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ABSTRACT

Objectives: To determine if height or BMI have a causal role in five measures of socioeconomic status (SES).

Design: A Mendelian randomisation study to test for causal effects of differences in stature and BMI on five measures of SES. Mendelian randomisation exploits the fact that genotypes are randomly assigned at conception and thus not confounded by non-genetic factors. Using data from up to 119,669 individuals, height genetic variants and BMI genetic variants were used to estimate the causal effect of differences in stature and BMI on five different measures of SES. Analyses were also performed in men and women separately.

Setting: UK Biobank

Participants: Men and women of British ancestry, aged between 40 and 73 years

Main outcome measures: Age completed full time education, degree level education, job class, annual household income and Townsend deprivation index (TDI)

Results: In the UK Biobank study shorter stature and higher BMI were observationally associated with several measures of lower SES. The associations between shorter stature and lower SES tended to be stronger in men and the associations between higher BMI and lower SES tended to be stronger in women. For example, a 1 standard deviation higher BMI was associated with a £210 ([95%CI:£84,£420], $p=6x10^{-3}$) lower annual household income in men and a £1,890 ([95%CI:£1,680, £2,100], $p=6x10^{-106}$) lower annual household income in women. Genetic analysis provided evidence that these associations were partly causal. A genetically determined 1 standard deviation (SD) (6.3 cm) taller stature caused a 0.06 year ([95%CI:0.02,0.09], p=0.01) older age of completing full time education, a 1.12 ([95%CI:1.07,1.18], $p=6x10^{-7}$) times higher odds of working in a skilled profession and a £1,130 ([95%CI:£680,£1,580], $p=4x10^{-8}$) higher annual household income. Associations were stronger in men. A genetically determined 1 SD higher BMI (4.6 kgm^{-2}) caused a £2,940 ([95%CI:£1,680, £4,200] $p=1x10^{-5}$) lower annual household income and a 0.10 SD ([95%CI:0.04,0.16] p=0.001) higher level of deprivation in women only.

Conclusions: These data support evidence that height and BMI play an important partial role in determining several aspects of an individual's SES, especially women's BMI for income and deprivation and men's height for education, income and job class. These findings have

important social and health implications, supporting evidence that overweight individuals, especially women, are at a disadvantage, and that taller individuals, especially men, are at an advantage.

What is already known?

Socioeconomic status (SES) influences morbidity and mortality, with a recent review in the lancet highlighting the 18 year gap in life expectancy between men living in the poorest and richest boroughs of Westminster. Taller stature and lower BMI are associated with higher SES. The causal directions of these associations are poorly understood because they are likely to be heavily confounded. Higher SES will likely increase stature and lower BMI due to improved lifestyles in childhood and adult life, but there may also be effects in the opposite direction – taller stature and lower BMI may causally improve SES, through mechanisms such as discrimination against shorter and fatter individuals. Understanding the causal directions of these associations is important for public health and well-being policies.

What this paper adds?

This paper provides what we believe to be the highest level of evidence for a causal effect from shorter stature and higher BMI to lower measures of SES. We provide the most substantial evidence to date that shorter height, as estimated by genetics, leads to lower levels of education, lower job status and less income in men in particular. Using the same approach, higher BMI, as estimated by genetics, leads to lower income and greater deprivation in women. Previous studies had been limited to observational associations or genetic studies of few variants of uncertain influence with BMI or height and used less than 3000 individuals. Our study uses many hundreds of genetic variants robustly associated with height and BMI and 119,000 individuals from the UK Biobank. Genetic evidence has the advantage of being largely free from the problems that afflict observational studies – analyses using inherited DNA variation are much more robust to confounding, bias and reverse causality.

INTRODUCTION

Higher socioeconomic status (SES) is associated with better health and longer life [1 2]. For example, a recent article highlighted the strength of the association between wealth and health by pointing out the 18 and 20 year gaps in male life expectancy between the least and most wealthy parts of London, UK and Baltimore, USA respectively [3]. Two easily measured markers associated with SES are adult height [4 5] and BMI [6]. In developed counties, taller stature and lower BMI are associated with higher SES[4-10] and better health [11 12]. Higher SES is generally thought to cause taller stature and lower BMI due to higher standards of nutrition in childhood, but there may also be effects in the opposite direction – taller stature and lower BMI may causally improve SES, for example through discrimination against shorter [13] and fatter individuals [14] or differences in self-esteem that affect employability[13]. There is limited evidence as to whether or not height and BMI have causal effects on SES through these, or other, pathways. For example, to our knowledge, there are no large studies comparing siblings or twins of different heights and BMIs, where childhood environment could be controlled for. If differences in BMI and height can lead to differences in SES, this would have implications for policy makers. For example, evidence of a causal link would further highlight the need to adjust for unconscious biases in decision making in education and employment.

Gene-based analyses such as Mendelian randomisation[15] can be used to test for a causal relationship between SES and a genetically influenced phenotype such as BMI. Genetic variants can act as unconfounded proxies for the risk factors under investigation – here BMI and height - because inherited genetic variation is randomly allocated at conception. The outcomes being tested, here measures of SES, cannot influence genetic variation, and so reverse causality is avoided in genetic studies. The principle of Mendelian randomisation is illustrated in Figure 1. Previous studies have used genetic variants to test causal relationships between health traits such as BMI and SES related outcomes such as academic performance. However, these studies were limited by a lack of genetic variants robustly associated with BMI and by sample sizes of fewer than 2300 individuals [16 17]. Recent genome wide association studies have identified many 10s and 100s of genetic variants associated with BMI and height, respectively [18 19] and so provide the tools for Mendelian randomisation tests.

Here, we performed Mendelian randomisation analysis to test the hypothesis that there are causal pathways from BMI and height to differences in five different measures of SES. We used the first release of data from the UK Biobank. The UK Biobank has 119,669 participants of British Caucasian ancestry with genetic data, measures of SES and height and BMI measures. Therefore, the UK Biobank represents a very powerful resource in which to investigate the causal relationship between BMI, height and SES using Mendelian randomisation analysis.

METHODOLOGY

UK Biobank

The UK Biobank recruited over 500,000 individuals aged 37-73 years (99.5% were between 40 and 69 years) in 2006-2010 from across the country. Participants provided a range of information via questionnaires and interviews (e.g. demographics, health status, life style) and anthropometric measurements, blood pressure readings, blood, urine and saliva samples were taken for future analysis: this has been described in more detail elsewhere [20]. We used 120,286 individuals of British Caucasian descent from the initial UK Biobank dataset, of these 119,669 had valid genetic data and both BMI and height measures available. We did not include other ethnic groups, because individually they were underpowered. Basic characteristics are given in **table 1**. British Caucasian descent was defined as individuals who both self-identified as white British and were confirmed as ancestrally Caucasian using principal components analyses (PCA) of genome wide genetic information. This dataset underwent extensive central quality control (http://biobank.ctsu.ox.ac.uk) (Supplementary methods).

Exposure and outcome measures

Exposure and outcome measures were all collected at baseline when participants attended the assessment centre.

Height: Height (cm) was measured in all participants in the UK Biobank using a Seca 202 device (n=500,120). Sitting height was also measured (n=496,380). We excluded one individual from the 500,120 with a height more than 4.56SD away from the mean and a sitting height to standing height ratio of greater than 0.75 that is not compatible with normal growth. 119,669 individuals of British Caucasian ancestry with genetic data available also had a valid height and BMI measure.

BMI: The UK Biobank has 2 different measures of BMI – one calculated from weight/height^2 and one using electrical impedance to quantify mass. We excluded individuals with significant differences (i.e. more than 4.56SD from the mean) between impedance and normal BMI measures (n=1,172) where both variables were available. If only one measure of BMI was available this was used (n=7,290). Valid BMI was available for 119,669 individuals with genetic and height data available.

Socio economic status: Five different SES variables were used:

1. Age completed full time education in years – questionnaire based. Data were available for 82,543 individuals, and missing in 37,126 individuals with valid height, BMI and genetic data;
2. Education (coded as degree level or not) – derived from the questionnaire; participants were asked *"Which of the following qualifications do you have? (You can select more than one)"*, with the options College or University degree, A levels or equivalent, O levels or GCSEs or equivalent, CSEs, NVQ/HND/HNC, Professional qualifications (e.g. nursing or teaching). We created a dichotomous variable comparing degree level education or professional qualifications (n=53,652) to other qualifications (n=64,913). 1,104 individuals did not respond to this question.
3. Job class (coded as elementary occupations, process plant and machine operatives, sales and customer service occupations, leisure & other personal service occupations, personal service occupations, skilled trades, admin and secretarial roles, business and public sector associate professionals, associate professionals, professional occupations and managers and senior officials: this was coded from the UK Biobank job code variable. All participants were asked to select their current or most recent job. Data was available for 76,404 individuals, with missing data in 43,265. We dichotomised this variable into unskilled (n=21,036; elementary occupations to personal service occupations) and skilled (n=55,698; skilled trades to managers and senior officials).
4. A categorical income variable questionnaire based - representing annual household income of <£18,000; £18,000 to £30,999; £31,000 to £51,999; £52,000 to £100,000; >£100,000. Data were available for 103,327 individuals, and missing in 16,432 individuals with valid height, BMI and genetic data;
5. Townsend deprivation index (a composite measure of deprivation based on unemployment, non-car ownership, non-home ownership and household overcrowding; a negative value represents high SES). This was calculated prior to joining the UK Biobank and is based on the preceding national census data, with each participant assigned a score corresponding to the postcode of their home dwelling. Data was available for 119,519 individuals, and missing in 150 individuals with valid height, BMI and genetic data

For each of the five traits individuals missing data were compared to those reporting data; generally, those with missing data were older, shorter individuals with higher BMIs (**Supplementary table 1**). The relationship of these 5 SES measures and 4 health outcomes

were investigated – self reported coronary artery disease (CAD), hypertension (Hypertension was defined as a systolic blood pressure of ≥ 140, or a diastolic blood pressure of ≥ 90, or the report of blood pressure medication usage), any self-reported long term illness (based on the UK Biobank question *"Do you have a long standing illness, disability or infirmity?"*) and type 2 diabetes (based on self-report, excluding individuals using insulin in the first year of diagnosis and those diagnosed before 35 years of age and excluding those diagnosed in the last year) (**Supplementary table 2**).

For three of the traits, (the exceptions being education and job class, both binary traits) we converted the data to a normal distribution to limit the influence of any subtle population stratification, and to provide standard deviation effect sizes. We took residuals of the exposure and outcome measures from standard linear regression using 9 covariates: age, sex, assessment centre location, 5 (within UK) ancestry principal components and microarray used to measure genotypes. We then inverse normalised the residualised variables. To convert our results back to meaningful units following Mendelian randomisation we multiplied our SD betas by a 1SD change in the SES measure. For example, a 1SD change in TDI was equivalent to 2.68 units. Therefore, a 0.05 SD equated to 0.134 unit change in TDI.

Observational associations: We regressed each SES measure against height and BMI using linear regression for continuous outcome variables and logistic regression for binary outcomes. We adjusted these associations for age and sex. We also investigated the association of each SES measure with a range of health outcomes.

Genetic variants: The genetic variants utilised were extracted genotypes from UK Biobank's imputation dataset (Supplementary methods provides more information on the UK Biobank quality control). Individual genotypes were excluded if the genotype probability was < 0.9. We confirmed that the variants were imputed with high quality by comparing to the directly genotyped data, where available. Details of imputation quality are given in **supplementary table 3**.

Genetic variants height: We selected 396 of 404 height genetic variants from independent loci that were associated with height at genome wide significance in the GIANT studies of up to 253,288 individuals (Supplementary table 3) [19]. We excluded 8 variants that were either unavailable (rs1420023, rs567401), poorly imputed, with an imputation quality < 0.9

(rs11683207, rs7534365) or not in Hardy-Weinberg Equilibrium (HWE $P<1x10^{-6}$; rs1401795, rs7692995, rs915506, rs3790086). The 396 variants explained 12.3% of the variance in adult height in the UK Biobank individuals used.

Genetic variants BMI: We selected 69 of 76 common genetic variants that were associated with BMI at genome wide significance in the GIANT consortium in studies of up to 339,224 individuals (Supplementary table 3) [18]. We limited the BMI SNPs to those that were associated with BMI in the analysis of all European ancestry individuals and did not include those that only reached genome-wide levels of statistical confidence in one-sex only, or one-strata only. Variants were also excluded if known to be classified as a secondary signal within a locus. Three variants were excluded from the score due to potential pleiotropy (rs11030104 [*BDNF* reward phenotypes], rs13107325 [*SLC39A8* lipids, blood pressure], rs3888190 [*SH2B1* multiple traits]), 3 SNPs not in HWE ($P<1x10^{-6}$; rs17001654, rs2075650, rs9925964) or the SNP was unavailable (rs2033529). The 69 variants explained 1.5% of the variance in BMI in the UK Biobank individuals.

Individual SNPs were recoded as 0, 1, and 2 according to the number of height or BMI-increasing alleles for that particular SNP. A height and BMI genetic risk score (GRS) was created using the SNPs. Each SNP was weighted by its relative effect size (β-coefficient) obtained from the reported meta-analysis data [18]. A weighted score was created (equation 1) in which β is the β-coefficient of representing the association between each SNP and height/BMI.

$$Weighted\ score = \beta_1\, x\, SNP_1 + \beta_2\, x\, SNP_2 + \cdots \beta_n\, x\, SNP_n$$

The weighted score was rescaled to reflect the number of trait-increasing alleles (Equation 2).

$$Weighted\ GRS = \frac{weighted\ score\ x\ number\ of\ SNPs}{sum\ of\ the\ \beta\ coefficients}$$

Mendelian randomisation: The Mendelian randomisation approach used in this study made the following assumptions [15]:

- The height and BMI genetic risk scores were robustly associated with measured height and BMI;
- The height and BMI genetic risk scores were not associated with confounding factors that bias conventional epidemiological associations between height/BMI and SES;
- The height and BMI genetic risk scores were only related to the outcome via its association with the modifiable exposure;
- The associations represented in Figure 1 are linear and unaffected by statistical interactions.

Instrumental variable analysis. We used two methods that use genetic variants to assess causal relationships between two traits. First, to estimate the causal effect of height or BMI on individual SES measures, we performed instrumental variable analysis using the height or BMI GRS [15]. The two-stage least-squares estimator method that uses predicted levels of BMI or height per genotype and regresses each outcome against these predicted values was utilised.

For continuous SES outcomes, we utilised the ivreg2 command in STATA to perform the instrumental variable analysis. Results from observational and instrumental variable regressions were compared using the Durbin–Wu–Hausman test for endogeneity which examines the difference between the estimates from linear regression (observational) and instrumental variable analysis[21].

For binary outcomes the instrumental variable analysis was performed in 2 stages. First, we assessed the association between the height GRS and the BMI GRS and height and BMI respectively. The predicted values and residuals from this regression model were saved. Second, the predicted values from stage 1 were used as the independent variable (reflecting an unconfounded estimate of variation in BMI or height) and degree status or job class as the dependent variable in a logistic or ordinal logistic regression model. Robust standard errors were utilised to correct for uncertainty in the estimate. The *F*-statistics from first-stage regressions were examined to evaluate the strength of the instruments; weak instruments can bias results toward the (confounded) multivariable regression association or towards the null in a two stage design [22 23].

Mendelian randomisation: Egger method

We used a second method of Mendelian Randomisation- the Egger method[24] as a sensitivity analysis if the instrumental variables test result was noteworthy. This method is more robust to potential violations of the standard instrumental variable assumptions. It uses a weighted regression with an unconstrained intercept to regress the effect sizes of SNP-outcome associations (here height or BMI SNPs versus SES measures) against effect sizes of SNP-risk factor associations (here height or BMI SNPs versus height or BMI). The unconstrained intercept removes the assumption that all genetic variants are valid instrumental variables and therefore this method is less susceptible to confounding from potentially pleiotropic variants that will likely have stronger effects on outcomes compared to their effects on the primary trait. The approach is analogous to correcting for small study publication bias in meta-analyses[24]. Details of the STATA and R code utilised are provided in Bowden *et al*., 2015.

To ensure the robustness of our findings we have only highlighted results where we see consistent results across the two different methodologies.

Differences between men and women

To test the hypothesis that the effects of height and BMI on SES may differ in males and females, we repeated observational and genetic analyses separately in each sex. The selected height and BMI genetic variants have very similar effects in men and women and therefore the same genetic risk scores were used in all participants, males only and females only. The beta values for males and females were compared using Fisher's z-score method (equation 3) [25].

$$z = \frac{Beta_1 - Beta_2}{\sqrt{SE1^2 + SE2^2}}$$

RESULTS

The demographics of the 119,669 UK Biobank individuals with valid genetic data and BMI and height measures are summarised in Table 1. The height and BMI genetic risk scores were robustly associated with height and BMI (Table 1). The association between the SES measures and health outcomes and the associations between known height variants and height and known BMI variants and BMI in the UK Biobank are summarised in supplementary tables 1-3.

