BMJ Open

Does the use of prediction equations to correct self-reported height and weight improve obesity prevalence estimates? A pooled cross-sectional analysis of Health Survey for England data

Shaun Scholes, Linda Ng Fat, Alison Moody, Jennifer S Mindell

To cite: Scholes S, Ng Fat L, Moody A, *et al*. Does the use of prediction equations to correct self-reported height and weight improve obesity prevalence estimates? A pooled cross-sectional analysis of Health Survey for England data. *BMJ Open* 2023;**13**:e061809. doi:10.1136/bmjopen-2022-061809

► Prepublication history and additional supplemental material for this paper are available online. To view these files, please visit the journal online (http://dx.doi.org/10.1136/bmjopen-2022-061809).

Received 07 February 2022
Accepted 29 November 2022

Epidemiology and Public Health, University College London, London, UK

Correspondence to
Dr Shaun Scholes;
s.scholes@ucl.ac.uk

ABSTRACT

Objective Adults typically overestimate height and underestimate weight compared with directly measured values, and such misreporting varies by sociodemographic and health-related factors. Using self-reported and interviewer-measured height and weight, collected from the same participants, we aimed to develop a set of prediction equations to correct bias in self-reported height and weight and assess whether this adjustment improved the accuracy of obesity prevalence estimates relative to those based only on self-report.

Design Population-based cross-sectional study.

Participants 38 940 participants aged 16+ (Health Survey for England 2011–2016) with non-missing self-reported and interviewer-measured height and weight.

Main outcome measures Comparisons between self-reported, interviewer-measured (gold standard) and corrected (based on prediction equations) body mass index (BMI: kg/m^2) including (1) difference between means and obesity prevalence and (2) measures of agreement for BMI classification.

Results On average, men overestimated height more than women (1.6 cm and 1.0 cm, respectively; p<0.001), while women underestimated weight more than men (2.1 kg and 1.5 kg, respectively; p<0.001). Underestimation of BMI was slightly larger for women than for men (1.1 kg/m^2 and 1.0 kg/m^2, respectively; p<0.001). Obesity prevalence based on BMI from self-report was 6.8 and 6.0 percentage points (pp) lower than that estimated using measured BMI for men and women, respectively. Corrected BMI (based on models containing all significant predictors of misreporting of height and weight) lowered underestimation of obesity to 0.8pp in both sexes and improved the sensitivity of obesity over self-reported BMI by 15.0pp for men and 12.2pp for women. Results based on simpler models using age alone as a predictor of misreporting were similar.

Conclusions Compared with self-reported data, applying prediction equations improved the accuracy of obesity prevalence estimates and increased sensitivity of being classified as obese. Including additional sociodemographic variables did not improve obesity classification enough to justify the added complexity of including them in prediction equations.

STRENGTHS AND LIMITATIONS OF THE STUDY

- ⇒ The limitations of body mass index (BMI) calculated from self-reported height and weight are well known.
- ⇒ Health examination surveys such as the Health Survey for England (HSE) enable study of reporting bias when they collect both self-report and directly measured data on height and weight from the same participants.
- ⇒ This study used HSE 2011–2016 data to derive a set of adjustments to self-reported height and weight based on linear regression models that predicted measured height and weight from self-reported height and weight, with additional corrections for sociodemographic and health-related factors predictive of misreporting.
- ⇒ Corrected and measured BMI (the gold standard) were compared to quantify by how much obesity prevalence estimates were improved relative to those based on self-report data only.
- ⇒ Prediction equations are specific to time, place, target population and methods of data collection. As such, these may not be applicable to surveys with more recent data, or with different sociodemographic, health and self-reported anthropometric profiles.

INTRODUCTION

A few large cross-sectional surveys in England and the USA include only self-reports of height and weight, as direct measurement is not feasible due to factors such as cost. In lieu of direct measures, body mass index (BMI) derived from self-reported height and weight (hereafter, self-reported BMI) is sometimes used for research[1] and regularly for estimating obesity prevalence at a subnational level as part of monitoring efforts.[2 3] However, systematic literature reviews[4 5] and epidemiologic studies[6–11] have consistently shown that adults on average overestimate height and underestimate weight compared with measured values. While such misreporting is typically moderate on average for continuous variables, self-reported BMI often results in a systematic misclassification of BMI categories. Misreporting of height and weight, plus the skewness of BMI distributions, results in significant underestimation of obesity prevalence.[11]

Misreporting of height and weight varies by sociodemographic factors, for example, by sex,[11] age,[12] race/ethnicity[10] and socioeconomic status,[9] and by health-related factors such as current smoking status[8] and self-perceived health.[8] Younger women, in particular, underestimate weight (linked to social desirability bias),[13] while older persons overestimate height (linked to reporting height measured earlier in life, prior to becoming shorter due to changes in bone and muscle).[6 12] Misreporting of weight is greater in higher BMI categories[10 11 14–16]: the term 'flat slope syndrome' in obesity epidemiology describes the systematic tendency for self-reported BMI (relative to measured BMI) to overestimate low values and underestimate high values.[7 17 18]

Health examination surveys (eg, the Health Survey for England (HSE) and the US National Health and Nutrition Examination Survey (NHANES)) often collect both self-report and measured data on height and weight from the same participants, enabling study of self-reporting bias.[10 11] As such analyses have shown systematic patterns in misreporting, equations including variables predictive of misreporting have been developed for use with surveys collecting self-report but not measured height and weight.[9 10 16 19] In England, self-reported height and weight in the Active Lives Survey (ALS) data sets are adjusted by formulae based on HSE data to monitor the proportion of excess weight (BMI≥25 kg/m^2) at local authority (LA) level for the Public Health Outcomes Framework (PHOF). For surveys such as the ALS with no direct measurements of height and weight, these adjustments are made in the expectation that corrected values improve accuracy of BMI classification, and so estimate levels of excess weight and obesity more accurately, compared with reliance on self-report data alone.[3 16]

The HSE is the main data source for monitoring overweight and obesity in the general population in England. Annually since 1991, trained interviewers have measured participants' height and weight. Self-reported height and weight were included in each survey year between 2011 and 2016. The present study aims to analyse HSE 2011–2016 data to develop a set of equations to correct self-reported height and weight to more closely approximate measured height and weight. Should corrected BMI show an improvement over self-reported BMI, these equations could then be applied to (1) self-report data in HSE 2021 (where interviewer measurement was not possible for a substantial portion of fieldwork due to COVID-19 pandemic precautions) and (2) other interview-based surveys (eg, ALS) to improve accuracy of excess weight and obesity prevalence estimates. Our objectives were to (1) identify which variables are associated with misreporting (thereby meriting inclusion in prediction equations) and (2) assess whether applying the chosen equations improved the classification of adults into BMI categories.

METHODS

Study design and participants

The present study used HSE data on adults (aged 16+ years) from all survey years between 2011 and 2016, when both self-reported and measured height and weight were collected. The HSE is a cross-sectional, general population survey of individuals living in private households, with a new sample each year randomly selected by address.[20] Data collection occurs throughout the year. The first stage is a health interview, including questions about sociodemographic factors, diagnosed health conditions, self-rated health, health-related lifestyle behaviours and direct measurements of—and in 2011–2016, self-reported—height and weight. The second stage is a nurse-visit, including biophysical measurements. Interviews and nurse visits take place in the participants' own homes. All adults in selected households were eligible (maximum 10); the percentage of eligible households participating ranged from 66% in 2011 to 59% in 2016. Participants gave verbal consent to be interviewed, visited by a nurse, and to have anthropometric measurements taken. Research ethics approval was obtained from relevant committees.

