# Population level trends in the distribution of body mass index in England, 1992-2013

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## MeSH Keywords

Obesity; Population Dynamics; Socioeconomic Factors; England.

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1498

**Abstract**

Background: Changes over time of mean body weight or prevalence of overweight and obesity have been well documented. Less consideration has been given to describing the distribution to these changes particularly by socioeconomic status and sex.

Methods: We use data from the Health Survey for England for the years 1992 to 2013 to calculate the median, $5^{th}$ and $95^{th}$ percentiles, and standard deviation of BMI (body mass index). We tested differences using ANOVA and quantile regression. Analyses were stratified by sex and level of education.

Results: There have been increases in the standard deviation of BMI values over the period. Whilst median BMI has increased, there has been a larger increase of the $95^{th}$ percentile. These trends were consistent by sex and level of education, although significant differences were observed in values.

Conclusion: Our results demonstrate that changes in median BMI over time do not reflect changes in the distribution of BMI. Failing to understand the distribution of body weight in the population will hamper our projections of future patterns, as well as our ability to design effective public health strategies.

**Summary Box**

*What is already known on this subject?*

Whilst changes in prevalence of overweight and obesity, as well as trends in mean body mass index (BMI) are well documented, there has been little investigation of trends in the distribution of body weight particularly by socioeconomic status and sex.

*What does this study add?*

There has been increased dispersion of BMI values over time, driven by growth at the upper end of the distribution (e.g. $95^{th}$ percentile) while the median BMI did not increase at the same rate. This pattern was consistent by sex and level of education. This study produces the first evidence of this pattern for England as well as by socioeconomic groups. Our results suggest that the slowing down of median BMI hailed by some public health officials may not be quite the success it first appeared.

## INTRODUCTION

Two thirds of males and 57% of females in the UK are currently estimated to be either overweight or obese (1). This is important as overweight and obesity costs the NHS over £5 billion annually due to its associated health effects (2). Current research into the changing trend in body weight in the UK has focused on either mean changes in BMI (body mass index) or changes in the prevalence of WHO cut-off groupings (with particular focus on the latter). These studies have shown an increased prevalence of excess body weight over time consistent across sex and social groups at the population level (3–9).

Whilst exploring the prevalence of BMI groupings and changes in mean BMI are important for understanding population health, they do not capture the whole distribution of BMI. Understanding the actual distribution of trends in BMI is important since mean values may hide differences in patterns at both the upper and lower ends of the distribution (7). Future projections of BMI, and hence our ability to design effective public health strategies in line with recommendations from these projections, will be wrong if they fail to account for the distribution of body weight. An improved understanding of changes in the distribution of BMI at the population level will also help policy makers decide where to focus strategies and interventions.

There is little research in the UK that has attempted to explore population level trends beyond simply mean BMI or prevalence of overweight or obesity. Sperrin and colleagues (6) found that even amongst increasing mean BMI there is both a 'resistant' normal BMI sub-population that has not experienced increasing mean BMI and a different sub-population that has witnessed large increases in mean BMI. Johnson and colleagues (7) analysed trajectories of BMI by age finding larger increases at the upper end of the distribution of BMI, however did not explore how trends were changing over time. No study to our knowledge has examined the dispersion of BMI and how it varies by socioeconomic status in the UK. Socioeconomic status is an important factor associated with body weight, with greater prevalence of obesity in lower social groups (4,10). Addressing social inequalities is a key focus of local and national government, therefore understanding how their BMI distributions have changed will be key to informing policy debates.

Our study explores the distribution and dispersion of BMI between 1992 and 2013 in England. This builds on a growing international evidence base demonstrating increased dispersion of BMI over time at the population level (11,12). We examine sex-specific trends by education level (as a proxy for socioeconomic status) to explore whether patterns are consistent between these key risk factors of body weight.

## METHODS

We use data from the Health Survey for England (HSE) (13). The HSE is an annual repeated cross-sectional survey in England which began in 1991 and is currently ongoing. It is a representative survey of England and is the largest survey that collects timely population level health data. Data are collected through interviewer-led questionnaires, with interviewers' also objectively measuring height and weight. We included all adults aged 20 and over, and the mean annual sample size for the period 1992-2013 was 10,418. Sample weights were applied to analyses when available (weights were only produced from 2002 onwards). Mean and median age remained similar between years (Supplementary Table S1).