Table 1: Summary of the demographics of the 119,669 individuals of British Caucasian ancestry with valid genetic data and height and BMI measures available stratified by sex

Demographic	All (n=119,669)	Male (n=56,652)	Females (n=63,017)	P^
Mean age at recruitment in years (SD)	56.9 (7.9)	57.3 (8.0)	56.6 (7.8)	<1E-15
Male, n (%)	56,652 (47.3)	NA	NA	
Mean body mass index in kgm^{-2} (SD)	27.5 (4.8)	27.9 (4.3)	27.2 (5.2)	<1E-15
Mean height in centimetres (SD)	168.8 (9.2)	175.7 (6.7)	162.6 (6.2)	<1E-15
Smoking status				
Never, n (%)	63,806 (53.3)	27,834 (49.1)	35,972 (57.1)	<1E-15
Former, n (%)	40,890 (34.2)	21,162 (37.4)	19,728 (31.3)	
Current, n (%)	13,332 (11.1)	6,767 (11.9)	6,565 (10.4)	
Missing, n (%)	1,641 (1.4)	889 (1.6)	752 (1.2)	
Mean age completed full time education (SD)	16.6 (2.2)	16.6 (2.4)	16.5 (2.0)	2E-9
Degree education, n (%)	53,652 (44.8)	25,956 (45.8)	27,696 (44.0)	6E-15
Job Class				
Elementary occupations, n (%)	3,932 (3.3)	2,054 (3.6)	1,878 (3.0)	<1E-15
Process plant and machine operatives, n (%)	3,740 (3.1)	3,299 (5.8)	441 (0.7)	
Sales and customer service occupations, n (%)	2,658 (2.2)	588 (1.0)	2,070 (3.3)	
Leisure & other personal service occupations, n (%)	963 (0.8)	379 (0.7)	584 (0.9)	
Personal service occupations, n (%)	3,567 (3.0)	404 (0.7)	3,163 (5.0)	
Skilled trades, n (%)	6,077 (5.1)	5,404 (9.5)	673 (1.1)	
Admin and secretarial roles, n (%)	11,878 (9.9)	2,329 (4.1)	9,549 (15.2)	
Business and public sector associate professionals, n (%)	4,631 (3.9)	2,548 (4.5)	2,083 (3.3)	
Associate professionals, n (%)	8,388 (7.0)	3,148 (5.6)	5,240 (8.3)	
Professional occupations, n (%)	17,044 (14.2)	8,934 (15.8)	8,110 (12.9)	
Senior officials, n (%)	13,526 (11.3)	8,521 (15.0)	5,005 (7.9)	
Income				
<£18,000, n (%)	23,817 (19.9)	10,499 (18.5)	13,318 (21.1)	<1E-15
£18,000 to £30,999, n (%)	26,808 (22.4)	12,788 (22.6)	14,020 (22.3)	
£31,000 to £51,999, n (%)	27,245 (22.8)	13,848 (24.4)	13,397 (21.3)	
£52,000 to £100,000, n (%)	20,397 (17.0)	10,950 (19.3)	9,447 (15.0)	

>£100,000, n (%)	5,060 (4.2)	2,777 (4.9)	2,283 (3.6)	
Mean Townsend deprivation index (SD)	-1.5 (3.0)	-1.51 (3.0)	-1.45 (2.9)	5E-5
Overall per-allele height SNP association with height	0.021 (0.021, 0.022) $p<1x10^{-15}$	0.022 (0.022, 0.023) $p<1x10^{-15}$	0.020 (0.020, 0.021) $p<1x10^{-15}$	
Overall per-allele BMI SNP association with BMI	0.022 (0.021, 0.023) $p<1x10^{-15}$	0.022 (0.021, 0.024) $p<1x10^{-15}$	0.025 (0.023, 0.026) $p<1x10^{-15}$	

^ The p value presented represents the comparison between males and females. Models were adjusted for age at recruitment.

Note all five SES measures were not available in all 119,669 individuals. For further information please see Supplementary Table 1.

Genetically determined taller stature causally leads to higher SES measures in the UK Biobank

Education: duration in full time education

Using 82,543 individuals, taller stature was strongly correlated with participants spending longer in full time education (Table 2). This association was similar in men and women. A 1 SD (6.3 cm) higher height was associated with 0.11 (0.10-0.12) SD older age (approximately 0.2 years) at which full time education was completed. Genetic analyses provided evidence that this association was partly causal – a genetically determined 1 SD (6.3 cm) higher height was associated with a 0.03 (0.01-0.05) SD older age (approximately 0.06 years) at which full time education was completed (Table 2, Figure 2a).

Education: degree level (or equivalent) or not

Using 118,565 individuals, taller stature was strongly correlated with participants' chances of having obtained a degree. A 1 SD (6.3 cm) higher height was associated with 1.25 (95%CI: 1.24, 1.27) increased odds of reporting degree level education. This association was similar in men and women (Pcomparison>0.05). Genetic analyses provided no consistent evidence for a causal role of height in obtaining degree level education (Table 2, Figure 2b).

Job class

Using 76,404 individuals, taller stature was strongly correlated with job class. A 1 SD higher height (6.3 cm) was associated with increased odds of working in skilled job roles (OR: 1.29 (95%CI: 1.27, 1.32)). Genetic analyses provided evidence that this association was partly causal – a 1 SD (6.3 cm) genetically determined higher height was associated with increased odds of working in more professional roles (odds ratio: 1.12 [95%CI: 1.07, 1.18]). (Table 2, Figure 2c). This relationship was consistent when we analysed the data as 11 ordered job classes (Supplementary table 4). There was no genetic evidence that the effect was stronger in men or women.

Annual household income

Using 103,327 individuals, taller stature was strongly correlated with higher household income. The correlation was approximately 50% stronger in men (Table 2). A 1 SD higher height (6.3 cm) was associated with a 0.13 SD (95% CI: 0.12, 0.14) increase in income (Table 2). This difference is approximately equivalent to a £2,940 (95% CI: £2,730, £2,940) higher annual household income. Genetic analyses provided evidence that this association

was partly causal – a genetically determined 1SD (6.3 cm) higher height was associated with a 0.05 (95%CI: 0.03, 0.07) SD increase in annual household income, equivalent to £1,130 (95%CI: £680, £1,580) (Table 2 and Figure 2d). The genetic analyses showed that the effect was approximately twice as strong in men compared to women (*P*comparison=$5x10^{-4}$), with a 1 SD higher height in men causing a £1,580 increase in household income (Figure 2d). This relationship was consistent when we analysed the data as 5 ordered income classes (Supplementary table 4).

Townsend deprivation index

Using 119,519 individuals, taller stature was strongly correlated with lower levels of social deprivation, as measured by the TDI score. This association was stronger in men than women. A 1 SD (6.3 cm) higher height was associated with a 0.08 SD (95%CI: 0.07, 0.09) lower TDI, which is equivalent to 0.21 (95%CI: 0.18, 0.24) TDI units lower (Table 2). Genetic analyses provided evidence that this association was partly causal in men, but not when all individuals or women were considered. In all individuals genetically determined height was not associated with TDI (Table 2, Figure 2e). In men a genetically determined 1SD (6.3 cm) higher height was associated with a 0.02 SD (95%CI: 0.00, 0.05) reduction in TDI (Figure 2e). This difference is equivalent to a 0.05 (95%CI: 0.00, 0.13) unit lower TDI.

Table 2: Associations between taller stature and five measures of socio-economic using linear or logistic regression and instrumental variable analysis

			Observational^		Genetic^^		Genetic – Egger^^^	
Socio economic status measure	**Subcategories**	**N**	**Change in SES (95%CI) per SD taller stature**	**P**	**Change in SES (95%CI) per SD taller stature**	**P**	**Change in SES (95%CI) per SD taller stature**	**P**
Age completed full time education	All	82543	0.11 (0.10, 0.12)	<1E15	0.03 (0.01, 0.05)	0.01	0.07 (0.03, 0.11)	0.0004
	Male only	38342	0.11 (0.10, 0.12)	<1E15	0.04 (0.01, 0.07)	0.009	0.08 (0.02, 0.14)	0.004
	Female only	44201	0.11 (0.10, 0.12)	<1E15	0.01 (-0.02, 0.04)	0.40	NA	
Degree education	All	118565	OR: 1.25 (1.24, 1.27)	<1E15	1.02 (0.99, 1.05)	0.22	NA	
	Male only	56111	OR: 1.25 (1.23, 1.27)	<1E15	1.04 (1.00, 1.09)	0.08	NA	
	Female only	62454	OR: 1.26 (1.24, 1.28)	<1E15	1.00 (0.95, 1.05)	0.97	NA	
Job class (skilled/unskilled)	All	76404	OR: 1.29 (1.27, 1.32)	<1E15	1.12 (1.07, 1.18)	6E-7	1.18 (1.08, 1.29)	0.0002
	Male only	37608	OR: 1.31 (1.28, 1.34)	<1E15	1.13 (1.07, 1.21)	2E-5	1.23 (1.10, 1.37)	0.0004
	Female only	38796	OR: 1.27 (1.24, 1.31)	<1E15	1.14 (1.05, 1.24)	0.003	1.21 (1.08, 1.36)	0.002
Annual household income	All	103327	0.13 (0.12, 0.14)	<1E15	0.05 (0.03, 0.07)	4E-8	0.05 (0.02, 0.08)	0.0009
	Male only	50862	0.15 (0.14, 0.16)	<1E15	0.07 (0.05, 0.10)	1E-9	0.08 (0.04, 0.12)	0.0002
	Female only	52465	0.11 (0.10, 0.12)	<1E15	0.02 (0.00, 0.05)	0.09	NA	
Townsend deprivation index	All	119519	-0.08 (-0.09, -0.07)	<1E15	0.00 (-0.02, 0.01)	0.71	NA	
	Male only	56582	-0.10 (-0.10, -0.09)	<1E15	-0.02 (-0.05, 0.00)	0.05	-0.08 (-0.12, -0.04)	0.0004
	Female only	62937	-0.07 (-0.07, -0.06)	<1E15	0.02 (-0.01, 0.04)	0.19	NA	

^ Age and sex adjusted associations

^^Utilises instrumental variable analysis via the ivreg2 command in STATA for continuous variables and the 2-step procedure for binary outcomes using the height Genetic Risk Score. The F-stat when considering all individuals is ≥10898 for each SES measure, in males only the F-stat is ≥5308 for each SES measure and in females only the F-stat is ≥5615 for each SES measure.

^^^An alternative genetic approach detailed in Bowden et al., 2015 utilised as a sensitivity analysis when the IV was P<0.05

For age completed full time education, annual household income and Townsend deprivation index the changes reported are standard deviation. For degree and job class odds ratios are presented, representing odds of higher SES per SD higher height.

Genetically determined higher BMI causally leads to reduced income and deprivation measures of SES in the UK Biobank

Education: duration in full time education

Using 82,543 individuals, higher BMI was strongly correlated with participants finishing full time education at a younger age. The association was similar in men and women (Table 3, *P*comparison>0.05). A 1SD (4.6 kgm^{-2}) higher BMI was associated with a 0.08 (0.07-0.08) SD younger age (approximately 0.15 years) at which full time education was completed. There was no genetic evidence that this relationship was causal when considering all individuals, men only or women only (Figure 3a).

Education: degree level (or equivalent or not)

Using 118,565 individuals, higher BMI was associated with lower odds of having obtained a degree. A 1SD higher BMI was associated with lower odds of obtaining degree level education (OR: 0.83 (95% CI: 0.82, 0.84). There was no consistent genetic evidence that this relationship was causal when considering all individuals, men only or women only (Figure 3b).

Job class

Using 76,404 individuals, higher BMI was associated with employment in less skilled professions. A 1 SD higher BMI (4.6 kgm^{-2}) was associated with lower odds of working in skilled job roles (0.91 [95%CI: 0.89, 0.92]) and the association was stronger in women. There was no consistent genetic evidence that this relationship was causal when considering all individuals, men only or women only (Figure 3c). However there was some evidence of causality when we analysed the data as 11 ordered job classes (Supplementary table 4).

Annual household income

Using 103,327 individuals, higher BMI was associated with a lower annual household income but this effect very strongly driven by the association in women. A 1SD higher BMI was associated with a 0.09 SD (95% CI: 0.08, 0.10) lower household income for women. This effect equates to £1,890 (95%CI: £1,680, £2,100) less income per annum for women. Genetic analyses were consistent with these observations being causal in women but not in men (*P*comparison with men =9E-5) – a genetically determined 1 SD higher BMI was associated with an annual household income of 0.14 SD (95%CI: 0.08, 0.20) less in women.

This effect is equivalent to £2,940 (95%CI: £1,680, £4,200) less for women. (Table 3, Figure 3d). This relationship was consistent when we analysed the data as 5 ordered income classes (Supplementary table 4). The association between higher BMI and lower income was consistent in women who worked, with or without a husband/partner at home and women who did not work with a husband/partner at home (Supplementary table 5). It was also consistent when only women without health conditions were considered (Supplementary table 5).

Townsend deprivation index

Higher BMI was associated with higher levels of deprivation as assessed by the Townsend deprivation index. A 1 SD higher BMI was associated with a 0.08 SD (95%CI: 0.07, 0.08) higher deprivation value, which is equivalent to a 0.21 (0.19, 0.21) unit increase in TDI (Table 3). This relationship was twice as strong in women. There was limited genetic evidence of a causal relationship between BMI and TDI in in men, but some evidence in women. A 1 SD genetically higher BMI was associated with a 0.10SD (95%CI: 0.04, 0.16) higher level of deprivation in women (Table 3; Figure 3e).

Sensitivity analyses

The Egger method provided consistent results for causal relationships between height and duration in full time education, job class, income and Townsend deprivation index in males (Table 2; Supplementary table 6). The Egger method also provided consistent associations between higher BMI and income in females (Table 3; Supplementary table 7). Utilising genome wide methods to account for genetic and SES correlations between close and distant relatives did not alter our findings (Supplementary table 8).

Table 3: Associations between higher BMI and five measures of socio-economic using linear or logistic regression and instrumental variable analysis

			Observational^		Genetic^^		Genetic Egger^^^	
Socio economic status measure	**Subcategories**	**N**	**Change in SES (95%CI) per SD higher BMI**	**P**	**Change in SES (95%CI) per SD higher BMI**	**P**	**Change in SES (95%CI) per SD higher BMI**	**P**
Age completed full time education	All	82543	-0.08 (-0.08, -0.07)	<1E15	-0.01 (-0.07, 0.04)	0.63	NA	
	Male only	38342	-0.07 (-0.08, -0.06)	<1E15	0.00 (-0.09, 0.09)	0.98		
	Female only	44201	-0.08 (-0.09, -0.07)	<1E15	-0.02 (-0.09, 0.05)	0.56		
Degree education	All	118565	OR: 0.83 (0.82, 0.84)	<1E15	0.94 (0.85, 1.03)	0.18	NA	
	Male only	56111	OR: 0.82 (0.81, 0.84)	<1E15	0.94 (0.81, 1.09)	0.43		
	Female only	62454	OR: 0.83 (0.82, 0.84)	<1E15	0.93 (0.82, 1.06)	0.28		
Job class (skilled/unskilled)	All	76404	OR: 0.91 (0.89, 0.92)	<1E15	0.90 (0.79, 1.02)	0.10	NA	
	Male only	37608	OR: 0.93 (0.91, 0.95)	8E-9	0.88 (0.73, 1.08)	0.22		
	Female only	38796	OR: 0.89 (0.87, 0.91)	<1E15	0.91 (0.76, 1.08)	0.29		
Annual household income	All	103327	-0.06 (-0.06, -0.05)	<1E15	-0.05 (-0.10, -0.00)	0.041	-0.03 (-0.11, 0.05)	0.58
	Male only	50862	-0.01 (-0.02, -0.00)	<1E15	0.06 (-0.02, 0.14)	0.15	NA	
	Female only	52465	-0.09 (-0.10, -0.08)	<1E15	-0.14 (-0.20, -0.08)	1E-5	-0.17 (-0.25, -0.05)	0.004
Townsend deprivation index	All	119519	0.08 (0.07, 0.08)	<1E15	0.05 (0.01, 0.10)	0.024	-0.00 (-0.08, 0.08)	0.96
	Male only	56582	0.05 (0.04, 0.05)	<1E15	-0.01 (-0.08, 0.06)	0.78	NA	
	Female only	62937	0.10 (0.09, 0.11)	<1E15	0.10 (0.04, 0.16)	0.001	0.10 (-0.01, 0.21)	0.08

^ Age and sex adjusted associations

^^Utilises instrumental variable analysis, via the ivreg2 command in STATA for continuous variables and the 2-step approach for binary outcomes, using the BMI Genetic Risk Score. The F-stat for all individuals is ≥1257 for each SES measure, in males only the F-stat is ≥591 for each SES measure and in females only the F-stat is ≥666 for each SES measure.

For age completed full time education, annual household income and Townsend deprivation index the changes reported are standard deviation. For degree and job class odds ratios are presented, representing odds of higher SES per SD higher BMI.

DISCUSSION

Using genetic variants as unconfounded proxies for height and BMI, our study provides evidence that shorter stature and higher BMI lead to lower measures of several aspects of socio-economic status. It is important to note that our data are consistent with the height and BMI to SES associations being only partly causal – we have not excluded a causal effect in the other direction. The study adds causal evidence to a large number of observational studies. This work may have important implications for public health as low SES increases mortality and morbidity [2 3]. The association between SES measures and health was strong in the UK Biobank data, where, for example, individuals possessing a university degree had a 38% lower odds of coronary artery disease compared to individuals without a degree level education. Our study also demonstrated sex differences in the causal relationships between height or BMI and SES that are consistent with observational data. Height effects were stronger in men, but the BMI effects tended to be stronger in women.

Genetic analyses provide evidence for taller stature leading to higher SES

The causal effect, as estimated using genetics, of taller stature on higher SES was present in four of the five measures of SES. For income, where the statistical evidence was strongest, the estimated causal effects were approximately 2 to 3 times stronger in men than women. The causal evidence for taller height leading to higher levels of SES is consistent with observational studies, in which taller stature was associated with job class[4], earnings[4] and educational attainment[5]. One US based study demonstrated a reduction in earnings of $789 per annum per inch of height. With the current exchange rate this equates to £1,250 per SD of height in our study (6.3 cm), which is very similar to our genetic estimate of £1,130[13]. Despite the strong evidence that taller stature directly influences SES measures, the genetic estimates were consistently smaller than the observational estimates. These differences indicate that the observed association between taller stature and higher SES is a mixture of direct causal effects and other factors that could include a causal effect in the opposite direction.

A range of factors could link taller stature to higher SES, although this study does not address which of these factors are involved. Some of the possibilities include complex interactions between self-esteem, stigma and positive discrimination[13] and increased intelligence[4 26

27]. There is evidence that self-esteem, leadership perception and height discrimination tend to be greater in men compared to women, which fits with our findings [28-30].

