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Associations of obesity and weight change with physical and mental impairments in elderly Chinese people

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Abstract

Objective—To examine the associations between anthropometric measurements and functional impairments in a sample of urban elderly Chinese people.

Methods—In two population-based cohort studies, the Shanghai Women's Health Study (SWHS) and Shanghai Men's Health Study (SMHS), 11,505 men and 17,166 women aged 70–88 years at the time of the functional assessment were studied. Weight history was collected and anthropometric data were taken at study enrollment (from 1996 to 2000 for the SWHS, 2002 to 2006 for the SMHS). Information on functional status and current weight was collected at the most recent follow-up survey (from 2011 to 2015). Logistic regression analyses were applied to estimate the associations of body mass index (BMI), waist-hip-ratio (WHR), and weight changes with functional decline.

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Contributors

Jingjing Zhu analysed the data and drafted the paper.

Yong-Bing Xiang designed the study.

Hui Cai analysed the data.

Honglan Li collected data.

Yu-Tang Gao designed the study.

Wei Zheng designed the study.

Xiao-Ou Shu designed the study, analysed the data and drafted the paper.

All authors meet the criteria for authorship stated in the Uniform Requirements for Manuscripts Submitted to Biomedical Journals.

Conflict of interest

The authors declare that they have no conflict of interest.

Ethical approval The study was approved by the institutional review boards of participating institutions and written informed consent was acquired from all participants.

Provenance and peer review

This article has undergone peer review.

Results—After a median follow-up of 14.4 years (range 5.4–18.2 years), we found that BMI/WHR at or after middle age, and weight gain during adulthood were significantly associated with impaired walking ability and mental functioning. Being underweight after age 70 was associated with poorer hearing and/or vision as well as poorer memory. The associations between obesity and functional impairment were generally not modified by sex, comorbidity or exercise.

Conclusion—Weight gain, obesity at or after middle age, and underweight after age 70 were associated with physical and mental functional impairments among elderly Chinese people. These findings highlight the importance of maintaining healthy weight to reduce age-related functional decline.

Keywords

function impairments; body mass index; weight; fat; Chinese

1. Introduction

Physiological changes that take place during the aging process can result in functional impairments, which include limitations in mobility, communication, interpersonal interactions, and independence in carrying out daily activities[1]. Increased lifespan has resulted in a steady rise of the aged population as well as corresponding health problems. According to a recent study conducted in the US, for example, about 15% of the older non-nursing home population has physical impairments.[2] Another national study conducted in 2010 found that about 41% of the US population between 62 and 90 years old has at least mild mental impairment.[3] Decline in functional ability can substantially influence the independence and quality of life for the elderly population[4–7]. However, to date, limited medical interventions have been available to address these impairments[8,9]. A better understanding of factors associated with functional impairments is of utmost public health importance for developing strategies to prevent or delay the onset of functional impairments in old age and to reduce the associated economic and societal burden.

Overweight and obesity are growing health concerns in many countries around the world. The prevalence of obesity in the US has increased from 12% in 1991 to 35% in 2012, based on data from the Centers for Disease Control and Prevention.[10,11] The trend of obesity is also increasing in developing countries, including China, the most populous country in the world.[12] Multiple studies have linked overweight and obesity to functional impairments. A systematic review assessing risk factors for functional status decline in community-dwelling elderly populations has suggested that body mass index (BMI) is one of the most relevant factors in the acceleration of physical function decline.[13] Another study published in 2005 also identified central obesity as a possible risk factor for impairments in physical function, especially for those over 70 years old.[14] However, the majority of existing studies focus on physical functioning; the associations between body size and body composition with mental functioning are insufficiently investigated. Furthermore, most of the published studies were conducted in western populations. Whether the reported associations extend to Asian populations remains unclear.

The purpose of this study is to comprehensively investigate the associations between body size and body composition variables with physical, hearing/vision, and mental functional decline in the elderly urban Chinese population by analyzing two large-scale prospective cohort studies, the Shanghai Men's Health Study (SMHS) and Shanghai Women's Health Study (SWHS).