Self-reported height and weight were collected with the questions: '*How tall are you without shoes?*' and '*How much do you weigh without clothes and shoes*?' Height was reported in either metres or feet and inches; weight was reported in kilograms (kg) or stones and pounds. Height was measured using a portable stadiometer with a sliding head plate, a base plate and connecting rods marked with a measuring scale. Participants were asked to remove their shoes. One measurement (to the nearest even millimetre) was taken, with participants' stretching to the maximum height and the head positioned in the Frankfort plane. For those not pregnant, a single weight measurement (to the nearest 100 g; maximum 200 kg) was recorded using Class III Seca scales; participants were asked to remove their shoes and any bulky clothing or heavy items in pockets, etc. No adjustment was made for the weight of clothing. Participants unable to stand or unsteady on their feet were not measured. Those who weighed 200+ kg were asked for their estimated weight because the scales are inaccurate above this level. Participants were assigned missing values if they were considered by the interviewer to have unreliable measurements, for example, those who were too stooped or wore excessive clothing. Participants were not told at the time of interview that their height and weight would be measured; however, given their informed consent, it is likely that they might have anticipated being measured subsequent to their report.

Analytical sample

All participants (n=49 817) were asked their height and weight soon after starting the interview, and the measurements took place near the end. As our aim was to study self-reporting bias, the analytical sample was limited to n=38 940 participants with non-missing self-reported and measured height and weight. The participants excluded were as follows: pregnant (n=471); missing self-report and measured data (n=1001); missing self-report but not measured data (n=2550) and missing measured but not self-report data (n=6855). Missing self-report and measured data were primarily due to 'don't knows' and refusals, respectively.

Key variables

BMI was calculated as weight in kg divided by height in metres squared, and the WHO classification[21] was used to group participants into five categories: underweight (<18.5 kg/m^2); normal weight (18.5 –24.9 kg/m^2); overweight, not obese (25.0–29.9 kg/m^2); obesity grades I and II (30.0–39.9 kg/m^2) and obesity grade III (≥40 kg/m^2). Participants were also classified according to the binary categories of (1) overweight including obesity (excess weight: ≥25 kg/m^2) and (2) obesity (≥30 kg/m^2). These definitions were applied to all participants as adults are defined in the HSE series as aged 16+ years.

Age was used as a categorical variable in our main analysis (16–17 years, 18–19 years, and in 5-year intervals up to 85+ years), so that researchers can reproduce the results and revise/update equations accordingly using the public-use HSE data sets (since 2015 only categorical age has been provided to preserve anonymity of participants). Other potential predictors of misreporting included ethnic group (white, black, Asian, mixed, other); Government Office Region (North East, North West, Yorkshire and the Humber, East Midlands, West Midlands, East of England, London, South East, South West); cigarette smoking status (current, exsmoker, never-smoker); self-reported general health (very good/good, fair, bad/very bad); self-reported presence of a limiting longstanding illness and two indicators of socioeconomic status: (1) highest educational qualification (university degree or equivalent, A level/diploma, O level/General Certificate of Secondary Education (GCSE)/vocational equivalent or none) and (2) Index of Multiple Deprivation quintile, a small-area based measure of deprivation (least deprived to most deprived). These variables were chosen based on a review of the literature and data availability (collected in HSE 2011–2016 main interview). To maximise sample sizes, missing values on independent variables were assigned to a separate category (n≥30) or the modal category (n<30).

Statistical analyses

1. Descriptive analysis: comparing self-reported and measured data.

We decided *a priori* to conduct sex-specific analyses due to documented differences in reporting[6 8–10 14 22] and the sexual dimorphisms in height, weight and adiposity.[23] Initial analyses showed no linear trend in misreporting over the 6-year period in either sex (online supplemental table S1): pooled data were therefore used for subsequent analysis.

Among complete cases (n=38 940), self-reported and measured mean height, weight and BMI were calculated with 95% CIs. To compare across distributions,[24] we computed values at the 5th, 10th, 25th, 50th, 75th, 90th and 95th percentiles.[11] To compare self-report and measured data, we first calculated the difference (self-reported minus measured) between means (height, weight and BMI) and between prevalence (overweight including obesity and obesity). The degree of individual variability in the difference between self-reported and measured values was summarised by the SD.[4 6] Bland-Altman limits of agreement (LOA) were calculated for height, weight and BMI. Second, we cross-tabulated self-reported and measured BMI categories. Using measured BMI as gold standard, we calculated estimates of sensitivity (the per cent of true positives) and specificity (the per cent of true negatives) to quantify the classification accuracy of self-reported BMI. We also calculated the Youden J statistic, a summary index that combines sensitivity and specificity, assuming both have equal importance.[25] Cohen's Kappa (κ) statistic was also used to assess the degree of agreement after accounting for agreement at random.[13]

2. Developing prediction equations in our main analysis.

Linear regression modelling was used to develop equations to predict measured values of height and weight from self-reported height and weight, with appropriate adjustments for any variables independently associated with misreporting.[8–10 16 26] This involved three main steps.

Step 1: predictors of misreporting

First, as in other studies,[6 9 22 27] participants with an absolute difference (self-reported minus measured) ≥4 SD from the mean were considered outliers (with possible unrealistic reported values): these were excluded (height: n=189; weight: n=276) to avoid potentially undue influence on the equations. For those remaining (n=38 475), separately for height and weight, linear regression modelling was used to identify which variables were independently predictive of the difference between self-reported and measured values. The backward elimination stepwise method was used to select candidates for inclusion in prediction equations. Continuous variables for self-reported height and weight were entered as linear, quadratic and cubic terms to allow for possible non-linearity[10]; as part of model refinement, the model was refitted with just the linear and quadratic terms if the p value for the cubic term in the model containing all three terms was >0.05. For variables with more than two categories, we used joint Wald tests (null hypothesis being that all coefficients were equal to zero) to decide whether to retain the variable in the model. At each step, after adjustment for self-reported height/weight and age-group, the sociodemographic or health-related predictor with the highest p value (>0.05) was removed from the model.

Step 2: deriving the prediction equations

Second, as in other studies,[9 22] the sample was randomly split into a training (hereafter, split-sample A) and testing (split-sample B) data set using a 70:30 ratio. Split-sample A (n=27 033) was used for model-fitting and refinement and parameter estimation (prediction equations). Split-sample B (n=11 442) provided an independent assessment of predictive accuracy of the equations. Although we followed the approach of previous studies, we acknowledge that the most optimal approach would have been to randomly split the full sample prior to examining the significance of individual variables in predicting misreporting. To develop the prediction equations via linear regression modelling, measured height and weight were the dependent variables,[8] and self-reported height and weight (including any non-linear terms), age-group and any other variables significantly associated with misreporting (from step 1) were the independent variables. In a final refinement step, only significant variables ($p<0.05$) were retained (hereafter, full models) for reasons of parsimony (ie, achieved similar goodness-of-fit with as few predictors as possible). We also fitted models containing age-group alone as a predictor of misreporting (hereafter, reduced models): such simpler equations may be particularly useful for researchers using surveys other than the HSE that do not contain all the independent variables retained in the full models. For these and other equations (see below), the adjusted R^2 and root mean square error (RMSE) summarised model goodness-of-fit: high R^2 and low RMSE represent explained variability and good precision, respectively.

Step 3: assessing the accuracy of the equations

Third, the equations generated from split-sample A were applied to split-sample B. Corrected BMI was derived using predicted height and weight. Descriptive statistics (means for continuous variables and percentages for BMI categories) were used to compare self-reported, measured and corrected values.

To compare predicted and measured height and weight (and BMI derived from these) across a set of equations, the mean difference (predicted minus measured) estimated bias and the SD of the difference quantified the variability in error (an estimate of reliability).[6] Using measured BMI as gold standard, estimates of sensitivity, specificity and the Youden Index were calculated to quantify by how much corrected BMI improved BMI classification. The models considered were as follows:

- A ‘mean-correction’ equation (derived from the full model for an *all mean/reference* individual).
- Equation 1: self-reported height/weight alone (including any non-linear terms).
- Equation 2: self-reported height/weight, categorical age (reduced model).
- Equation 3: self-reported height/weight, categorical age, sociodemographic and health-related factors associated with misreporting (full model).

