**Original Article**
EPIDEMIOLOGY/GENETICS

Obesity

# Association of Body Mass Index and Waist Circumference with Successful Aging

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**Objective:** The prediction of successful aging by midlife body mass index (BMI) and waist circumference (WC) was examined.

**Methods:** BMI/WC were assessed in 4869 persons (mean age 51.2, range 42-63 in 1991/1993) and *survival* and *successful aging* (alive, no chronic disease at age >60 years, not in the worst age- and sex-standardized quintile of cognitive, physical, respiratory,cardiovascular, and mental health) ascertained over a 16-year follow-up, analyzed using logistic regression adjusted for sociodemographic factors and health behaviors.

**Results:** 507 participants died, 1008 met the criteria for successful aging. Those with BMI $\geq$ 30 kg/m$^2$ had lower odds of successful aging (odds ratio or OR) = 0.37; 95% confidence interval or CI: 0.27, 0.50) and survival (OR = 0.55; 95% CI: 0.41, 0.74) compared to BMI between 18.5 and 25 kg/m$^2$. Those with a large WC ($\geq$102/88 cm in men/women) had lower odds of successful aging (OR = 0.41; 95% CI: 0.31, 0.54) and survival (OR = 0.57; 95% CI: 0.44, 0.73) compared with those with a small waist (<94/80 cm in men/women). Analysis with finer categories showed lower odds of successful aging starting at BMI $\geq$ 23.5 kg/m$^2$ and WC 82/68 cm in men/women.

**Conclusions:** Optimal midlife BMI and WC for successful aging might be substantially below the current thresholds used to define obesity.

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## Introduction

Five hundred million adults, corresponding to more than a tenth of the total world adult population, were obese in 2008 (1). There is considerable evidence of the adverse effects of obesity on mortality (2-4), with concerns growing that the obesity epidemic will reduce gains made in cardiovascular disease prevention (5,6) and life expectancy (7). Besides mortality and chronic diseases, obesity is linked to disability (8-10), poor physical (11-16), and cognitive functioning (17-20). Given population aging and the adverse effect of obesity on multiple age-related health conditions (21), research on the impact of obesity on aging outcomes has considerable public health significance.

The primary objective of this study is to examine the effect of obesity on health at older ages. Mortality, chronic diseases, and functioning examined as separate outcomes do not allow an evaluation of the extent to which obesity influences overall health at older ages. The concept of "successful" (22) or "healthy" aging allows multiple dimensions of health to be assessed together. In this article, we examine if midlife indicators of adiposity, body mass index (BMI) and waist circumference (WC) predict "successful aging," defined as being free of major chronic diseases and having good physical, cognitive, respiratory, cardiovascular, and mental health. Besides successful aging, we also estimate associations of adiposity markers with survival in the same cohort, irrespective of the health status of the person, in order to allow better interpretation and comparison with the adiposity–successful aging associations.

## Methods

Data are drawn from the Whitehall II study, established in 1985 on 10,308 employees (response rate 73%), aged 35-55 years (67%

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men), of 20 London-based civil service departments (23). All participants in the study were white-collar workers, but a wide range of occupations was represented with a salary difference of over 10-fold between the top and bottom of the hierarchy. Study design consisted of a clinical examination approximately every 5 years: 1985/1988, 1991/1993, 1997/1999, 2002/2004, and 2008/2009. As WC was added to the anthropometry measures in 1991/1993, it is the baseline in the present analysis. All participants provided written consent and the University College London ethics committee approved the study.

## Baseline measurements (1991/1993)

*BMI (weight kg/height metres$^2$)*: Weight was measured in underwear to the nearest 0.1 kg on Soehnle electronic scales with digital readout (Leifheit AS, Nassau, Germany). Height was measured in bare feet to the nearest 1 mm using a stadiometer with the participant standing erect with head in the Frankfurt plane. Reproducibility of the weight and height measurements over 1 month (i.e., between-subject variability/total [between + within subject] variability), undertaken on 331 participants, was 0.99. WHO classification was used to categorise BMI (24): 18.5-24.99 kg/m$^2$ (normal weight), 25-29.99 kg/m$^2$ (overweight), and $\geq$30 kg/m$^2$ (obese).

