

Cross-sectional and longitudinal associations of obesity with disability between age 50 and 90 in the SHARE study

Aurore Fayosse, MSc^a

Julien Dumurgier, PhD^{a,b}

Aline Dugravot, MSc^a

Benjamin Landré, PhD^a

Archana Singh-Manoux, PhD^{a,c†*}

Séverine Sabia, PhD^{a,c†}

† **Equal contribution**

^aUniversité Paris Cité, Inserm U1153, Epidemiology of Ageing and Neurodegenerative diseases, France

^bCognitive Neurology Center, Saint Louis -Lariboisiere - Fernand Widal Hospital, AP-HP; Université Paris Diderot, France

^cFaculty of Brain Sciences, Division of Psychiatry, University College London, UK

*Corresponding author & address

Université Paris Cité, Inserm U1153

Epidemiology of Ageing and Neurodegenerative diseases

75010 Paris, France

Tel: +33 (0)1 77 74 74 10

Email: Archana.Singh-Manoux@inserm.fr

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Abstract

Background Obesity is associated with disability but whether age and ageing modify this association remains unclear. We examined whether this association changes between 50 and 90 years, and whether change in disability rates over 14 years differs by body mass index (BMI) categories.

Methods BMI and ADL-disability data on 28,453 individuals from 6 waves (2004-2018, SHARE study) were used to examine the cross-sectional absolute and relative associations, extracted at age 50, 60, 70, 80, and 90 years using logistic mixed models. Then baseline BMI and change in disability rates over 14-years were examined using logistic-mixed models.

Results At age 50, the probabilities of ADL disability in individuals with BMI 30-34.9 and ≥ 35 kg/m² were 0.07 (0.06, 0.09) and 0.11 (0.09, 0.12), increasing to 0.47 (0.44, 0.50) and 0.55 (0.50, 0.60) at age 90; the increase in both these groups was greater than that in the normal-weight group (p for increase with age < 0.001). On the relative scale the OR at age 50 in these obesity groups was 2.37 (1.79, 3.13) and 5.03 (3.38, 7.48), decreasing to 1.51 (1.20, 1.89) and 2.19 (1.50, 3.21) at age 90; p for decrease with age = 0.05 and 0.02 respectively. The 14-year increase in probability of disability was greatest in those with BMI ≥ 35 kg/m² at age 50, 60, and 70 at baseline: differences in increase compared to normal weight were 0.08 (0.02, 0.14), 0.11 (0.07, 0.15), and 0.09 (0.02, 0.16) respectively.

Conclusions ADL disability is increasingly prevalent with age in individuals with obesity. Relative measures of change obscure the association between obesity and disability due to age-related increase in disability rates in all groups.

Keywords: Obesity; Disability; ADL; ageing

The prevalence of obesity, a major risk factor for several chronic diseases and mortality, is increasing rapidly worldwide.¹ Better management of risk factors has allowed the age-adjusted rates of disease and death in obese persons to stabilize,² but younger cohorts would have spent more years with obesity and this may well change the impact on health outcomes in the future, particularly in older adults. Ageing of populations will lead to an unprecedented rise in the number of people over 60 years or older,³ and as age is the strongest risk factor for disability⁴ most countries are likely to face an increasing burden of disability related health and social care costs.

The association between obesity and disability, usually measured using limitations in activities of daily living (ADL), is well established as documented in previous reviews^{5,6} and two meta-analyses.^{7,8} Most studies also find a curvilinear association between body mass index (BMI) and disability such that some excess risk is also observed in underweight persons.^{5,6,9} Among older adults, underweight is a marker of poorer health, as reflected in its association with frailty,¹⁰ a geriatric syndrome defined as a state of increased vulnerability to stressors.

Most studies on obesity and disability are based on older adults, often older than 65 years. Whether the association is present before 65 years and how it changes as a function of age remains unclear. In addition, most prospective studies examine “incident” disability as the outcome. While this information is useful, the estimates do not provide a dynamic view of how disability rates change over time groups defined by BMI. A further limitation in previous research is reliance on relative measures of association that are known to be dependent on rates in the reference group,^{11,12} often normal-weight individuals in such analyses. In order to address these limitations, we used data from the Survey of Health, Ageing and Retirement in Europe study (SHARE) to examine the association of BMI categories with disability. Using repeat data spanning 14 years and both absolute and relative measures of association, our aim was to examine 1) whether the cross-sectional association of BMI with disability varies as a function of age between 50 and 90 years, and 2) the prospective association of BMI with subsequent change in disability rates over 14 years.

