Body mass index trajectories preceding first report of poor self-rated health: a longitudinal case-control analysis of the English Longitudinal Study of Ageing

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ABSTRACT

Background Studies have consistently found that obesity is associated with poor self-rated health, but how body mass index (BMI) developed in the lead up to poor self-rated health is unknown.

Methods We nested a longitudinal case-control study in the English Longitudinal Study of Ageing (1998-2015) to investigate BMI trajectories in the years preceding a first self-report of poor health. Participants rated their health at each data collection; every other collection included a BMI assessment by a nurse. Case status was defined as a first report of poor health during follow-up. Three age- and sex-matched controls were identified per case using density sampling. BMI trajectories were fitted to time backwards prior to first report of poor health using mixed-effects models including a random intercept and slope. Age and sex were potential modifiers. We conducted subgroup analyses of those not reporting diabetes, chronic lung disease or smoking.

Results We identified 732 cases and 2195 controls. Age, but not sex, modified the association between BMI and self-rated health. Participants reporting poor health at age 60 had a 1.5 kg/m^2 (95% CI: 0.8 to 2.1) higher BMI than controls, and their BMI had previously increased sharply. After age 75, cases no longer had higher BMI than controls, and their BMI had decreased sharply prior to reporting poor health. Age was also an effect modifier among those without diabetes, however BMI trajectories were more similar among the middle-aged.

Conclusions Development of BMI was associated with poor self-rated health; however, the nature of the association depended markedly on age.

Keywords: Self-rated health, body mass index, longitudinal case-control study, trajectory

Key Messages

- Studies based on a single body mass index (BMI) measurement have consistently found that being underweight or obese was associated with poor self-rated health. How BMI developed in the lead up to poor self-rated health was unknown.
- In the present study, BMI trajectories leading up to poor self-rated health were strongly dependent on age at first report of poor health. Middle-aged participants with poor self-rated health had higher BMI than controls; both groups had increasing BMI over time.
- In contrast, a report of poor health at age 75 or later was preceded by a decrease in BMI; controls were 10 years older than cases before they started to lose BMI.
- Our results suggest that future prospective studies and clinical decision making should take into account the age-dependent association between development of BMI preceding poor self-rated health.

Introduction

Self-rated health is a robust and independent predictor of health outcomes and mortality.[1, 2] It is a construct that encapsulates physical, mental and social dimensions of health. The weighting of these dimensions within each individual is generally unknown,[3] although studies indicate that self-assessment of physical functioning is a substantial contributor to self-rated overall health.[4, 5] Numerous observational studies have investigated whether body mass index (BMI) is associated with self-rated health among middle-aged adults, generally finding that obese persons are more likely to report poor self-rated health and to live more years with poor health than persons of normal weight.[6-8]

The mechanisms underlying the overall trends between BMI and self-rated health are likely to vary substantially according to age, as conditions contributing to self-rated health change in importance across the lifespan. Developments in overall BMI may be important, because in sedentary populations BMI mainly reflects fat mass,[9] which may affect physical functioning and incidence of disease such as type 2 diabetes. However, among the elderly, changes in BMI generally reflect loss of muscle mass, and sarcopenia has been associated with greater mortality.[10] Chronic conditions, such as chronic obstructive pulmonary disease (COPD), are among the main potential causes of unintended weight loss among elderly.[11] Despite the health implications of different body compositions at a given BMI, measurement of BMI remains the most common assessment of adiposity at all ages in the general population. Yet, little is known about the development of BMI in the years prior to poor self-rated health, nor how this may differ by age and sex.

We investigated the differences in BMI trajectories up to 10 years prior to a first report of poor self-rated heath, compared to age- and sex-matched controls, taking into account a potential modifying effect of age at first report of poor self-rated health, and sex. We

hypothesized that poor self-rated health in middle-aged individuals would be positively associated with having higher BMI in preceding years, but that this association would be weaker at older ages.

Methods

Ethics statement

The English Longitudinal Study of Ageing (ELSA) was approved by the London Multicentre Research Ethics Committee (MREC/01/2/91), and informed consent was obtained from all participants.

Study population

Our study is based on data from ELSA.[12] ELSA was originally set up in 2002 to address different aspects of the ageing process and to inform policy makers in an ageing population. Participants at wave 1 (ELSA baseline) were sampled from three years of the Health Survey for England (1998, 1999 and 2001) that we consider as wave 0 in the current study. Only those born before 1 March 1952 were considered as core members in ELSA as the goal of the original study was to recruit a sample representing the population older than 50 years, however younger partners or children living in the same household might also have been interviewed. Participants were followed-up and interviewed every two-three years between 1998 and 2015 (waves 0-7). Waves 0, 2, 4 and 6 included a nurse visit with clinical measurements.

