relationship between mental toughness and aversive experiences such as pain tolerance, threshold, and intensity. Considered together, these studies indicate that individuals higher in mental toughness are able to perform better during physically and psychologically demanding exercise tasks. Where mental toughness has been shown to be developable, individual performance in such tasks can be improved. There also appears to be thresholds of intensity that need to be reached before psychological resources such as mental toughness are utilized, and that these thresholds are unique to the individual. Therefore, the nature of the task employed when researching this area is extremely important (e.g., an exercise that becomes exponentially harder the longer it goes on). However, it is the inclusion of subjective pain experiences (i.e., cognition and negative affect) and objective behavioral measures associated with sport pain (i.e., avoidance of pain and facial expressions) that would better inform identification and understanding of any such relationship.

Mental Toughness Resources and Pain

Andersen (2011) identified more than 70 attributes, characteristics, behaviors, constructs, cognitions, and emotions suggested to be components of mental toughness (Mahoney, Gucciardi, Ntoumanis, & Mallett, 2014). More recently this figure has been shown to have increased greater than two fold (Crampton, 2014). While high global levels of mental toughness certainly indicate a propensity to achieve consistent optimal levels of performance, global measures of mental toughness may lack the sensitivity to identify areas for potential development, even within the elite. This could be in-part due to the apparent breadth of resources considered to conceptualize mental toughness. Therefore it seems pertinent to consider the specific resources within an individual's "resource caravan" that enable them to tolerate sport pain, in addition to considering the broad nature of mental toughness. For mental toughness to be considered relevant to the prediction of pain experiences there should be incremental validity in combining subordinate traits, values, and attitudes beyond subordinate traits, values, and attitudes in isolation. With regards to the relationship between mental toughness and pain associated with sport, it would seem warranted to identify the specific mental toughness attributes associated with sport pain.

A literature search was conducted to identify key mental toughness resources that hold associations with pain. This was achieved by examining the resources of mental toughness (Crampton, 2014) and identifying those related to pain. Using the same search strategy detailed previously, the term "mental toughness" was replaced sequentially by each identified resource (Crampton, 2014) and a search of the literature undertaken. In the following sections, research will be presented showing evidence of specific mental toughness resources that have been shown to predict pain experiences.

Optimism

Gatchel et al. (2007) proposed that optimism is one of the most important personality traits associated with positive adjustment to chronic pain. Researchers have shown this association also exists with acute pain stimuli, more relevant to conditions associated with sport pain (Boselie, Vancleef, Smeets, & Peters, 2014; Hanssen, Peters, Vlaeyen, Meevissen, & Vancleef, 2012). Scheier and Carver (1985) defined outcomes of optimism in these terms: "optimists expect things to go their way, and generally believe that good rather than bad things will happen to them" (p. 219). Research using acute experimental pain induction has shown optimism to be associated with lower ratings of pain intensity in pain free participants (Goodin & Bulls, 2013) and increased pain tolerance in subjects suffering with temporomandibular disorder (Costello et al., 2002).

A key mechanism by which optimism is suggested to exert beneficial effect is through the type of coping strategy employed. High levels of optimism have been found to commonly result in adoption of approach/adaptive coping strategies, as opposed to avoidance/maladaptive methods (Carver, Scheier, & Segerstrom, 2010). For example, researchers have identified pain catastrophizing as a mediator of the optimism and pain relationship (Hanssen et al., 2012). Defined as exaggerated cognitions in anticipation of, or actual experience of pain (Sturgeon & Zautra, 2013), pain catastrophizing is characterized by rumination, magnification and helplessness factors resulting in avoidance behaviors (Sullivan et al., 2002).

Associations with proactive coping strategies draw parallels with coping behaviors used by mentally tough individuals (Nicholls, Polmann, Levy, & Backhouse, 2008). Boselie et al. (2014) postulated use of approach type coping enables attention to remain on a task when in the presence of pain. Boselie et al. identified optimism to be associated with maintenance of executive function during task performance when experiencing experimentally induced pain, as opposed to reductions in executive function with individuals low in optimism. This highlights a relationship between optimism and goal-directed attention, again drawing parallels with pain related attributes associated with mental toughness (Goodin & Bulls, 2013; Jones et al., 2007).