2. Materials and Methods

2.1 Study subjects

The SWHS and SMHS are two population-based prospective cohorts that recruited a total of 74,941 Chinese women (aged 40–70 years) and 61,480 Chinese men (aged 40–74) from 8 urban communities of Shanghai, China. The baseline surveys, conducted from 1996 to 2000 for SWHS and from 2002 to 2006 for SMHS, collected information on participants' socio-demographic and lifestyle factors, medical history, and usual dietary habits. Anthropometric measurements were taken. Since the initial surveys, participants have been followed up every 2–4 years through in-person interviews to update their health and lifestyle information (follow-up rates 92% for both cohorts). Up to July 2016, there have been in total 5 follow-up surveys for SWHS and 3 for SMHS. Detailed information on study design and recruitment methods have been published previously.[15,16] Our study has been approved by the institutional review boards of participating institutions and written informed consent was acquired from all participants. In the latest follow-up surveys, self-reported information on participants' functional status was collected for those aged 70 or older (n=12,150 for men, n=18,602 for women). For this study, we excluded participants with missing information on the functional status evaluation (n=124 for men, n=144 for women), missing information on anthropometric measurements either at baseline (n=11 for men, n=5 for women), or the last follow-up surveys (n=510 for men, n=1,287 for women). Ultimately, a total of 11,505 men and 17,166 women were included in this study.

2.2 Functional status assessment

Four sets of questions were used to measure different aspects of functional status, including two on physical functioning and the other two on mental functioning. Briefly, in terms of independent walking ability, subjects who needed any assistance to walk on a flat surface were categorized as having an inability to walk independently, while those who could walk without any assistance were classified as independent walkers. With regard to hearing and vision capabilities, participants were divided into three groups—those with a serious problem, those with a minor problem, and those with no impairment. As for memory status, subjects were grouped into three categories: serious, minor, or no problem in memory function. For independent decision-making, participants were classified into three groups: always having difficulty, sometimes having difficulty, or having no difficulty in making decisions by themselves.

2.3 Anthropometric Assessment

Anthropometric measurements, including height, weight, and circumferences of waist and hips, were taken at cohort study enrollment. For each individual, those measurements were taken twice, and a third measurement taken if the difference between the first two

measurements exceeded 1 cm for height or waist and hip circumferences, or exceeded 1 kg for weight. Self-reported information on height and weight at 20 years old, weight at 40 years old for men, and weight at 50 years old for women was also collected. Measured and self-reported heights and weights were used to calculate body mass index (BMI, kg/m²) at each age level. BMI was used to classify participants into groups of underweight (<18.5 kg/m²), normal (18.5–24.9 kg/m²), overweight (25–29.9 kg/m²), and obese (≥30 kg/m²) according to the BMI cut-off points recommended by the World Health Organization[17]. Waist-hip ratio (WHR) was calculated by using the measured waist and hip circumferences at baseline and categorized by quartile distribution. Participants' weight changes from 20 years old to age at study enrollment and from 20 years old to middle age (40 years old for men, 50 years old for women) were also calculated.

2.4 Statistical analysis

Weight changes and WHR were categorized into quartiles based on distributions among women and men separately. Those variables were also treated as continuous variables in the data analysis with one unit for weight change being 2.5kg and for WHR, 0.1. Logistic regressions were used to derive odds ratios (ORs) and 95% confidence intervals (CIs) for the association of body size and body composition variables with functional status. For analyses on BMI, participants in the normal weight category (BMI between 18.5 to 25) were treated as the reference group. For the other exposure variables, the lowest quartile was used as the reference group. Stratified analyses were also conducted to evaluate potential effect modification by sex, comorbidity scores, and exercise participation at baseline. Likelihood ratio tests were performed to evaluate statistical significance of the homogeneity. The adjusted covariates in the final analyses included sex, age (continuous), marital status (married, other), occupation (manual, clerical, professional), annual income (low, average, high), education (less than high school, high school, college or above), comorbidity score (Charlson comorbidity score index[18] = 1 or 0), alcohol use (continuous), smoking status (previous or current smoker, non-smoker), protein intake (g/day), vegetable intake (g/day), fruit consumption (g/day), and exercise (regular exerciser being defined as exercising at least once a week for more than three months) at the baseline survey. Since missing data are very rare in our study population (≤3% for all the variables), any covariates with missing values were imputed with the median for continuous variables, or with the most common category for categorical variables. The associations of combined effect of BMI and WHR, both assessed at baseline, were also evaluated. For this particular analysis, BMI was classified into three groups by combining overweight and obese as one group, while WHR data were categorized into tertiles. Participants in the normal weight range and those with WHR in the 1st tertile were used as reference groups. Data were analyzed using SAS version 9.4 (SAS Institute, Inc., Cary, NC). P value less than 0.05 was considered statistically significant.