*WC* was measured in the standing position with the participant in underwear, using a fiberglass tape measure at 600 g tension. It was taken as the smallest circumference at or below the costal margin. Waist circumference categories used were small (<94/80 cm in men/women), intermediate (94 to <102/80 to <88 cm in men/women), and large ($\geq$102/88 cm in men/women) (21).

*Covariates*: Baseline covariates were age, sex, marital status (married vs. other), and socioeconomic status (SES), using the measure of occupational position (high, intermediate, low), a comprehensive marker of socioeconomic circumstances related to salary, social status, and level of responsibility at work (23).

Analyses were also adjusted for *health behaviors*, assessed by questionnaire. Smoking status was categorized as current, ex-, and never smokers. Alcohol consumption was assessed via questions on the number of alcoholic drinks consumed in the last seven days, converted to units of alcohol consumed in a week. Level of physical activity was defined as "active" ($\geq$2.5 hours/week of moderate physical activity or $\geq$1 hour/week of vigorous physical activity), "inactive" (<1 hour/week of moderate and vigorous activity) and intermediate level of activity for all others. Dietary behavior was assessed using a question on frequency of fruit and vegetable consumed in a week.

## Outcome ascertainment (follow-up 1991/1993 to 2008/2009)

Two key outcomes were ascertained at the end of a mean follow-up of 16.3 years (SD = 2.4 years): survival (being alive at the end of the follow-up) and successful aging. Multiple health outcomes, in order to reflect the multidimensionality of the successful aging concept, were used to define successful aging. These included (i) being alive at the end of the follow-up and aged $\geq$ 60, (ii) absence of coronary heart disease, stroke, cancer, and diabetes over the follow-up, (iii) good cardiovascular, metabolic, respiratory, physical, and cognitive functioning, and (iv) absence of mental health problems at the clinical examination in 2008/2009. These components are described below.

*Mortality*. Mortality data were drawn from the British national mortality register (National Health Services Central Registry). The tracing exercise was carried out using the National Health Service identification number assigned to each British resident.

*Chronic diseases*. Coronary heart disease (CHD) was identified at baseline (1991/1993), to exclude prevalent disease, and over the follow-up using MONICA criteria (25). Data for this procedure came from the medical examinations carried out every 5 years, hospital records of acute electrocardiograms (ECGs) and cardiac enzymes. Stroke diagnosis was self-reported and included history of stroke or a transient ischemic attack. Cancer status was assessed using the National Health Service Cancer Registry. At each medical examination, diabetes mellitus was determined by self-report of doctor diagnosis and/or medication or oral glucose tolerance test (a fasting glucose $\geq$7.0 mmol/l, a 2-h postload glucose $\geq$11.1 mmol/l, reported doctor-diagnosed diabetes, or use of diabetes medication) (26).

*Functional status*. Functional measures were assessed at the 2008/2009 clinical examination using standard protocols. Good functional status was defined as not being in the worst quintile of any of the domains assessed, with the worst quintile standardized using age in 5-year bands and sex because of the association of these measures with functioning. Systolic blood pressure (average of 2 measurements in sitting position after 5 minutes of rest with the OMRON HEM 907), a marker of cardiovascular health in our analysis, is a major risk factor for coronary heart disease and the most important risk factor for stroke (27). The highest quintile of systolic blood pressure described poor cardiovascular health. Physical function using walking speed measured over a clearly marked eight foot walking course at usual pace (28), respiratory function as forced expiratory volume in 1 second/height$^2$ (FEV1 in l/m$^2$) (29),[34] and cognitive functioning using a global cognitive score composed of five tests (30). Mental functioning were indicated by a score of $\leq$42 in the mental health scale of the short form general health survey (SF-36) (31), part of the study questionnaire administered at 2008/2009.

## Statistical analysis

Survival and successful aging were ascertained as described above. As there was no evidence of sex differences in the associations (*p* for interaction with sex = 0.16-0.97 depending on the outcome), men and women were combined in the analysis. Logistic regression was used to examine associations of baseline BMI (18.5-24.99, 25-29.99, and $\geq$30 kg/m$^2$) and WC categories (men/women: <94/80, 94 to <102/80 to <88, and $\geq$102/88 cm) with survival and successful aging.