While there is good evidence to suggest optimism has the potential to provide beneficial effects with regards to indices of sport pain, this is not without caveats. Although Costello et al. (2002) found high optimism temporomandibular disorder patients to exhibit greater pain tolerance and lower pain unpleasantness than those with low optimism, high optimism healthy controls demonstrated the lowest pain tolerance times and reported greater pain unpleasantness. One potential reason for this could be that repeated rather than single exposure to pain stimuli is required before the effect of optimism becomes apparent. Smith et al. (2009) found optimism predicted greater habituation to cold pain in healthy females. It can be suggested that temporomandibular disorder patients have adapted to pain through chronic exposure and as a result optimism plays a role in whether patients adapt well or not. Acute experimental pain research has found optimism's effect on pain sensitivity, distress, and cardiovascular reactivity to be situational (Geers, Wellman, Helfer, Fowler, & France, 2008). Therefore, we postulate that in athletes, high optimism may exert greatest effect on indices of sport pain when the individual has had time to adapt to the experience of sport pain. This area warrants further investigation.

Resilience

Resilience is suggested to provide a protective factor against the development of maladaptive cognitions associated with pain (Gatchel et al., 2007). In respect to mental toughness, resilience has been described as a resource that enables athletes to rebound from performance setbacks through increased determination for success (Jones et al., 2002). Sport may also represent an environment conducive to the development of resilient qualities through growth and development as a result of challenging situations (Galli & Vealey, 2008).

Researchers have shown evidence of the protective effect of resilience to acute pain conditions in healthy and athletic populations (Freund et al., 2013; Galli & Vealey, 2008; Jones & Jetten, 2011; Smith et al., 2009). Research on personality traits and pain tolerance between ultra-marathon athletes has shown sources of pain to include myofascial pain, compartmental syndrome, and inflammation of joints and tendons; symptomology that the athletes are considered to be highly resilient to (Freund et al., 2013). Ultra-marathon athletes were reported to have significantly higher pain tolerance than control participants in a cold pressor task. This is a quality that has been shown elsewhere in healthy participants with higher levels of resilience and suggested to result from resilience enabling better habituation to painful stimuli (Smith et al., 2009). High pain tolerance in ultra-marathon athletes may represent a prerequisite ability to cope with all types of progressive and physical overload, a contention relevant to the training and/or competition associated with the majority of sports (Freund et al., 2013). Resilience however was not directly measured, rather inferred through association with other variables and therefore caution is advised when interpreting the presence and effect of resilience in this study.

Membership of multiple groups has been shown to represent a source of resilience (Jones & Jetten, 2011). In two separate studies greater resilience was found to result in increased heart rate recovery following a winter sport training session in athletes (study 1) and superior endurance in a cold pressor task in students (study 2). It was postulated that group membership provides a resource for development of resilience through factors such as sense of belonging, purpose, and meaning and that this in turn may provide a buffer to negative well-being effects of stressors (Jones & Jetten, 2011).

There appears limited but promising evidence for the protective effects of resilience on acute pain. However, the majority of research suggests resilience does not exert its effect alone but rather alongside or through other mechanisms, many of which hold an association with the constituent components of mental toughness. For example approach coping, optimism, positive emotion, motivation, goal focus, and self-efficacy (Galli & Vealey, 2008; Jones & Jetten, 2011; Machida, Irwin, & Feltz, 2013; Ong, Zautra, & Reid, 2010). This highlights a question of whether individual factors associated with sport pain such as resilience, would predict indices of sport pain to a lesser or greater extent in isolation or as part of a model of predictors of sport pain.

Goal Attention

Achieving goals represents a fundamental component of mental toughness (Jones et al., 2002). Of the twelve mental toughness attributes identified in a sample of elite performers by Jones et al. (2002), having an unshakeable belief in one's ability to achieve their competition goals was ranked as the most important attribute for sporting success. Gucciardi et al. (2008) defined mental toughness as enabling individuals to consistently achieve their goals, suggesting goal success to be a major outcome of mental toughness. A key factor in goal success is goal commitment or focus (Locke & Latham, 2002), a characteristic frequently highlighted in the mental toughness literature (Crampton, 2014) and a significant area of research into coping with pain.