For a final set of correction factors (equation 4), self-reported BMI was added to the full model to estimate any specific improvement in model performance.

Finally, to investigate the presence of any systematic error in *self-reported* BMI (ie, the ‘flat slope syndrome’ mentioned earlier), we fitted a linear regression model in which the difference between self-reported and measured BMI was the dependent variable and measured BMI was the independent variable. To investigate any such error in *corrected* BMI, we fitted a linear regression model in which the difference between corrected and measured BMI was the dependent variable and measured BMI was the independent variable.[16] For each case, a significantly negative slope for BMI would indicate the tendency for BMI underestimation to increase as measured BMI increases.

Supplementary analysis

Self-reported height and weight in ALS data sets are currently adjusted by formulae based on HSE data (2012–2014) to monitor levels of excess weight (BMI ≥25 kg/m^2) across English LAs. Similar to the approach of Jain *et al*,[10] the prediction equations were based on linear regression models to predict measured height/weight as a function of self-reported height/weight and age (as a continuous variable). These equations might not be entirely applicable to self-reported data on height and weight collected since 2014 as the pattern and/or magnitude of misreporting bias is subject to change over time. To support these monitoring efforts for the PHOF, as a supplementary analysis, we updated these equations using the same modelling approach on the most recent HSE data (2011–2016). Linear, quadratic and cubic terms were entered for self-reported height and weight, and linear and quadratic terms were entered for age. Each term was retained in the model (thereby included in the equation) irrespective of statistical significance to maintain consistency with the earlier study and to allow for possible associations in future data sets.[10]

All analyses accounted for the complex survey design, incorporating survey non-response weights and geographical clustering. Statistical significance was set at $p<0.05$ for two-tailed tests, with no adjustment for multiple comparisons. HSE data sets are available via the UK Data Service (www.ukdataservice.ac.uk)[28–33] and are subjected to an end-user license agreement. Data set preparation was performed in SPSS V.24.0 (IBM, Armonk, New York); analysis was performed in Stata V.17.1 (StataCorp LLC, College Station, Texas). Reproducible code will be openly accessible via GitHub (https://github.com/shauns11; GitHub, San Francisco, California).

Patient and public involvement

Patients or the public were not involved in the design, or conduct, or reporting or dissemination plans of our research (which involves secondary analysis of existing data). The project was shaped by discussions with the HSE Steering Group, including representatives from various national government agencies and local authorities.

Table 1 Means and differences in means for self-reported and measured height, weight and BMI by sex

	Self-reported (95% CI)	Measured (95% CI)	Absolute difference (95% CI)*	Relative difference (95% CI)†
Men (n=17 868)				
Height (cm)	177.1 (177.0 to 177.3)	175.5 (175.4 to 175.7)	1.6 (1.5 to 1.6)	0.9% (0.9 to 0.9)
Weight (kg)	82.9 (82.6 to 83.1)	84.4 (84.1 to 84.7)	−1.5 (−1.6 to −1.4)	−1.5% (−1.6 to −1.5)
BMI (kg/m^2)	26.4 (26.3 to 26.5)	27.4 (27.3 to 27.5)	−1.0 (−1.0 to −0.9)	−3.2% (−3.3 to −3.1)
Overweight including obese (%)	*58.7 (57.8 to 59.5)*	*66.7 (65.8 to 67.5)*	*−8.0pp (−8.6 to −7.5)*	*−12%*
Obese (%)	*18.4 (17.7 to 19.0)*	*25.1 (24.4 to 25.8)*	*−6.8pp (−7.2 to −6.3)*	*−27%*
Women (n=21 072)				
Height (cm)	162.9 (162.8 to 163.0)	161.9 (161.8 to 162.0)	1.0 (1.0 to 1.1)	0.6% (0.6 to 0.7)
Weight (kg)	68.4 (68.2 to 68.7)	70.5 (70.3 to 70.7)	−2.1 (−2.1 to −2.0)	−2.6% (−2.7 to −2.6)
BMI (kg/m^2)	25.8 (25.7 to 25.9)	26.9 (26.8 to 27.0)	−1.1 (−1.1 to −1.1)	−3.8% (−3.9 to −3.7)
Overweight including obese (%)	*47.6 (46.9 to 48.4)*	*56.6 (55.8 to 57.3)*	*−9.0pp (−9.4 to −8.5)*	*−16%*
Obese (%)	*18.6 (18.0 to 19.2)*	*24.6 (24.0 to 25.3)*	*−6.0pp (−6.4 to −5.7)*	*−25%*

Participants with valid self-reported and measured height and weight (n=38 940). Estimates for height, weight and BMI are mean (95% CI). Overweight including obese (≥25.0 kg/m^2). Obese (≥30.0 kg/m^2).
*Self-report minus measured. Positive values indicate overestimation; negative values underestimation.
†((Self-report minus measured)/measured) × 100.
BMI, body mass index; pp, percentage points.

RESULTS

Comparing self-reported and measured height, weight and BMI in the full sample

To compare self-reported and measured data, table 1 presents the difference between means (height, weight, BMI) and prevalence (BMI categories). On average, men overestimated height more than women (difference: 1.6 cm and 1.0 cm, respectively; p<0.001 for sex difference), while women underestimated weight more than men (difference: 2.1 kg and 1.5 kg; p<0.001). Underestimation of BMI was slightly larger on average for women than for men (1.1 kg/m^2 and 1.0 kg/m^2; p<0.001). About three-quarters of adults had self-reported BMI values within 2 units of measured BMI (data not shown); however, underestimation of BMI was greater in higher BMI categories (online supplemental table S2). For both sexes, the upper percentiles of BMI were lower for self-reported than for measured data, indicating more compressed distributions (online supplemental table S3 and figure S1).

The Bland-Altman LOA shows the range within which approximately 95% of the differences between self-reported and measured values would be expected to fall.[34] The LOA for self-reported BMI was in the range of −4.7 to 2.6 BMI units for men and from −5.1 to 2.8 units for women (unweighted data: online supplemental table S4 and figure S2). The SD of the differences for height, weight and BMI was 2.8 cm, 4.4 kg and 1.7 kg/m^2 for men, respectively, and 3.2 cm, 4.5 kg and 2.0 kg/m^2, respectively, for women (online supplemental table S4); the distribution of reporting error was greater in higher BMI categories (online supplemental figure S3).

The prevalence of overweight including obesity was 8.0 and 9.0 percentage points (pp) lower for self-reported than measured data for men and women, respectively. The equivalent figures for obesity were 6.8pp and 6.0pp (table 1). Using measured BMI as gold standard, 77% of men and 78% of women were correctly classified using self-reported BMI (table 2). The sensitivity of the self-reported obese category was 69% for men and 72% for women; specificity values were 99% for both sexes, indicating that very few non-obese participants according to measured BMI were classified as obese based on BMI derived from self-report (table 2).

Predicting measured height from self-reported height and other variables (split-sample A)

Among men, based on multivariable linear regression analysis (dependent variable: self-reported minus measured height), older age, lower educational status (O level or no qualifications vs having a degree), being Asian (vs white), living in the North East, the North West and the West Midlands (vs the South East) and reporting bad/very bad general health (vs good/very good) were associated with greater overestimation of height. For women, older age, lower educational status (O level or no qualifications vs having a degree), living in the North West (vs the South East), living in the most (vs least) deprived areas, and being in the black, Asian or mixed ethnic groups (vs white) were associated with greater overestimation of height (online supplemental table S5A,B). The R^2 values for the full models (indicating the proportion of variance in reporting error explained by these variables) were 16.1% (men) and 22.3% (women).