Genetic analyses provide evidence for higher BMI leading to a lower SES

Higher BMI, as estimated using genetics, was causally associated with having a lower annual household income and higher levels of deprivation. These associations were stronger in women, with no consistent evidence of a causal relationship between higher BMI and lower SES measures in men. These findings were consistent with previous literature where the majority of BMI SES associations were observed in women only [7 31]. There was no evidence that the associations between higher BMI and educational outcomes were causal, a result consistent with a review of the impact of BMI on social outcomes[31]. Our findings add to evidence from observational studies, where BMI is associated with lower levels of employment[31], less skilled work and lower income[32]. A range of factors could link higher BMI to lower income and deprivation in women, although this study does not address which of these factors are involved. One of the possibilities is discrimination in the workplace, with overweight job applicants and employees evaluated more negatively [31]. The disparity between the sexes may be partially explained by discrimination, which may occur at lower weight levels for women than men [33 34]. Additionally, cultivation theory in social science indicates that very thin women are idealised and more socially valued, compared with their normal weight and obese peers [32]. In contrast a very different set of social standards exists regarding men's weight and therefore discrimination based on body size could well be different in men and women[32]. Two of the strongest measures in women, were household income and TDI, which are not just specific to the individual, but also indicative of partner's income. However, additional analyses showed that genetically determined higher BMI was associated with lower income in both non-working women with partners and in working women without a partner, suggesting the associations were not just driven by partner's income.

Limitations

Whilst our results are consistent with a direct causal effect of shorter stature and higher BMI on lower SES, there are some qualifications to consider. First, the UK Biobank individuals were born between 1938 and 1971 and the causal associations may not remain in today's society or be generalizable to societies outside of the UK. The causal associations may have been influenced by parental genotype-SES associations. For example, the causal pathway

could reflect parental genetic predisposition to higher BMI resulting in families moving to a more obese and lower SES neighbourhood which in turn could lower childrens' SES. Because parental and child genotypes are correlated, this pathway could lead to a genetic association between UK Biobank participants' SES and BMI that reflects parental factors during the 20th century. However, such a pathway would be unlikely to result in genetic associations between BMI and SES that were stronger in women than men. Second, higher BMI leads to poorer health which could affect productivity which in turn could affect SES. However, we saw similar evidence of genetic associations between higher BMI and lower SES in women reporting no adverse health outcomes as well as those reporting health problems (supplementary table 5). We also need to take care in interpreting negative results - whilst the large sample size of the UK Biobank provided >95% power for investigating the causal relationships of height and SES, power was limited for some of the BMI causal associations. It is possible that the SNPs selected for height and BMI may have effects on SES not mediated by their effects on height or BMI (pleiotropy), which were not measured but which could potentially impact on SES. However, to minimise this possibility, we selected SNPs carefully and utilised the Egger method which can detect and adjust for pleiotropy bias in many scenarios [24] (hence the broader confidence intervals observed). The educational, job status and income data used in this study were self-reported, which may result in measurement bias. However, Townsend deprivation index was derived by the UK Biobank and here we observe consistent trends across the different SES constructs, therefore suggesting limited bias due to self-report. SES is a very complex multidimensional construct. Here we looked at a range of individual components and observed similar trends for each, but it is possible that the selected variables do not cover the entirety of social status. This study utilised a homogenous population and therefore the results may not be generalizable to other ethnic groups. Finally, height and BMI and SES are subtly stratified across the UK, with people living and working in the North having lower SES, higher BMI and shorter stature, on average, than those in the South. If genetic variants are also subtly different between North and South this could have confounded our results. However a number of factors mean this population stratification should not have caused false positive results. First we would not have expected to have seen differences between men and women (because gene allele frequencies do not differ between the sexes). Second we used both within-UK genetic ancestry principle components and a second method that corrects for all levels of relatedness and our results did not change.

In summary, using up to 119,000 individuals from the UK Biobank, we provide evidence that high BMI and short stature, as estimated by genetics, causally lower socio economic status. Further work is needed to understand the factors that lead to and from anthropometric traits to SES.

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Conflict of Interest. All authors have completed the ICMJE uniform disclosure form at http://www.icmje.org/coi_disclosure.pdf and declare: no support from any organisation for the submitted work; M.N.W has received speakers fees from Ipsen and Merck, and T.M.F has consulted for Boehringer Ingelheim, no other relationships or activities that could appear to have influenced the submitted work.

Data access. The data reported in this paper are available via application directly to the UK Biobank.

FIGURE LIST

Figure 1: Principle of Mendelian randomisation: If height or BMI causally influences SES, genetic variants associated with that trait will also be associated with SES. Since genotype is assigned at conception, it should not be associated with factors that normally confound the association between BMI and height and SES (e.g. environmental and behavioural factors). We can use our estimates of the genetic – height or BMI association (w) and the genetic - SES association (x) to infer the causal effect of height or BMI on SES (y = x/w), which is expected to be free from confounding. If the estimated causal effect, y, is different from the observational association between the height or BMI and SES, this would suggest that the observational association is confounded (assuming that the assumptions of the Mendelian randomisation analyses are valid).

Figure 2: Forest plots of the observational and genetic associations between a 1SD higher height and SES: A) Age completed full time education; B) degree education; C) Job class; D) Income; E) Townsend deprivation index. The plots display the observational association (Observational) and the genetic association using instrumental variable analysis with the genetic risk score (Genetic-instrumental variables).

Figure 3: Forest plots of the observational and genetic associations between a 1SD higher BMI and SES: A) Age completed full time education; B) degree education; C) Job class; D) Income; E) Townsend deprivation index. The plots display the observational association (Observational) and the genetic association using instrumental variable analysis with the genetic risk score (Genetic-instrumental variables).

Supplementary Information

MATERIALS AND METHODS

UK Biobank Quality Control

The UK Biobank performed extensive quality control on the genetic data including the exclusion of the majority of third degree or closer relatives from a genetic kinship analysis of 96% of individuals. We performed an additional round of principal components analysis (PCA) on these 120,286 UK Biobank participants. We selected 95,535 independent SNPs (pairwise r^2 <0.1) directly genotyped with a minor allele frequency (MAF) ≥ 2.5% and missingness <1.5% across all UK Biobank participants with genetic data available at the time of this study (n=152,732), and with HWE P>1x10^{-6} within the white British participants. Principal components were subsequently generated using FlashPCA (*1*) and the first five adjusted for in all analyses.

In a sensitivity analysis to further confirm that our results were robust to any potential influence of population stratification we used the linear mixed models approach as implemented in the software BOLT-LMM(*2*) . This approach corrects for all levels of inter-individual correlation of genotypes due to relatedness, from close relatives to cryptic relatedness caused by population stratification. We inverse normalised the SES measures, then took the residuals using 3 covariates (age, sex, assessment centre location) and then inverse normalised again.

Power calculation*:* To assess the power of our study, we calculated the approximate number of individuals we would need to detect the expected effect given the gene score – height/BMI associations and the height/BMI-SES measure associations: TDI, income, degree level education or job class associations. We used the product of the variance explained by the instrumental variable-height or BMI association and the height or BMI – SES associations and a range of P values including 0.05, 0.01 and 0.001 to determine the numbers required to have at least 80% power.

Supplementary table 1: Comparison of key demographics for individuals reporting or not reporting each SES measure

Demographic variable	Data available	Data missing	P^
Age completed full time education			
N	82,543	37,126	
Age at recruitment in years (SD)	57.5 (7.9)	55.6 (7.9)	<1E-15
Male, N (%)	38,342 (46.5)	18,310 (49.3)	<0.001
Mean height in m (SD)	168 (9)	170 (9)	<1E-15
Mean BMI in kgm-2 (SD)	27.9 (4.9)	26.7 (4.5)	<1E-15
Degree level education			
N	118,565	1,104	
Age at recruitment in years (SD)	56.9 (7.9)	59.6 (7.5)	<1E-15
Male, N (%)	56,111 (47.3)	541 (49.0)	0.27
Mean height in m (SD)	169 (9)	167 (9)	1.00E-11
Mean BMI in kgm-2 (SD)	27.5 (4.8)	28.2 (5.0)	3.00E-05
Job class			
N	76,404	43,265	
Age at recruitment in years (SD)	54.4 (7.6)	61.4 (6.3)	<1E-15
Male, N (%)	37,608 (49.2)	19,044 (44.0)	<0.001
Mean height in m (SD)	170 (9)	167 (9)	<1E-15
Mean BMI in kgm-2 (SD)	27.4 (4.7)	27.7 (5.0)	3.00E-15
Income			
N	103,327	16,342	
Age at recruitment in years (SD)	56.5 (8.0)	59.3 (7.4)	<1E-15
Male, N (%)	50,862 (49.2)	5,790 (35.4)	<0.001
Mean height in m (SD)	169 (9)	166 (9)	<1E-15
Mean BMI in kgm-2 (SD)	27.5 (4.8)	27.6 (5.0)	2.00E-05
Townsend deprivation index			
N	119,519	150	
Age at recruitment in years (SD)	56.9 (7.9)	55.3 (8.0)	0.015
Male, N (%)	56,582 (47.3)	70 (46.7)	0.87
Mean height in m (SD)	169 (9.2)	169 (8.9)	0.51
Mean BMI in kgm-2 (SD)	27.5 (4.8)	27.8 (5.4)	0.43

^ P values represent age and sex adjusted comparisons of the two groups of individuals with and without data available.

Supplementary table 2: Associations between the 5 SES markers and a range of health outcomes in the UK Biobank

Disease	SES measure	N cases (controls)	Odds ratio for disease in the UK Biobank per SD higher SES (95%CI)^	p
CAD	Age completed full time education	4670 (77890)	0.85 (0.82, 0.88)	7.00E-25
Hypertension	Age completed full time education	47915 (34151)	0.96 (0.94, 0.97)	3.00E-08
Long illness	Age completed full time education	28515 (51982)	0.91 (0.89, 0.92)	8.00E-37
Type 2 diabetes	Age completed full time education	3144 (77544)	1.00 (0.96, 1.03)	8.10E-01
CAD	Degree	5663 (112921)	0.62 (0.59, 0.66)	1.00E-55
Hypertension	Degree	64881 (53040)	0.81 (0.79, 0.83)	9.00E-63
Long illness	Degree	38872 (77100)	0.87 (0.85, 0.89)	3.00E-27
Type 2 diabetes	Degree	3958 (112185)	0.81 (0.76, 0.87)	3.00E-09
CAD	Job class	2280 (74133)	0.71 (0.65, 0.78)	6.00E-14
Hypertension	Job class	37446 (38507)	0.80 (0.77, 0.83)	1.00E-34
Long illness	Job class	20712 (54147)	0.86 (0.83, 0.89)	2.00E-16
Type 2 diabetes	Job class	1914 (73217)	0.98 (0.89, 1.08)	6.90E-01
CAD	Income	4778 (98563)	0.73 (0.71, 0.76)	2.00E-76
Hypertension	Income	55864 (46947)	0.93 (0.91, 0.94)	5.00E-28
Long illness	Income	33431 (67856)	0.74 (0.73, 0.75)	<1E-15
Type 2 diabetes	Income	3420 (97860)	0.83 (0.80, 0.86)	6.00E-23
CAD	TDI	5752 (113786)	0.78 (0.76, 0.80)	4.00E-68
Hypertension	TDI	65499 (53314)	0.96 (0.95, 0.98)	5.00E-09
Long illness	TDI	39239 (77617)	0.80 (0.79, 0.81)	2.00E-158
Type 2 diabetes	TDI	3998 (113062)	0.86 (0.83, 0.89)	9.00E-19

^ adjusted for age, sex and BMI

Supplementary table 3: Summary of the body mass index (BMI) and height SNPs previously identified as associated with those traits at genome wide significance

Trait	SNP	Locus	Exclude from score	Reason for exclusion	Trait raising allele	Trait lowering allele	Directly genotyped or Imputed	Imputation quality	Beta representing SD change in BMI or height for each SNP in UK Biobank data	P value
BMI	rs1000940	*RABEP1*	No	NA	G	A	Imputed	0.99624	0.011 (0.004)	1.60E-02
BMI	rs10132280	*STXBP6*	No	NA	C	A	Imputed	0.97496	0.020 (0.005)	1.10E-05
BMI	rs1016287	*FLJ30838*	No	NA	T	C	Imputed	0.99411	0.019 (0.004)	2.00E-05
BMI	rs10182181	*ADCY3*	No	NA	G	A	Imputed	0.99521	0.033 (0.004)	1.40E-15
BMI	rs10733682	*LMX1B*	No	NA	A	G	Imputed	0.9576	0.019 (0.004)	5.90E-06
BMI	rs10938397	*GNPDA2*	No	NA	G	A	Imputed	1	0.030 (0.004)	5.80E-13
BMI	rs10968576	*LINGO2*	No	NA	G	A	Imputed	1	0.024 (0.004)	6.90E-08
BMI	rs11030104	*BDNF*	Yes	BMI-raising allele also associated with regular smoking (which itself has a causal effect on BMI in opposite direction)	A	G	Imputed	0.99931	NA	NA
BMI	rs11057405	*CLIP1*	No	NA	G	A	Imputed	1	0.030 (0.007)	4.70E-06
BMI	rs11126666	*KCNK3*	No	NA	A	G	Imputed	0.99485	0.002 (0.005)	7.10E-01
BMI	rs11165643	*PTBP2*	No	NA	T	C	Imputed	0.99575	0.016 (0.004)	9.50E-05
BMI	rs11191560	*NT5C2*	No	NA	C	T	Imputed	0.99989	0.026 (0.008)	6.50E-04

BMI	rs11583200	*ELAVL4*	No	NA	C	T	Imputed	0.98728	0.019 (0.004)	7.70E-06
BMI	rs1167827	*HIP1*	No	NA	G	A	Imputed	1	0.020 (0.004)	1.80E-06
BMI	rs11688816	*EHBP1*	No	NA	G	A	Imputed	0.98096	0.014 (0.004)	9.40E-04
BMI	rs11727676	*HHIP*	No	NA	T	C	Imputed	1	-0.003 (0.007)	6.60E-01
BMI	rs11847697	*PRKD1*	No	NA	T	C	Imputed	1	0.014 (0.010)	1.70E-01
BMI	rs12286929	*CADM1*	No	NA	G	A	Imputed	0.99124	0.010 (0.004)	1.20E-02
BMI	rs12401738	*FUBP1*	No	NA	A	G	Imputed	0.99528	0.012 (0.004)	3.30E-03
BMI	rs12429545	*OLFM4*	No	NA	A	G	Imputed	0.97759	0.027 (0.006)	8.00E-06
BMI	rs12446632	*GPRC5B*	No	NA	G	A	Imputed	0.99978	0.028 (0.006)	2.40E-06
BMI	rs12566985	*FPGT-TNNI3K*	No	NA	G	A	Imputed	0.9947	0.011 (0.004)	6.10E-03
BMI	rs12885454	*PRKD1*	No	NA	C	A	Imputed	0.99569	0.015 (0.004)	4.60E-04
BMI	rs12940622	*RPTOR*	No	NA	G	A	Imputed	0.99796	0.017 (0.004)	5.90E-05
BMI	rs13021737	*TMEM18*	No	NA	G	A	Imputed	0.99072	0.059 (0.005)	9.10E-27
BMI	rs13078960	*CADM2*	No	NA	G	T	Imputed	0.9915	0.024 (0.005)	2.50E-06
BMI	rs13107325	*SLC39A8*	Yes	Missense Ala/Thr polymorphism located in exon 7 of SLC39A8, which encodes a zinc transporter that also transports cadmium and manganese. It is also associated with BP and HDL levels,	T	C	Imputed	1	NA	NA

				and presumably these and the BMI effect are secondary to the metal ion transport variation.						
BMI	rs13191362	*PARK2*	No	NA	A	G	Imputed	0.98973	0.026 (0.006)	3.10E-05
BMI	rs1516725	*ETV5*	No	NA	C	T	Imputed	0.99495	0.032 (0.006)	1.00E-07
BMI	rs1528435	*UBE2E3*	No	NA	T	C	Imputed	0.99738	0.014 (0.004)	6.60E-04
BMI	rs1558902	*FTO*	No	NA	A	T	Imputed	0.99914	0.077 (0.004)	1.50E-75
BMI	rs16851483	*RASA2*	No	NA	T	G	Imputed	0.99906	0.028 (0.008)	6.80E-04
BMI	rs16951275	*MAP2K5*	No	NA	T	C	Imputed	0.99819	0.032 (0.005)	4.40E-11
BMI	rs17001654	*SCARB2*	Yes	SNP not in HWE	G	C	Imputed	0.9483	NA	NA
BMI	rs17024393	*GNAT2*	No	NA	C	T	Imputed	0.98934	0.074 (0.013)	1.20E-08
BMI	rs17094222	*HIF1AN*	No	NA	C	T	Imputed	0.96874	0.013 (0.005)	8.50E-03
BMI	rs17405819	*HNF4G*	No	NA	T	C	Imputed	0.99793	0.014 (0.004)	1.30E-03
BMI	rs17724992	*PGPEP1*	No	NA	A	G	Imputed	0.98342	0.023 (0.005)	1.10E-06
BMI	rs1808579	*C18orf8*	No	NA	C	T	Imputed	0.99797	0.022 (0.004)	1.50E-07
BMI	rs1928295	*TLR4*	No	NA	T	C	Imputed	0.99998	0.010 (0.004)	1.60E-02
BMI	rs2033529	*TDRG1*	Yes	SNP not available	G	A	NA	NA	NA	NA
BMI	rs2033732	*RALYL*	No	NA	C	T	Imputed	1	0.002 (0.005)	6.70E-01
BMI	rs205262	*C6orf106*	No	NA	G	A	Imputed	0.9968	0.028 (0.005)	1.10E-09
BMI	rs2075650	*TOMM40*	Yes	SNP not in HWE	A	G	Imputed	0.9865	NA	NA
BMI	rs2112347	*POC5*	No	NA	T	G	Imputed	1	0.026 (0.004)	6.30E-10
BMI	rs2121279	*LRP1B*	No	NA	T	C	Imputed	0.98723	0.006	3.70E-01