We designed a longitudinal case-control study to be able to compare differences in BMI trajectories between those reporting poor health for the first time during follow-up and the source population not reporting poor health. We considered only core members in our study.

The selection of cases is described in Figure 1. Those reporting poor health in one or more waves were potential cases. As we were examining BMI trajectories before first self-report of poor health, we excluded those who already had reported poor health at waves 0 or 1 and those with fewer than two BMI measurements. To compare BMI trajectories with a control sample not reporting poor health up to and including the wave of the index case, we selected three controls per case using density sampling, matching on age (±1 year) and sex. The wave in which an index case reported poor health defined the time of event occurrence and defined time=0 for the controls (described in details in the Statistical Analysis section).

Self-rated health

Self-rated health was assessed in each wave during an interview using the following question: "Would you say your health is (1) excellent, (2) very good, (3) good, (4) fair or (5) poor?" Our outcome was defined as answering (5) poor. The question was slightly different in waves 0 and 3, where the answer (1) excellent was dropped and (5) poor was replaced with "bad" and "very bad". We combined these two to represent poor health.

Body mass index

Body mass index was calculated using weight and height measurements performed by trained personnel during nurse visits or clinical examinations (BMI (kg/m^2) = weight / height-squared). The measurements were conducted during waves 0, 2, 4 and 6. If a participant was chair-bound then an estimate was obtained from the respondent instead. If the nurse thought that these were likely to deviate from the true figures more than 2 cm for height and 1 kg for weight, then they were marked as unreliable and were not used in our analysis.

Covariates

Information on socioeconomic class, smoking and marital status was assessed with standard questionnaires. We used information on these variables from the baseline of ELSA (wave 1). Socioeconomic class was categorised into four groups (Professional or Managerial technical (I/II), Skilled non-manual (IIIN), Skilled manual (IIIM), Semi-skilled or Unskilled manual (IV/V)). Smoking status was defined as a binary variable (never vs. ever) and was used as a time-invariant factor assuming that people are not likely to start smoking in this age if they never smoked before. Diabetes and chronic lung disease status was assessed and updated at each wave based on self-reports.

Statistical analysis

BMI trajectories were fitted using mixed-effects models including both a random intercept and a slope. This approach accounts for the repeated measurement structure in the data set. Models were specified with a linear term for time. Time was defined as years backwards from first report of poor health (event outcome) among cases and a corresponding matched time for controls. We considered BMI measurements for up to ten years before the event resulting in a [-10, 0] interval as time range. A binary indicator variable was defined to distinguish cases from controls. We included this variable and its interaction with time in the model to assess differences in both level (intercept) and slope, respectively, between cases and controls. Then we included age at event occurrence (time=0) and its interaction with time in the model, to investigate the effect of age on the level and slope of the trajectories. We also included the interaction between the case-indicator variable and age to examine whether age had a differential effect on the level of BMI between cases and controls. Finally, we included a three-way interaction between the case-indicator, age and time, to examine

whether age had a differential effect on the BMI slope between cases and controls. We calculated how much of the between-person variation of the intercepts and the slopes was explained by age. We also tested whether sex had a modifying effect on BMI development by including the main term and an interaction with time in a model. The final model was fitted with and without adjustment for socioeconomic class. Also, we conducted three subgroup analyses including only those who did not have diabetes, those who did not have chronic lung disease and those who reported that they had never smoked at baseline, as these factors are associated with BMI.[13, 14]

The mixed-effects models were fitted using the nlme package (version 3.1-128) in R (version 3.3.1). Confidence intervals and combined coefficient estimates were assessed using the Epi package (version 2.9). The entire code of the statistical analysis is available as an RMarkdown document in the electronic supplement.

Results

Almost 80% of the 11,205 core members did not report poor health at any point in the study, leaving 2483 potential cases (Figure 1). After excluding those who reported poor health at waves 0 or 1 (n=1429), those with zero (n=71) or only one (n=251) BMI measurement, the final case sample included 732 individuals (56% women). Three controls were successfully matched to all but one case, where only two controls were identified, resulting in a final study population of 732 cases and 2195 controls.