3. Results

With an average age of 67.6 [standard deviation (SD) =4.1] for men, and 62.5 (SD=4.2) for women at study enrollment, the mean BMI for study participants at baseline was 24.0 (SD=3.0) for men and 24.8 (SD=3.5) for women. The mean WHR at baseline was 0.90

(SD=0.06) for men, and 0.83 (SD=0.06) for women. Participants with lower BMI or WHR measurements were generally more likely to be male, with higher education and income, more likely to have a professional occupation, to be married, to participate in physical activity regularly, to smoke and drink alcohol regularly, and on average, to have a lower total dietary protein, fruit, and vegetable intake. There were no significant differences in marital status and the level of dietary protein and fruit intake among different WHR quartiles (Table 1).

Adjusted ORs and 95% CIs for the association of anthropometric measurements with functional status are presented in Table 2 and Table 3. BMI assessments at or after middle age, i.e. age 40 (men)/50 (women), at baseline, and at the latest follow-up, as well as weight change from 20 years old to age at baseline and to age 40/50, and WHR at baseline were all significantly associated with being unable to walk independently, after adjustment for potential confounders. Exposures that showed the strongest positive associations were obesity (BMI ≥ 30) at middle age (i.e., 40/50 years old), with an OR of 2.84 (95% CI: 2.27, 3.54), and obesity after age 70, with an OR of 2.48 (95% CI: 2.12, 2.90). Underweight (BMI < 18.5) at middle age was negatively associated with impaired walking capability (OR=0.69, 95% CI: 0.56, 0.84). The ORs comparing participants with the most weight gain to those with the least weight gain were 1.58 (95% CI: 1.39, 1.79) for weight change from 20 years old to study enrollment, and 1.85 (95% CI: 1.62, 2.11) for weight change from 20 years old to baseline. The OR comparing the highest to the lowest category of WHR was 1.68 (95% CI: 1.51, 1.86). BMI at age 20 years was not significantly associated with impaired walking ability.

Being underweight at middle age (OR=0.86, 95% CI: 0.76, 0.97) was inversely associated with having minor problems in hearing/vision. Conversely, being underweight (BMI < 18.5) after age 70 (OR=1.53, 95% CI: 1.29, 1.82) was positively associated with decreased function in hearing or vision. Weight gain from 20 years old to age at baseline was inversely associated with serious impairments in hearing or vision, with an OR of 0.83 (95% CI: 0.72, 0.95), when comparing the highest to the lowest category of weight gain.

With respect to memory, obesity at middle age (OR=1.38, 95% CI: 1.00, 1.90) and being underweight at baseline (OR=1.64, 95% CI: 1.38, 1.94) were significantly associated with having a serious problem with memory. Weight gain from 20 years old to middle age was also significantly associated with declining memory, with an OR of 1.24 (95% CI: 1.05, 1.47) when comparing the highest to the lowest category of weight gain.

In terms of independent decision-making, low BMI or being obese at middle age, at baseline, and at the latest follow-up, as well as weight change from 20 years old to middle age were all significantly associated with having difficulty in making decisions. Exposures that showed the strongest associations were being underweight after age 70 (OR=1.63, 95% CI: 1.40, 1.91), and obese at middle age (OR=1.46, 95% CI: 1.09, 1.95).

Table 4 presents the combined effect of BMI and WHR at baseline on functional status. High BMI was associated with impairments in walking capability even among subjects who were in the lowest category of WHR (OR=1.32, 95% CI: 1.12, 1.55). Similarly, high WHR

was also associated with impaired walking ability among subjects who were not obese/overweight (OR=1.36, 95% CI: 1.18, 1.57). The risk of functional impairments was highest among subjects who had the highest BMI and WHR, with respect to both walking ability (OR=1.88, 95% CI: 1.68, 2.11) and decision-making (OR=1.17, 95% CI: 1.02, 1.33). With regard to a decline in memory, the highest risk appeared among subjects who had the lowest BMI and WHR. No significant associations were shown for impairments in hearing/vision.