									(0.006)	
BMI	rs2176598	*HSD17B12*	No	NA	T	C	Imputed	1	0.023 (0.005)	1.30E-06
BMI	rs2207139	*TFAP2B*	No	NA	G	A	Imputed	0.9989	0.038 (0.005)	1.80E-12
BMI	rs2245368	*PMS2L11*	No	NA	C	T	Imputed	1	0.022 (0.005)	8.00E-05
BMI	rs2287019	*QPCTL*	No	NA	C	T	Imputed	0.97852	0.035 (0.005)	1.00E-10
BMI	rs2365389	*FHIT*	No	NA	C	T	Imputed	0.99305	0.029 (0.004)	2.70E-12
BMI	rs2650492	*SBK1*	No	NA	A	G	Imputed	0.98144	0.019 (0.005)	3.60E-05
BMI	rs2820292	*NAV1*	No	NA	C	A	Imputed	1	0.019 (0.004)	3.60E-06
BMI	rs29941	*KCTD15*	No	NA	G	A	Imputed	1	0.018 (0.004)	5.00E-05
BMI	rs3101336	*NEGR1*	No	NA	C	T	Imputed	1	0.027 (0.004)	9.50E-11
BMI	rs3736485	*DMXL2*	No	NA	A	G	Imputed	0.98728	0.011 (0.004)	6.40E-03
BMI	rs3810291	*ZC3H4*	No	NA	A	G	Imputed	1	0.028 (0.004)	1.80E-10
BMI	rs3817334	*MTCH2*	No	NA	T	C	Imputed	1	0.031 (0.004)	1.40E-13
BMI	rs3849570	*GBE1*	No	NA	A	C	Imputed	0.99509	0.011 (0.004)	7.80E-03
BMI	rs3888190	*ATP2A1*	Yes	Associated with lots of other traits and is a big haplotype	A	C	Imputed	0.99808	NA	NA
BMI	rs4256980	*TRIM66*	No	NA	G	C	Imputed	0.99283	0.021 (0.004)	1.70E-06
BMI	rs4740619	*C9orf93*	No	NA	T	C	Imputed	0.99762	0.017 (0.004)	5.70E-05
BMI	rs543874	*SEC16B*	No	NA	G	A	Imputed	1	0.049 (0.005)	3.40E-22
BMI	rs6477694	*EPB41L4B*	No	NA	C	T	Imputed	0.99022	0.008 (0.004)	6.70E-02

BMI	rs6567160	*MC4R*	No	NA	C	T	Imputed	0.99663	0.054 (0.005)	9.50E-29
BMI	rs657452	*AGBL4*	No	NA	A	G	Imputed	0.98709	0.014 (0.004)	8.40E-04
BMI	rs6804842	*RARB*	No	NA	G	A	Imputed	0.98778	0.009 (0.004)	3.20E-02
BMI	rs7138803	*BCDIN3D*	No	NA	A	G	Imputed	1	0.034 (0.004)	1.30E-15
BMI	rs7141420	*NRXN3*	No	NA	T	C	Imputed	0.98379	0.019 (0.004)	6.70E-06
BMI	rs7243357	*GRP*	No	NA	T	G	Imputed	0.98998	0.012 (0.005)	2.10E-02
BMI	rs758747	*NLRC3*	No	NA	T	C	Imputed	0.97187	0.014 (0.005)	2.00E-03
BMI	rs7599312	*ERBB4*	No	NA	G	A	Imputed	0.97294	0.019 (0.005)	3.60E-05
BMI	rs7899106	*GRID1*	No	NA	G	A	Imputed	0.98612	0.023 (0.009)	1.40E-02
BMI	rs9400239	*FOXO3*	No	NA	C	T	Imputed	0.99206	0.017 (0.005)	2.30E-04
BMI	rs9581854	*MTIF3*	No	NA	T	C	Imputed	0.98643	0.015 (0.005)	6.20E-03
BMI	rs9925964	*KAT8*	Yes	SNP not in HWE	A	G	Imputed	1		
Height	rs10083886	*SOX9*	No	NA	T	C	Imputed	0.96954	0.021 (0.005)	1E-05
Height	rs10131337	*PAX9*	No	NA	T	C	Imputed	0.98303	0.026 (0.005)	6E-08
Height	rs10152739	*SPRED1*	No	NA	T	A	Imputed	0.9879	0.016 (0.005)	7E-04
Height	rs1036477	*FBN1*	No	NA	A	G	Imputed	0.9957	0.029 (0.007)	2E-05
Height	rs1036821	*ZFAT*	No	NA	G	A	Imputed	0.97861	0.042 (0.004)	1E-20
Height	rs1047014	*ID4*	No	NA	C	T	Imputed	1	0.028 (0.005)	4E-09
Height	rs1055144	*NFE2L3*	No	NA	T	C	Imputed	1	0.029 (0.005)	2E-08

Height	rs1074683	*PXMP4*	No	NA	C	G	Imputed	0.99541	0.042 (0.005)	4E-19
Height	rs10748128	*FRS2*	No	NA	T	G	Imputed	1	0.032 (0.004)	6E-14
Height	rs10767838	*C11orf46*	No	NA	A	G	Imputed	0.99185	0.011 (0.005)	2E-02
Height	rs10770705	*SLCO1C1*	No	NA	A	C	Imputed	1	0.022 (0.004)	3E-07
Height	rs10779751	*FRAP1*	No	NA	A	G	Imputed	1	0.017 (0.005)	2E-04
Height	rs10780910	*SPIN1*	No	NA	T	A	Imputed	0.98414	0.028 (0.004)	2E-11
Height	rs10790381	*ARHGEF12*	No	NA	A	G	Imputed	0.99606	0.029 (0.005)	9E-08
Height	rs10794175	*FAM53B*	No	NA	T	G	Imputed	0.99344	0.018 (0.004)	9E-06
Height	rs10863936	*DTL*	No	NA	G	A	Imputed	1	0.019 (0.004)	4E-06
Height	rs10877030	*CTDSP2*	No	NA	T	G	Imputed	0.98828	0.033 (0.004)	2E-14
Height	rs10880969	*SLC38A2*	No	NA	C	T	Imputed	0.99792	0.029 (0.004)	6E-11
Height	rs10883563	*FAM178A*	No	NA	A	C	Imputed	1	0.024 (0.004)	3E-09
Height	rs10948222	*SUPT3H*	No	NA	C	T	Imputed	0.99409	0.014 (0.004)	6E-04
Height	rs10995319	*PRKG1*	No	NA	T	C	Imputed	0.9964	0.019 (0.005)	1E-04
Height	rs10997979	*MYPN*	No	NA	G	A	Imputed	0.99812	0.030 (0.004)	3E-13
Height	rs11047239	*SOX5*	No	NA	G	C	Imputed	0.99285	0.025 (0.004)	1E-08
Height	rs11049611	*CCDC91*	No	NA	C	T	Imputed	0.99616	0.041 (0.004)	1E-20
Height	rs1113765	*SEPT14*	No	NA	G	A	Imputed	0.98428	0.015 (0.005)	6E-03
Height	rs11144688	*PCSK5*	No	NA	G	A	Imputed	1	0.051 (0.006)	4E-16

Height	rs11152213	*MC4R*	No	NA	C	A	Imputed	0.99902	0.034 (0.005)	3E-12
Height	rs11156098	*ARID1B*	No	NA	T	C	Imputed	0.97473	0.024 (0.007)	4E-04
Height	rs11221442	*FLI1*	No	NA	G	C	Imputed	0.99462	-0.005 (0.005)	3E-01
Height	rs1155939	*C6orf173*	No	NA	A	C	Imputed	0.99833	0.048 (0.004)	2E-32
Height	rs11612228	*B4GALNT3*	No	NA	T	C	Imputed	0.96996	0.036 (0.004)	1E-16
Height	rs11616067	*MED13L*	No	NA	A	G	Imputed	1	0.018 (0.005)	1E-04
Height	rs11616380	*SPRY2*	No	NA	T	G	Imputed	0.98577	0.014 (0.005)	3E-03
Height	rs11618507	*SLC7A1*	No	NA	T	G	Imputed	0.99005	0.013 (0.005)	8E-03
Height	rs11624136	*DAAM1*	No	NA	A	G	Imputed	0.99632	0.013 (0.004)	1E-03
Height	rs11640018	*CFDP1*	No	NA	C	T	Imputed	1	0.010 (0.004)	1E-02
Height	rs11642612	*FLJ25404*	No	NA	C	A	Imputed	0.99914	0.017 (0.004)	4E-05
Height	rs11648796	*NARFL*	No	NA	G	A	Imputed	0.90086	0.045 (0.005)	3E-18
Height	rs11659752	*NFATC1*	No	NA	T	G	Imputed	0.99007	0.022 (0.004)	1E-06
Height	rs11683207	*ZAP70*	Yes	Imputation r2<0.9	T	C	NA	NA	NA	NA
Height	rs11684404	*EIF2AK3*	No	NA	C	T	Imputed	0.99855	0.036 (0.004)	1E-16
Height	rs11687941	*HDLBP*	No	NA	C	G	Imputed	0.99945	0.021 (0.005)	1E-05
Height	rs1171615	*SLC16A9*	No	NA	C	T	Imputed	0.99323	0.031 (0.005)	1E-10
Height	rs11750568	*ADAMTS2*	No	NA	A	G	Imputed	0.99518	0.016 (0.004)	2E-04
Height	rs11783655	*PLEC1*	No	NA	T	A	Imputed	0.98049	0.031 (0.004)	2E-13
Height	rs11799609	*SDCCAG8*	No	NA	T	G	Imputed	0.98286	0.012	4E-02

									(0.006)	
Height	rs11835818	*BCL7A*	No	NA	C	T	Imputed	0.98771	0.015	2E-04
									(0.004)	
Height	rs11855014	*PDE8A*	No	NA	G	A	Imputed	0.97241	0.013	4E-03
									(0.004)	
Height	rs11867479	*KCNJ16*	No	NA	T	C	Imputed	1	0.030	3E-12
									(0.004)	
Height	rs11880992	*DOT1L*	No	NA	A	G	Imputed	0.99401	0.039	2E-20
									(0.004)	
Height	rs1199734	*LATS2*	No	NA	G	T	Imputed	0.99442	0.028	2E-07
									(0.005)	
Height	rs12120956	*CAPZA1*	No	NA	G	A	Imputed	1	0.021	2E-05
									(0.005)	
Height	rs12137162	*CAPZB*	No	NA	A	C	Imputed	1	0.022	2E-06
									(0.005)	
Height	rs12186664	*PCSK1*	No	NA	T	A	Imputed	0.9915	0.013	2E-03
									(0.004)	
Height	rs12190423	*OGFRL1*	No	NA	G	C	Imputed	0.98213	0.016	3E-04
									(0.004)	
Height	rs12209223	*FILIP1*	No	NA	A	C	Imputed	0.98097	0.046	2E-11
									(0.007)	
Height	rs12214804	*HMGA1*	No	NA	C	T	Imputed	0.99476	0.091	3E-36
									(0.007)	
Height	rs12323101	*PDS5B*	No	NA	A	G	Imputed	0.99874	0.018	2E-05
									(0.004)	
Height	rs12330322	*RYBP*	No	NA	C	T	Imputed	0.99412	0.034	8E-12
									(0.005)	
Height	rs1233627	*TRIM27*	No	NA	T	C	Imputed	0.99851	0.023	3E-08
									(0.004)	
Height	rs12435366	*NFKBIA*	No	NA	C	T	Imputed	0.98427	0.010	5E-02
									(0.005)	
Height	rs12470505	*CCDC108*	No	NA	T	G	Imputed	1	0.048	3E-12
									(0.007)	
Height	rs12474201	*SOCS5*	No	NA	A	G	Imputed	1	0.032	1E-13
									(0.004)	
Height	rs12513181	*NUDT6*	No	NA	C	A	Imputed	0.99914	0.020	1E-05
									(0.005)	
Height	rs12519505	*AP3B1*	No	NA	C	T	Imputed	0.99272	0.022	6E-06

									(0.005)	
Height	rs12538407	*IGF2BP3*	No	NA	A	G	Imputed	0.99068	0.036	6E-18
									(0.004)	
Height	rs12639764	*TET2*	No	NA	T	C	Imputed	0.98841	0.031	3E-13
									(0.004)	
Height	rs12669267	*WBSCR28*	No	NA	C	T	Imputed	0.97258	0.028	7E-06
									(0.006)	
Height	rs12693589	*STAT1*	No	NA	C	T	Imputed	0.98669	0.021	9E-06
									(0.005)	
Height	rs12779328	*CCDC3*	No	NA	C	T	Imputed	0.99272	0.035	1E-14
									(0.005)	
Height	rs12855	*CDKN2C*	No	NA	T	C	Imputed	1	0.060	4E-17
									(0.007)	
Height	rs12882130	*MARK3*	No	NA	C	G	Imputed	0.95464	0.024	1E-08
									(0.004)	
Height	rs12904334	*ARIH1*	No	NA	A	G	Imputed	1	0.068	7E-05
									(0.017)	
Height	rs12987566	*METTL8*	No	NA	T	C	Imputed	0.99346	0.026	4E-08
									(0.005)	
Height	rs13006748	*WDR35*	No	NA	C	G	Imputed	0.96536	0.003	6E-01
									(0.005)	
Height	rs13088462	*DOCK3*	No	NA	C	T	Imputed	1	0.060	2E-10
									(0.009)	
Height	rs13113518	*CLOCK*	No	NA	C	T	Imputed	0.99849	0.016	2E-04
									(0.004)	
Height	rs13150868	*ESSPL*	No	NA	T	G	Imputed	0.99747	0.012	4E-03
									(0.004)	
Height	rs13177718	*FER*	No	NA	C	T	Imputed	1	0.031	7E-05
									(0.008)	
Height	rs1325596	*PAPPA2*	No	NA	A	G	Imputed	1	0.029	3E-12
									(0.004)	
Height	rs1326023	*MC3R*	No	NA	A	G	Imputed	0.98457	0.012	8E-03
									(0.005)	
Height	rs13388725	*GCC2*	No	NA	G	A	Imputed	0.99389	0.008	7E-02
									(0.004)	
Height	rs13416119	*EML4*	No	NA	A	G	Imputed	0.98764	0.024	9E-04
									(0.007)	
Height	rs1401795	*C17orf67*	Yes	Excluded based on	A	G	NA	NA	NA	NA

				HWE						
Height	rs1405212	*VGLL2*	No	NA	C	T	Imputed	0.9969	0.027 (0.004)	2E-10
Height	rs14062	*MIB1*	No	NA	G	A	Imputed	0.99528	0.009 (0.004)	5E-02
Height	rs1420023	*CDKN1B*	Yes	SNP not available	C	G	NA	NA	NA	NA
Height	rs143384	*GDF5*	No	NA	G	A	Imputed	1	0.092 (0.004)	1E-109
Height	rs1461503	*BSX*	No	NA	C	A	Imputed	0.99729	0.021 (0.004)	4E-07
Height	rs1546391	*ZBTB20*	No	NA	G	C	Imputed	0.98751	0.031 (0.008)	1E-04
Height	rs1550162	*EIF3H*	No	NA	G	A	Imputed	0.97822	0.022 (0.005)	3E-06
Height	rs1552173	*PSCD1*	No	NA	C	T	Imputed	0.98704	0.013 (0.004)	1E-03
Height	rs1562975	*RPL34*	No	NA	A	G	Imputed	0.99896	0.027 (0.004)	2E-09
Height	rs1576900	*ADAMTSL1*	No	NA	G	A	Imputed	0.97217	0.011 (0.005)	2E-02
Height	rs1582931	*CCDC100*	No	NA	G	A	Imputed	1	0.023 (0.004)	2E-08
Height	rs1599473	*NOV*	No	NA	G	T	Imputed	0.98821	0.030 (0.005)	7E-10
Height	rs1614303	*FGFR2*	No	NA	T	G	Imputed	0.99718	0.015 (0.005)	6E-03
Height	rs165189	*PSD2*	No	NA	G	A	Imputed	0.9813	0.014 (0.006)	2E-02
Height	rs1658351	*FLNB*	No	NA	C	T	Imputed	0.99121	0.024 (0.004)	2E-08
Height	rs1659127	*MKL2*	No	NA	A	G	Imputed	1	0.022 (0.004)	2E-07
Height	rs1681630	*PTPRJ*	No	NA	T	C	Imputed	0.99573	0.024 (0.004)	2E-08
Height	rs16834765	*PTP4A2*	No	NA	T	C	Imputed	1	0.051 (0.009)	6E-09
Height	rs16895130	*CCND3*	No	NA	G	A	Imputed	0.98958	0.024 (0.005)	3E-07

Height	rs16964211	*CYP19A1*	No	NA	G	A	Imputed	1	0.043 (0.010)	1E-05
Height	rs16968242	*SCAPER*	No	NA	G	C	Imputed	0.99962	0.035 (0.008)	3E-05
Height	rs17038954	*PXDN*	No	NA	T	C	Imputed	0.95649	0.029 (0.009)	7E-04
Height	rs17081935	*C4orf14*	No	NA	T	C	Imputed	0.9998	0.035 (0.005)	2E-11
Height	rs17113369	*RWDD3*	No	NA	T	C	Imputed	1	0.009 (0.012)	5E-01
Height	rs17122659	*SLC16A7*	No	NA	G	A	Imputed	0.99103	0.023 (0.007)	5E-04
Height	rs17250196	*GATS/PVRIG*	No	NA	T	G	Imputed	0.96925	0.035 (0.009)	1E-04
Height	rs17264185	*SMAD6*	No	NA	G	A	Imputed	0.99628	0.026 (0.005)	6E-08
Height	rs17330192	*FAM8A1*	No	NA	C	T	Imputed	0.98161	-0.004 (0.005)	4E-01
Height	rs17349981	*MEX3B*	No	NA	A	T	Imputed	0.99669	0.012 (0.006)	4E-02
Height	rs17391694	*GIPC2*	No	NA	T	C	Imputed	1	0.036 (0.006)	5E-10
Height	rs17410035	*C5orf22*	No	NA	T	G	Imputed	0.99922	-0.006 (0.004)	2E-01
Height	rs17450430	*STAU1*	No	NA	T	A	Imputed	0.9959	0.044 (0.005)	2E-20
Height	rs17511102	*CDC42EP3*	No	NA	T	A	Imputed	1	0.047 (0.007)	3E-11
Height	rs17556750	*PRKG2*	No	NA	A	C	Imputed	0.99479	0.042 (0.005)	8E-21
Height	rs17574650	*GHR*	No	NA	C	A	Imputed	1	0.043 (0.007)	3E-10
Height	rs17783015	*ATP2B1*	No	NA	C	T	Imputed	1	0.009 (0.006)	1E-01
Height	rs17792664	*CHD8*	No	NA	G	C	Imputed	1	0.025 (0.006)	8E-06
Height	rs17806888	*SUCLG2*	No	NA	T	C	Imputed	1	0.030 (0.006)	2E-06