The regression coefficients (prediction equations) for the aforementioned variables based on the models with measured height as the dependent variable correct self-reported height upwards (positive signs) or downwards (negative signs) as appropriate (online supplemental table S5A,B): for example, compared

Table 2 Cross-tabulation of measured and self-reported BMI categories by sex

Self-reported BMI categories	Measured BMI categories				
	Under-weight	Normal	Overweight but not obese	Obese I & II	Obese III
	n (%)	n (%)	n (%)	n (%)	n (%)
Men (n=17 868)					
Underweight	209 (69.2)	167 (2.7)	4 (0.0)	2 (0.0)	0 (0.0)
Normal	91 (30.1)	5704 (91.0)	1927 (23.5)	49 (1.1)	0 (0.0)
Overweight but not obese	2 (0.7)	390 (6.2)	6081 (74.2)	1475 (32.0)	5 (1.4)
Obese I and II	0 (0.0)	7 (0.1)	184 (2.2)	3051 (66.2)	178 (50.9)
Obese III	0 (0.0)	1 (0.0)	1 (0.0)	32 (0.7)	166 (47.6)
Sensitivity	69%	91%	74%	66%	48%
Specificity	99%	85%	84%	98%	100%
Youden Index	68%	76%	58%	64%	47%
κ	0.66				
Women (n=21 072)					
Underweight	303 (73.7)	292 (3.6)	8 (0.1)	0 (0.0)	0 (0.0)
Normal	106 (25.8)	7524 (93.5)	1886 (30.3)	79 (1.9)	5 (0.7)
Overweight but not obese	2 (0.5)	223 (2.8)	4176 (67.1)	1244 (29.9)	10 (1.5)
Obese I and II	0 (0.0)	7 (0.1)	152 (2.4)	2796 (67.1)	272 (43.3)
Obese III	0 (0.0)	1 (0.0)	2 (0.0)	47 (1.1)	342 (54.5)
Sensitivity	74%	93%	67%	67%	54%
Specificity	98%	82%	89%	97%	100%
Youden Index	72%	75%	56%	64%	54%
κ	0.67				

κ (Cohen's kappa statistic). Participants with valid self-reported and measured height and weight (n=38 940). Cell counts are weighted (rounded); estimates are column percentages. Shaded cells indicate those who were classified in the same category of BMI based on self-reported and measured height and weight. Underweight (<18.5 kg/m^2); normal (≥18.5–24.9 kg/m^2); overweight but not obese (≥25.0–29.9 kg/m^2); obese I and II (≥30.0–39.9 kg/m^2); obese III (≥40.0 kg/m^2).
BMI, body mass index.

with those in the white group, the predicted measured height from the self-reported height of participants in the Asian group is corrected downwards by 0.61 cm (men) and 1.78 cm (women).

Predicting measured weight from self-reported weight and other variables (split-sample A)

For men, being an ex-regular or never (vs current) smoker were associated with greater underestimation of weight; lower educational status (O level or no qualifications vs having a degree) was associated with lower underestimation. For women, being an ex-regular or never (vs current) smoker and being in the black (vs white) ethnic group were associated with greater underestimation of weight (online supplemental table S6A,B). The R^2 values for the full-models were markedly lower than for height: 2.0% (men) and 1.9% (women). Online supplemental table S6A,B show the prediction equations for deriving corrected values of weight: for example, compared with current smokers, the predicted measured weight from the self-reported weight of never smokers was adjusted upwards by 0.65 kg (men) and 0.18 kg (women).

Assessing the predictive accuracy of the equations (split-sample B)

Descriptive statistics

The prediction equations were applied to split-sample B to generate corrected values. Table 3 shows the means (height, weight, BMI) and percentages (BMI categories) for the self-reported, measured and corrected (full models and reduced models) values. In each case, corrected estimates were closer than self-reported estimates to measured estimates, and the difference in means between corrected and measured values was not significantly different from zero, with the exception of height for women (eg, measured height was underestimated on average by 0.1 cm in the full model (p=0.003; data not shown)).

Compared with measured BMI, obesity prevalence based on self-reported BMI was 6.5pp and 5.2pp lower for men and women, respectively. The corresponding value for corrected

Table 3 Mean height, weight and BMI for self-reported, measured and corrected data by sex (split-sample B)

			Corrected data	
	Self-reported (95% CI)	Measured (95% CI)	Full model (95% CI)	Reduced model (95% CI)
Men (n=5297)				
Height (cm)	177.1 (176.9 to 177.4)	175.6 (175.3 to 175.8)	175.5 (175.3 to 175.7)	175.5 (175.3 to 175.7)
Weight (kg)	82.7 (82.2 to 83.2)	84.2 (83.7 to 84.7)	84.2 (83.7 to 84.6)	84.2 (83.7 to 84.7)
BMI (kg/m^2)	26.3 (26.2 to 26.5)	27.3 (27.1 to 27.4)	27.3 (27.1 to 27.4)	27.3 (27.1 to 27.4)
BMI category (%):				
Underweight	2.2 (1.8 to 2.7)	1.7 (1.3 to 2.1)	1.3 (1.0 to 1.7)	1.3 (0.9 to 1.7)
Normal weight	39.6 (38.1 to 41.1)	32.0 (30.6 to 33.5)	31.4 (30.0 to 32.9)	31.3 (29.8 to 32.7)
Overweight but not obese	39.9 (38.5 to 41.3)	41.5 (40.0 to 42.9)	43.3 (41.8 to 44.7)	43.5 (42.0 to 45.0)
Obese I and II	17.3 (16.2 to 18.5)	23.0 (21.8 to 24.3)	22.4 (21.2 to 23.6)	22.3 (21.1 to 23.6)
Obese III	1.0 (0.8 to 1.4)	1.8 (1.4 to 2.3)	1.6 (1.3 to 2.1)	1.7 (1.3 to 2.1)
Overweight including obese	*58.2 (56.7 to 59.7)*	*66.3 (64.8 to 67.8)*	*67.3 (65.8 to 68.8)*	*67.5 (66.0 to 69.0)*
Obese	*18.3 (17.2 to 19.5)*	*24.8 (23.5 to 26.1)*	*24.0 (22.8 to 25.3)*	*24.0 (22.7 to 25.3)*
Women (n=6145)				
Height (cm)	162.9 (162.7 to 163.1)	162.0 (161.8 to 162.2)	161.9 (161.7 to 162.1)	161.9 (161.7 to 162.1)
Weight (kg)	68.2 (67.8 to 68.6)	70.2 (69.8 to 70.6)	70.2 (69.8 to 70.6)	70.2 (69.8 to 70.6)
BMI (kg/m^2)	25.7 (25.6 to 25.9)	26.7 (26.6 to 26.9)	26.8 (26.6 to 26.9)	26.8 (26.6 to 26.9)
BMI category (%):				
Underweight	3.6 (3.1 to 4.2)	2.5 (2.1 to 3.0)	2.0 (1.6 to 2.4)	2.0 (1.6 to 2.4)
Normal weight	49.8 (48.4 to 51.2)	42.3 (41.0 to 43.7)	42.4 (41.0 to 43.8)	42.1 (40.8 to 43.5)
Overweight but not obese	28.0 (26.8 to 29.2)	31.3 (30.1 to 32.6)	32.6 (31.4 to 33.9)	32.9 (31.6 to 34.1)
Obese I and II	16.9 (15.9 to 17.9)	20.8 (19.7 to 21.8)	20.4 (19.3 to 21.5)	20.4 (19.4 to 21.5)
Obese III	1.8 (1.5 to 2.1)	3.1 (2.7 to 3.6)	2.7 (2.3 to 3.1)	2.6 (2.2 to 3.1)
Overweight including obese	*46.6 (45.2 to 48.0)*	*55.2 (53.8 to 56.6)*	*55.6 (54.3 to 57.0)*	*55.9 (54.5 to 57.3)*
Obese	*18.6 (17.6 to 19.6)*	*23.9 (22.7 to 25.0)*	*23.0 (21.9 to 24.2)*	*23.0 (21.9 to 24.1)*

Participants with valid self-reported and measured height and weight in split-sample B (n=11 442). Estimates for height, weight and BMI are mean (95% CI). Full model: measured height/weight predicted from self-reported height/weight, categorical age, socio-demographic and health-related factors associated with misreporting. Reduced model: measured height/weight predicted from self-reported height/weight, categorical age. Formulae used to generate corrected BMI values are shown in online supplemental tables S5 and S6 (Supplementary data). Underweight (<18.5 kg/m^2); normal (≥18.5–24.9 kg/m^2); overweight but not obese (≥25.0–29.9 kg/m^2); obese I and II (≥30.0–39.9 kg/m^2); obese III (≥40.0 kg/m^2). Overweight including obese (≥25.0 kg/m^2); obese (≥30.0 kg/m^2).
BMI, body mass index.