Our outcome variable was BMI, which is a measure of relative weight status calculated by dividing weight (kg) by the square of height (m). We also disaggregated BMI by sex and highest educational qualification. Education was used as a proxy for socioeconomic status since it reflects an ability to access employment opportunities that provide high social and economic resources (10). Individuals were placed into one of three hierarchical categories to represent their highest educational qualification: 'degree or higher' (defined as having a University degree or equivalent), 'below degree' (tertiary or secondary qualification or equivalent), or 'no qualifications' (see 13 for more details).

We calculated the sex-specific standard deviation of BMI both overall and by education category as a measure of dispersion. We then calculated the Brown-Forsythe test to test for significant differences in the variances by education group. To understand what changes in the distribution of BMI were occurring, we then estimated the median, $5^{th}$ and $95^{th}$ percentiles of BMI using sex-specific quantile regression models for each education category. Quantile regression allowed us to estimate the 95% confidence intervals to understand the uncertainty of our estimates. We tested for the existence of a linear trend in our estimates as well using Welch correction ANOVA test (corrected due to the unequal variances). All analyses were conducted in R.

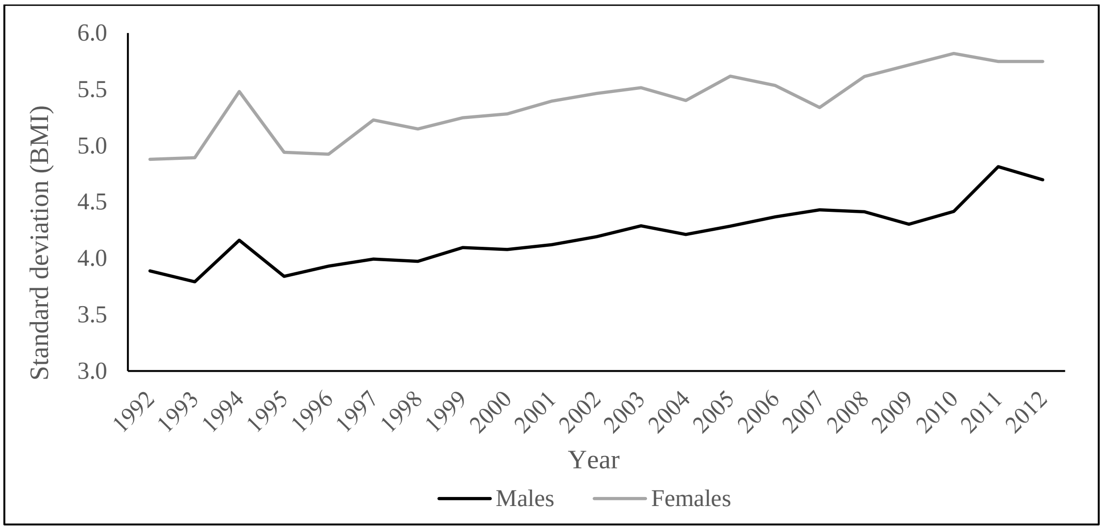
Since the paper details the analysis of secondary data, ethical approval was not required.

## RESULTS

Figure 1 displays the sex-specific standard deviation of BMI between 1992 and 2013 at the population level for all individuals, as well as split by education category. The graphs all present a similar pattern of increasing dispersion over time and this is consistent by sex and level of education. There was consistently higher standard deviation for females in comparison to males, as well as for lower levels of education. The results from the Brown-Forsythe test indicated that the variances between education categories were statistically different for both sexes across each year (Supplementary Table S2).

Figure 2 explores these changes in the distribution by plotting the estimated median, $5^{th}$ and $95^{th}$ percentiles of BMI for each sex-specific education category (as well as overall). There is increasing median BMI throughout the 1990s, however from 2001 onwards this trend begins to slow down overall for males and females (Figure 2a). This pattern is not observed at both the $5^{th}$ and $95^{th}$ percentiles. There is little change of the $5^{th}$ percentile, however the $95^{th}$ percentile continues to rise for the whole period (and the overall increase over the period were larger than compared to the median for both sexes). There are also clear differences by