METHODS

Study population

Data are drawn from SHARE, a longitudinal survey established in 2004 on over 30,000 individuals from 11 European countries and Israel. SHARE includes a range of sociological, economic, and health-related measures as described elsewhere.^{13,14} Since baseline (2004/06), 6 additional waves of data were collected in 2006/07, 2008/10, 2011/12, 2013, 2015, and 2017/18;. Several countries have joined SHARE over the course of the study, with participants now drawn from 28 European countries. For the present analysis, we used data from the 12 countries included at baseline in 2004/06 to allow longitudinal analysis with a sufficiently long follow-up period. The SHARE study has been reviewed and approved by the Ethics Committee of the University of Mannheim (until 2018) and subsequently by the Ethics Council of the Max Planck Society.

BMI

Body weight and height were self-reported at each wave and BMI calculated as weight in kilograms divided by the square of height in meters. For all the analyses BMI was categorized using WHO criteria as <18.5 kg/m² (underweight), 18.5-24.9 kg/m² (normal weight), 25.0-29.9 kg/m² (overweight), 30-34.9 kg/m² (obese class I) and ≥35 kg/m² (obese classes II and III).¹⁵

Disability

Two disability domains were measured 6 times over 14 years (in 2004/06, 2006/07, 2011/12, 2013, 2015, and 2017/18) in face-to-face interview and included difficulties in instrumental activities of daily living (IADL)¹⁶ and basic activities of daily living (ADL).¹⁷ No information on IADL and ADL were collected in 2008/10 leading us not to use data from this study wave.

Participants were asked if they had difficulties in IADL and ADL because of a physical, mental, emotional or memory problem, lasting longer than 3 months. IADLs were ascertained based on the Lawton-Brody scale¹⁶ with the following 6 items: using a map, preparing a meal, shopping, using a telephone, taking medications, and managing money. ADLs were ascertained based on the Katz scale¹⁷ and included the following 6 items: dressing, walking across a room, bathing,

transferring, eating, and toileting. The response to each item was “having difficulties” or “no difficulties”. For both IADL and ADL scales, disability was defined as having difficulties in at least 1 item out of 6. In addition, we also examined disability defined as having difficulties in at least 2 out of the 6 items.

Covariates

Covariates, assessed concurrently with BMI at each wave of data collection, included country, socio-demographic factors, health behaviours, and self-reported health conditions. Sociodemographic covariates were age, sex, education (measured according to the International Standard Classification of Educational Degrees (ISCED-97) and categorized as none or primary school, secondary school, university), and marital status (married or in a partnership, not married or single or widowed). Health behaviours included smoking status (never, ex-smoker, current smoker), alcohol consumption (none, 1-14 drinks per week, >14 drinks per week) and physical activity (none, intermediate level, active). Multimorbidity was defined as having two or more of the following 9 self-reported health conditions: coronary heart disease, hypertension, high cholesterol, stroke, diabetes, chronic lung disease, arthritis, cancer, and hip fracture.

Statistical analysis

We first examined the cross-sectional association of BMI with IADL and ADL disability as a function of age and then the prospective association between BMI at baseline and subsequent 14-year change in IADL and ADL disability rates. In all the analyses BMI was used as a categorical variable with normal weight group (BMI 18.5-24.9 kg/m²) being the reference, and we estimated both absolute and relative measures of association using difference in probability of disability and the odds ratio, respectively. All analyses were undertaken separately for IADL and ADL disability.