In analysis where survival was the outcome, cases were participants who survived (comprising both successful and unsuccessful aging) and non-cases were those who died during the follow-up. When successful aging was the outcome, non-cases were those who died and those alive but deemed not to have aged successfully. Analyses were adjusted for age, sex, marital status, SES and health behaviors (smoking, alcohol consumption, physical activity, and dietary

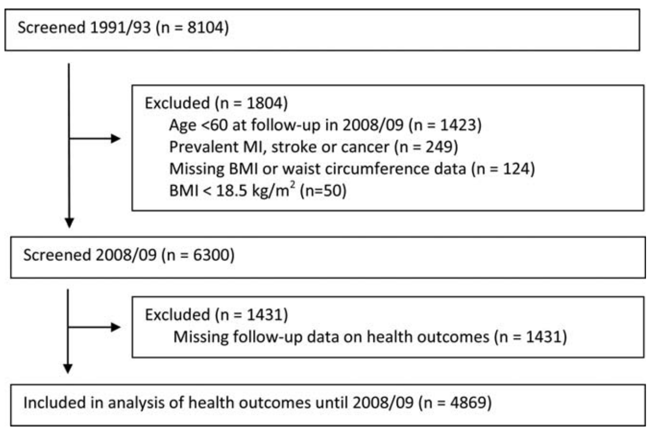


**FIGURE 1** Flow chart of sample selection.

behavior).We also examined associations of BMI and WC with individual components used to define successful aging.

We also examined finer categories of BMI and WC for their association with both outcomes. Statistical tests were two-sided and a *P*-value of <0.05 was considered statistically significant.

*Sensitivity analysis*. One, we first examined the influence of missing data on the results by examining the association of BMI and WC with "missingness" at the end of follow-up using logistic regression. As all participants are linked to the national mortality registers, we repeated the mortality analyses in all participants with data on BMI and WC. Two, we examined associations of BMI and WC with successful aging and survival in non-smokers. Finally, the main analysis was repeated using multinomial logistic regression to analyse both outcomes (successful aging, mortality) in a single analytic framework. All analyses were performed with STATA statistical software, version 12.

## Results

Figure 1 shows a flow chart of the sample selection. Of the 8104 participants at the 1991/1993 clinical screening where BMI and WC were assessed, we excluded those who were alive but not yet aged 60 ($n$ = 1423) at the end of the follow-up (2008/2009) as they were too young to be considered to have aged successfully, those with prevalent cardiovascular disease or cancer at baseline ($n$ = 249), those with missing data on BMI or WC ($n$ = 124) or BMI <18.5 ($n$ = 50), and those lost to follow-up ($N$ = 1431) between the assessment of adiposity (1991/1993) and functioning (2008/2009). Of the 8104 participants at 1991/1993 assessment, mortality along with socio-demographic data were available for 7902 participants. Supplementary Table S1 shows that the associations of BMI and WC with mortality were similar in the two samples.

Compared to those with missing data the sample included in the analysis ($N$ = 4869) was composed of fewer women (33.2% vs. 29.4% women $P$ < 0.001) and more individuals from the higher SES group (32.7% vs. 41.3%, $P$ < 0.001); both BMI and WC were only slightly higher in the sample included in the analysis (age and sex adjusted differences of 0.4 kg/m$^2$ and 0.7 cm, respectively). Compared to normal weight participants, missingness was no different in overweight (OR = 0.93, 95% CI: 0.83, 1.03) and obese (OR = 0.84, 95% CI: 0.71, 1.00) persons in analysis adjusted for age and sex ($N$ = 7902). Those with a small waist had similar odds ratio of missingness to those in the intermediate (OR = 1.02, 95% CI: 0.90 1.105) and large (OR = 0.90, 95% CI: 0.77, 1.05) WC categories. The measures of BMI and WC were strongly correlated (correlation coefficient = 0.74, $P$ < 0.001).