Height	rs17807185	*RSBN1L*	No	NA	G	A	Imputed	0.9897	0.011 (0.004)	1E-02
Height	rs1797625	*C3orf17*	No	NA	T	A	Imputed	0.9765	0.021 (0.004)	2E-06
Height	rs1812175	*HHIP*	No	NA	G	A	Imputed	1	0.087 (0.005)	3E-57
Height	rs181338	*ZCCHC6*	No	NA	T	C	Imputed	0.99635	0.035 (0.004)	9E-18
Height	rs1832871	*TULP4*	No	NA	A	G	Imputed	0.99881	0.025 (0.004)	6E-09
Height	rs1884897	*BMP2*	No	NA	A	G	Imputed	0.9921	0.055 (0.004)	4E-38
Height	rs1923367	*ZCCHC24*	No	NA	G	C	Imputed	0.98201	0.036 (0.004)	6E-18
Height	rs1935157	*HLX*	No	NA	G	C	Imputed	1	0.018 (0.005)	9E-05
Height	rs1950500	*NFATC4*	No	NA	T	C	Imputed	1	0.027 (0.004)	1E-09
Height	rs1966913	*LRRC36*	No	NA	A	T	Imputed	0.99972	0.058 (0.010)	8E-09
Height	rs1980850	*RAD51L1*	No	NA	G	A	Imputed	0.99858	0.017 (0.006)	2E-03
Height	rs1996422	*FRYL*	No	NA	G	A	Imputed	0.98043	-0.007 (0.005)	1E-01
Height	rs2013265	*ADAM28*	No	NA	C	T	Imputed	1	0.028 (0.005)	2E-09
Height	rs2023693	*DCUN1D3*	No	NA	G	A	Imputed	0.99918	0.008 (0.004)	5E-02
Height	rs2034172	*WNT5A*	No	NA	G	A	Imputed	0.99308	0.011 (0.004)	1E-02
Height	rs2057291	*GNAS*	No	NA	A	G	Imputed	1	0.019 (0.004)	9E-06
Height	rs2058092	*NUMB*	No	NA	T	C	Imputed	0.98608	0.011 (0.004)	9E-03
Height	rs2072268	*ARSG*	No	NA	G	A	Imputed	1	0.014 (0.004)	7E-04
Height	rs2074977	*NFIC*	No	NA	C	A	Imputed	1	0.024 (0.004)	1E-08

Height	rs2079795	*C17orf82*	No	NA	T	C	Imputed	1	0.048 (0.004)	1E-28
Height	rs2093210	*C14orf39*	No	NA	C	T	Imputed	0.97693	0.038 (0.004)	1E-19
Height	rs2117563	*GRB2*	No	NA	G	A	Imputed	0.99931	0.023 (0.006)	2E-05
Height	rs2120335	*PPP3R1*	No	NA	G	A	Imputed	0.99937	0.018 (0.004)	1E-05
Height	rs2123731	*UHRF1*	No	NA	A	G	Imputed	1	0.032 (0.005)	3E-12
Height	rs212524	*ECE1*	No	NA	C	T	Imputed	1	0.022 (0.004)	1E-07
Height	rs2145357	*NT5DC1*	No	NA	G	A	Imputed	0.99659	0.019 (0.005)	4E-05
Height	rs2149163	*BNC2*	No	NA	C	G	Imputed	0.99152	0.017 (0.004)	5E-05
Height	rs2164747	*HSP90B1*	No	NA	G	A	Imputed	0.99925	0.027 (0.007)	3E-05
Height	rs2166898	*GLI2*	No	NA	G	A	Imputed	1	0.034 (0.005)	4E-10
Height	rs217181	*HPR*	No	NA	T	C	Imputed	1	0.021 (0.005)	7E-05
Height	rs2175513	*FAM19A1*	No	NA	G	A	Imputed	0.98947	0.000 (0.004)	1E+00
Height	rs2211866	*KCNJ15*	No	NA	A	G	Imputed	0.98188	0.037 (0.004)	4E-18
Height	rs2224538	*MAFB*	No	NA	T	C	Imputed	0.98816	0.020 (0.004)	4E-06
Height	rs2237886	*KCNQ1*	No	NA	T	C	Imputed	1	0.063 (0.007)	4E-21
Height	rs2272566	*PSMD13*	No	NA	A	G	Imputed	0.99421	-0.007 (0.004)	9E-02
Height	rs2275325	*ZC3H11A*	No	NA	C	G	Imputed	1	0.019 (0.005)	4E-05
Height	rs2280470	*ACAN*	No	NA	A	G	Imputed	1	0.044 (0.004)	3E-24
Height	rs2284746	*MFAP2*	No	NA	G	C	Imputed	1	0.036 (0.004)	2E-18

Height	rs2289195	*DNMT3A*	No	NA	A	G	Imputed	1	0.044 (0.004)	6E-26
Height	rs2298265	*ZNF687*	No	NA	C	T	Imputed	1	0.014 (0.007)	3E-02
Height	rs2302580	*CPZ*	No	NA	C	T	Imputed	0.98211	0.025 (0.004)	1E-09
Height	rs2306596	*RFC1*	No	NA	A	C	Imputed	0.99585	0.018 (0.004)	2E-05
Height	rs2306694	*CS*	No	NA	G	A	Imputed	0.99922	0.042 (0.008)	4E-07
Height	rs2326458	*ZDHHC7*	No	NA	C	A	Imputed	1	0.024 (0.005)	3E-07
Height	rs2338115	*PIP4K2B*	No	NA	T	C	Imputed	0.99426	0.027 (0.004)	6E-11
Height	rs2345835	*RDH14*	No	NA	C	T	Imputed	0.99246	0.003 (0.004)	4E-01
Height	rs2510396	*GAL*	No	NA	C	G	Imputed	0.99288	0.041 (0.006)	2E-13
Height	rs2581830	*RFT1*	No	NA	T	C	Imputed	0.99506	0.032 (0.004)	1E-14
Height	rs2597513	*HDAC11*	No	NA	C	T	Imputed	1	0.033 (0.007)	1E-06
Height	rs26024	*FBN2*	No	NA	C	A	Imputed	0.98519	0.014 (0.004)	8E-04
Height	rs2631676	*PCGF5*	No	NA	G	A	Imputed	0.99202	0.039 (0.005)	1E-13
Height	rs2633761	*ITPR1*	No	NA	A	G	Imputed	0.95603	0.010 (0.004)	2E-02
Height	rs2662027	*MIER3*	No	NA	G	T	Imputed	1	0.025 (0.007)	2E-04
Height	rs2682587	*XRCC1*	No	NA	A	C	Imputed	0.99138	0.029 (0.005)	3E-08
Height	rs26868	*CASKIN1*	No	NA	A	T	Imputed	0.99848	0.028 (0.004)	8E-12
Height	rs2715094	*GRB10*	No	NA	G	A	Imputed	0.98915	0.020 (0.005)	3E-05
Height	rs273945	*CREB3L2*	No	NA	C	A	Imputed	0.94152	0.021 (0.004)	1E-06

Height	rs2748483	*GRM1*	No	NA	A	T	Imputed	0.99855	0.016 (0.004)	9E-05
Height	rs2763273	*SMOC2*	No	NA	C	T	Imputed	0.99591	0.034 (0.005)	3E-12
Height	rs2781373	*MAX*	No	NA	G	A	Imputed	0.99932	0.028 (0.004)	3E-11
Height	rs2806561	*LUZP1*	No	NA	A	G	Imputed	1	0.019 (0.004)	4E-06
Height	rs2811594	*FAM69A*	No	NA	G	A	Imputed	1	0.014 (0.004)	8E-04
Height	rs2815379	*SLC35D1*	No	NA	G	A	Imputed	1	0.014 (0.005)	2E-03
Height	rs2829941	*APP*	No	NA	T	G	Imputed	0.99247	0.002 (0.004)	7E-01
Height	rs2834442	*KCNE2*	No	NA	A	T	Imputed	1	0.018 (0.004)	2E-05
Height	rs2854207	*CSH2*	No	NA	G	C	Imputed	0.99608	0.053 (0.005)	7E-31
Height	rs2856321	*ETV6*	No	NA	G	A	Imputed	1	0.029 (0.004)	1E-11
Height	rs2871865	*IGF1R*	No	NA	C	G	Imputed	1	0.063 (0.006)	4E-23
Height	rs2888893	*C12orf23*	No	NA	C	T	Imputed	0.99863	0.013 (0.004)	1E-03
Height	rs291979	*GRK5*	No	NA	A	G	Imputed	0.9937	0.022 (0.005)	7E-06
Height	rs2956605	*CRISPLD1*	No	NA	A	C	Imputed	0.97906	0.027 (0.004)	2E-10
Height	rs2961830	*ISL1*	No	NA	A	T	Imputed	0.99448	0.017 (0.004)	8E-05
Height	rs2974438	*SLIT3*	No	NA	G	A	Imputed	0.98375	0.037 (0.005)	2E-13
Height	rs3014219	*AKR1A1*	No	NA	G	A	Imputed	1	0.013 (0.004)	1E-03
Height	rs301901	*NIPBL*	No	NA	A	G	Imputed	0.99547	0.028 (0.004)	3E-11
Height	rs310421	*FAM46A*	No	NA	T	G	Imputed	0.99828	0.031 (0.004)	3E-14

Height	rs3116168	*DIS3L2*	No	NA	C	T	Imputed	0.99802	0.046 (0.005)	8E-24
Height	rs3118905	*DLEU7*	No	NA	G	A	Imputed	1	0.056 (0.005)	6E-35
Height	rs3132297	*RXRA*	No	NA	G	A	Imputed	1	0.005 (0.006)	4E-01
Height	rs314263	*LIN28B*	No	NA	C	T	Imputed	0.99833	0.048 (0.004)	3E-28
Height	rs316618	*LTK*	No	NA	T	A	Imputed	0.95894	0.015 (0.005)	4E-03
Height	rs318095	*ATP5G1*	No	NA	T	C	Imputed	0.99849	0.034 (0.004)	1E-16
Height	rs32855	*FAM151B*	No	NA	A	G	Imputed	0.9916	0.019 (0.005)	1E-04
Height	rs34651	*TNPO1*	No	NA	C	T	Imputed	0.96907	0.042 (0.008)	4E-08
Height	rs354196	*SPTBN1*	No	NA	G	A	Imputed	0.97687	0.006 (0.004)	2E-01
Height	rs3739707	*LPAR1*	No	NA	C	A	Imputed	0.9919	0.029 (0.005)	2E-09
Height	rs3760318	*CENTA2*	No	NA	G	A	Imputed	1	0.051 (0.004)	9E-34
Height	rs3763631	*NPR2/SPAG8*	No	NA	C	G	Imputed	0.99079	0.017 (0.004)	1E-04
Height	rs3782089	*SSSCA1*	No	NA	C	T	Imputed	1	0.027 (0.008)	8E-04
Height	rs3790086	*WWP2*	Yes	Excluded based on HWE	C	G	NA	NA	NA	NA
Height	rs3791679	*EFEMP1*	No	NA	A	G	Imputed	1	0.080 (0.005)	9E-60
Height	rs3802758	*PEX16*	No	NA	A	G	Imputed	0.9886	0.009 (0.008)	2E-01
Height	rs3807931	*ITGB8*	No	NA	A	G	Imputed	0.99273	0.031 (0.004)	3E-14
Height	rs3809790	*SSH2*	No	NA	C	T	Imputed	0.99929	0.016 (0.004)	8E-05
Height	rs3812040	*DAB2*	No	NA	T	C	Imputed	0.99127	0.018 (0.005)	1E-04

Height	rs3812423	*KCTD9*	No	NA	G	C	Imputed	0.99973	0.013 (0.004)	2E-03
Height	rs3814333	*GLT25D2*	No	NA	T	C	Imputed	1	0.049 (0.004)	2E-28
Height	rs3818416	*EDNRB*	No	NA	C	A	Imputed	0.99548	0.019 (0.005)	7E-05
Height	rs3825199	*SOCS2*	No	NA	G	A	Imputed	1	0.059 (0.005)	2E-32
Height	rs3885668	*KLF11*	No	NA	C	T	Imputed	0.99257	0.023 (0.004)	4E-08
Height	rs3915129	*CTNNB1*	No	NA	G	T	Imputed	0.99872	0.024 (0.004)	3E-09
Height	rs3923086	*AXIN2*	No	NA	C	A	Imputed	0.9707	0.029 (0.004)	6E-12
Height	rs3958122	*SLBP*	No	NA	T	C	Imputed	0.99446	0.025 (0.004)	4E-09
Height	rs39623	*ADAMTS19*	No	NA	A	T	Imputed	0.99499	0.049 (0.008)	2E-10
Height	rs4072910	*ADAMTS10*	No	NA	G	C	Imputed	1	0.033 (0.004)	4E-16
Height	rs42039	*CDK6*	No	NA	T	C	Imputed	0.99565	0.058 (0.005)	4E-34
Height	rs422421	*FGFR4*	No	NA	C	T	Imputed	1	0.044 (0.005)	1E-18
Height	rs4239020	*CCDC57*	No	NA	C	T	Imputed	1	0.017 (0.004)	1E-04
Height	rs425277	*PRKCZ*	No	NA	T	C	Imputed	1	0.018 (0.005)	8E-05
Height	rs429433	*MFHAS1*	No	NA	A	G	Imputed	1	0.045 (0.010)	2E-06
Height	rs4332428	*AKR1C1*	No	NA	A	G	Imputed	0.9991	0.047 (0.006)	2E-13
Height	rs4350272	*ARHGAP21*	No	NA	A	G	Imputed	0.99009	0.012 (0.005)	9E-03
Height	rs4369779	*CABLES1*	No	NA	C	T	Imputed	1	0.075 (0.005)	2E-50
Height	rs4425077	*FN1*	No	NA	G	C	Imputed	0.99732	0.008 (0.004)	5E-02

Height	rs4548838	*ADAMTS17*	No	NA	T	C	Imputed	0.99398	0.035 (0.004)	3E-17
Height	rs4601530	*CLIC4*	No	NA	C	T	Imputed	1	0.001 (0.005)	8E-01
Height	rs4605213	*NME1-NME2/NME2*	No	NA	C	G	Imputed	1	0.017 (0.004)	8E-05
Height	rs4624820	*SPRY4*	No	NA	A	G	Imputed	1	0.005 (0.004)	2E-01
Height	rs4640244	*KCNJ12*	No	NA	A	G	Imputed	1	0.028 (0.004)	2E-11
Height	rs4656220	*PRRX1*	No	NA	T	C	Imputed	1	0.017 (0.004)	1E-04
Height	rs4686904	*BCL6*	No	NA	C	T	Imputed	0.99701	0.025 (0.004)	5E-09
Height	rs4725061	*GLCCI1*	No	NA	G	A	Imputed	0.99019	0.021 (0.004)	3E-07
Height	rs4733724	*MLZE*	No	NA	A	G	Imputed	0.99728	0.057 (0.005)	6E-29
Height	rs4735677	*PXMP3*	No	NA	T	A	Imputed	0.99776	0.045 (0.005)	4E-23
Height	rs4785393	*PAPD5*	No	NA	G	A	Imputed	0.98617	0.011 (0.005)	5E-02
Height	rs4802134	*SIPA1L3*	No	NA	A	G	Imputed	0.99656	0.006 (0.005)	2E-01
Height	rs4803468	*BCKDHA*	No	NA	A	G	Imputed	0.99945	0.031 (0.004)	7E-14
Height	rs4812586	*SAMHD1*	No	NA	A	G	Imputed	0.99743	0.035 (0.006)	2E-09
Height	rs4843367	*RAB28*	No	NA	G	A	Imputed	0.99706	0.007 (0.004)	1E-01
Height	rs4868126	*FBXW11*	No	NA	G	T	Imputed	0.93315	0.035 (0.004)	7E-16
Height	rs4875421	*CSMD1*	No	NA	T	A	Imputed	0.99645	0.010 (0.004)	1E-02
Height	rs4883972	*KLF12*	No	NA	C	G	Imputed	0.99117	-0.005 (0.004)	2E-01
Height	rs4896582	*GPR126*	No	NA	G	A	Imputed	1	0.058 (0.004)	6E-38