Cross-sectional association of BMI with IADL and ADL disability between age 50 and 90

The cross-sectional association between BMI and disability was examined using logistic mixed models with age as the timescale, and random intercept and slope. The shape of the association for age

was determined by comparing the AIC and BIC of linear, quadratic and cubic modelling of age. A linear form for age was retained for ADL and a quadratic form (age and age²) for IADL. All covariates were time-varying apart from country, sex, and education. The model included age (and age² for IADL), categorical BMI, country, sex, education, marital status, and their interactions with age (and age² for IADL if $p < 0.05$ on the Wald test). Age was centred at 65 years, the mean age at baseline. Analyses were sequentially adjusted for sociodemographic factors (model 1) and for health behaviours and multimorbidity (model 2). Predicted probabilities of IADL and ADL disability in BMI categories (using 10-year age-groups) were plotted and the absolute (probability and 95% confidence interval (CI)) and relative (Odds Ratio (OR) and 95% CI) difference in IADL and ADL disability as a function of BMI categories were estimated at age 50, 60, 70, 80, and 90 years. We examined whether absolute and relative differences in ADL/IADL disability by BMI categories differed at age 50, 60, 70, 80, and 90 years using the Wald test.

Prospective association of baseline BMI with subsequent change in disability over 14 years

The association of BMI categories at baseline (2004/06) with change in IADL and ADL disability over the 14-year follow-up was examined using logistic mixed models with time since baseline as the timescale and random intercept and slope. The shape of the association for time was determined by comparing the AIC and BIC of linear, quadratic and cubic modelling of time and a linear form was retained. The models included time since baseline (divided by 14 to yield estimates of change over 14 years), baseline BMI and covariates, and their interactions with time. As there were significant interactions between BMI and baseline age at intercept for both IADL ($p < 0.001$) and ADL ($p < 0.001$) disability, the interactions between BMI and age and between BMI, age, and time were also included. Analyses were adjusted for sociodemographic factors (model 1), and additionally for health behaviours and multimorbidity (model 2). The 14-year change in the predicted probabilities of IADL and ADL disability in the BMI categories were plotted at age 50, 60, 70, and 80 years. The absolute differences in 14-year change in probabilities in IADL and ADL disability in the BMI categories and their associated ORs were derived from the model and estimated at age 50, 60, 70, 80 years. We tested

whether absolute and relative differences in 14-year change in ADL/IADL disability by BMI categories differed at age 50, 60, 70, and 80 years using the Wald test. Older participants were excluded due to lack of disability data over 14 years after the measure of BMI.

In sensitivity analysis, we repeated the main analysis by defining disability as having difficulties in 2 or more items of the ADL (IADL) scales. All analyses were undertaken using STATA, version 17. Statistical tests were 2-sided and P-values <0.05 were considered statistically significant.

Data availability: Data available on <http://www.share-project.org/home0.html>

Results

A total of 30,424 participants across 12 countries participated in the baseline wave of SHARE. We excluded participants with missing data or those younger than 50 years at baseline, leading to analyses on 28,453 participants (flow-chart in **e-figure 1**). Of these participants, 5431 (19.1%) had data on disability at all 6 waves, 3018 (10.6%) at 5 waves, 4406 (15.5%) at 4 waves, 3129 (11.0%) at 3 waves, 5889 (20.7%) at 2 waves, and 6580 (23.1%) at one wave.

In the total study population, the prevalence of class I obesity was 13.6% (n=3876), and 3.6% (n=1028) for class II-III obesity; the overweight category was the largest (42.8%, N=12170) and the underweight (BMI<18.5 kg/m²) the smallest (1.2%, N=349) at baseline. **Figure 1** shows these data as a function of BMI categories with age in 10-year groups. The overweight group was the largest between age 56 and 78 years, after 79 years the largest group was composed of normal-weight participants. Baseline characteristics of the study participants as a function of BMI categories are shown in **e-table 1**.

Cross-sectional association of BMI with IADL and ADL disability between age 50 and 90

The association between BMI and disability was similar in men and women (p for interaction terms for IADL disability was 0.68 and 0.41 for ADL limitations), leading us to combine men and

women in all the analyses. **Figure 2** shows IADL and ADL disability rates (%) as a function of BMI with estimates, adjusted for country and sociodemographic variables, extracted at age 50, 60, 70, 80, and 90 years. IADL disability rates were highest in the underweight group and ADL disability rates highest in those with class II and III obesity at all ages (**e-table 2**).