It has been suggested pain should always be considered with regards to goal pursuit (Van Damme, Legrain, Vogt, & Crombez, 2010). The authors contended that occurrence of pain may either unintentionally capture attention even though it may not be relevant to a pursued goal, or that attention to pain may be driven by a goal related to pain (e.g., chronic pain sufferers attempting to gain control over their pain; Van Damme et al., 2010). Equally, athletes chasing performance success may realize the need to push through pain to increase the chances of winning. Phrases such as ‘train hard, fight easy’ commonly used in combat sports, are indicative of the type of mentality employed in attempts to achieve certain sport related goals. Conversely, distracting attention away from pain during the pursuit of a goal would remove processing of any pain related information, resulting in an analgesic effect of goal focus (Legrain et al., 2009). Therefore when pain is present, attention to pain appears to be a key factor in the process of goal pursuit and pain related outcomes may change due to differences in cognitive processing. An ability to remain focused on a task in the presence of pain (e.g., not attentive to pain) has been posited to be due to top-down (goal-directed) cognitive processing (Legrain et al., 2009). Attention directed away from the task and towards pain related information would suggest an increase in bottom-up (stimulus driven) processing and likely result in a reduction in task performance (for a detailed description on the neurocognitive processing of pain, the reader is directed to Legrain et al., 2009). These differences in cognitive processing highlight the importance of goal salience as a key factor in an individual’s ability to remain focused on a task, which would be especially relevant to athletes experiencing sport pain whilst in pursuit of their athletic goals.

Pain stimuli in the form of a cold-pressor task and combinations of goal and non-goal instruction with temporal cues (i.e., time elapsed, time remaining, tonal, or no cue) were employed to investigate pain tolerance (Stevenson, Kanfer, & Higgins, 1984). The ‘no goal, no cue’ group (where participants were simply asked to keep their hand in the water long enough for the researcher to collect data) demonstrated the longest pain tolerance times. The authors concluded this result may have been mediated by an increase in self-set goals by the participants and would indicate that if any self-set goals had been employed, perhaps the salience of the goal would be higher compared to a researcher set goal (Stevenson et al., 1984). This contention may indicate an important contributor to individual variability in pain tolerance. For example, Jones et al. (2002) suggested an awareness of personal limitations would enable an individual to set and achieve realistic goals. New, more challenging goals can then be set, increasing chances of success and facilitating development of mental toughness (Jones et al., 2002). Therefore 'having an unshakable self-belief in your ability to achieve your competition goals' (Jones et al., 2002, p. 210) may engender mentally tough individuals to be more adept at setting personally meaningful goals. This would potentially enable them to be better able to tolerate pain, if pain tolerance facilitated goal success.

Attentional bias to pain signals has been investigated using a spatial-viewing task with pain and non-pain cues (Schrooten et al., 2012). Pain stimuli were delivered through cutaneous electrical stimulation. A performance related monetary incentive and punishment system were utilized in some of the spatial-viewing trials to increase affective motivation towards the task goal but only in the goal group. Attentional bias to pain was observed in the control group but not the goal group, leading to the conclusion that reduced task performance due to experimentally induced pain can be modulated if the task is motivationally salient and cognitive load is high (Schrooten et al., 2012). Furthermore, following the task, participants in the goal group rated the pain stimulus as less unpleasant and painful than the control group, a result supported by Verhoeven et al. (2010) in a similar study. This finding was also attributed to motivational salience and cognitive demand within the task (Schrooten et al., 2012), which has been observed previously where pain has been shown to only modulate cognitive related activity when cognitive load was minimal (Seminowics & Davis, 2007).

The findings of the aforementioned research indicate that maintenance of goal directed attention may not only result in increased task performance and in turn pain tolerance but also lower individual's perceptions of pain intensity. For athletes who regularly experience sport pain through training and competition, this highlights important considerations for setting salient goals where strong motivation can be maintained.