A quarter of cases were younger than 64 years of age when they reported poor health, while a quarter were older than 80 years. Cases were more likely to be in a lower socioeconomic class and to have diabetes than controls. A higher proportion of cases were

divorced or separated at baseline, and a lower proportion of them reported that they had never smoked. Cases and controls had on average 2.3 and 2.4 BMI measurements, respectively.

Age had a modifying effect on the association between BMI trajectories and self-rated health, but we found no sex differences in BMI trajectories. Estimated BMI levels and slopes by age at first report of poor self-rated health are presented for cases and controls in Figure 2. Modelled BMI trajectories by self-reported health for four different ages at first report of poor health are presented in Figure 3A. The average case and control were overweight (25-30 kg/m^2) throughout the ten years, regardless of age. However, differences in BMI between cases and controls depended strongly on age at first report of poor health with regard to both level and slope. Poor self-rated health was associated with a higher BMI before 76 years of age but no difference afterwards. E.g. participants reporting poor health at age 60 had a 1.5 kg/m^2 (95% CI: 0.8 to 2.1) higher BMI than controls. Slopes were similarly increasing among middle-aged cases and controls, but cases reporting poor health at age 75 and later exhibited a declining pattern in BMI preceding their report of poor health. Corresponding controls were on more stable trajectories, such decline in BMI happened at an approx. 10 years older age. The difference in slopes between the two groups increased with age (case x age (10y) x time (10y) interaction: -0.6 95% CI: -0.9 to -0.3; p=0.0004). Adding age at first report of poor health and its interaction with time to the model explained a substantial portion (13%) of the between-person variation in slopes, but not in levels of BMI (2%). Adjustment for socioeconomic class did not have a major influence on our results (see pages 29 and 31 in the electronic supplementary materials). Cases and controls without diabetes (n=2576; 88%) were more similar to each other with respect to BMI in middle-age, but the divergence of slopes with ageing was still strongly present (case x age (10y) x time

(10y) interaction: -0.6 95% CI: -1.0 to -0.3; p=0.0003; Figure 3B). The subgroup analysis of those without chronic lung disease (n=2702; 92%) showed very similar results to the main findings (Figure 3C). There were even larger level differences between cases and controls among participants who never smoked (n=1047; 36%) and the effect of age at first report of poor health on BMI slopes was still present (Figure 3D).

Discussion

In this study of BMI trajectories prior to a first report of poor health in a middle-aged and elderly, generally overweight population, we found that development of BMI differed markedly between those who went on to report poor health, and their age- and sex-matched controls. These differences in trajectories varied by age, but were similar among men and women. Our results further indicate that among middle-aged men and women with poor self-rated health, a higher BMI is likely to be related to diabetes. Among the elderly, BMI decreased sharply prior to a report of poor health, regardless of diabetes, chronic lung disease and smoking status.

A major strength of our study is the use of multiple measurements of BMI, which enabled us to investigate trajectories of BMI prior to reporting poor self-rated health. Measurements of BMI were performed by trained personnel and we only included the measurements that were deemed reliable to minimise the potential for measurement error. In addition, the control sampling strategy, using density sampling and matching on age at self-reported poor health and sex, provide a control group that was representative of the BMI trajectories experienced by participants in the ELSA study. Study participants had to have at least two valid BMI measurements by design, which led to an exclusion of 322 potential cases from the analyses. This missingness might have been related to both BMI and self-rated health,

which could bias our estimates. We restricted our analysis to individuals who rated their health poor for the first time during follow-up but not in waves 0 or 1, excluding 1429 participants. Therefore, our results may be generalizable mainly to people of good health until middle age. Lastly, given the observational nature of the study, the possibility of confounding cannot be excluded. For example, smoking has an effect on body weight and composition.[14] If smoking cessation is a consequence of a disease diagnosis leading to poor health (e.g. a cardiovascular event), then it could have led to a less steep decline in BMI among elderly cases. However, we observed similar results in a subgroup who never smoked, which supports that our findings are not likely to be confounded by smoking.