The probability of IADL disability in the fully adjusted analyses using normal weight group as the reference (**e-table 3, Model 2**) was higher in the underweight group at all ages (all $p < 0.05$), with absolute differences increasing from 0.07 (0.01, 0.14) at age 50 to 0.10 (0.03, 0.16) at age 90, p for difference with age < 0.001 . Use of relative measures to compare IADL disability in the underweight group to those in the normal weight group yielded an OR of 3.77 (1.49, 9.59) at age 50 and 2.02 (1.28, 3.20) at age 90; these estimates did not differ by age ($p = 0.22$). Compared to the normal-weight group, IADL disability was also higher in the obese class II-III group, both in absolute and relative terms, at age 50, 60, 70, and 80 but not at age 90.

The probability of ADL disability, using normal weight group as the reference (**table 1, Model 2**), was higher in the underweight, obese class I and class II-III groups; with absolute differences increasing with age (all $p < 0.001$). For example, in the obese class I and class II-III groups the difference at age 50 was 0.03 (0.02, 0.04) and 0.06 (0.04, 0.08); this increased to 0.05 (0.02, 0.08) and 0.10 (0.05, 0.15) at age 90. Relative measures suggested otherwise, the OR for ADL disability in the class I and class II-III groups at age 50 was 2.37 (1.79, 3.13) and 5.03 (3.38, 7.48), this decreased to 1.51 (1.20, 1.89) and 2.19 (1.50, 3.21) at age 90 respectively with the p for decrease being 0.05 and 0.02 respectively.

Prospective association of baseline BMI with subsequent change in disability over 14 years

There was no evidence that sex modified the association between BMI and change in IADL ($p = 0.88$) and ADL ($p = 0.29$) disability; leading us to again combine men and women in the analyses.

The changes in probability of IADL and ADL disability over the 14-year follow-up as a function of BMI in participants 50, 60, 70, and 80 years at baseline, are shown in **figure 3 and e-table**

4. In the fully adjusted analyses of IADL disability (**Model 2, e-table 5**), the obese class II-III group had greater absolute and relative increase compared to the normal-weight group among participants aged 50, and 60 at baseline. The pattern of results was similar for increase in ADL disability (**table 2**), difference in increase was 0.08 (0.02, 0.14) and 0.11 (0.07, 0.15) respectively for participants 50 and 60 years. Relative differences in increase had an OR of 3.61 (1.31, 9.97) and 2.23 (1.24, 4.00) respectively in participants 50 and 60 years at baseline.

Additional analysis using the 2+ items on the IADL/ADL scale to define disability yielded findings that were similar to the main results although the estimated effect sizes were smaller (**e-table 6-7**).

Discussion

Our analysis of 28,453 individuals from the SHARE study presents four key findings. One, cross-sectional analyses show both IADL and ADL disability rates to increase rapidly between 50 and 90 years in all BMI groups. Compared to the normal weight group, IADL disability was persistently higher at all ages only in the underweight group while ADL disability was higher in both the underweight and obese groups. Two, absolute differences (differences in probability) suggested a trend of increasing differences with age while the relative measures suggested a weakening of associations of obesity with IADL and ADL disability. Relative differences decreased primarily due to an increase in disability in all groups with age, including the normal weight group – the reference in these analyses. Three, for the prospective analyses of change in disability rates in the groups defined by baseline BMI we found an increase in IADL and ADL disability in the obese group compared to the normal weight group in the analyses of absolute changes. Absolute changes in IADL and ADL disability were smallest in the underweight group and no different to that in the normal-weight group. Four, the adverse effect of obesity on disability was stronger in those with BMI over 35 kg/m² but also present in the 30-34.9 kg/m² group.

Disability can be measured in various ways and a gold standard definition remains to be established. Most studies use IADL and/or ADL limitations, with the convention being to classify individuals as having disability based on the presence of one or more limitations.^{7,18,19 20} IADL and ADL are thought to have a hierarchical relationship;²¹ IADL reflects early part of the disablement process,²¹ and implicates complex, cognitively demanding skills,²² while ADL represents a higher level of physical disability.