Self-efficacy

Bandura (1977) posited efficacy to be distinct to response-outcome expectancies, which refer to an individual's estimate that a specific behavior will lead to a given outcome. This suggests self–efficacy represents an individual's belief they can execute specific behaviors required to achieve desired outcomes. Major sources of self-efficacy are proposed to be performance accomplishments, vicarious experience, verbal persuasion, and physiological states (Bandura, 1977), with previous behavior (both successful and non-successful)/mastery experiences, representing the primary contributor to self-efficacy expectations (Dolce et al., 1986; Hutchinson, Sherman, Martinovic, & Tenenbaum, 2008). An individual's belief whether they can accomplish a given task equates a personal appraisal that they possess adequate resources to cope with the demands of that task. In the context of pain experience and behavioral outcome, Dolce et al. (1986) suggested self-efficacy mediates pain coping behavior through self-efficacy expectancies, which result from appraisals of past experience of coping with pain and in turn are attributed to personal resources.

Identified as a component of mental toughness (Crampton, 2014), self-efficacy has been shown by researchers to be predictive of higher levels of pain tolerance and lower levels of pain sensitivity (Bandura, O'Leary, Taylor, Gauthier, & Gossard, 1987; Dolce et al., 1986; Jackson, Iezzi, Gunderson, Nagasaki, & Fritch, 2002; Johnson, Stewart, Humphries, & Chamove, 2011; Litt, 1988; Rokke, Flemming-Ficek, Siemens, & Hegstad, 2004; Vallis & Bucher, 1986), and increased performance and reduced perception of effort in physically aversive tasks (Feltz & Riessinger, 1990; Hutchinson et al., 2008).

Pain threshold, pain tolerance, and self-efficacy were investigated in marathon runners and matched (age and gender) controls (Johnson et al., 2011). Potassium iontophoresis was used to induce pain, a technique which has been suggested to have good ecological validity to pain experienced by marathon runners as it mimics the potassium ion release associated with intense muscle activity and anoxia (Johnson et al., 2011). The marathon runners displayed significantly higher pain specific self-efficacy, pain threshold, and pain tolerance times compared to the control group. Differences between groups were postulated to be due to repetitive exposure to sport pain in marathon runners, leading to positive mastery experiences which resulted in the athletes having greater confidence in their ability to deal with pain, specifically pain associated with intense athletic activity (Johnson et al., 2011).

Self-efficacy manipulations on perceptions of leg muscle pain have been assessed during moderate intensity exercise in females (Motl, Konopack, Hu, & McAuley, 2006). Higher levels of self-efficacy showed a moderate inverse relationship with leg muscle pain during early stages of maximal exercise at baseline. Bogus feedback was then used to either increase or decrease self-efficacy dependent on whether participants were assigned to the low or high self-efficacy condition. Although manipulation of self-efficacy was successful, this effect held no association with perceptions of leg muscle pain during subsequent exercise. These findings contradict numerous studies that have identified increases in pain tolerance or decreases in pain sensitivity following interventions that successfully increase self-efficacy (Bandura et al., 1987; Hutchinson et al., 2008; Vallis & Bucher, 1986). A possible reason for this could be related to the specificity of the self-efficacy measured. Participant's self-efficacy regarding whether they felt they could engage in moderate intensity exercise was examined by Motl et al. (2006). Conversely, the studies mentioned above that have observed changes in pain experience or outcome, have assessed pain or task specific self-efficacy. This contention highlights the importance of identifying an individual's beliefs that they can cope with the pain associated with a task, if measures of pain experience or behavior are to be assessed. This would also be a consideration if interventions are employed that aim to improve pain experience or outcome behaviors. Another confounder that may have affected Motl et al.'s findings, could be related to the intensity of the task. The authors identified this limitation, suggesting self-efficacy may not exert an effect at low to moderate intensities of exercise. It is an important consideration that studies aiming to induce experimental pain select an effective pain stimulus that accounts for individual variability in pain experience.