Analyses stratified by comorbidity status at baseline generally showed no effect modification, except for the associations of independent decision-making. The likelihood ratio tests showed a significant interaction ($P=0.02$) between BMI at baseline and comorbidity as well as the interaction between WHR and comorbidity ($P<0.01$). For subjects without comorbidity, obesity at baseline was significantly associated with always having difficulty in making decisions. However, this association was not significant for subjects with comorbidity at baseline. On the contrary, WHR was only associated with serious decision-making difficulty for participants with comorbidity. Analyses stratified by exercise and sex did not reveal any modifying effect from these two factors. (Data not shown.)

4. Discussion

In this large-scale population-based study of Chinese men and women between the ages of 70 and 88, we found that general obesity (measured by BMI), central fat deposition (measured by WHR) and weight gain at or after middle age were associated with physical and mental functional impairments in the elderly. We also found that being underweight after 70 years old was related to a higher probability of impaired hearing or vision. Also, greater weight gain from 20 years old to baseline was inversely associated with impairments in hearing/vision. Furthermore, while having both high BMI and high WHR concurrently was related to the highest risk of functional impairment, having one of these two factors without the other was also associated with increased risk.

Our findings generally agree with those from previous studies, namely, that BMI, weight change and central obesity are associated with declines in walking ability[19,20], hearing and vision[21,22], memory, and decision-making[23,24]. A large body of research has linked excessive body fat storage with a variety of chronic diseases, which in turn have been shown to be major risk factors for functional decline in the literature and in our own study[25–27]. This is the rationale for our only adjusting for comorbidity at the baseline survey instead of for that reported during the follow-up surveys, to avoid potential over-adjustments (i.e., adjusting for variables in the causal pathway). Regarding physical function, obesity has been previously reported to be strongly associated with inflammation[28–30], insulin resistance[31–33], low levels of growth hormone[34] and testosterone secretion[35], factors that are associated with muscle strength decline[36–38], a leading contributor of physical function impairment.[39] With regard to mental performance, several factors, including inflammation, insulin resistance, and hypertriglyceridemia, as well as elevated fasting plasma glucose, have been proposed as potential mediators for the obesity association[23,40]. In our study, the obesity associations were more consistent for independent decision-making than for memory. While obesity may influence these mental functions differently, differences in our ability to measure these outcomes accurately may

also be an explanation. Further studies are needed for clarification. We also found that low body weight after age 70 was significantly associated with higher likelihood of impairment in walking, hearing/vision, memory, and decision-making. This could be partially explained by the fact that unintentional weight loss is mainly caused by acute or chronic diseases among the aged population, a situation that could concomitantly lead to decreased functional capability. Also, studies have shown that the elderly population is more vulnerable to poor nutritional status because a greater portion of their available nutrition is spent on repair mechanisms to cope with the cumulative effects of oxidative, inflammatory, and other environmental insults[41], leading to an undersupply of nutrients for normal cellular maintenance. One additional explanation is that for subjects who are in the same category of BMI, those who are older tend to have a lower proportion of lean body mass[42], which is essential for all metabolically-active tissues and organs to maintain protein synthesis and normal function[43].

One of our key findings, that the strongest association between weight and functional decline occurred when combining BMI and WHR measurements, highlights the fact that BMI alone may not be a sufficient index to measure the adverse effect of adiposity. We showed that central obesity is an independent risk factor regardless of BMI measurement. This result suggests that controlling abdominal fat in a healthy range is as important as maintaining a normal BMI when it comes to preventing functional decline in walking ability, memory, and decision-making.

Our study found that excessive weight gain during adulthood, especially from age 20 to 40/50, could possibly be linked to greater likelihood of later impairments in walking, memory and decision-making, which suggests the importance of maintaining healthy weight throughout adulthood. However, the inverse associations we found of impairments in hearing/vision with being underweight at middle age and with weight gain from age 20 to baseline were unexpected—no existing literature can be found to support or explain this finding. More studies are needed to rule out a chance finding or to understand the underlying mechanism(s).

The major strengths of our study include its prospective and population-based design, its large sample size, and the detailed information on anthropometric measurements assessed longitudinally at different stages of life. Several limitations also need to be considered for our results interpretation. First, although this is a prospective study, outcomes were only evaluated at the latest follow-up survey, and thus we cannot exclude the possibility that some of the participants may already have had impaired functional status at the time of study enrollment, which might have contributed to weight change afterwards. Second, BMI at middle age is defined differently for men (40 years old) and women (50 years old) due to a study design difference for the two parent cohorts. Third, hearing and vision were evaluated together by a single question in the survey so that we cannot make inferences from the estimated associations for each of them separately.