**(a)**

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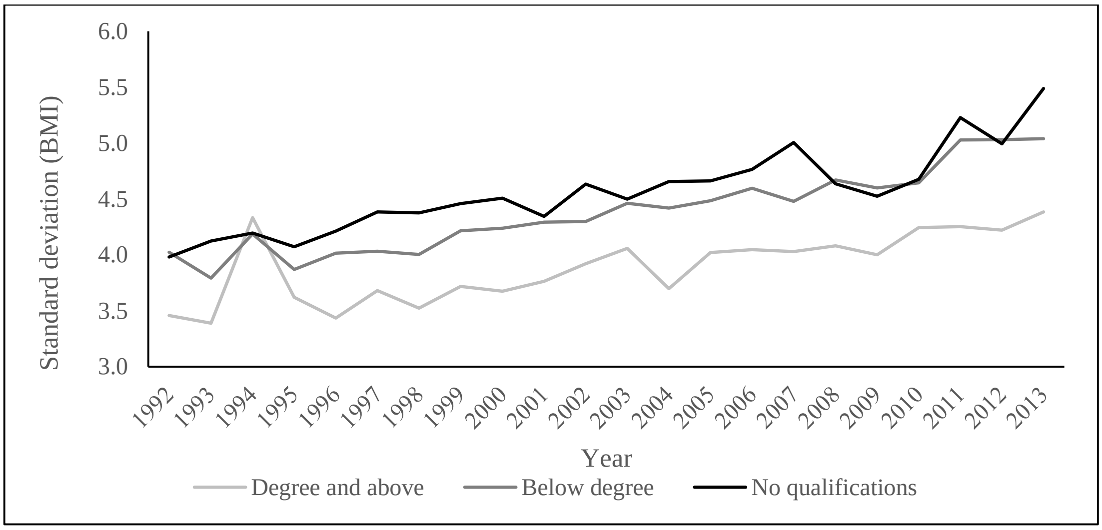


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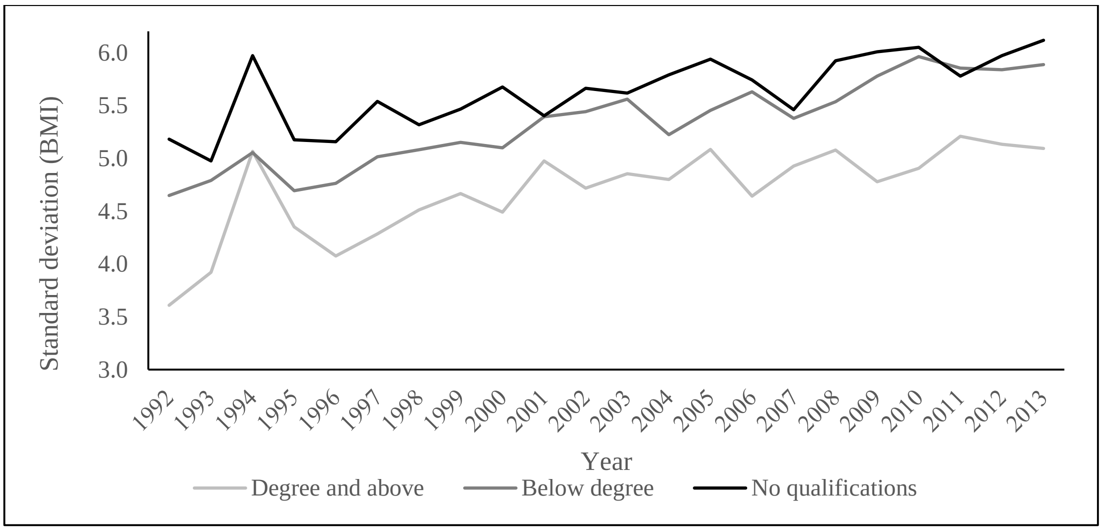
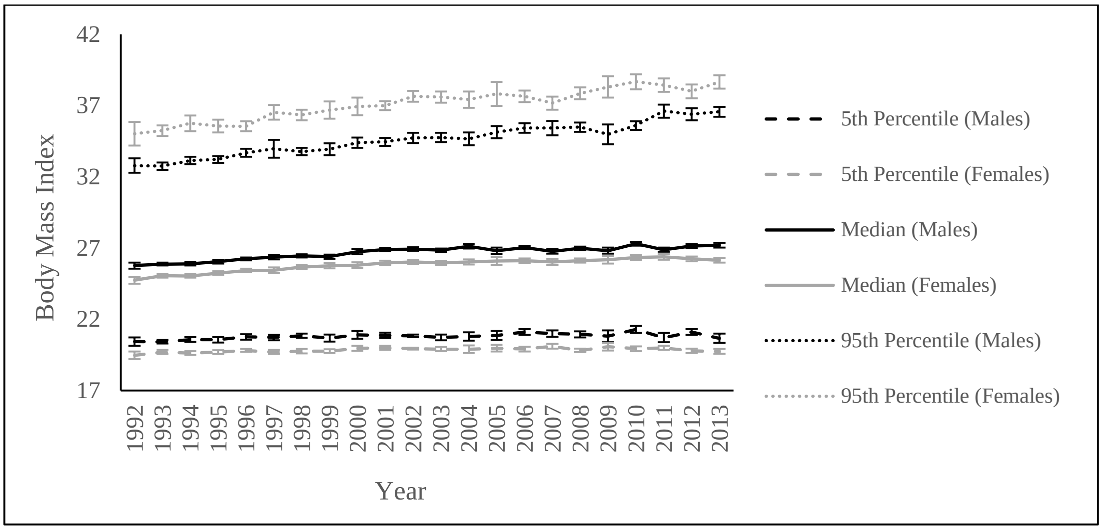