Previous prospective studies of BMI and self-rated health have only investigated baseline BMI in relation to self-rated health during follow-up.[15-17] These studies have consistently found that a higher BMI at baseline was associated with a higher risk of poor self-rated health. Only few other studies have investigated changes in BMI in relation to future poor self-rated health, in very specific study populations.[18, 19] Dennerstein et al. found concurrent weight gain to be associated with a decline in self-rated health among women during their menopausal transition.[18] In a study of female nurses older than 44 years, a shift from being underweight to being normal weight during a six-year period was associated with lower odds of experiencing worse self-rated health during follow-up, while a shift from normal weight to overweight was associated with higher odds of worse self-rated health.[19] The results from the studies of baseline BMI[11-13], and the studies of changes in BMI[14, 15] are only in line with our results for middle-aged participants, but not the elderly. Analogous to these studies, a meta-analysis of 230 studies found a J-shaped dose-response association between BMI and all-cause mortality.[20] In an age-stratified analysis, this association was stronger among those aged <65 years old. In participants aged ≥65 years old, the strong association

between BMI and mortality attenuated markedly in the overweight and obese range, whereas the association in the underweight range persisted. In our study, we also found a modifying effect of age, but here on the association between BMI trajectories and first report of poor self-rated health. Thus, future studies would benefit from taking this dynamically changing association across the lifespan into account.

Our findings suggest that there could be different etiologies underlying the BMI trajectory preceding poor self-rated health, depending on age. Obesity is linked to the development of many chronic diseases that have a major effect on general health, such as diabetes.[21] After restricting our analysis to individuals without diabetes, middle-aged, but not elderly, cases and controls had more similar BMI trajectories preceding poor self-rated health. Indeed, these results indicate that development of diabetes may partly explain the difference observed between middle-aged cases and controls. In contrast, among the elderly, a declining BMI trajectory preceding poor self-rated health was still present. COPD is one of the main causes of unintended weight loss among the elderly.[11] However, after restricting our analysis to participants without chronic lung disease or those who never smoked, we found very similar results to our main findings, suggesting that pulmonary diseases themselves cannot explain the differences in BMI slopes among the elderly. Another potential underlying mechanism explaining weight loss among the elderly could be depression related to the loss and bereavement of a spouse.[22] However, a higher proportion of controls were married at baseline, so it is not likely that cases experienced such an event more frequently during follow-up than controls.

Obesity is well known to be associated with shorter healthy life expectancy.[6, 8] In light of our results, tackling obesity earlier during the life course is crucial to achieve healthy ageing. Clinical practitioners and policy makers should consider age when suggesting weight loss

to patients or planning interventions targeting weight loss. Given that self-rated health is a valid measure of experienced health, and is strongly related to objectively measured health outcomes, more research is needed into the correlates and determinants of our observed association. For example, our BMI trajectory results do not cast light on the importance of adiposity or lean muscle mass in relation to self-rated health at different ages.

In conclusion, BMI trajectories were associated with self-rated health, however the nature of the association depended on age. A higher level of BMI characterised those experiencing poor health among middle-aged participants, while among their older peers, poor health was rather associated with a steeper decline in BMI. These results could not have been captured by studies using only one BMI measurement.

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Author contributions

AH, DBI, ASDL, and CCD conceived the study. AH and CCD wrote the first and successive drafts of the manuscript with substantial contribution from DBI and ASDL. AH carried out the statistical analysis. DBI and ASDL contributed to the data analysis. All authors revised the manuscript for important intellectual content. AH had full access to the data and take responsibility for the integrity of the data and the accuracy of the data analysis. AH is the guarantor.

Conflict of interest

None declared.

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Table 1. Study population characteristics at first report of poor health

	Case	Control
N	732	2195
Age (year)[1]	73 (64-80)	72 (64-80)
Sex (male, %)	44	44
Social class (%)[2,3]		
Professional or managerial technical	31	38
Skilled non-manual	22	26
Skilled manual	18	17
Semi-skilled or unskilled manual	29	19
Marital status (%)[2]		
Single	5	5
Married	61	67
Divorced/separated	14	9
Widowed	21	19
Diabetes (%)	19	9
Chronic lung disease (%)	15	5
Never smoked (%)[2]	29	38
Self-rated health (%)		
Excellent	0	15
Very good	0	34
Good	0	35
Fair	0	17
Poor	100	0
Number of BMI measurements (%)[4,5]		
2	70	64
3	30	36

[1]median age at first report of poor self-rated health (cases) or age when sampled (controls) and interquartile range
[2]information assessed at wave 1
[3]missing for 3% of the cohort (n=83)
[4]within the last 10 years
[5]one control had four measurements