Quintiles used to ascertain poor functional status accumulated over the measures so that only 33.8% of participants in the study had good functioning on all measures; 59.4% were free of chronic diseases and combining these two led to 1008 (20.7% of those included in the analysis) successful agers, see Table 1 for sample characteristics. At baseline, those aging successfully had a better sociodemographic and behavioral profile. A total of 507 (10.4%) participants

**TABLE 1** Sample characteristics at baseline (1991/1993) a function of ageing outcomes at the end of follow-up (2008/2009)

| Characteristic | | Successful ageing ($n$ = 1008) | Others ($n$ = 3861) | $P$ |
|---|---|---|---|---|
| Age, (year) | $M$ (SD) | 49.8 (5.0) | 51.5 (5.3) | <0.0001 |
| Sex, (% women) | $N$ (%) | 279 (27.7) | 1151 (29.8) | 0.19 |
| BMI, (kg/m$^2$) | $M$ (SD) | 24.5 (3.0) | 25.8 (3.9) | <0.0001 |
| Waist circumference, (cm) | | | | |
| Men | $M$ (SD) | 87.2 (8.2) | 90.7 (9.4) | <0.0001 |
| Women | $M$ (SD) | 74.8 (10.5) | 80.5 (12.8) | <0.0001 |
| Married | $N$ (%) | 815 (80.6) | 2979 (77.2) | 0.01 |
| High socioeconomic status[a] | $N$ (%) | 542 (53.8) | 1441 (37.3) | <0.0001 |
| Smoker | $N$ (%) | 72 (7.2) | 521 (14.1) | <0.0001 |
| Alcohol consumption, units/week | $M$ (SD) | 10.7 (11.2) | 10.1 (12.9) | 0.14 |
| Physical activity, inactive | $N$ (%) | 144 (14.3) | 855 (22.2) | <0.0001 |
| Fruit/vegetable consumed/week | $M$ (SD) | 6.7 (1.6) | 6.4 (1.4) | <0.0001 |

*M*, mean; SD, standard deviation; *N*, number.
[a]Top occupational position, out of three.

**TABLE 2** Association of BMI and waist circumference in 1991/1993 with ageing outcomes in 2008/2009

| | *N* | Model 1 OR (95% CI) | Model 2 OR (95% CI) |
|---|---|---|---|
| BMI | | | |
| Successful ageing | Successful ageing/*N* | | |
| Normal weight (18.5-24.99 kg/m$^2$) | 613/2420 | 1 (ref) | 1 (ref) |
| Overweight (25-29.99 kg/m$^2$) | 345/1940 | 0.69 (0.59, 0.80) | 0.71 (0.61, 0.82) |
| Obese ($\geq$30 kg/m$^2$) | 50/509 | 0.35 (0.26, 0.48) | 0.37 (0.27, 0.50) |
| Survival | Survival/*N* | | |
| Normal weight (18.5-24.99 kg/m$^2$) | 2203/2420 | 1 (ref) | 1 (ref) |
| Overweight (25-29.99 kg/m$^2$) | 1732/1940 | 0.87 (0.71, 1.06) | 0.90 (0.73, 1.11) |
| Obese ($\geq$30 kg/m$^2$) | 427/509 | 0.53 (0.40, 0.71) | 0.55 (0.41, 0.74) |
| Waist circumference | | | |
| Successful ageing | Successful ageing/*N* | | |
| Small (men: <94 cm, women: <80 cm) | 788/3255 | 1 (ref) | 1 (ref) |
| Intermediate (men: 94 to <102 cm, women: 80 to <88 cm) | 154/958 | 0.65 (0.53, 0.79) | 0.66 (0.55, 0.81) |
| Large (men: $\geq$102 cm, women: $\geq$ 88 cm) | 66/656 | 0.38 (0.29, 0.51) | 0.41 (0.31, 0.54) |
| Survival | Survival/*N* | | |
| Small (men: <94 cm, women: <80 cm) | 2959/3255 | 1 (ref) | 1 (ref) |
| Intermediate (men: 94 to <102 cm, women: 80 to <88 cm) | 859/958 | 0.92 (0.72, 1.18) | 0.96 (0.75, 1.23) |
| Large (men: $\geq$102 cm, women: $\geq$ 88 cm) | 544/656 | 0.52 (0.41, 0.67) | 0.57 (0.44, 0.73) |

OR, Oodds Rratio, CI, Cconfidence Iinterval.
Model 1: Analyses adjusted for age, sex, SES, and marital status.
Model 2: Model 1 + smoking, alcohol consumption, physical activity and dietary behaviour.

died over the follow-up; 107 were aged <60 at the time of death (mean age = 55.9, SD = 3.2, range = 46.2-59.9) and 400 over 60 years (mean age = 68.0, SD = 4.8, range = 60.0-79.0). Participants who died over the follow-up had higher BMI and WC at baseline and were less likely to be married or from the high SES group ($P <$ 0.001).