**Figure 1:** Changes in the standard deviation of body mass index (BMI) for England, 1992-2013: (a) Overall. (b) Highest level of education (males). (c) Highest level of education (females).

**(a)**

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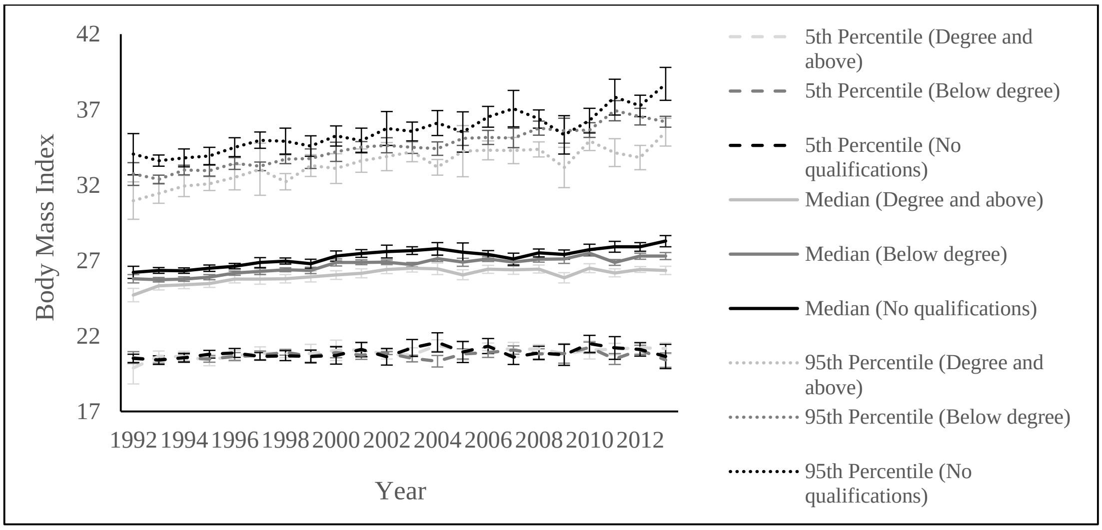