Figure 1. Identification of cases

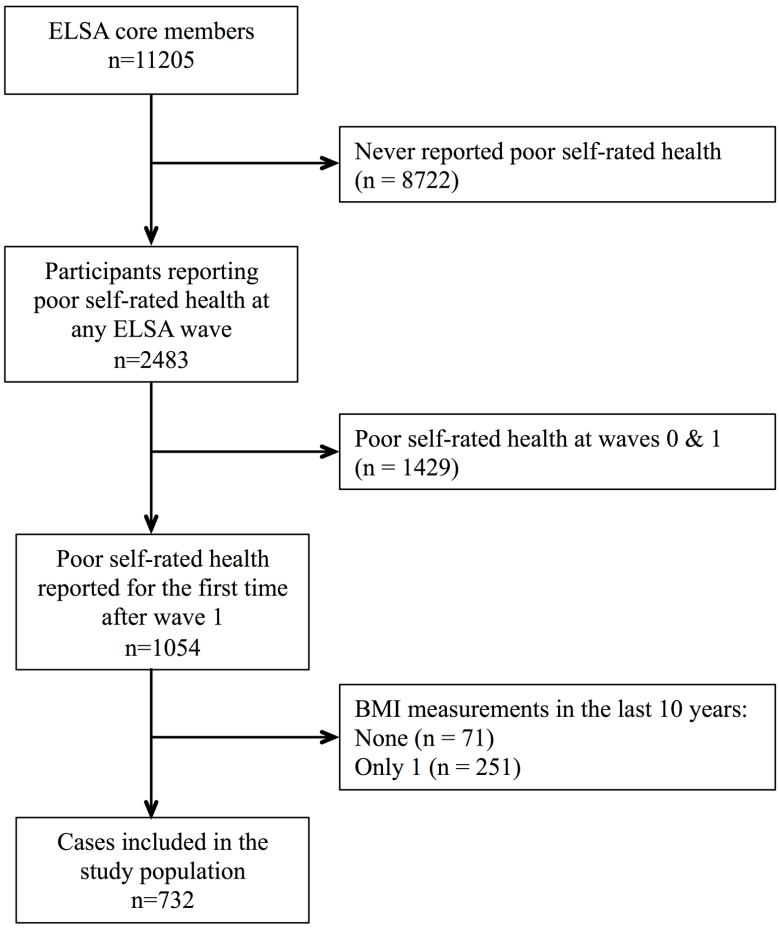


Figure 2. Estimated body mass index levels (A) and slopes (B) by age at first report of poor health (cases) or age when sampled (controls).