Height	rs4953951	*ZRANB3*	No	NA	C	T	Imputed	0.99645	0.039 (0.003)	1E-31
Height	rs497273	*SPPL3*	No	NA	C	G	Imputed	0.99824	0.019 (0.004)	7E-06
Height	rs4974480	*ANAPC13*	No	NA	T	A	Imputed	0.98669	0.024 (0.004)	8E-08
Height	rs4986172	*ACBD4*	No	NA	C	T	Imputed	1	0.030 (0.004)	7E-12
Height	rs526896	*PITX1*	No	NA	T	G	Imputed	1	0.030 (0.005)	6E-11
Height	rs540652	*NOSTRIN*	No	NA	T	C	Imputed	1	0.024 (0.004)	3E-09
Height	rs552707	*JAZF1*	No	NA	T	C	Imputed	0.99867	0.051 (0.004)	2E-29
Height	rs564914	*FOXD2*	No	NA	T	A	Imputed	1	0.016 (0.004)	1E-04
Height	rs567401	*DDAH1*	Yes	Imputation r2<0.9	T	C	NA	NA	NA	NA
Height	rs568610	*SCARA3*	No	NA	T	C	Imputed	0.98877	0.023 (0.005)	3E-06
Height	rs5742915	*PML*	No	NA	C	T	Imputed	1	0.037 (0.004)	8E-20
Height	rs584828	*IGFBP4*	No	NA	C	T	Imputed	0.99238	0.028 (0.004)	1E-11
Height	rs6061231	*RPS21*	No	NA	C	A	Imputed	0.98656	0.017 (0.005)	2E-04
Height	rs606452	*SERPINH1*	No	NA	A	C	Imputed	1	0.055 (0.006)	1E-20
Height	rs6080830	*BANF2*	No	NA	A	G	Imputed	0.99462	0.016 (0.004)	8E-05
Height	rs632124	*DDX6*	No	NA	A	T	Imputed	0.99825	0.017 (0.004)	4E-05
Height	rs6420435	*MPHOSPH6*	No	NA	A	C	Imputed	0.97978	0.022 (0.005)	5E-06
Height	rs6435143	*NOP5/NOP58*	No	NA	A	C	Imputed	0.98904	0.003 (0.004)	4E-01
Height	rs6439168	*H1FX*	No	NA	G	A	Imputed	0.9904	0.045 (0.005)	1E-19
Height	rs6441170	*SHOX2*	No	NA	C	T	Imputed	0.99934	0.024	1E-08

									(0.004)	
Height	rs6446315	*CYTL1*	No	NA	G	A	Imputed	0.98569	0.013	2E-02
									(0.006)	
Height	rs6457374	*HLA-C*	No	NA	C	T	Imputed	1	0.046	8E-25
									(0.004)	
Height	rs6462432	*KBTBD2*	No	NA	A	G	Imputed	1	0.010	2E-02
									(0.004)	
Height	rs6485978	*TEAD1*	No	NA	C	T	Imputed	0.99307	0.023	4E-08
									(0.004)	
Height	rs6540834	*PTPN14*	No	NA	C	T	Imputed	1	0.018	2E-05
									(0.004)	
Height	rs6561319	*LRCH1*	No	NA	A	C	Imputed	0.99061	0.025	5E-09
									(0.004)	
Height	rs6584575	*SH3PXD2A*	No	NA	A	G	Imputed	0.98594	0.026	2E-04
									(0.007)	
Height	rs6600365	*SCMH1*	No	NA	C	T	Imputed	1	0.028	5E-12
									(0.004)	
Height	rs6658763	*FMO5*	No	NA	C	T	Imputed	1	0.012	1E-01
									(0.008)	
Height	rs6688100	*VANGL2*	No	NA	T	C	Imputed	1	0.006	1E-01
									(0.004)	
Height	rs6691924	*ACOT11*	No	NA	T	C	Imputed	1	0.019	3E-03
									(0.006)	
Height	rs6694089	*DNM3*	No	NA	A	G	Imputed	1	0.035	2E-14
									(0.005)	
Height	rs6696239	*ZNF678*	No	NA	G	A	Imputed	1	0.043	1E-16
									(0.005)	
Height	rs6714546	*LTBP1*	No	NA	G	A	Imputed	1	0.036	6E-16
									(0.005)	
Height	rs6746356	*SP3*	No	NA	A	C	Imputed	0.99407	0.020	2E-05
									(0.005)	
Height	rs6761041	*SERPINE2*	No	NA	T	C	Imputed	0.98915	0.024	1E-08
									(0.004)	
Height	rs6794009	*PTPRG*	No	NA	G	A	Imputed	0.9852	0.030	5E-13
									(0.004)	
Height	rs6813055	*DMP1*	No	NA	A	T	Imputed	0.99764	0.020	7E-07
									(0.004)	
Height	rs6838153	*EXOSC9*	No	NA	G	A	Imputed	0.98791	0.017	2E-04

									(0.004)	
Height	rs6879260	*GFPT2*	No	NA	C	T	Imputed	1	0.024	6E-09
									(0.004)	
Height	rs6894139	*MEF2C*	No	NA	T	G	Imputed	0.99738	0.031	4E-14
									(0.004)	
Height	rs6902771	*ESR1*	No	NA	T	C	Imputed	1	0.033	8E-16
									(0.004)	
Height	rs6920372	*PPIL6*	No	NA	G	A	Imputed	0.99527	0.024	6E-09
									(0.004)	
Height	rs692964	*CEP192*	No	NA	G	A	Imputed	0.99944	0.015	4E-04
									(0.004)	
Height	rs6949739	*IGFBP3*	No	NA	T	A	Imputed	0.99158	0.037	1E-06
									(0.007)	
Height	rs6952113	*C7orf58*	No	NA	G	A	Imputed	0.99963	0.019	5E-06
									(0.004)	
Height	rs6955948	*TMEM176A*	No	NA	T	C	Imputed	0.99692	0.018	7E-05
									(0.005)	
Height	rs6962887	*CNOT4*	No	NA	T	G	Imputed	0.97958	0.025	3E-08
									(0.004)	
Height	rs6971575	*SLC25A13*	No	NA	C	G	Imputed	0.97974	0.009	4E-02
									(0.004)	
Height	rs6974574	*STARD3NL*	No	NA	T	A	Imputed	0.99796	0.026	8E-10
									(0.004)	
Height	rs6988484	*EFCAB1*	No	NA	C	T	Imputed	0.99665	0.023	1E-06
									(0.005)	
Height	rs7027110	*ZNF462*	No	NA	A	G	Imputed	1	0.032	8E-11
									(0.005)	
Height	rs7033487	*PAPPA*	No	NA	T	C	Imputed	0.99616	0.038	2E-13
									(0.005)	
Height	rs7033940	*UHRF2*	No	NA	G	C	Imputed	0.99	0.011	8E-02
									(0.007)	
Height	rs7043114	*IPPK*	No	NA	C	T	Imputed	0.99813	0.014	5E-04
									(0.004)	
Height	rs7069985	*RAB18*	No	NA	G	A	Imputed	0.99489	0.016	1E-03
									(0.005)	
Height	rs7112925	*RHOD*	No	NA	C	T	Imputed	1	0.034	2E-15
									(0.004)	
Height	rs7154721	*TRIP11*	No	NA	T	C	Imputed	0.99827	0.026	5E-10

									(0.004)	
Height	rs7162542	*ADAMTSL3*	No	NA	G	C	Imputed	0.9977	0.048	6E-31
									(0.004)	
Height	rs7162825	*LACTB*	No	NA	T	C	Imputed	0.99789	0.007	8E-02
									(0.004)	
Height	rs7177711	*FAM148A*	No	NA	A	G	Imputed	0.99794	0.022	1E-07
									(0.004)	
Height	rs7181724	*MCTP2*	No	NA	G	A	Imputed	0.96555	0.022	3E-07
									(0.004)	
Height	rs720390	*IGF2BP2*	No	NA	A	G	Imputed	1	0.034	8E-16
									(0.004)	
Height	rs724016	*ZBTB38*	No	NA	G	A	Imputed	1	0.085	2E-94
									(0.004)	
Height	rs7253628	*ZNF536*	No	NA	G	A	Imputed	0.99548	0.029	1E-07
									(0.005)	
Height	rs7259684	*LOC729747*	No	NA	G	A	Imputed	0.99894	0.047	5E-10
									(0.008)	
Height	rs7261425	*C20orf26*	No	NA	C	G	Imputed	1	0.015	1E-03
									(0.005)	
Height	rs7273787	*SMOX*	No	NA	G	A	Imputed	0.99541	0.031	4E-13
									(0.004)	
Height	rs7284476	*TRIOBP*	No	NA	A	G	Imputed	0.99699	0.017	4E-05
									(0.004)	
Height	rs7319045	*GPC5*	No	NA	A	G	Imputed	1	0.030	1E-12
									(0.004)	
Height	rs738288	*SMCR7L*	No	NA	G	A	Imputed	0.98417	0.010	2E-02
									(0.004)	
Height	rs7466269	*FUBP3*	No	NA	A	G	Imputed	1	0.035	2E-16
									(0.004)	
Height	rs749234	*ZEB2*	No	NA	A	G	Imputed	0.99884	0.013	4E-03
									(0.004)	
Height	rs7517682	*COL11A1*	No	NA	G	A	Imputed	1	0.032	9E-15
									(0.004)	
Height	rs7534365	*SV2A*	Yes	Imputation r2<0.9	C	T	NA	NA	NA	NA
Height	rs7544462	*C1orf149*	No	NA	A	C	Imputed	1	0.035	2E-06
									(0.007)	
Height	rs7551732	*PKN2*	No	NA	A	T	Imputed	1	0.029	2E-12
									(0.004)	

Height	rs7567288	*NAP5*	No	NA	C	T	Imputed	1	0.017 (0.005)	9E-04
Height	rs7567851	*PDE11A*	No	NA	C	G	Imputed	1	0.027 (0.008)	4E-04
Height	rs7568069	*ZNF638*	No	NA	G	A	Imputed	0.99949	0.031 (0.004)	2E-13
Height	rs757081	*NUCB2*	No	NA	G	C	Imputed	1	0.019 (0.004)	1E-05
Height	rs761391	*TBX18*	No	NA	C	T	Imputed	0.99562	0.015 (0.004)	3E-04
Height	rs763318	*RAB28*	No	NA	G	A	Imputed	0.98628	0.031 (0.004)	2E-14
Height	rs7652177	*FNDC3B*	No	NA	G	C	Imputed	1	0.031 (0.004)	2E-14
Height	rs7659107	*CAMK2D*	No	NA	G	A	Imputed	0.99028	0.004 (0.005)	4E-01
Height	rs7692995	*LCORL*	Yes	Excluded based on HWE	T	C	NA	NA	NA	NA
Height	rs7701414	*PDLIM4*	No	NA	G	A	Imputed	0.99613	0.043 (0.004)	9E-26
Height	rs7716219	*SLC38A9*	No	NA	T	C	Imputed	0.9953	0.035 (0.004)	6E-15
Height	rs7727731	*ADAMTS6*	No	NA	T	C	Imputed	0.99557	0.020 (0.006)	1E-03
Height	rs7733195	*FAM44B*	No	NA	G	A	Imputed	0.99698	0.022 (0.004)	4E-07
Height	rs7740107	*L3MBTL3*	No	NA	T	A	Imputed	0.99629	0.062 (0.005)	2E-40
Height	rs780094	*GCKR*	No	NA	C	T	Imputed	1	0.022 (0.004)	2E-07
Height	rs7834383	*DLC1*	No	NA	T	G	Imputed	0.98385	0.011 (0.004)	1E-02
Height	rs7849585	*QSOX2*	No	NA	T	G	Imputed	0.99758	0.031 (0.004)	2E-12
Height	rs7853235	*RMI1*	No	NA	T	C	Imputed	0.98874	0.030 (0.005)	7E-09
Height	rs7899004	*SUFU*	No	NA	T	C	Imputed	0.99647	0.035 (0.004)	1E-17

Height	rs7971536	*CCDC53*	No	NA	T	A	Imputed	0.99239	0.028 (0.004)	5E-12
Height	rs7980687	*SBNO1*	No	NA	A	G	Imputed	1	0.043 (0.005)	1E-17
Height	rs798497	*GNA12*	No	NA	A	G	Imputed	1	0.062 (0.004)	1E-43
Height	rs7985356	*CDC16*	No	NA	T	A	Imputed	0.99639	0.026 (0.005)	1E-07
Height	rs8006657	*SAMD4A*	No	NA	G	A	Imputed	0.97777	0.014 (0.004)	1E-03
Height	rs8017130	*HOMEZ*	No	NA	G	A	Imputed	0.96175	0.017 (0.004)	1E-04
Height	rs8052560	*C16orf84*	No	NA	A	C	Imputed	1	0.031 (0.005)	2E-10
Height	rs8058684	*RBL2*	No	NA	A	G	Imputed	0.99637	0.031 (0.004)	3E-12
Height	rs806794	*HIST1H2BF*	No	NA	A	G	Imputed	1	0.063 (0.005)	4E-43
Height	rs8097893	*GALR1*	No	NA	A	G	Imputed	0.99143	0.037 (0.010)	3E-04
Height	rs8102380	*ILF3*	No	NA	G	A	Imputed	0.99499	0.024 (0.004)	3E-08
Height	rs8103068	*BST2*	No	NA	T	C	Imputed	0.99332	0.024 (0.006)	1E-04
Height	rs8103992	*PBX4*	No	NA	A	C	Imputed	0.98893	0.032 (0.005)	9E-10
Height	rs817300	*PTCH1*	No	NA	G	A	Imputed	1	0.082 (0.008)	2E-26
Height	rs8180991	*TRIB1*	No	NA	C	G	Imputed	0.99501	0.026 (0.005)	3E-08
Height	rs820848	*HEXB*	No	NA	G	A	Imputed	0.98738	0.012 (0.005)	1E-02
Height	rs822531	*EZH2*	No	NA	T	C	Imputed	0.97338	0.053 (0.005)	6E-25
Height	rs833152	*PDE1A*	No	NA	C	A	Imputed	0.98533	0.020 (0.004)	2E-06
Height	rs862034	*LTBP2*	No	NA	G	A	Imputed	1	0.027 (0.004)	3E-10

Height	rs870183	*VPS53*	No	NA	G	A	Imputed	0.99432	0.001 (0.004)	8E-01
Height	rs8756	*HMGA2*	No	NA	C	A	Imputed	1	0.056 (0.004)	4E-42
Height	rs888403	*SMCHD1*	No	NA	G	A	Imputed	0.99488	0.011 (0.004)	8E-03
Height	rs891088	*INSR*	No	NA	G	A	Imputed	1	0.027 (0.005)	9E-09
Height	rs897080	*C2orf34*	No	NA	C	T	Imputed	0.99077	0.026 (0.005)	9E-08
Height	rs915506	*CCNJ*	Yes	Excluded based on HWE	G	A	NA	NA	NA	NA
Height	rs9217	*ZBTB4*	No	NA	C	T	Imputed	1	0.043 (0.004)	2E-24
Height	rs9291926	*PIK3R1*	No	NA	T	G	Imputed	0.99821	0.021 (0.004)	3E-07
Height	rs9292468	*C5orf23*	No	NA	T	C	Imputed	0.99566	0.034 (0.004)	3E-16
Height	rs929637	*TMEM106B*	No	NA	G	T	Imputed	0.99652	0.014 (0.005)	3E-03
Height	rs9309101	*THADA*	No	NA	G	A	Imputed	0.98804	0.014 (0.004)	8E-04
Height	rs932445	*GMDS*	No	NA	T	C	Imputed	0.99851	0.016 (0.004)	9E-05
Height	rs936339	*PCOLCE2*	No	NA	T	C	Imputed	0.98118	0.016 (0.005)	2E-03
Height	rs9392918	*BMP6*	No	NA	C	T	Imputed	0.99254	0.050 (0.004)	4E-34
Height	rs9395264	*CD2AP*	No	NA	G	T	Imputed	0.99488	0.026 (0.004)	5E-09
Height	rs9404952	*HLA-G*	No	NA	A	G	Imputed	0.99737	0.003 (0.004)	5E-01
Height	rs9428104	*SPAG17*	No	NA	G	A	Imputed	1	0.049 (0.005)	1E-25
Height	rs9434723	*H6PD*	No	NA	A	G	Imputed	1	0.024 (0.006)	6E-05
Height	rs955748	*WWC2*	No	NA	G	A	Imputed	1	0.019 (0.005)	7E-05

Height	rs9650315	*CHCHD7*	No	NA	G	T	Imputed	1	0.066 (0.006)	3E-27
Height	rs975210	*TLE3*	No	NA	A	G	Imputed	0.98941	0.035 (0.005)	5E-11
Height	rs9766	*EZH1*	No	NA	A	G	Imputed	0.99396	0.019 (0.004)	5E-06
Height	rs9816693	*VILL*	No	NA	C	G	Imputed	1	0.023 (0.005)	1E-05
Height	rs9825951	*COL8A1*	No	NA	T	A	Imputed	0.98378	0.019 (0.004)	6E-06
Height	rs9835332	*C3orf63*	No	NA	G	C	Imputed	1	0.024 (0.004)	5E-09
Height	rs9841435	*CCDC50*	No	NA	G	A	Imputed	0.99917	0.011 (0.004)	1E-02
Height	rs9858528	*KLHL24*	No	NA	A	G	Imputed	0.99428	0.000 (0.005)	9E-01
Height	rs9880211	*STAG1*	No	NA	G	A	Imputed	0.99892	0.024 (0.005)	3E-07
Height	rs989393	*COL15A1*	No	NA	T	C	Imputed	0.99371	0.019 (0.005)	2E-05
Height	rs991946	*T*	No	NA	C	T	Imputed	0.99381	0.022 (0.004)	4E-08
Height	rs991967	*TGFB2*	No	NA	C	A	Imputed	1	0.049 (0.005)	4E-27
Height	rs9967417	*DYM*	No	NA	G	C	Imputed	1	0.040 (0.004)	3E-22
Height	rs9977276	*COL6A1*	No	NA	G	T	Imputed	0.99096	0.026 (0.005)	2E-07
Height	rs9993613	*ADAMTS3*	No	NA	T	G	Imputed	0.99351	0.040 (0.004)	7E-22

Supplementary Table 4: Observational and genetic associations for A) height and B) body mass index (BMI) with job class and annual household income using ordinal regression models.