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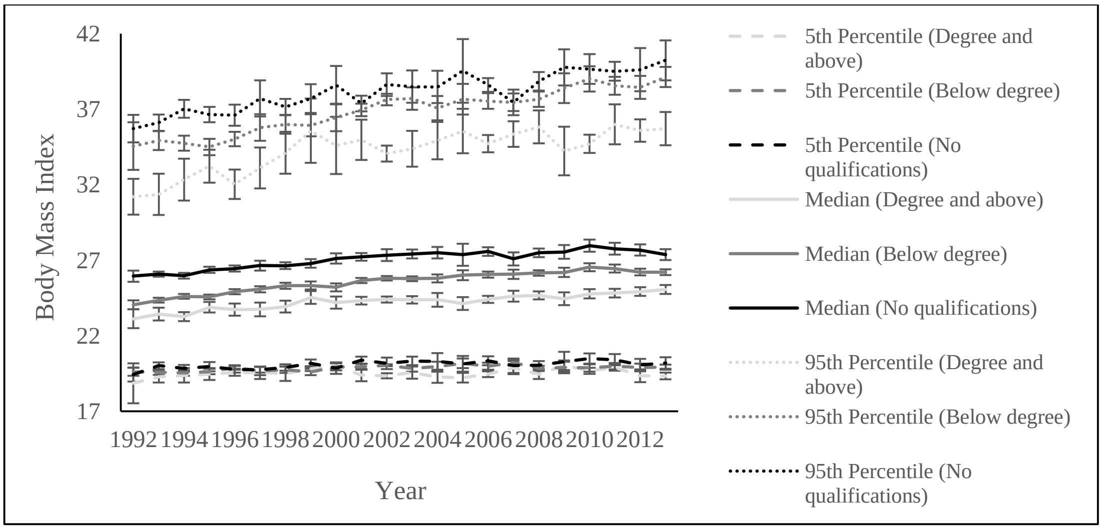


**Figure 2:** Estimated median, 5th and 95th percentiles (including 95% confidence intervals) of body mass index (BMI) for England, 1991-2013: (a) Overall. (b) Highest level of education (males). (c) Highest level of education (females)

sex with little overlap of confidence intervals; whilst the 5th percentile and median BMI were consistently higher in males, this pattern reversed at the 95th percentile.

This pattern is similar by education category (Figures 2b and 2c). Individuals with no qualifications have consistently higher median BMI than compared to individuals with a degree or higher. Gaps between education categories were wider for females, with less overlap of confidence intervals and larger differences in estimates. We found evidence of an increasing linear trend in BMI for all education categories in both sexes (Supplementary Table S3). There is also a consistent rise of the 95th percentile for all groups throughout the time period (at a faster rate than the other percentiles).

## DISCUSSION

Our study presents evidence of varying temporal patterns in the distribution of BMI. Although there has been an increase of median BMI (which appears to be slowing down), this ignores the larger increases in the 95th percentile and small change in the 5th percentile. Just focussing on the median will poorly reflect population level trends in body weight (7). Our findings were consistent across sex and level of education, indicating a population increase in the dispersion of BMI values. An important finding was that increases in dispersion of BMI occurred for the most educated group despite the group having a lower median BMI (and risk of obesity; 4). Increased dispersion of BMI occurred within each educational category demonstrating that (simple) social groupings are not sufficiently explaining how individuals are diverging.

The understanding provided by our results is important given the 'u-' or 'j-shaped' association between BMI and mortality (14). The growth of 95th percentile indicates increases at the upper end of BMI and this is where the increased risk of many health conditions and premature mortality are concentrated. If this pattern continues to rise following current trends, then we may expect increased prevalence of ill health associated with excess body weight. The slowing down of median BMI hailed by some public health officials may not be quite the success it first appeared. Understanding the characteristics of the individuals at the upper end of the BMI distribution will be important for future research to feed into intervention design to tackle these trends observed (6).

There are multiple strengths and limitations to our study. Our results corroborate with national (6,7) and international evidence (11,12). We use data from a large representative survey of England over a time period of 23 years. Whilst our data are not longitudinal, our study focuses on population level trends and therefore is useful at understanding overall trends in public health (11). The results also follow those of longitudinal data which explore age based trajectories of BMI (7). Whilst the data are representative of England at each time point (we use sample weights where possible, although those without are still representative; 13), the HSE has experienced declining response rates over time (falling from 74% in 1993 to 64% in 2013). This may have created the potential for increased bias in the most recent surveys (4, 13).

**Competing Interests**

None declared.

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## Supplementary Information