The mean (SD) follow-up in those who died was 11.3 (4.7) years and 16.8 (SD = 0.6) years in the survivors. Successful aging and mortality in the BMI groups were as follows: 25.3% and 9% in normal weight persons, 17.8% and 10.7% in the overweight and 9.8% and 16.1% in the obese. In the WC categories, these numbers were 24.2% and 9.1% in those in the small, 16.1% and 10.3% in the intermediate and 10.1% and 17.1% in the large category. Table 2 presents the association of BMI and WC with successful aging and survival in analyses adjusted for sociodemographic measures (model 1) and health behaviors (model 2). Successful aging had a dose–response relation with both measures of adiposity, but the associations with survival were statistically significant only for those with a BMI $\geq$30 kg/m$^2$ and those in the largest WC category. Sensitivity analysis showed similar associations in analysis excluding current smokers at baseline (supplementary Table S2) and that using multinomial logistic regression (supplementary Table S3) yielded results similar to those in Table 2. In persons with both BMI $\geq$30 kg/m$^2$ and a large WC ($n$ = 423, 83% of obese and 65% of those with large WC), the associations with successful aging (OR = 0.35, 95% CI: 0.24, 0.49) and survival (OR = 0.51, 95% CI: 0.37, 0.69) were similar in fully adjusted analyses.

Table 3 shows results of the association of BMI and WC with the components used to define successful aging. Individuals classified as obese were less likely to have good functioning on all components except mental health (OR = 0.96, 95% CI: 0.68, 1.36), they also had lower odds of being free of chronic diseases (OR = 0.38, 95% CI: 0.31, 0.46). Both BMI and WC had the strongest association with chronic diseases. However, functioning components did contribute to the associations as when with successful aging was defined without taking into consideration chronic diseases, the overweight (OR = 0.85, 95% CI: 0.73, 0.98) and the obese (OR = 0.56, 95% CI: 0.43, 0.72) had lower odds ratio of successful aging in fully adjusted analyses. Similarly, odds ratio of successful aging were lower in those with an intermediate (OR = 0.81, 95% CI: 0.68, 0.96) and large (OR = 0.58, 95% CI: 0.46, 0.72) compared to small WC.

Figure 2 shows results of analysis using finer categories of BMI (Panel A) and WC (Panel B) with successful aging and survival as the outcomes. In these data, higher BMI was significantly associated with lower survival only when $\geq$30 kg/m$^2$ (OR = 0.53; 95% CI: 0.36, 0.77). However, the odds ratio of successful aging was significantly lower in those with BMI starting at 23.5-25 kg/m$^2$ (OR = 0.69, 95% CI: 0.55, 0.88). The results for WC are similar (Figure 2B); here again poorer survival was observed in the highest WC category, $\geq$102/88 cm in men/women, but the odds ratio of successful aging were lower (OR = 0.78, 95% CI: 0.63, 0.97) starting at 82-87/68-73 cm in men/women.

## Discussion

In this 16-year follow-up of nearly 5000 British men and women, we found both high BMI and WC in midlife to be associated with substantially reduced likelihood of successful aging. The obese

**TABLE 3** Association of BMI and waist circumference (1991/1993) with components of successful ageing (2008/2009)

| | Good lung function | Good cognitive function | Good physical function | Good systolic blood pressure | Good mental health | No Chronic disease |
|---|---|---|---|---|---|---|
| | OR (95% CI) | OR (95% CI) | OR (95% CI) | OR (95% CI) | OR (95% CI) | OR (95% CI) |
| **BMI** | | | | | | |
| **Normal weight (18.5-24.99 kg/m$^2$)** | 1 (ref) | 1 (ref) | 1 (ref) | 1 (ref) | 1 (ref) | 1 (ref) |
| **Overweight (25 29.99 kg/m$^2$)** | 0.92 (0.76, 1.10) | 0.78 (0.65, 0.93) | 0.81 (0.68, 0.96) | 0.90 (0.77, 1.06) | 1.06 (0.85, 1.33) | 0.66 (0.58, 0.75) |
| **Obese ($\geq$30 kg/m$^2$)** | 0.64 (0.47, 0.86) | 0.71 (0.53, 0.96) | 0.41 (0.32, 0.53) | 0.61 (0.48,0.79) | 0.96 (0.68, 1.36) | 0.38 (0.31, 0.46) |
| **Waist circumference** | | | | | | |
| **Small (men: <94 cm, women: <80 cm)** | 1 (ref) | 1 (ref) | 1 (ref) | 1 (ref) | 1 (ref) | 1 (ref) |
| **Intermediate (men: 94 to <102 cm, women: 80 to <88 cm)** | 0.85 (0.68, 1.06) | 0.70 (0.57, 0.86) | 0.76 (0.62, 0.92) | 0.96 (0.79, 1.17) | 0.96 (0.74, 1.26) | 0.71 (0.61, 0.82) |
| **Large (men: $\geq$102 cm, women: $\geq$88 cm)** | 0.59 (0.45, 0.76) | 0.93 (0.71, 1.22) | 0.47 (0.37, 0.59) | 0.63 (0.50, 0.80) | 0.80 (0.59, 1.08) | 0.45 (0.37, 0.53) |