5. Conclusions

In conclusion, general obesity, weight gain and abnormal body fat storage at or after middle age were associated with physical and mental functional status in the elderly Chinese. These associations were particularly consistent for the outcomes of impaired independent walking and decision-making. Being underweight, however, did not result in a much better outcome, and was likewise associated with physical and mental impairments, especially after age 70. These results add to the mounting evidence on the benefits of maintaining healthy weight in middle age.

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Highlights

- Obesity at or after middle age and weight gain during adulthood are associated with a higher likelihood of developing functional impairments when elderly.
- Being underweight after the age of 70 is also associated with a higher probability of functional decline.
- Central obesity is an independent risk factor for functional impairment, regardless of body mass index.

Fig. 1.

Timeline for data collection of study variables in SWHS (1996–2016) and SMHS (2002–2016)

Table 1

Characteristics by BMI and WHR, the SWHS (1996–2015) and SMHS (2002–2015).

	Baseline BMI categories				
Characteristics	<18.5	18.5–24.9	25–29.9	30	P
Number (%)	902 (3.2)	15841 (55.2)	10372 (36.2)	1556 (5.4)	
Age at baseline, years (mean±sd)	64.9±5.0	64.6±5.0	64.5±4.8	64.0±4.4	<0.001
Age at function status assessment, years (mean±sd)	77.7±4.2	77.3±4.1	77.6±4.1	78.0±4.0	<0.001
Sex, male (%)	44.5	44.1	36.5	21.1	<0.001
Education (%)					
Less than high school	44.6	49.8	62.3	75.1	<0.001
High school	27.4	23.3	19.0	14.3	
College or above	28.0	26.9	18.7	10.6	
Income (%)					
Low	12.7	12.4	14.9	20.3	<0.001
Average	81.5	80.3	79.1	76.2	
High	5.8	7.3	6.0	3.5	
Occupation					
Manual workers	42.0	42.6	49.8	59.4	<0.001
Clerical	17.1	16.9	17.7	18.8	
Professional	40.9	40.5	32.5	21.8	
Marital status, married (%)	89.0	90.6	89.4	86.3	<0.001
Physical activity, regularly (%)	50.9	57.8	56.9	54.8	<0.001
Ever or current smoker (%)	30.0	24.3	20.9	15.6	<0.001
Alcohol use, 3 drinks/week (%)	11.4	12.1	10.1	7.1	<0.001
Dietary protein intake (g/day, mean±sd)	65.3±20.7	68.9±21.4	69.1±22.1	68.3±24.4	<0.001
Total fruit intake (g/day,mean±sd)	164.0±132.8	198.4±147.3	216.5±162.2	221.7±167.8	<0.001
Total vegetable intake (g/day,mean±sd)	267.3±158.9	303.3±171.9	314.2±182.6	322.0±198.5	<0.001
	Baseline WHR Quartiles ^a				
Characteristics	Q1 (lowest)	Q2	Q3	Q4 (highest)	P

Characteristics	Baseline BMI categories					P
	<18.5	18.5–24.9	25–29.9	30		
Number (%)	8259 (28.8)	6334 (22.1)	7426 (25.9)	6652 (23.2)		
Age at baseline, years (mean±sd)	64.2±5.1	64.3±4.9	64.5±4.8	65.1±4.6		<0.001
Age at function status assessment, years (mean±sd)	77.1±4.2	77.3±4.1	77.5±4.1	78.0±4.1		<0.001
Sex, male (%)	41.4	39.3	38.8	40.8		0.003
Education (%)						
Less than high school	49.9	53.5	57.7	62.1		<0.001
High school	23.7	22.3	20.6	18.5		
College or above	26.4	24.2	21.7	19.4		
Income						
Low	11.9	13.4	14.8	15.2		<0.001
Average	80.7	80.1	78.6	79.0		
High	7.3	6.5	6.6	5.8		
Occupation						
Manual workers	42.7	45.0	47.6	49.7		<0.001
Clerical	16.6	17.2	16.9	18.7		
Professional	40.7	37.8	35.5	31.6		
Marital status, married (%)	90.4	89.9	89.4	89.6		0.20
Physical activity, regularly (%)	57.6	57.0	58.5	55.1		<0.001
Ever or current smoker (%)	22.8	21.2	21.8	25.2		<0.001
Alcohol use, 3 drinks/week (%)	10.5	10.4	11.1	12.4		<0.001
Dietary protein intake, g/day	68.7±21.7	68.7±21.0	69.0±22.1	68.8±22.4		0.79
Total fruit intake, g/day	203.0±149.4	208.0±151.2	205.6±155.7	204.6±160.4		0.28
Total vegetable intake, g/day	304.6±175.5	307.8±173.4	311.7±180.2	304.6±179.4		0.04

^aQuartile cutoffs for men are: 0.87, 0.90, and 0.94; for women are: 0.79, 0.82, and 0.86.