**Table S1: Descriptive statistics of age by sex and year of survey.**

| Year | Males | | | Females | | |
|---|---|---|---|---|---|---|
| | Mean | Median | Standard deviation | Mean | Median | Standard deviation |
| 1992 | 47.4 | 45.0 | 17.4 | 48.8 | 46.0 | 18.5 |
| 1993 | 46.5 | 45.0 | 17.1 | 48.2 | 46.0 | 18.2 |
| 1994 | 46.9 | 45.0 | 17.3 | 48.3 | 46.0 | 18.4 |
| 1995 | 47.7 | 46.0 | 17.3 | 48.4 | 46.0 | 18.2 |
| 1996 | 48.0 | 46.0 | 17.1 | 48.7 | 47.0 | 18.1 |
| 1997 | 47.3 | 46.0 | 16.8 | 48.4 | 46.0 | 17.9 |
| 1998 | 48.2 | 47.0 | 17.2 | 49.0 | 47.0 | 18.0 |
| 1999 | 48.6 | 47.0 | 17.0 | 49.2 | 47.0 | 17.7 |
| 2000 | 48.7 | 47.0 | 17.2 | 49.2 | 47.0 | 17.6 |
| 2001 | 49.1 | 48.0 | 17.1 | 49.4 | 48.0 | 17.8 |
| 2002 | 49.0 | 47.0 | 17.1 | 49.6 | 48.0 | 17.6 |
| 2003 | 47.4 | 45.0 | 17.0 | 49.0 | 47.0 | 18.0 |
| 2004 | 47.6 | 46.0 | 17.0 | 49.1 | 47.0 | 18.0 |
| 2005 | 47.7 | 46.0 | 17.0 | 49.2 | 47.0 | 18.2 |
| 2006 | 47.7 | 46.0 | 17.1 | 49.4 | 47.0 | 18.2 |
| 2007 | 47.6 | 46.0 | 17.2 | 49.1 | 47.0 | 18.1 |
| 2008 | 47.7 | 46.0 | 17.2 | 49.1 | 47.0 | 18.1 |
| 2009 | 47.7 | 46.0 | 17.2 | 49.3 | 47.0 | 18.0 |
| 2010 | 48.0 | 47.0 | 17.4 | 49.4 | 48.0 | 18.2 |
| 2011 | 47.9 | 46.0 | 17.5 | 49.3 | 48.0 | 18.1 |
| 2012 | 48.2 | 47.0 | 17.3 | 49.0 | 48.0 | 18.2 |
| 2013 | 48.4 | 47.0 | 17.4 | 49.4 | 48.0 | 18.2 |

**Table S2: Brown-Forsythe ANOVA F-test of unequal variances of body mass index by education level.**

| Year | Males | | Females | |
|---|---|---|---|---|
| | F-test | P-value | F-test | P-value |
| 1992 | 11.723 | <0.001 | 35.920 | <0.001 |
| 1993 | 32.690 | <0.001 | 139.727 | <0.001 |
| 1994 | 17.360 | <0.001 | 99.813 | <0.001 |
| 1995 | 27.831 | <0.001 | 127.403 | <0.001 |
| 1996 | 27.940 | <0.001 | 120.259 | <0.001 |
| 1997 | 12.523 | <0.001 | 63.173 | <0.001 |
| 1998 | 35.185 | <0.001 | 78.090 | <0.001 |
| 1999 | 9.020 | <0.001 | 39.588 | <0.001 |
| 2000 | 13.788 | <0.001 | 58.661 | <0.001 |
| 2001 | 22.977 | <0.001 | 85.907 | <0.001 |
| 2002 | 18.482 | <0.001 | 88.360 | <0.001 |
| 2003 | 25.209 | <0.001 | 97.111 | <0.001 |
| 2004 | 260.729 | <0.001 | 680.115 | <0.001 |
| 2005 | 16.088 | <0.001 | 48.467 | <0.001 |
| 2006 | 25.134 | <0.001 | 105.679 | <0.001 |
| 2007 | 6.786 | <0.001 | 25.185 | <0.001 |
| 2008 | 20.106 | <0.001 | 80.825 | <0.001 |
| 2009 | 15.039 | <0.001 | 31.025 | <0.001 |
| 2010 | 17.474 | <0.001 | 54.271 | <0.001 |
| 2011 | 22.394 | <0.001 | 40.163 | <0.001 |
| 2012 | 20.849 | <0.001 | 40.451 | <0.001 |
| 2013 | 24.558 | <0.001 | 40.502 | <0.001 |

**Table S3: Welch correct ANOVA test for a linear trend in body mass index by education level.**

| Education | Males | | Females | |
|---|---|---|---|---|
| | F-test | P-value | F-test | P-value |
| Degree or above | 16.004 | <0.001 | 9.871 | <0.001 |
| Below degree | 51.376 | <0.001 | 53.95 | <0.001 |
| No qualifications | 31.675 | <0.001 | 26.171 | <0.001 |