BMI (full models) was 0.8pp for both sexes (table 3; figure 1). The prevalence of overweight including obesity was slightly overestimated (1.0% men; 0.4% women).

Model performance criteria

To compare the simpler and more complex equations, table 4 shows their estimated precision and accuracy using the adjusted R^2, RMSE, mean and SD of the difference (corrected minus measured) and LOA.

Results were similar for both sexes. First, compared with self-report (before correction) and mean-corrected data, the four regression models reduced the mean error in predicting measured height and weight. Second, model performance for height was improved by adding age to the model that included self-reported height alone, as shown by the decreases in both the RMSE and the SD of the difference between corrected and measured height. In general, the simpler equations containing self-reported height/weight and age performed comparably to the more complex models, which included other variables predictive of misreporting, and self-reported BMI.

Table 5 compares their estimated accuracy and reliability for BMI using the mean, and SD, of the difference. To compare accuracy of BMI classifications, sensitivity and specificity values (and the Youden Index) are shown for (1) overweight including obesity (excess weight) and (2) obesity.

Compared with self-report (before correction) and mean-corrected data, the four regression models for height/weight reduced the mean error in predicting measured BMI; the more complex equations also slightly reduced error variability. Corrected BMI based on the full models showed similar distance between the lower and upper LOA (men: −3.0 kg/m^2 to 3.0 kg/m^2; women: −3.0 kg/m^2 to 3.1 kg/m^2: unweighted data, shown in online supplemental figure S4) as the simpler equations containing self-reported height/weight and age.

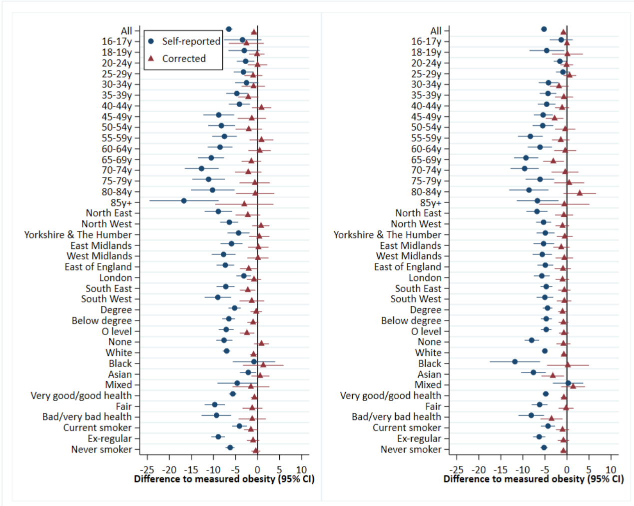

Figure 1 Difference in obesity prevalence across population subgroups by sex (men: left-panel; women: right-panel). Negative values indicate underestimation; positive value overestimation.

Based on the full models for measured height and weight (equation 3), the sensitivity of obesity based on corrected BMI increased to 86% and 87% for men and women, respectively, an absolute improvement over self-reported data by 15.0pp and 12.2pp. Specificity values for obesity remained very high but were slightly lower for corrected versus self-reported data. Sensitivity values for excess weight showed improvement for corrected versus self-reported BMI (increased by 8.9pp and 10.5pp for men and women, respectively), but larger decreases in specificity (decreased by 9.3pp and 7.3pp). In general, the simpler equations predicting measured height/weight from self-reported height/weight and age performed comparably to the more complex equations.

Measures of agreement for the five category BMI classification are shown in the supplementary material (online supplemental table S7). Sensitivity values in the normal weight category (18.5–24.9 kg/m^2) were higher for self-reported (91% men; 94% women) than corrected BMI (full model: 83% men; 89% women) but specificity values were lower (self-report: 85% men and 82% women; full-model: 93% men and 92% women). Sensitivity values in the underweight category were also higher for self-reported (80% men; 81% women) than corrected BMI (full model: 54% men and 60% women); all equations achieved very high specificity.

The results of linear regression analyses in which measured BMI was the predictor of error are shown in supplementary data (online supplemental table S8). The significantly negative slope for BMI (p<0.001 for both sexes) indicates that the differences between corrected and measured BMI showed a systematic, though smaller (relative to uncorrected data), bias in relation to measured BMI.

Supplementary analysis

The fitted regression equations describing the relationship between self-reported and measured height/weight

Table 4 Adjusted R^2, RMSE, mean difference and SD of the difference, and LOA from regression models developed to predict measured height/weight from self-reported height/weight

	Men				Women			
Model*	**Adjusted R^2**	**RMSE**	**Mean difference (SD)**	**LOA**	**Adjusted R^2**	**RMSE**	**Mean difference (SD)**	**LOA**
Height								
Self-report alone	–	–	1.59 (2.58)	−3.8, 7.2	–	–	0.93 (2.80)	−4.4, 6.4
Mean correction	–	–	0.63 (2.58)	−4.7, 6.3	–	–	1.15 (2.80)	−4.2, 6.6
Equation 1	0.87	2.61	−0.02 (2.52)	−5.2, 5.5	0.85	2.67	−0.11 (2.73)	−5.3, 5.2
Equation 2	0.88	2.47	−0.02 (2.37)	−5.0, 5.0	0.87	2.47	−0.10 (2.54)	−5.0, 4.8
Equation 3	0.89	2.45	−0.02 (2.36)	−5.0, 4.9	0.88	2.42	−0.10 (2.50)	−4.9, 4.7
Equation 4	0.89	2.45	−0.02 (2.35)	−5.0, 4.9	0.88	2.41	−0.10 (2.49)	−4.9, 4.7
Model using continuous age	0.88	2.47	−0.11 (2.36)	−5.1, 4.9	0.87	2.48	−0.11 (2.54)	−5.0, 4.8
Weight								
Self-report alone	–	–	−1.47 (3.70)	−9.2, 6.1	–	–	−1.95 (3.52)	−8.7, 4.7
Mean correction	–	–	−0.51 (3.70)	−8.2, 7.1	–	–	0.67 (3.52)	−6.1, 7.4
Equation 1	0.94	3.84	0.02 (3.69)	−7.7, 7.6	0.95	3.37	−0.01 (3.49)	−6.7, 6.6
Equation 2	0.94	3.82	−0.01 (3.68)	−7.6, 7.6	0.95	3.36	−0.01 (3.49)	−6.7, 6.6
Equation 3	0.94	3.81	−0.02 (3.67)	−7.6, 7.6	0.95	3.36	−0.01 (3.48)	−6.6, 6.6
Equation 4	0.94	3.81	−0.01 (3.67)	−7.6, 7.6	0.95	3.36	0.00 (3.48)	−6.6, 6.6
Model using continuous age	0.94	3.83	0.01 (3.68)	−7.6, 7.6	0.95	3.37	−0.01 (3.49)	−6.7, 6.6

Model goodness-of-fit (adjusted R^2 and RMSE) estimated using split-sample A; mean difference (SD) and LOA estimated using split-sample B.
*Mean-correction equation (derived from the full model for an *all mean/reference* individual: see online supplemental tables S5–S6. **Equation 1**: self-reported height/weight alone (including any non-linear terms). **Equation 2**: self-reported height/weight, categorical age (reduced model). **Equation 3**: self-reported height/weight, categorical age, other socio-demographic/health-related variables associated with misreporting (full model). **Equation 4**: self-reported height/weight, categorical age, other variables, self-reported BMI. LOA estimated using unweighted data.
.LOA, limits of agreement; RMSE, root mean square error.