Table 2

Associations of body mass indexes with functional status, *the SMHS and SWHS*.

	Walking independently Unable to OR ^a (95% CI)	Hearing and vision		Memory		Making decisions independently	
		Minor problem OR ^a (95% CI)	Serious problem OR ^a (95% CI)	Some problem OR ^a (95% CI)	Serious problem OR ^a (95% CI)	Sometimes difficult OR ^a (95% CI)	Always difficult OR ^a (95% CI)
BMI at 20 years old							
<18.5	0.95 (0.86, 1.05)	0.98 (0.91, 1.05)	1.03 (0.93, 1.15)	1.00 (0.93, 1.07)	1.15 (1.02, 1.31)	0.97 (0.89, 1.07)	1.09 (0.97, 1.22)
18.5–24.9 (ref)	1.0	1.0	1.0	1.0	1.0	1.0	1.0
25–29.9	0.86 (0.63, 1.17)	1.04 (0.82, 1.32)	1.31 (0.94, 1.81)	0.98 (0.79, 1.22)	0.96 (0.66, 1.42)	0.99 (0.75, 1.30)	1.08 (0.78, 1.51)
30	2.60 (0.66, 10.19)	0.42 (0.09, 1.87)	2.17 (0.47, 9.90)	1.02 (0.26, 3.96)	1.28 (0.15, 10.58)	1.49 (0.30, 7.26)	2.52 (0.51, 12.45)
BMI at 40/50 years old							
<18.5	0.69 (0.56, 0.84)	0.86 (0.76, 0.97)	1.01 (0.84, 1.21)	0.96 (0.85, 1.09)	0.93 (0.74, 1.17)	0.88 (0.74, 1.04)	0.94 (0.76, 1.15)
18.5–24.9 (ref)	1.0	1.0	1.0	1.0	1.0	1.0	1.0
25–29.9	1.57 (1.43, 1.73)	1.06 (0.98, 1.15)	1.08 (0.96, 1.22)	1.07 (0.99, 1.15)	1.14 (1.00, 1.29)	1.12 (1.02, 1.23)	1.28 (1.14, 1.44)
30	2.84 (2.27, 3.54)	0.93 (0.74, 1.17)	0.95 (0.75, 1.19)	1.16 (0.94, 1.42)	1.38 (1.00, 1.90)	1.26 (0.99, 1.62)	1.46 (1.09, 1.95)
BMI at baseline							
<18.5	0.79 (0.62, 1.01)	1.15 (0.97, 1.36)	1.22 (0.96, 1.56)	0.93 (0.79, 1.10)	1.20 (0.92, 1.56)	0.87 (0.70, 1.08)	1.03 (0.81, 1.32)
18.5–24.9 (ref)	1.0	1.0	1.0	1.0	1.0	1.0	1.0
25–29.9	1.36 (1.25, 1.47)	1.02 (0.96, 1.08)	0.97 (0.89, 1.07)	0.98 (0.93, 1.04)	1.01 (0.91, 1.12)	1.02 (0.95, 1.11)	1.01 (0.92, 1.11)
30	2.45 (2.14, 2.82)	1.07 (0.93, 1.22)	1.05 (0.86, 1.27)	1.07 (0.95, 1.21)	1.10 (0.90, 1.35)	1.12 (0.96, 1.30)	1.26 (1.06, 1.50)
Most recent BMI							
<18.5	1.61 (1.40, 1.85)	1.12 (0.99, 1.27)	1.53 (1.29, 1.82)	1.08 (0.96, 1.21)	1.64 (1.38, 1.94)	1.20 (1.04, 1.38)	1.63 (1.40, 1.91)
18.5–24.9 (ref)	1.0	1.0	1.0	1.0	1.0	1.0	1.0
25–29.9	1.43 (1.31, 1.56)	1.01 (0.95, 1.08)	0.98 (0.89, 1.08)	1.00 (0.94, 1.06)	1.00 (0.89, 1.12)	1.03 (0.95, 1.11)	1.03 (0.94, 1.14)
30	2.48 (2.12, 2.90)	1.05 (0.91, 1.22)	1.06 (0.85, 1.31)	1.12 (0.97, 1.28)	1.21 (0.96, 1.52)	0.96 (0.81, 1.15)	1.31 (1.08, 1.60)