A

			Observational associations		Genetic associations	
Socio economic status measure	**Subcategories**	**N**	**Odds ratio (95%CI) for higher SES SD increase in height**	**P**	**Odds ratio (95%CI) for higher SES per SD increase in height**	**P**
Job class	All	76404	1.22 (1.20, 1.23)	<1E-15	1.08 (1.04, 1.11)	7E-5
	Male only	37608	1.22 (1.20, 1.24)	<1E-15	1.09 (1.04, 1.15)	0.0004
	Female only	38796	1.21 (1.19, 1.23)	<1E-15	1.04 (0.99, 1.10)	0.08
Annual household income	All	103327	1.26 (1.24, 1.27)	<1E-15	1.09 (1.06, 1.13)	2E-8
	Male only	50862	1.30 (1.28, 1.32)	<1E-15	1.14 (1.10, 1.19)	5E-10
	Female only	52465	1.21 (1.19, 1.23)	<1E-15	1.04 (0.99, 1.09)	0.09

B

			Observational associations		Genetic associations	
Socio economic status measure	**Subcategories**	**N**	**Odds ratio (95%CI) for higher SES per SD higher BMI**	**P**	**Odds ratio (95%CI) for higher SES per SD higher BMI**	**P**
Job class	All	76404	0.94 (0.93, 0.96)	<1E-15	0.89 (0.81, 0.99)	0.029
	Male only	37608	0.99 (0.97, 1.01)	0.16	0.90 (0.77, 1.06)	0.22
	Female only	38796	0.91 (0.90, 0.93)	<1E-15	0.89 (0.78, 1.01)	0.07
Annual household income	All	103327	0.90 (0.89, 0.91)	<1E-15	0.89 (0.81, 0.97)	0.01
	Male only	50862	0.98 (0.96, 0.99)	0.005	1.08 (0.94, 1.24)	0.29
	Female only	52465	0.86 (0.84, 0.87)	<1E-15	0.76 (0.68, 0.86)	5E-6

Supplementary Table 5: Genetic associations between BMI and income in women stratified on A) employment status and marital status or B) health status

Employment Status	Marital status	N	Beta (95%CI) representing a SD change in income per SD change in BMI	P
Working	All	33,939	-0.15 (-0.23, -0.07)	4E-4
Working	Live with husband/partner	23,575	-0.12 (-0.22, -0.03)	0.01
Working	Do not live with husband/partner	9,563	-0.10 (-0.22, 0.01)	0.08
Non-working	All	28,914	-0.11 (-0.21, -0.01)	0.03
Non-working	Live with husband/partner	20,305	-0.12 (-0.25, 0.01)	0.07
Non-working	Do not live with husband/partner	6,981	0.01 (-0.10, 0.13)	0.82

Health status	N	Beta (95%CI) representing a SD change in income per SD change in BMI	P
No non-cancer or cancer disease reported	12,127	-0.23 (-0.39, -0.08)	0.004

Note marital status classified as living with husband or partner versus those not living with a husband/partner

Supplementary Table 6: Associations between taller stature and five measures of socio-economic comparing standard instrumental variable analysis and the Egger method

Socio economic status measure	Subcategories	N	Genetic^ Change in SES (95%CI) per SD taller stature	P	Genetic – Egger^^ Change in SES (95%CI) per SD taller stature	P
Age completed full time education	All	82543	0.03 (0.01, 0.05)	0.01	0.07 (0.03, 0.11)	0.0004
	Male only	38342	0.04 (0.01, 0.07)	0.009	0.08 (0.02, 0.14)	0.004
	Female only	44201	0.01 (-0.02, 0.04)	0.40	0.05 (0.01, 0.09)	0.018
Degree education	All	118565	1.02 (0.99, 1.05)	0.22	1.06 (0.99, 1.13)	0.09
	Male only	56111	1.04 (1.00, 1.09)	0.08	1.10 (1.01, 1.19)	0.026
	Female only	62454	1.00 (0.95, 1.05)	0.97	1.09 (1.00, 1.19)	0.06
Job class (skilled/unskilled)	All	76404	1.12 (1.07, 1.18)	6E-7	1.18 (1.08, 1.29)	0.0002
	Male only	37608	1.13 (1.07, 1.21)	2E-5	1.23 (1.10, 1.37)	0.0004
	Female only	38796	1.14 (1.05, 1.24)	0.003	1.21 (1.08, 1.36)	0.002
Annual household income	All	103327	0.05 (0.03, 0.07)	4E-8	0.05 (0.02, 0.08)	0.0009
	Male only	50862	0.07 (0.05, 0.10)	1E-9	0.08 (0.04, 0.12)	0.0002
	Female only	52465	0.02 (0.00, 0.05)	0.09	0.05 (0.00, 0.10)	0.09
Townsend deprivation index	All	119519	0.00 (-0.02, 0.01)	0.71	-0.03 (-0.06, 0.00)	0.038
	Male only	56582	-0.02 (-0.05, 0.00)	0.05	-0.08 (-0.12, -0.04)	0.0004
	Female only	62937	0.02 (-0.01, 0.04)	0.19	-0.005 (-0.05, 0.04)	0.8

^Utilises instrumental variable analysis via the ivreg2 command in STATA for continuous variables and the 2-step procedure for binary outcomes using the height Genetic Risk Score. The F-stat when considering all individuals is ≥10898 for each SES measure, in males only the F-stat is ≥5308 for each SES measure and in females only the F-stat is ≥5615 for each SES measure.
^^An alternative genetic approach detailed in Bowden et al., 2015
For age completed full time education, annual household income and Townsend deprivation index the changes reported are standard deviation. For degree and job class odds ratios are presented, representing odds of higher SES per SD higher height.

Supplementary Table 7: Sensitivity analysis with the Egger Method to further investigate associations between higher BMI and two measures of socio-economic status

			Genetic^^		Genetic Egger^^^	
Socio economic status measure	**Subcategories**	**N**	**Change in SES (95%CI) per SD higher BMI**	**P**	**Change in SES (95%CI) per SD higher BMI**	**P**
Age completed full time education	All	82543	-0.01 (-0.07, 0.04)	0.63	0.04 (-0.05, 0.13)	0.44
	Male only	38342	0.00 (-0.09, 0.09)	0.98	0.12 (-0.01, 0.25)	0.08
	Female only	44201	-0.02 (-0.09, 0.05)	0.56	-0.03 (-0.14, 0.08)	0.38
Degree education	All	118565	0.94 (0.85, 1.03)	0.18	1.21 (1.01, 1.45)	0.038
	Male only	56111	0.94 (0.81, 1.09)	0.43	1.58 (1.23, 2.02)	0.0006
	Female only	62454	0.93 (0.82, 1.06)	0.28	0.97 (0.78, 1.21)	0.82
Job class (skilled/unskilled)	All	76404	0.90 (0.79, 1.02)	0.10	0.99 (0.78, 1.26)	0.93
	Male only	37608	0.88 (0.73, 1.08)	0.22	1.07 (0.80, 1.44)	0.65
	Female only	38796	0.91 (0.76, 1.08)	0.29	0.76 (0.56, 1.02)	0.08
Annual household income	All	103327	-0.05 (-0.10, -0.00)	0.041	-0.03 (-0.11, 0.05)	0.58
	Male only	50862	0.06 (-0.02, 0.14)	0.15	0.16 (0.04, 0.29)	0.012
	Female only	52465	-0.14 (-0.20, -0.08)	1E-5	-0.17 (-0.25, -0.05)	0.004
Townsend deprivation index	All	119519	0.05 (0.01, 0.10)	0.024	-0.00 (-0.08, 0.08)	0.96
	Male only	56582	-0.01 (-0.08, 0.06)	0.78	-0.12 (-0.23. -0.01)	0.032
	Female only	62937	0.10 (0.04, 0.16)	0.001	0.10 (-0.01, 0.21)	0.08

^Utilises instrumental variable analysis, via the ivreg2 command in STATA for continuous variables and the 2-step approach for binary outcomes, using the BMI Genetic Risk Score. The F-stat for all individuals is ≥1257 for each SES measure, in males only the F-stat is ≥591 for each SES measure and in females only the F-stat is ≥666 for each SES measure.
^^An alternative genetic approach detailed in Bowden et al., 2015
For age completed full time education and Townsend deprivation index the changes reported are standard deviation.

Supplementary table 8: Comparison of the A) height and B) BMI associations with the different SES measures using the standard method and the linear mixed models that correct for close and distant relatedness, as implemented in BOLT LMM (*2*).

A

SES measure	Method used	Beta (95%CI) for a change in SES measure per SD change in height using standard method^	P	Beta (95%CI) for a change in SES measure per SD change in height using BOLT LMM method^^	P
Age completed full time education	Genetic-IV	0.03 (0.01, 0.05)	0.0005	0.04 (0.02, 0.06)	1E-05
Age completed full time education	Genetic-Egger	0.07 (0.03, 0.10)	0.0004	0.05 (0.02, 0.09)	0.005
Job class	Genetic-IV	0.04 (0.02, 0.06)	2E-05	0.05 (0.03, 0.07)	1.E-06
Job class	Genetic-Egger	0.06 (0.02, 0.09)	0.004	0.05 (0.01, 0.09)	0.016
Income	Genetic-IV	0.06 (0.04, 0.07)	2E-12	0.05 (0.03, 0.07)	2E-09
Income	Genetic-Egger	0.05 (0.02, 0.09)	0.0009	0.04 (0.01, 0.08)	0.007
TDI	Genetic-IV	-0.01 (-0.02, 0.01)	0.14	-0.02 (-0.04, 0.00)	0.015
TDI	Genetic-Egger	-0.03 (-0.06, 0.00)	0.038	-0.04 (-0.07, -0.01)	0.018

B

SES measure	Method used	Beta (95%CI) for a change in SES measure per SD change in BMI using standard method^	P	Beta (95%CI) for a change in SES measure per SD change in BMI using BOLT LMM method^^	P
Age completed full time education	Genetic-IV	-0.02 (-0.07, 0.03)	0.48	-0.04 (-0.08, 0.01)	0.14
Job class	Genetic-IV	-0.07 (-0.12, -0.02)	0.011	-0.08 (-0.13, -0.02)	0.007
Job class	Genetic-Egger	-0.04 (-0.15, 0.07)	0.44	-0.02 (-0.13, 0.08)	0.66
Income	Genetic-IV	-0.06 (-0.10, -0.01)	0.017	-0.07 (-0.12, -0.02)	0.003

Income	Genetic-Egger	-0.03 (-0.11, 0.06)	0.58	-0.01 (-0.09, 0.07)	0.76
TDI	Genetic-IV	0.05 (0.01, 0.10)	0.015	0.05 (0.01, 0.09)	0.015
TDI	Genetic-Egger	0.00 (-0.08, 0.08)	0.96	-0.02 (-0.09, 0.05)	0.63

^ Standard method accounts for population stratification by taking the residuals of the exposure and outcome variables for standard linear regression using 9 covariates (age, sex, assessment centre location, 5 (within UK) ancestry principal components and microarray used to measure genotypes. These residualised variables where then inverse normalised.

^^ The BOLT-LMM approach uses a linear mixed models methodology and corrects for all levels of inter-individual correlation of genotypes due to relatedness, from close relatives to cryptic relatedness caused by population stratification. We inverse normalised the SES measures, then took the residuals using 3 covariates (age, sex, assessment centre location) and then inverse normalised again. Dichotomous traits were also tested using BOLT-LMM and consistent p-values were observed, but were not reported here due to the differences in the BOLT-LMM model for handling dichotomous traits.

Egger results were reported if the IV was significant in either the standard method or BOLT-LMM approach as a sensitivity analysis.

Supplementary references

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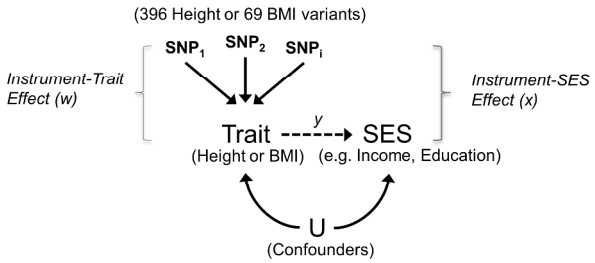

Figure 1: Principle of Mendelian randomisation: If height or BMI causally influences SES, genetic variants associated with that trait will also be associated with SES. Since genotype is assigned at conception, it should not be associated with factors that normally confound the association between BMI and height and SES (e.g. environmental and behavioural factors). We can use our estimates of the genetic – height or BMI association (w) and the genetic - SES association (x) to infer the causal effect of height or BMI on SES (y = x/w), which is expected to be free from confounding. If the estimated causal effect, y, is different from the observational association between the height or BMI and SES, this would suggest that the observational association is confounded (assuming that the assumptions of the Mendelian randomisation analyses are valid).
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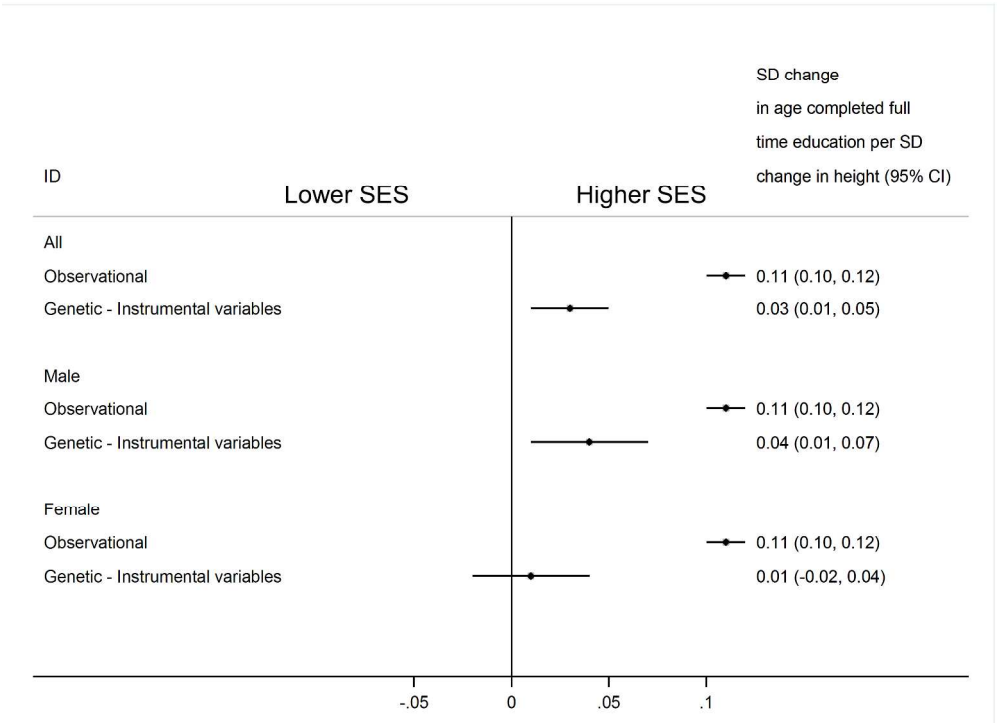

Figure 2: Forest plots of the observational and genetic associations between a 1SD higher height and SES: A) Age completed full time education; B) degree education; C) Job class; D) Income; E) Townsend deprivation index. The plots display the observational association (Observational) and the genetic association using instrumental variable analysis with the genetic risk score (Genetic-instrumental variables).
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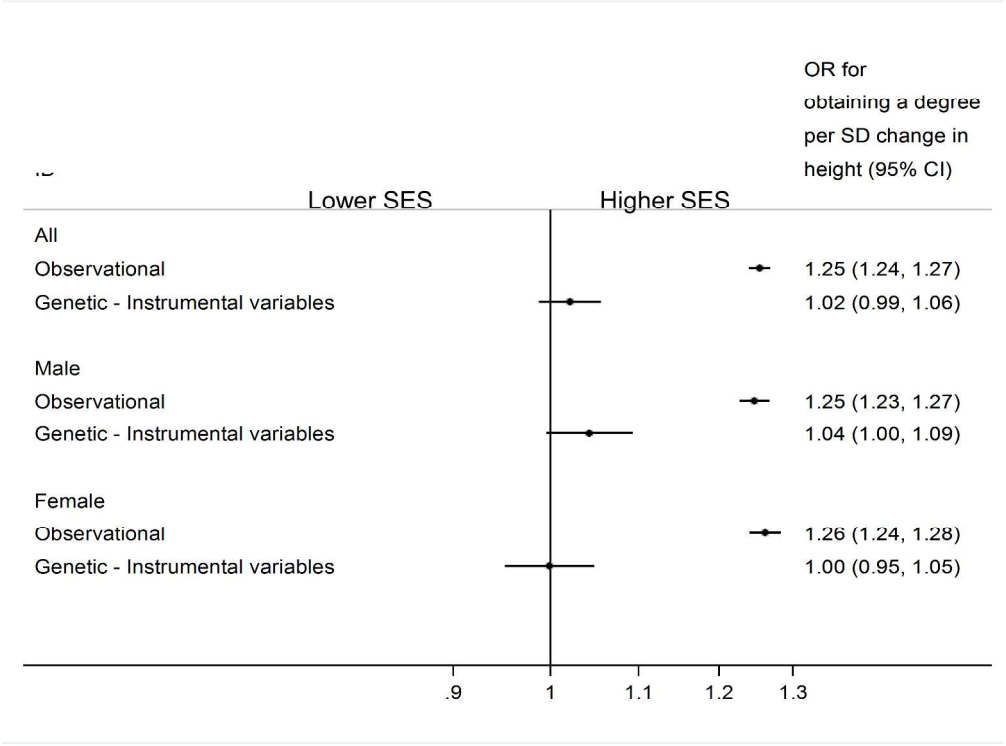