Table 5 Mean difference and SD of the difference, LOA, sensitivities, specificities and Youden index in predicting BMI, excess weight and obesity from regression models developed to predict measured height/weight from self-reported height/weight (split-sample B)

	BMI		Excess weight (BMI ≥25 kg/m^2)				Obesity (BMI ≥30 kg/m^2)			
			Cc.	Sens.	Spec.	Youden Index	Cc.	Sens.	Spec.	Youden Index
Model*	Mean difference (SD)	LOA	%	%	%	%	%	%	%	%
Men (n=5297)										
BMI from height and weight										
Self-report alone	−0.96 (1.47)	−4.1, 2.1	88.1	85.0	94.4	79.3	91.9	70.6	98.9	69.5
Mean correction	−0.36 (1.47)	−3.5, 2.7	90.1	91.5	87.3	78.8	93.2	79.3	97.8	77.0
Equation 1	0.00 (1.45)	−3.1, 3.0	90.3	93.7	83.6	77.2	93.2	85.0	96.0	81.0
Equation 2	0.00 (1.42)	−3.0, 3.0	90.8	94.0	84.6	78.6	93.7	85.7	96.4	82.0
Equation 3	0.00 (1.41)	−3.0, 3.0	90.9	93.9	85.1	79.0	93.6	85.6	96.4	82.0
Equation 4	−0.01 (1.41)	−3.0, 2.9	91.0	94.1	84.9	79.0	93.7	85.4	96.4	81.8
Model using continuous age	0.03 (1.41)	−2.9, 3.0	91.0	94.2	84.7	78.9	93.5	85.6	96.2	81.8
Women (n=6145)										
BMI from height and weight										
Self-report alone	−1.04 (1.65)	−4.2, 2.1	89.3	82.5	97.7	80.2	93.2	74.7	98.9	73.6
Mean correction	−0.12 (1.66)	−3.3, 3.0	91.5	92.0	90.8	82.8	94.3	83.9	97.6	81.5
Equation 1	0.02 (1.62)	−3.1, 3.1	91.4	93.5	88.8	82.3	94.3	86.1	96.9	83.0
Equation 2	0.02 (1.60)	−3.0, 3.1	91.7	93.1	89.9	83.0	94.3	86.4	96.8	83.2
Equation 3	0.02 (1.59)	−3.0, 3.1	91.8	93.0	90.4	83.4	94.5	86.9	97.0	83.8
Equation 4	0.02 (1.59)	−3.0, 3.1	91.8	93.1	90.3	83.4	94.5	86.7	97.0	83.7
Model using continuous age	0.02 (1.60)	−3.0, 3.1	91.8	93.1	90.2	83.3	94.3	86.2	96.8	83.0

*BMI derived from predicted values of height and weight. Mean-correction equation (derived from the full models for an *all mean/reference* individual: see online supplemental tables S5–S6. **Equation 1**: Measured height/weight predicted from self-reported height/weight alone (including any non-linear terms). **Equation 2**: Measured height/weight predicted from self-reported height/weight, categorical age (reduced model). **Equation 3**: Measured height/weight predicted from self-reported height/weight, categorical age, other variables associated with misreporting (full model). **Equation 4**: Measured height/weight predicted from self-reported height/weight, categorical age, other variables, self-reported BMI. LOA estimated using unweighted data.
.BMI, body mass index; Cc, correctly classified; LOA, limits of agreement; Sens, sensitivity; Spec, specificity.

with age as the single continuous predictor of misreporting are shown as supplementary data (online supplemental tables S9–S10). Model performance was comparable to the other regression-based equations, apart from a slight but greater underestimation of measured height among men (tables 4 and 5). The estimates of sensitivity (excess weight: 94% men and 93% women; obesity: 86% both sexes) and specificity (excess weight: 85% men and 90% women; obesity: 96% men and 97% women) were similar to the other regression-based equations.

DISCUSSION

Using pooled HSE 2011–2016 data containing self-reported and interviewer-measured height and weight, we developed different sets of prediction equations that can be easily used to correct to some extent for biases in self-reported BMI. Although not perfectly predictive of measured BMI, corrected BMI performed better than self-reported BMI in more closely approximating obesity prevalence based on measured BMI. Applying corrected values also increased sensitivity of obesity, while achieving high specificity. Using measured BMI as gold standard, the sensitivity of obesity for the full model-corrected BMI was estimated as 86% and 87% for men and women, respectively, an improvement in absolute terms over self-reported BMI by 15.0pp and 12.2pp. In contrast, sensitivity values for the normal weight category were lower for corrected than self-reported data, but specificity values were higher.

Misreporting

The present study showed that mean height was overestimated by self-report relative to measured height, and that mean weight was underestimated, resulting in a net underestimation of mean BMI. Our estimates for the difference between means in height, weight and BMI were within the range shown by systematic literature reviews.[4 5] In agreement with other studies,[9 11] we found that women underestimated weight more than men but that men overestimated height more than women. As reported elsewhere,[35] we do not know whether the differences between self-reported and measured anthropometrics arise due to participants' lack of knowledge about their current height and weight or whether it is due to misreporting of information that is accurately known.

The mean differences found in the present study between self-reported and measured data were moderate on average (around 1 kg/m^2 for BMI). However, it is important to look beyond differences in means, as moderate differences on average can be accompanied by (1) a large degree of variability in reporting error between individuals (shown by the SD of the difference between self-reported and measured values),[4] (2) a compression of the BMI distribution (shown by lower values at the upper percentiles for self-reported than for measured data)[11] and (3) sizeable misclassification of BMI categories based on self-reported data due to such compression (eg, shifting adults below the BMI cut-off of 30 kg/m^2 for obesity), resulting in an underestimation of obesity prevalence.[11] A large degree of misclassification can occur if a non-trivial number of adults have a moderate difference between self-reported and measured BMI at the margins of broadly defined BMI categories.[16] The positively skewed distribution of BMI increases this effect.

Prediction equations

Our results reaffirm findings from previous studies[9 16 19]: developing prediction equations to correct self-reported height and weight by sociodemographic and health-related variables to more closely approximate measured values is feasible. First, the improvements in obesity classification presented herein compare well with previous studies. Based on data from the 2005 Canadian Community Health Survey (CCHS), equations for measured height/weight including a full set of predictors improved the sensitivity of obesity by 17.3pp and 17.6pp among men and women, respectively: specificity values remained high (>94%) but were slightly lower for corrected versus self-report.[9] In the USA, based on 1999–2006 NHANES data, equations including age and race/ethnicity as predictors improved sensitivity values for obesity by 7.8pp (men) and 8.7pp (women)[10]; likewise, based on 2001–2006 NHANES data, the prediction equation for measured BMI using self-reported height, weight and demographic predictors improved obesity sensitivity by 8.2pp.[16]

Second, in our main analysis, corrected BMI reduced the underestimation of obesity prevalence compared with BMI from self-report,[9] but it remained underestimated (in absolute terms) by 0.8pp for both sexes. As found elsewhere,[16] measured BMI significantly predicted the difference between corrected and measured BMI, indicating that the systematic error in self-reported BMI was not eliminated by the prediction equations. The presence of such residual bias has been identified as a reason for not using equations to predict measured values from self-reported values.[7] However, the usefulness of prediction equations has been demonstrated by the ability to reduce considerably, although not eliminate, the differences between self-reported and measured anthropometrics across a few, easily gathered sociodemographic and health-related variables,[16] as well as increasing the sensitivity of obesity classification,[8] while maintaining high specificity. In our study, adding self-reported BMI to the full models did not materially improve model performance, suggesting that reporting error in BMI is more strongly associated with measured rather than self-reported BMI.[7]