^aOdds ratios were additionally adjusted for sex, age, marital status, occupation, income, education, physical activity, comorbidity score, alcohol use, smoking, protein intake, vegetable intake and fruit consumption;

Table 3

Associations of weight change trajectory and waist hip ratio with functional status, the *SMHS* and *SWHS*.

	Walking independently	Hearing and vision		Memory		Making decisions independently	
	Unable to OR ^a (95% CI)	Minor problem OR ^a (95% CI)	Serious problem OR ^a (95% CI)	Some problem OR ^a (95% CI)	Serious problem OR ^a (95% CI)	Sometimes difficult OR ^a (95% CI)	Always difficult OR ^a (95% CI)
Weight change (20 year old-baseline) ^b							
1 st quartile	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2 nd quartile	1.07 (0.94, 1.23)	0.96 (0.88, 1.05)	0.87 (0.75, 1.00)	0.94 (0.86, 1.03)	0.94 (0.80, 1.12)	0.96 (0.85, 1.09)	0.88 (0.76, 1.02)
3 rd quartile	1.22 (1.07, 1.40)	0.97 (0.88, 1.06)	0.81 (0.71, 0.93)	1.01 (0.92, 1.10)	1.00 (0.85, 1.18)	0.97 (0.86, 1.09)	0.93 (0.80, 1.08)
4 th quartile	1.58 (1.39, 1.79)	0.93 (0.85, 1.02)	0.83 (0.72, 0.95)	1.06 (0.97, 1.16)	1.07 (0.91, 1.26)	1.04 (0.92, 1.17)	0.97 (0.84, 1.13)
Weight change(2.5kg)	1.06 (1.04, 1.07)	1.00 (0.99, 1.01)	0.98 (0.97, 0.99)	1.01 (1.00, 1.02)	1.01 (1.00, 1.03)	1.00 (0.99, 1.01)	1.00 (0.99, 1.02)
Weight change (20 year old to middle age) ^c							
1 st quartile	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2 nd quartile	1.03 (0.90, 1.19)	1.03 (0.94, 1.13)	0.95 (0.82, 1.09)	0.96 (0.88, 1.06)	1.05 (0.88, 1.24)	1.06 (0.94, 1.20)	0.98 (0.84, 1.14)
3 rd quartile	1.36 (1.18, 1.56)	1.05 (0.96, 1.15)	1.04 (0.90, 1.20)	1.02 (0.93, 1.12)	1.09 (0.92, 1.30)	0.98 (0.87, 1.12)	1.14 (0.98, 1.32)
4 th quartile	1.85 (1.62, 2.11)	1.03 (0.94, 1.13)	0.90 (0.78, 1.04)	1.13 (1.03, 1.24)	1.24 (1.05, 1.47)	1.16 (1.02, 1.31)	1.18 (1.01, 1.38)
Weight change (2.5kg)	1.09 (1.08, 1.11)	1.01 (0.99, 1.02)	1.00 (0.98, 1.02)	1.01 (1.00, 1.03)	1.03 (1.01, 1.05)	1.01 (0.99, 1.03)	1.03 (0.99, 1.05)
WHR							
1 st quartile	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2 nd quartile	1.22 (1.08, 1.36)	0.99 (0.91, 1.07)	0.97 (0.86, 1.09)	1.03 (0.95, 1.11)	1.00 (0.86, 1.15)	1.04 (0.94, 1.15)	1.00 (0.88, 1.13)
3 rd quartile	1.36 (1.22, 1.51)	0.94 (0.87, 1.02)	1.03 (0.92, 1.16)	1.04 (0.96, 1.12)	1.05 (0.92, 1.20)	1.01 (0.91, 1.11)	1.07 (0.95, 1.21)
4 th quartile	1.68 (1.51, 1.86)	1.02 (0.94, 1.11)	1.07 (0.95, 1.20)	1.02 (0.95, 1.11)	1.06 (0.93, 1.21)	1.12 (1.01, 1.23)	1.13 (1.00, 1.27)
WHR (0.1)	1.38 (1.29, 1.47)	0.99 (0.94, 1.05)	1.02 (0.94, 1.10)	1.05 (1.00, 1.11)	1.07 (0.98, 1.16)	1.08 (1.01, 1.15)	1.10 (1.02, 1.18)