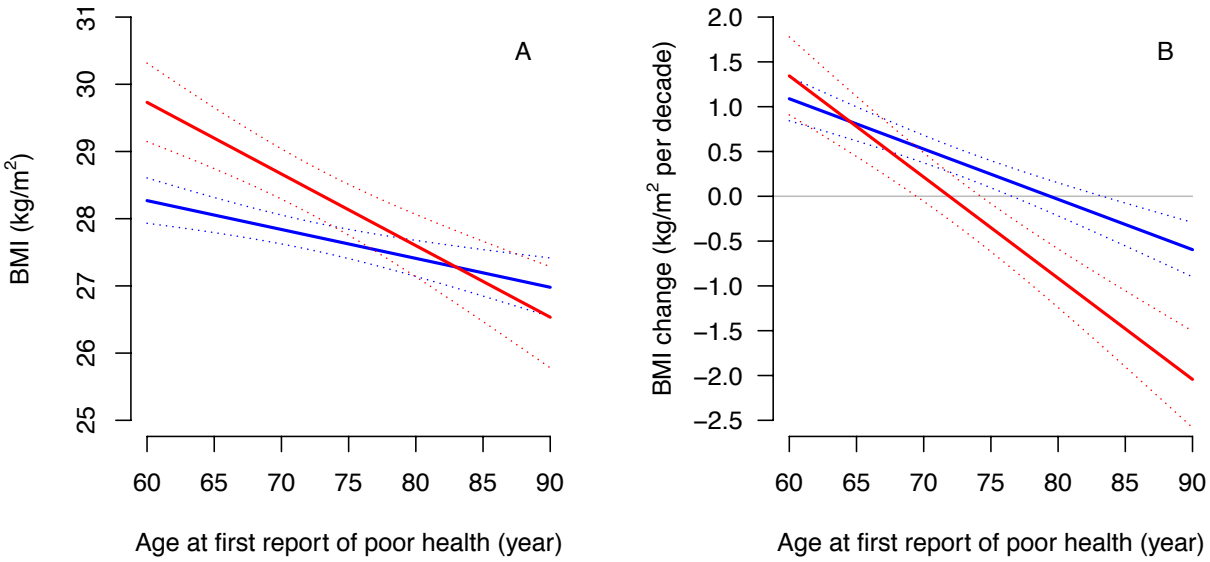
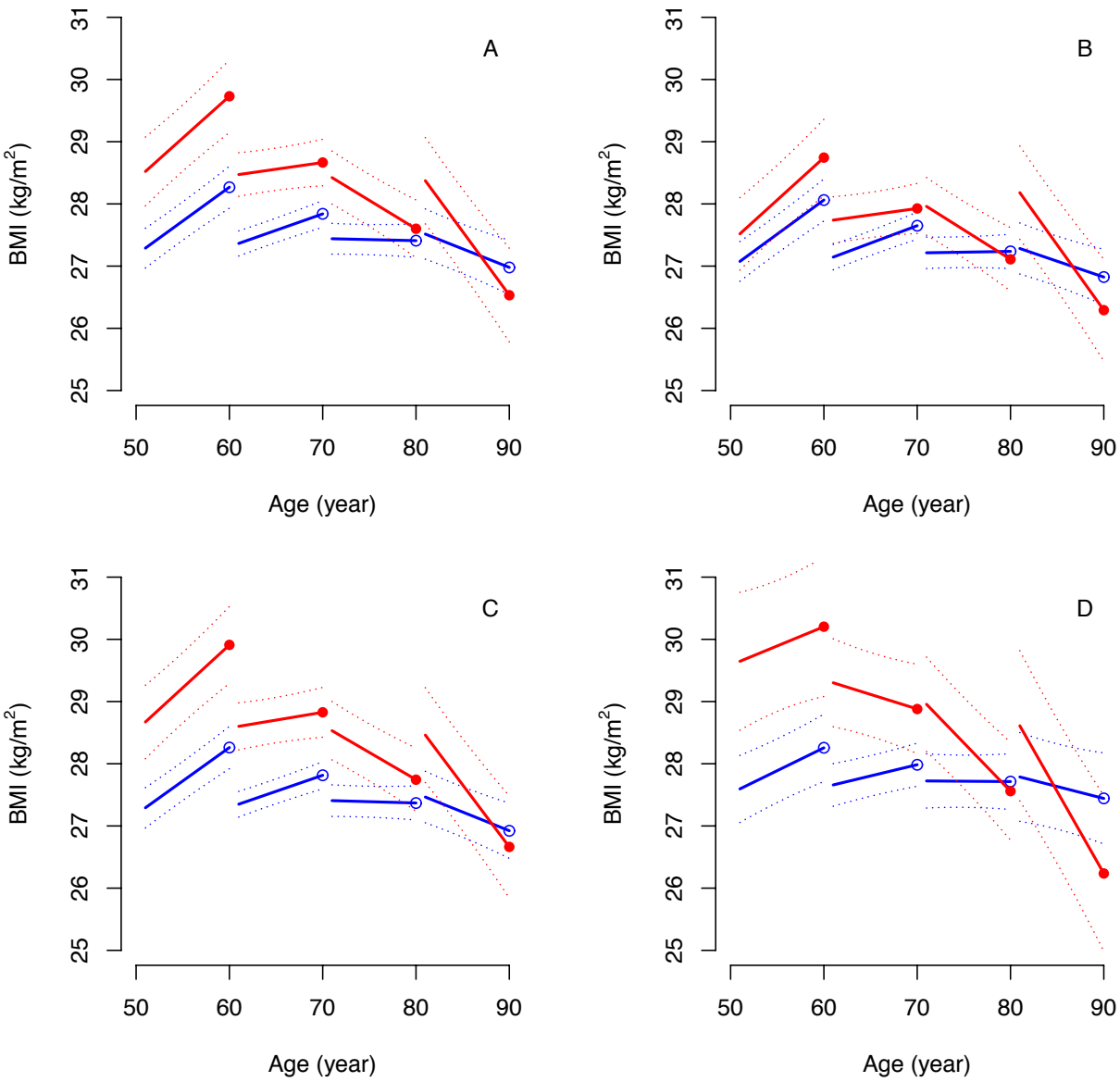


Figure 3. Modelled body mass index trajectories before first report of poor health at different ages (indicated by circles at 60, 70, 80 and 90 years) based on the entire sample (A), participants without diabetes (B), without chronic lung disease (C), and who never smoked (D)



Cases: filled circle and red line; controls: empty circle and blue line.