Our results also showed that the prediction equations decreased sensitivity in the normal weight category (through erroneously shifting a proportion of normal weight participants to the overweight but not obese category, leading to slight overestimation of levels of excess weight). This finding was consistent with previous studies (eg, sensitivity for the normal weight category based on the full models were 6.1pp (men) and 6.7pp (women) lower than self-report in the study based on CCHS data[9 22]) and likely reflects higher accuracy of self-reported anthropometrics among normal weight adults. In agreement with our study, specificity for the normal weight category was higher for corrected versus self-reported data (9.0pp and 8.8pp higher for men and women, respectively).[9]

Our finding of decreased sensitivity in the underweight category, along with the caution in our estimates due to the low prevalence at the extreme ends of the BMI distribution, suggests that the prediction equations presented are not suitable for classifying adults into the five mutually exclusive BMI categories. The equations are most suitable for classifying adults according to the more broadly defined dichotomous categories: either overweight or obese (vs not overweight nor obese), and obese (vs not obese). For these categories, the modest reduction in specificity compared with self-reported data is more than counterbalanced by the reduced gap in prevalence estimates and the increase in sensitivity.

Thirdly, as elsewhere,[8 9 27 36] our similar results based on full and reduced (age group only) models, and those of an alternative approach (predicting measured height/weight directly from self-reported height/weight and continuous age) currently used to monitor levels of excess weight across English LAs, confirmed that no single model stood out as the best overall candidate, and that adding variables such as ethnic group and educational status only marginally improved model performance. Differences between demographic subgroups in the misreporting of weight may be explained to some extent by differences in measured weight: adjustment for self-reported weight in regression models therefore results in attenuation of subgroup differences.[37 38] Bearing in mind the caveats to their use (see below), it may be reasonably concluded that including additional variables such as educational status and ethnic group does not add enough predictive power to the models to justify the added complexity of including them in prediction equations.

Strengths and limitations

Pooling data across 6 years ensured a sample size large enough to compare self-reported and measured height and weight overall and by various sociodemographic and health-related variables and allowed splitting the data into training and test datasets. Using a regression-based approach, we were able to correct for differences in misreporting of height and weight across various subgroups. Unlike other studies,[6] there was no time lapse between the collection of self-reported and measured height and weight, and consistent methodology was used in each survey. We used different approaches to develop prediction equations to enable researchers to evaluate for themselves whether either approach, and if so which, best suits their data and goals.

A study limitation is the sizeable number of participants excluded from our analyses due to missing anthropometric data (eg, about 16% of those interviewed were excluded due to missing height/weight measurements; in the HSE series, the propensity to have missing values for measured height/weight has been shown to be associated with older age, lower educational status, and fair/bad/very bad general health).[39] We used non-response weights available with the data to minimise the impact of selection bias on our findings. Nevertheless, our findings could be biased if complete cases were systematically different from those with missing data (eg, if those who refused to be measured were more likely than those who did not refuse to underestimate their weight due at least partly to being heavier), and such bias could result in prediction equations that are inaccurate.[22] To partially evaluate this bias, we compared obesity prevalence based on self-reported BMI among those with and without measured BMI.[27] Obesity prevalence via self-reported BMI was higher for those without measured BMI (22% men; 25% women) than for those with measured BMI (18% men; 19% women), indicating that heavier participants were less likely to agree to direct measurement.[27] Furthermore, as in other studies, in developing the prediction equations, we excluded a small but non-trivial number of participants with a large observed difference between self-reported and measured height and weight: this exclusion may have limited the generalisability of our analyses to some extent. Such cases would be impossible to identify and exclude in surveys that collect self-report but not measured data.[13]

Other limitations include potentially relevant variables that we could not include in regression models due to not being available in all HSE years (eg, physical activity; perceptions of weight). We acknowledge that a more optimal approach would have been to randomly split the full sample before, rather than after, identifying significant predictors of misreporting. We also decided *a priori* to use age as a categorical rather than continuous variable in our main analysis (full- and reduced-models). As only categorical age is now provided on publicly available HSE datasets (to preserve anonymity of participants), our approach enables researchers to easily reproduce our results and revise/update equations accordingly. These equations may be the only option available if continuous age on an interview-based survey is restricted from public access to reduce the risk of identifying participants. Equations using continuous age were presented herein to support monitoring efforts for the PHOF by updating the equations currently used to estimate levels of excess weight across English LAs. Our inclusion of 16–17 year olds was consistent with the definition of adults in the HSE series; however, we acknowledge that any misreporting of height/weight among the youngest age group may be of a different nature from reporting error among adults (as the self-reported height and weight of teenagers may be influenced by psychological vulnerabilities that are less prevalent in adulthood).[6]

Finally, although we showed no linear trend in misreporting over the study period, the external applicability of the prediction equations is subject to change over time in misreporting bias. Hence, these correction factors might not be entirely applicable to self-reported data on height and weight collected since 2016. This might be the case if the social desirability of having a normal weight was to change (eg, obesity becomes increasingly normative or health awareness of monitoring one's own weight increases/decreases), thereby changing the pattern and/or magnitude of misreporting bias. Changes in accuracy of home scales, or in the up-to-date knowledge of one's own height and weight (eg, if health workers began to routinely measure height as part of BMI assessment, and relay that information to patients) could also affect the applicability of these equations to more recent data. Likewise, any potential increase in misreporting of weight associated with weight gain during the COVID-19 pandemic (eg, due to fewer opportunities for outdoor physical activity) is not taken into account by the equations developed herein. The inclusion of both self-reported and measured height and weight in future HSE surveys will allow for monitoring of change over time in misreporting error, and assessment of whether new equations will need to be developed.

Our findings must also be interpreted with caution. It is likely that HSE 2011–16 participants might have anticipated that interviewers would take direct measurements of height and weight, resulting in more 'truthful' reporting compared, for example, with a telephone interview where participants would not anticipate being measured.[10] Previous studies have shown that misreporting of height (except for older adults) and weight was smaller for in-house interviews compared with telephone interviews.[36] More 'truthful' reporting is associated with an underestimation of the differences between self-reported and measured height and weight.[3] Applying the prediction equations developed in the present study on surveys which collect height and weight data by telephone interviews or mailed questionnaires would likely underestimate obesity prevalence to a greater extent than shown herein. Finally, as cautioned elsewhere,[9 11 22] prediction equations are specific to time, place, target population and methods of data collection. We do not assume that these equations developed using HSE data collected in 2011–16 are applicable to HSE data beyond this time span or to non-HSE samples with different sociodemographic, health and self-reported anthropometric profiles.

CONCLUSIONS

The prediction equations developed in the present study improved the sensitivity of self-reported obesity, while achieving high specificity, and took into account the variations in potential misreporting of height and weight by sociodemographic and health-related variables. Including additional sociodemographic variables does not add enough predictive power to justify the added complexity of including them in prediction equations. Potentially, these equations could be used to adjust for errors in BMI derived from self-reported height and weight, however, important caveats to their use need to be considered.

Twitter Jennifer S Mindell @j_mindell

Acknowledgements The authors thank the interviewers and nurses, the participants in the Health Survey for England series, and colleagues at NatCen Social Research. The authors also thank NHS Digital. NHS Digital is the trading name of the Health and Social Care Information Centre.

Contributors SS conceptualised the study and was responsible for conducting the analyses, interpreting the results and drafting the manuscript. SS, LNF, AM and JSM critically revised the manuscript. All authors have read and approved the manuscript. SS is responsible for the overall content as guarantor.

Funding The authors have not declared a specific grant for this research from any funding agency in the public, commercial or not-for-profit sectors.

Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not applicable.