Differences between individual (training in aerobic dominant activity more than 3 times per week), team (training in team sport events at least 3 times per week) and recreational/untrained (participating in regular physical activity less than 3 times per week or not at all) athletes/non-athletes, have been examined assessing exertion time in strength endurance tasks (Tenenbaum et al., 2001). Results showed individual and team athletes performed significantly longer than recreational/untrained non-athletes when squeezing a hand-grip dynamometer at 50% of their maximum force and that individual athletes rated perceived exertion significantly lower than team athletes and recreational/untrained non-athletes. Self-efficacy was assessed as part of a step-wise regression model which included variables such as group membership and goal orientations. The variables entered accounted for 59% of the variance in time spent during exertion, with self-efficacy accounting for 12% variance. When self-efficacy was entered earlier in the order of inclusion in the model and swapped with goal orientations, it accounted for approximately 20% of variance (Tenenbaum et al., 2001). In a subsequent study (study 4) investigating similar populations and measurement variables during an intense running task, self-efficacy was found to account for a non-significant 7% of the variance in exertion time as part of the regression model (Tenenbaum et al., 2001). The authors highlighted the important role of self-efficacy in facilitating an athlete's ability to tolerate exertion, suggesting those athletes within the study who were particularly accustomed to repeated exertion/physical discomfort such as runners and cyclists, would be more motivated to endure physical adversity and likely have developed effective strategies to cope with it. This in turn would be expected to promote high self-efficacy specific to attempting such tasks. Similar to the work of Motl et al. (2006) however, the specificity of the self-efficacy may be called into question. The physical self-efficacy scale (Ryckman, Robbins, Thornton, & Cantrell, 1982) was employed by Tenenbaum et al. (2001). The scale contains no questions pertaining to pain, however, it does ask questions of strength of grip and ability to run quickly. It can therefore be suggested that if a self-efficacy scale more sensitive to the sport pain involved in the tasks had been used by Tenenbaum et al., pain specific self-efficacy may have accounted for a larger proportion of variance in the respective models.

Despite the methodological issues discussed, there is strong research evidence indicating the predictive qualities of pain specific self-efficacy over pain experience and outcomes (e.g., perception of pain, pain tolerance) in acute pain settings. Encouragingly this effect has been shown in athletic populations during the experience of sport pain and this in consideration with research showing the changeable quality of self-efficacy, provides a promising area for future research.

Inter-relationship of Pain Associated Mental Toughness Components

The process of identifying the pain associated resources of mental toughness also highlighted a high degree of inter-relationship. For example, optimism informs expectancy for good as opposed to negative outcomes. If someone has high self-efficacy towards a task, they would equally be optimistic about the outcome. The qualities of resilience enable individuals to negotiate, adapt to, or manage stressful or traumatic events (Windle, 2010). The protective assets underlying resilience are suggested to include efficacy (Windle, 2010) and optimism is widely considered a resilience factor (Gatchel et al., 2007). A principle source in the formation of positive self-efficacy beliefs is suggested to be performance accomplishments (Bandura, 1977). While efficacy may be a suggested asset of resilience, if through the resilient process of ‘bouncing back’ from adversity an individual achieves successful performance, then resilient qualities can be postulated to also be a key driver of positive efficacious beliefs, as would optimism. These points potentially indicate the existence of an interdependent relationship. A dynamic interplay between optimism, resilience, and self-efficacy can be postulated to facilitate an ability to retain high levels of goal attention in the pursuit of achieving a specific goal. Given the evidence discussed throughout this review this can be suggested to represent a possible differentiating factor in positive outcomes to pain experience and provide areas for future exploration which will be discussed in the following section.