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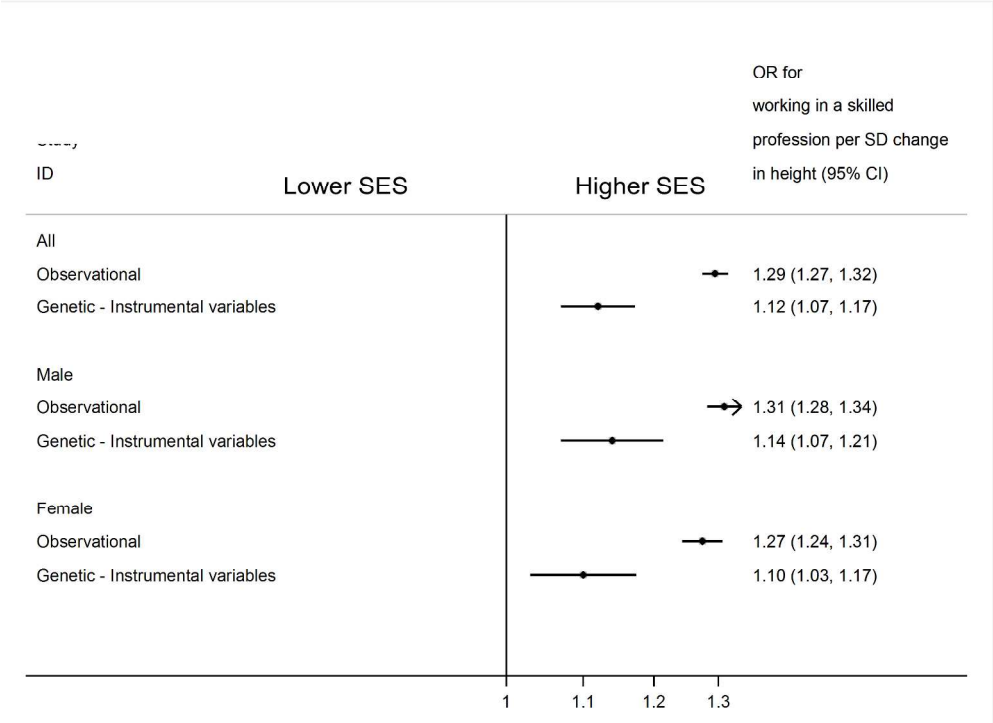

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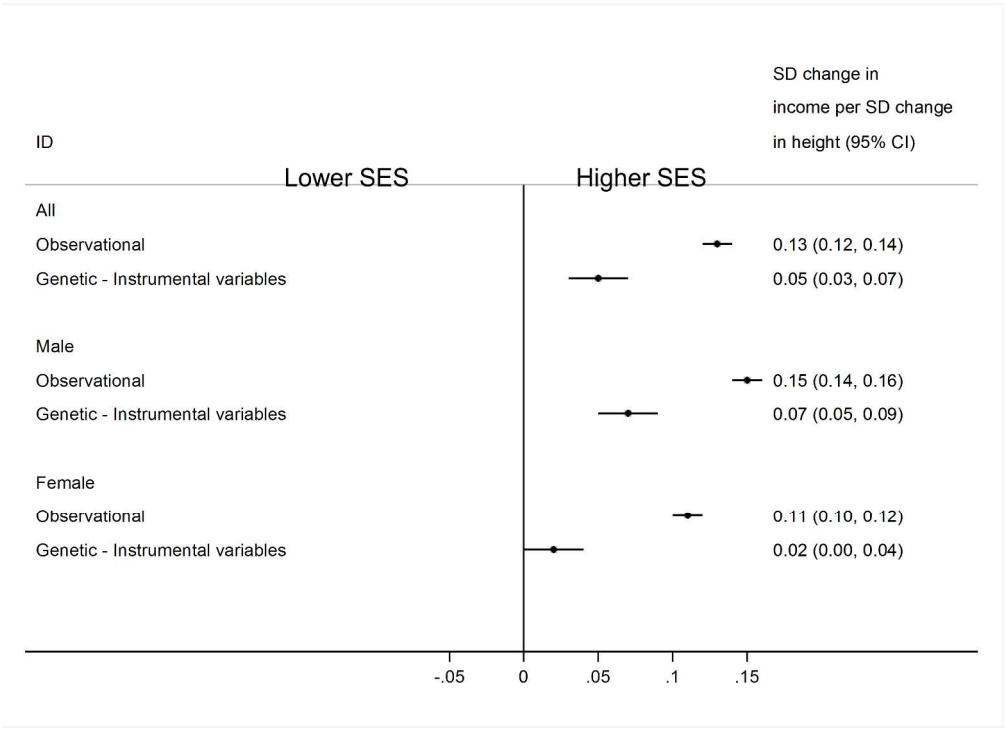

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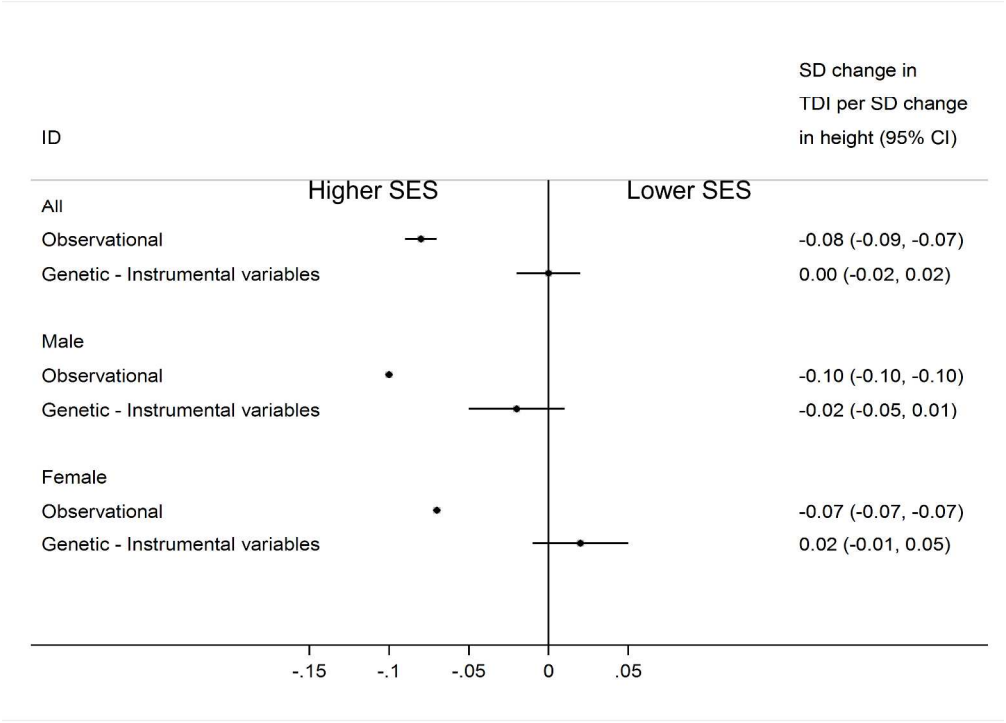

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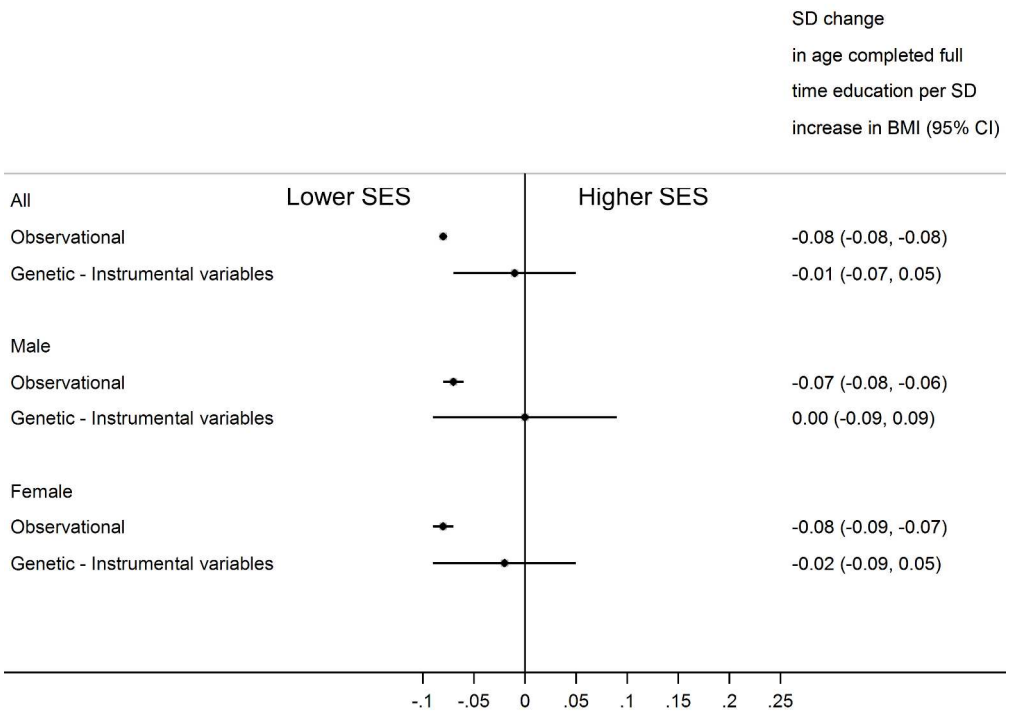

Figure 3: Forest plots of the observational and genetic associations between a 1SD higher BMI and SES: A) Age completed full time education; B) degree education; C) Job class; D) Income; E) Townsend deprivation index. The plots display the observational association (Observational) and the genetic association using instrumental variable analysis with the genetic risk score (Genetic-instrumental variables).
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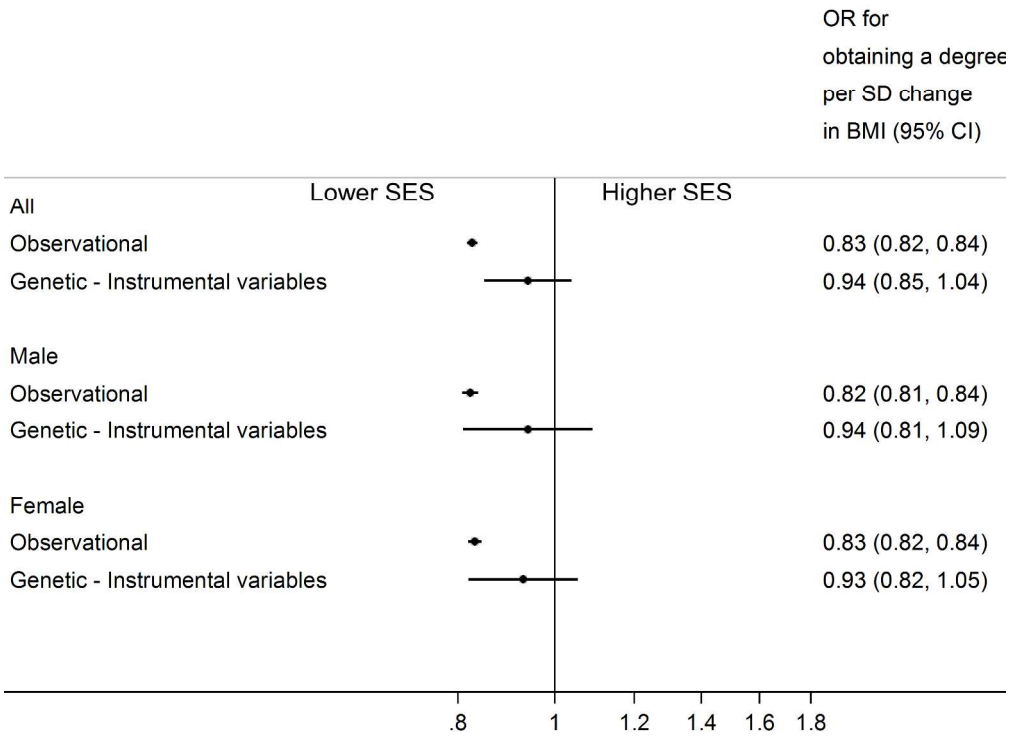

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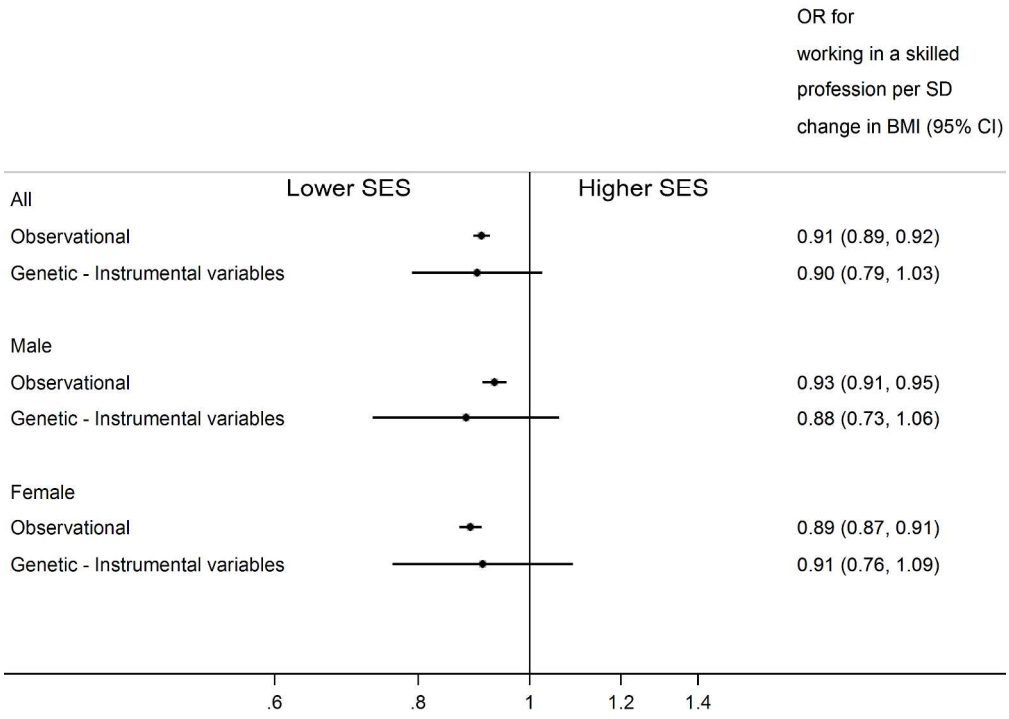

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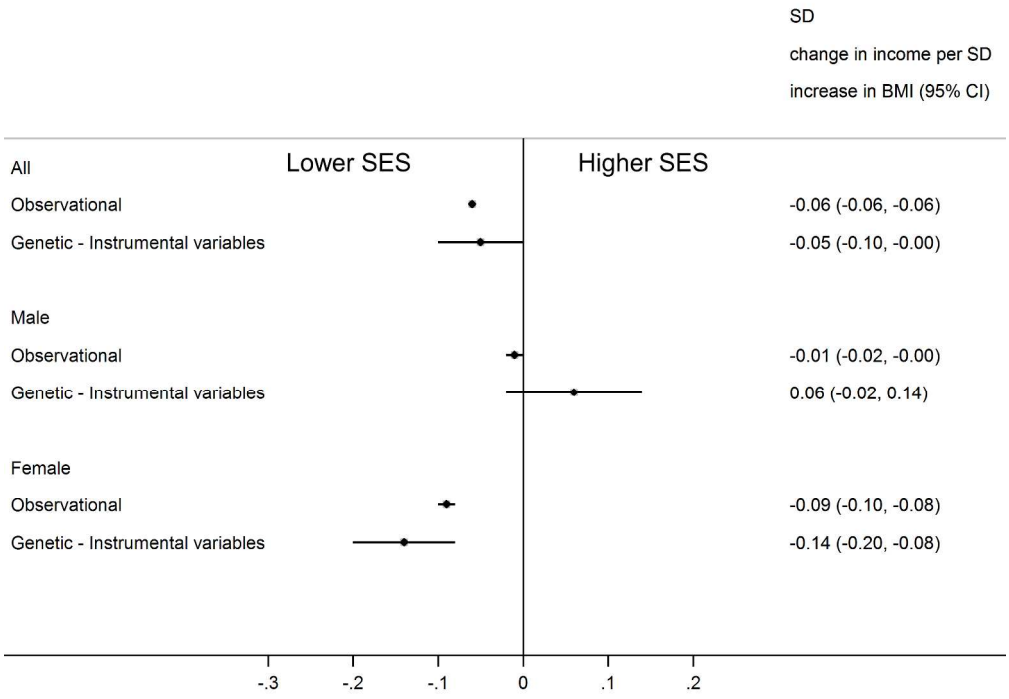

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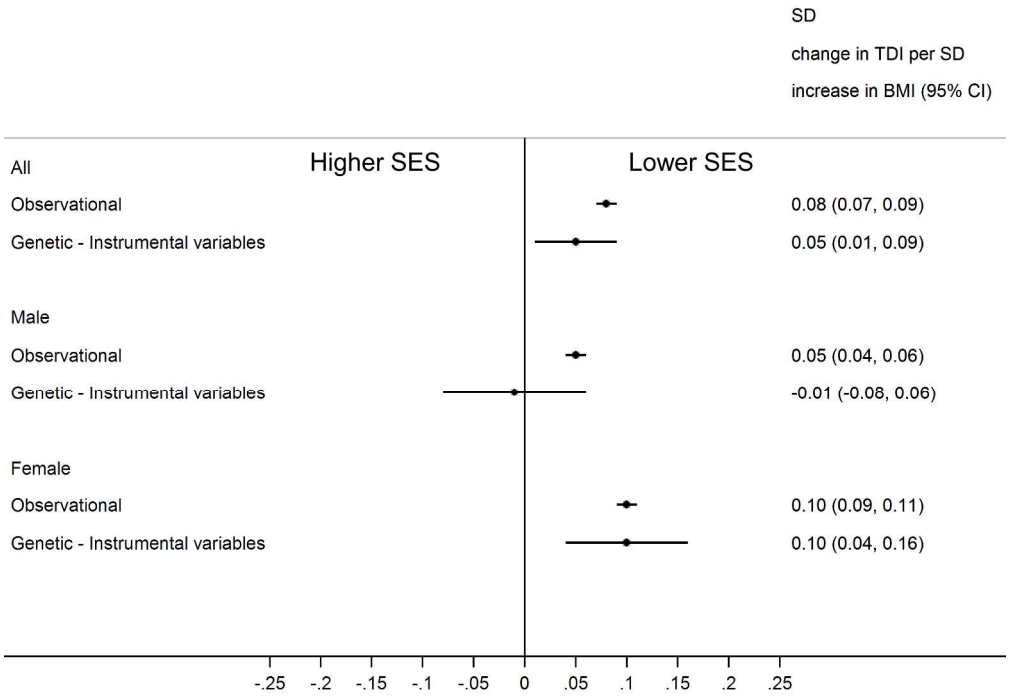

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