Ethics approval The procedures used in the HSE to obtain informed consent from survey participants are very closely scrutinised by a NHS ethics committee each year. Approval was obtained from the following Research Ethics Committees (REC): HSE 2011 and 2012: Oxford A REC: 10/H0604/56; HSE 2013 and 2014: Oxford A REC: 12/sc/0317; HSE 2015: West London NRES Committee: 14/LO/0862; HSE 2016: Nottingham REC: 15/EE/0299. This study is a secondary analysis of previously collected data and so additional ethical approval was not required. Participants gave informed consent to participate in the study before taking part.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available in a public, open access repository. The HSE datasets generated and analysed during the current study (age banding for participants) are available via the UK Data Service (UKDS: https://ukdataservice.ac.uk/), subject to their end user license agreement.

ORCID iDs
Shaun Scholes http://orcid.org/0000-0002-7865-5264
Linda Ng Fat http://orcid.org/0000-0002-7282-9526
Alison Moody http://orcid.org/0000-0002-8199-4830
Jennifer S Mindell http://orcid.org/0000-0002-7604-6131

REFERENCES

1 Berrington de Gonzalez A, Hartge P, Cerhan JR, *et al*. Body-Mass index and mortality among 1.46 million white adults. *N Engl J Med* 2010;363:2211–9.
2 Thomson KH, Renneberg A-C, McNamara CL, *et al*. Regional inequalities in self-reported conditions and non-communicable diseases in European countries: findings from the European social survey (2014) special module on the social determinants of health. *Eur J Public Health* 2017;27:14–21.
3 Drieskens S, Demarest S, Bel S, *et al*. Correction of self-reported BMI based on objective measurements: a Belgian experience. *Arch Public Health* 2018;76:1–8.
4 Connor Gorber S, Tremblay M, Moher D, *et al*. A comparison of direct vs. self-report measures for assessing height, weight and body mass index: a systematic review. *Obes Rev* 2007;8:307–26.
5 Maukonen M, Männistö S, Tolonen H. A comparison of measured versus self-reported anthropometrics for assessing obesity in adults: a literature review. *Scand J Public Health* 2018;46:565–79.
6 Rowland ML. Self-Reported weight and height. *Am J Clin Nutr* 1990;52:1125–33.
7 Plankey MW, Stevens J, Flegal KM, *et al*. Prediction equations do not eliminate systematic error in self-reported body mass index. *Obes Res* 1997;5:308–14.
8 Nyholm M, Gullberg B, Merlo J, *et al*. The validity of obesity based on self-reported weight and height: implications for population studies. *Obesity* 2007;15:197–97.
9 Connor Gorber S, Shields M, Tremblay MS, *et al*. The feasibility of establishing correction factors to adjust self-reported estimates of obesity. *Health Rep* 2008;19:71.
10 Jain RB. Regression models to predict corrected weight, height and obesity prevalence from self-reported data: data from BRFSS 1999–2007. *Int J Obes* 2010;34:1655–64.
11 Flegal KM, Ogden CL, Fryar C, *et al*. Comparisons of self-reported and measured height and weight, BMI, and obesity prevalence from national surveys: 1999-2016. *Obesity* 2019;27:1711–9.
12 Kuczmarski MF, Kuczmarski RJ, Najjar M. Effects of age on validity of self-reported height, weight, and body mass index: findings from the third National health and nutrition examination survey, 1988-1994. *J Am Diet Assoc* 2001;101:28–34.
13 Craig BM, Adams AK. Accuracy of body mass index categories based on self-reported height and weight among women in the United States. *Matern Child Health J* 2009;13:489–96.
14 Villanueva EV. The validity of self-reported weight in US adults: a population based cross-sectional study. *BMC Public Health* 2001;1:1–10.
15 Visscher TLS, Viet AL, Kroesbergen IHT, *et al*. Underreporting of BMI in adults and its effect on obesity prevalence estimations in the period 1998 to 2001. *Obesity* 2006;14:2054–63.
16 Stommel M, Schoenborn CA. Accuracy and usefulness of BMI measures based on self-reported weight and height: findings from the NHANES & NHIS 2001-2006. *BMC Public Health* 2009;9:1–10.
17 Kuskowska-Wolk A, Karlsson P, Stolt M, *et al*. The predictive validity of body mass index based on self-reported weight and height. *Int J Obes* 1989;13:441–53.
18 Flegal KM, Graubard BI, Ioannidis JPA. Evaluation of a suggested novel method to adjust BMI calculated from self-reported weight and height for measurement error. *Obesity* 2021;29:1700–7.
19 Hayes AJ, Kortt MA, Clarke PM, *et al*. Estimating equations to correct self-reported height and weight: implications for prevalence of overweight and obesity in Australia. *Aust N Z J Public Health* 2008;32:542–5.
20 Mindell J, Biddulph JP, Hirani V, *et al*. Cohort profile: the health survey for England. *Int J Epidemiol* 2012;41:1585–93.
21 World Health Organization. Bmi classification, 2006. Available: http://www.assessmentpsychology.com/icbmi.htm
22 Dutton DJ, McLaren L. The usefulness of "corrected" body mass index vs. self-reported body mass index: comparing the population distributions, sensitivity, specificity, and predictive utility of three correction equations using Canadian population-based data. *BMC Public Health* 2014;14:1–11.
23 Wells JCK. Sexual dimorphism in body composition across human populations: associations with climate and proxies for short- and long-term energy supply. *Am J Hum Biol* 2012;24:411–9.
24 Bann D, Fitzsimons E, Johnson W. Determinants of the population health distribution: an illustration examining body mass index. *Int J Epidemiol* 2020;49:731–7.
25 Youden WJ. Index for rating diagnostic tests. *Cancer* 1950;3:32–5.
26 Neermark S, Holst C, Bisgaard T, *et al*. Validation and calibration of self-reported height and weight in the Danish health examination survey. *Eur J Public Health* 2019;29:291–6.
27 Shields M, Connor Gorber S, Tremblay MS. Estimates of obesity based on self-report versus direct measures. *Health Rep* 2008;19:61.
28 University College London, NatCen Social Research, Department of Epidemiology and Public Health. *Health Survey for England, 2011*. UK Data Service, 2013: 7260.
29 University College London, NatCen Social Research, Department of Epidemiology and Public Health. *Health Survey for England, 2012*. UK Data Service, 2014: 7480.

30 University College London, NatCen Social Research, Department of Epidemiology and Public Health. *Health Survey for England, 2013*. UK Data Service, 2015: 7649.
31 University College London, NatCen Social Research, Department of Epidemiology and Public Health. *Health Survey for England, 2014*. 3rd. UK Data Service, 2018: 7919.
32 University College London, NatCen Social Research, Department of Epidemiology and Public Health. *Health Survey for England, 2015*. 2nd. UK Data Service, 2019: SN 8280.
33 NatCen Social Research, Department of Epidemiology and Public Health, University College London. *Health Survey for England, 2016*. 3rd. UK Data Service, 2019: SN: 8334.
34 Flegal KM, Graubard B, Ioannidis JPA. Use and reporting of Bland-Altman analyses in studies of self-reported versus measured weight and height. *Int J Obes* 2020;44:1311–8.
35 Nieto-García FJ, Bush TL, Keyl PM. Body mass definitions of obesity: sensitivity and specificity using self-reported weight and height. *Epidemiology* 1990;1:146–52.
36 Ezzati M, Martin H, Skjold S, *et al*. Trends in national and state-level obesity in the USA after correction for self-report bias: analysis of health surveys. *J R Soc Med* 2006;99:250–7.
37 Jeffery RW. Bias in reported body weight as a function of education, occupation, health and weight concern. *Addict Behav* 1996;21:217–22.
38 Hodge JM, Shah R, McCullough ML, *et al*. Validation of self-reported height and weight in a large, nationwide cohort of U.S. adults. *PLoS One* 2020;15:e0231229.
39 Scholes S, Fat LN, Mindell JS. Trends in cardiovascular disease risk factors by BMI category among adults in England, 2003-2018. *Obesity* 2021;29:1347–62.