^aOdds ratios were additionally adjusted for sex, age, marital status, occupation, income, education, physical activity, comorbidity score, alcohol use, smoking, protein intake, vegetable intake and fruit consumption;

^bQuartile cutoffs for men are: 5.6, 11.8, and 18.0 kilograms; for women are: 5.5, 11.5, and 17.7 kilograms.

^cQuartile cutoffs for men are: 1.7, 5.3, and 10.0 kilograms; for women are: 3.0, 7.6, and 13.1 kilograms.

Table 4

Associations of independent walking ability and decision-making with combined information of baseline/middle age BMI and WHR, *the SMHS and SWHS*.

			WHR^b	
		1st Tertile	2nd Tertile	3rd Tertile
Independent walking ability		OR ^a (95% CI)	OR ^a (95% CI)	OR ^a (95% CI)
BMI at baseline				
<18.5		0.81 (0.61, 1.08)	1.33 (0.74, 2.40)	1.28 (0.42, 3.85)
18.5–24.9		1.0	1.16 (1.02, 1.31)	1.36 (1.18, 1.57)
25		1.32 (1.12, 1.55)	1.62 (1.43, 1.83)	1.88 (1.68, 2.11)
Hearing and Vision				
BMI at baseline				
<18.5	Minor problem	1.16 (0.96, 1.40)	1.14 (0.70, 1.85)	1.18 (0.39, 3.56)
	Serious problem	1.29 (0.98, 1.68)	0.92 (0.44, 1.93)	1.66 (0.43, 6.36)
18.5–24.9	Minor problem	1.0	1.01 (0.93, 1.10)	1.02 (0.92, 1.13)
	Serious problem	1.0	1.03 (0.90, 1.17)	1.06 (0.91, 1.24)
25	Minor problem	1.05 (0.94, 1.18)	0.99 (0.90, 1.08)	1.06 (0.97, 1.16)
	Serious problem	0.88 (0.73, 1.05)	1.02 (0.89, 1.17)	1.04 (0.91, 1.19)
Memory				
BMI at baseline				
<18.5	Some problem	0.93 (0.78, 1.12)	1.01 (0.65, 1.57)	1.05 (0.44, 2.48)
	Serious problem	1.43 (1.08, 1.90)	0.53 (0.19, 1.48)	0.47 (0.06, 3.58)
18.5–24.9	Some problem	1.0	1.04 (0.96, 1.13)	1.01 (0.91, 1.11)
	Serious problem	1.0	1.07 (0.92, 1.25)	1.17 (0.99, 1.40)
25	Some problem	0.97 (0.87, 1.09)	1.03 (0.94, 1.13)	1.01 (0.93, 1.10)
	Serious problem	1.04 (0.85, 1.27)	1.08 (0.92, 1.26)	1.10 (0.95, 1.28)
Independent decision-making				
BMI at baseline				
<18.5	Sometimes difficult	0.88 (0.69, 1.13)	1.06 (0.61, 1.85)	0.72 (0.21, 2.51)
	Always difficult	1.16 (0.89, 1.52)	0.62 (0.27, 1.45)	1.46 (0.48, 4.48)
18.5–24.9	Sometimes difficult	1.0	1.04 (0.93, 1.16)	1.10 (0.97, 1.26)
	Always difficult	1.0	1.10 (0.97, 1.26)	1.15 (0.98, 1.34)
25	Sometimes difficult	1.04 (0.90, 1.20)	1.03 (0.92, 1.16)	1.12 (1.01, 1.25)
	Always difficult	1.07 (0.89, 1.28)	1.06 (0.92, 1.23)	1.17 (1.02, 1.33)

^aOdds ratios were additionally adjusted for sex, age, marital status, occupation, income, education, physical activity, alcohol use, smoking, comorbidity score, protein intake, vegetable intake and fruit consumption.

^bTertile cutoffs for men are: 0.88 and 0.93; for women are: 0.80 and 0.85.