OR, Oodds Rratio, CI, Cconfidence Iinterval.
Analysis adjusted for age, sex, marital status, SES, smoking, alcohol consumption, physical activity and dietary behaviour.
Good lung, cognitive, and physical function defined as scores not in the lowest age- and sex-standardized quintile of $FEV_1$/height$^2$, global cognitive score, and walking speed, respectively. Good systolic blood pressure defined as not being in the highest age- and sex-standardized quintile of systolic blood pressure. Good mental health defined as the SF36 mental component score $< 42$. Chronic diseases assessed were cancer, CHD, stroke, and/or diabetes.
Ns vary from 3346 to 4922 depending on the outcome.

(BMI $\geq$ 30 kg/m$^2$) had 63% and those with a large WC (men: $\geq$102 cm, women: $\geq$88 cm) 59% lower odds of successful aging than those of normal weight and small WC, respectively. Associations of adiposity markers with survival were consistently weaker than those with successful aging, obesity reduced the odds ratio of survival by 45% and large WC by 43%. Exploratory analysis of narrower categories of BMI and WC suggested that successful aging was less likely in those with BMI $>$ 23.5 kg/m$^2$ and WC >82/68 cm in men/women; much below the threshold for low risk of disease and mortality, that is, 25 kg/m$^2$ for BMI and 94/80 cm WC in men/women.

The doubling of the human lifespan this past century (32) has led to a rapid increase in the research on aging. Rowe and Kahn's seminal paper in 1987 highlighted the heterogeneity in the health of older persons and the importance of understanding "successful aging." (22). A recent review by Depp and colleagues (33) concluded that despite subsequent attempts to define successful aging, there is little consensus on the appropriate terminology, the components of such a concept, and whether it needs to be defined using objective or subjective criteria. Physical functioning, usually measured as the absence of reported disability is central to many definitions of successful aging, used in 26 out of 29 definitions reviewed by Depp et al. (33) while 13 definitions included measures of cognitive function. Life satisfaction/well-being and social engagement measures were used in a third of the studies. Many of the outcome measures in these studies were self-reported and the analysis did not take into account mortality and chronic diseases. In contrast, our outcome measure was assessed using objective data on physical and cognitive functioning, in addition to morbidity and death.

A third of the individuals (35.8%, SD = 19.8%) included in the 29 studies in the review by Depp et al. (33) qualified as successful agers. Nearly 21% in our study sample qualified as successful agers, this number would have been larger had we used a less restrictive definition. Our definition of successful aging requires good health in a greater number of components than any previous publication; however, utilizing fewer components would have increased heterogeneity in the group of successful agers, and potentially a less comprehensive assessment of the impact of obesity on aging outcomes.

Our study shows that midlife obesity shapes a range of aging outcomes, from morbidity and mortality to chances of successful aging. We used a prospective design to assess the impact of body weight as age is known to modify the association between obesity and death due to survivor effect and competing causes of death at older ages (34,35). There is increasing evidence of the importance of midlife bodyweight for adverse health outcomes at older ages. Associations in cross-sectional studies on older adults could be because body weight is a risk factor or because it is a correlate or consequence of the health outcome under investigation. Our use of a prospective design with a long follow-up ensures that the observed