Summary and Conclusions

This review has identified sport pain to be an engrained component of the demands associated with many sports. Theoretically, mental toughness should represent a desirable psychological attribute that promotes positive experiences and outcomes in the acute pain experiences of athletes. As discussed, although previous investigations provide some support for this contention, we highlight that existing research concerning mental toughness and pain related outcomes, is both sparse and methodologically flawed. This represents a limitation of the area. As discussed in the methods section search terms such as ‘sport’ and ‘athlete’ did not warrant inclusion. This is perhaps because the bulk of research on pain has been conducted into chronic pain, with much less on sport pain, which is likely transient and acute. We have therefore looked outside of studies directly associated with mental toughness and drawn upon non-sport pain related investigations in an attempt to encourage a research focus in this promising area. The process of stripping mental toughness back to its constituent components has identified strong associations between pain related factors such as pain threshold and pain tolerance, and the resources of mental toughness we suggest to most confidently predict pain related outcomes, namely; optimism, resilience, goal attention, and self-efficacy. This evaluation of both specific and wider research has identified some important considerations for future research. Researchers should examine whether mental toughness predicts pain experience at a generic level (e.g., arbitrary pain stimuli in healthy populations) and compare with the specific context of sport pain experience in athletes using valid and robust research methodology. To fill the gaps of previous research with athletic populations, a valid outcome measure of sport pain should be assessed, such as the magnitude of delayed onset muscle soreness (DOMS) following a muscle damaging task. The inclusion of some form of performance test (e.g., maximal voluntary contraction) pre and post DOMS, along with acute measures of pain (e.g., pain intensity) will enable more reliable interpretations and conclusions to be drawn from any identified associations between mental toughness and sport pain experience in athletes. A more detailed analysis of mental toughness and the resources associated with pain experience is warranted to identify any contributions from each. Despite similarities, the resources have been shown to be distinct (e.g., Nicholls et al., 2008). Therefore it would be prudent to assess the relationship between mental toughness and each of the four resources with pain experience separately. Alongside this, the resources could also be tested within a model to see if there is a synergistic effect. If mental toughness is found to strongly predict sport pain experience in athletes, the assessment of the resources would provide valuable insights into the mechanistic underpinnings of the relationship and may additionally highlight a proportion of variance not explained by the four resources identified in this review. An accurate understanding of any possible mechanisms would help inform intervention based research into athletes who are limited by a poor ability to endure sport pain.

In conclusion, this review highlights evidence of a relationship between mental toughness and sport pain, and drawn together wider research from specific resources of mental toughness to support the existence of this relationship. Given the importance of the ability to push through painful periods of training and competition in the quest for athletic success, this review builds a strong case for further research to be completed in this interesting area. Positive findings would help instruct applied coaching practices through the development of effective intervention programs which could be hugely beneficial to athletes of all levels and help ensure athletic potential is fulfilled.

Disclosure statement

No potential conflict of interest was reported by the authors.

Data availability statement

Data sharing is not applicable to this article as no new data were created or analyzed.

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Appendix

Table 1

Classification of sport pain associated with training and competition

Pain Type	Description	Possible Associated Sports/Training Modality
High physical volume	Physical soreness from long duration repetitive movements. High levels of fatigue through depletion of finite energy stores (e.g., muscle glycogen) resulting in phenomena such as 'hitting the wall'	Endurance sports such as marathon running, triathlon, rowing
High physical intensity	Stressing of physiological systems resulting in sensations such as muscle burn through muscle acidosis and accumulation of fatigue related metabolites	Short duration/intermittent sports such as 800m running, sprint cycling, or through resistance training
Delayed onset muscle soreness	Associated with intramuscular inflammatory responses following particularly demanding period/s of training and competition	Strength and conditioning training, endurance sport training and competition, combat sport fight camp preparation
Contact pain	Body to body or body to ground contact through actions such as tackling and mauling, crashes or falls in cycling or equestrian events and blows such as kicking and punching	Rugby, Australian Rules Football, American Football, Ice Hockey, cycling, equestrian, combat sports such as boxing and mixed martial arts

	that result in high pressure applied to soft tissues and contact injuries such as haematomas, bone fractures, and joint dislocations, or lacerations due to impact from playing equipment (e.g., being hit by a ball, contact with the blade of an ice hockey skate)	
Joint stressing	During attempted submissions via joint locks, force is applied to a joint in a hyperextended position	Grappling sports such as mixed martial arts, judo, Brazilian jiu jitsu
Isometric muscle pain	During maximal isometric holds for significant periods of time (e.g., gripping an opponent, holding a static posture)	Grappling sports such as mixed martial arts, judo, Brazilian jiu jitsu, wrestling and gymnastics events such as the rings, strongman events such as loaded carries