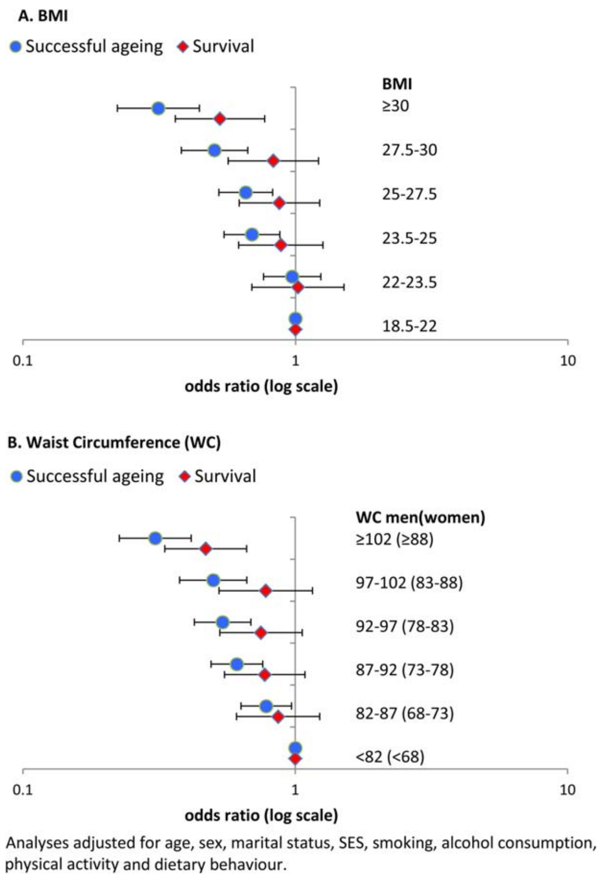


**FIGURE 2** Odds ratio of successful aging and survival as a function of BMI (**A**) and waist circumference (**B**) categories. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

results are not due to reverse causation bias. Two recent reviews highlight the importance of midlife BMI for dementia (36) and limitations in activities of daily living (37). Our use of "successful aging" as the outcome suggests that bodyweight influences multiple dimensions of health, the risk of chronic disease but also lung, cognitive, physical functioning and chronic diseases.

A BMI threshold of 25 kg/m$^2$ has been used extensively to define normal weight, but there is already some evidence that individuals with lower values have better cardiovascular outcomes (5). In the Nurses' Health Study midlife BMI $>$ 23 kg/m$^2$ was associated with worse odds of healthy aging (38). Our data show decrease in the odds ratio of successful aging to start at BMI $\geq$ 23.5 kg/m$^2$ in midlife, suggesting that carrying excess weight might accelerate the rate of aging in those well below the obesity threshold. Similarly, for WC successful aging was less likely starting much below the threshold used to define risk ($\geq$102/88 cm in men/women) (21).

The main strengths of this study include the conceptualization of successful aging based on multiple outcomes, including validated measures of chronic disease and objective measures of functioning. The estimates for successful aging were examined against those for survival showing that both BMI and WC have a stronger effect on survival in good health (successful aging) rather than survival alone. The large sample size and the long follow-up are further advantages. Finally, we were able to use linkage of all participants to national mortality register to show that associations of obesity measures with mortality were similar in those included and not included in the analysis. Thus, despite the loss to follow-up over the course of the study it is unlikely that our results are influenced by missing data.

There are also several limitations to the results reported here. One, despite the long follow-up, our study does not cover the oldest age-groups. The extent to which the results apply to the 80+ age-groups remains to be explored. Two, our effect estimates might lack precision as there is emerging evidence of the effect of duration of obesity, every two obese-years increases mortality risk by 6% (39). Three, the use of population specific cut-offs to define poor functional status is not ideal. Further research is required to define cut-offs for measures of functioning so that they are consistent across studies. Four, a large number of participants with data at baseline were not included in the analysis either by design (<60-year-old at the end of follow-up) or due to missing data on the functioning measures. However, this is unlikely to have biased the results as BMI and WC were not associated with missing data. Finally, these findings from an occupational cohort may not be fully generalizable to the general population.

In conclusion, our study highlights the importance of midlife adiposity for health at older ages. Although overweight and obesity may become less disabling due to improvement in the treatment of chronic diseases associated with obesity, our data suggest this might not be the case for overall health and functioning at older ages. These results highlight the importance of low BMI and WC, below the current thresholds used to define general and central obesity associated with risk of mortality and chronic diseases, for good health at older ages. O

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