Numerous studies have shown obesity to be associated with a higher risk of physical disability;^{5,18,19,23-28} our analyses of this association has three novel features. The first consists of not focussing on “incident” disability, based on the belief that disability is a gradual process and it is unlikely that in prospective studies individuals become disabled at a precise date. Such analyses also do not allow the examination of changes in disability rates over time as a function of the exposure, BMI in our analyses. The second feature is the examination of the role of age as typically studies are based on adults 65 years and older age,^{18,20} with the analyses adjusted for age, not allowing conclusions to be drawn on how age modifies the association of BMI with disability. The third feature is the explicit examination of both relative and absolute associations. Studies on BMI and disability often use relative measures of association but the population impact of BMI is best understood by examining both relative and absolute terms. These may not lead to the same conclusions, particularly when the interest is in examining change over time (or as a function of age) and the prevalence of the health outcome changes over the observation period.^{11,12} Absolute terms reflect the difference in probability of disability (IADL, ADL) between the BMI groups, using the normal weight group as the reference whereas relative differences are ratios. As is clear in our results (Tables 2 and 3) the fact that disability increases in all groups, comparison with the normal weight group shows smaller odds ratios at older ages, suggesting a weakening of association with age, while the absolute differences show an increase in disability rates at older ages.

A narrative review concluded that obesity at younger ages is likely to carry greater risk for disability than obesity at older ages,⁶ but the evidence to support this point of view is inconsistent.

Both IADL and ADL disability are known to increase with age,⁴ as was the case in our analyses between the age of 50 and 90, and use of relative measures of association may be misleading in this context. The view that obesity is less harmful at older ages comes from studies on mortality, primarily studies that examine relative risk. Studies that also examine absolute risk report that although relative risk is higher at younger ages the absolute excess mortality is higher in older adults.²⁹⁻³¹ A related question, given ageing of populations and increase in obesity rates, is change in the association between obesity and disability over time. Data on adults aged 60 years and older in the National Health and Nutrition Examination Survey show the relative odds of ADL impairment in obese compared to normal-weight increased between 1994 and 2004²³ but remained stable between 2005 and 2012.²⁸ There is some evidence to suggest that the obese population is getting healthier, particularly in relation to cardiovascular risk, over time.³² A recent study based on the Health and Retirement Study showed that although obesity increased rapidly between 1993–1998 to 2010–2014, the 2-year probability of becoming disabled decreased most rapidly in the obese (BMI between 30 and 35) group.³³ We did not examine temporal changes in the association between obesity and disability but these findings constitute an important backdrop to the present results.

Previous studies report a U or J-shaped association between BMI and disability,^{5-9,18,34} and our results also show higher IADL and ADL disability in the underweight compared to normal-weight group, irrespective of age in the cross-sectional analyses. This was not the case for change over time as both ADL and IADL disability levels in the underweight group were similar to that in the normal weight group. It is possible that the cross-sectional association is due to confounding although our analyses were adjusted for health behaviors and multimorbidity. Confounding due to health conditions other than those examined in the present study, such as frailty,¹⁰ could explain the consistently higher IADL disability between age 50 and 90 in the underweight group. As in previous studies, compared to normal weight participants we did not find robust evidence for a greater increase over 14-years in IADL^{8,9} or ADL disability^{7,18} in the overweight group.

Obesity is thought to be linked to disability through multiple pathways, the most important being chronic conditions associated with obesity.^{18,24,35-37} These include osteoarthritis of the weight-bearing joints, type 2 diabetes, coronary heart disease, stroke, asthma, several cancers, and cardiovascular disease. Whether the association of obesity with disability is primarily due to osteoarthritis, chronic back pain, and overall wear and tear on the musculoskeletal system remains unclear. Our results on IADL disability, where musculoskeletal system is implicated to a lesser extent, suggest that there are other likely explanations for this association.

The strengths of our study include the large sample size, with data from 12 countries. There are variations in the obesity and disability rates within the countries in SHARE,⁵ but the association between BMI categories and disability were broadly similar across all countries. Other strengths include the analytic strategy adopted, whereby both relative and absolute measures of association were used in the cross-sectional and prospective analyses. The primary limitation of the study is that all measures were self-reported. This is unlikely to substantially affect the conclusions drawn in the present study as all the analyses, on differences as a function of age or change over time, are based on self-report data. BMI may not be best measure of obesity,³⁸ and further research using measures of central obesity are needed to confirm our findings. A further limitation is residual confounding despite the adjustment for a range of covariates.

In conclusion, our results highlight the importance of obesity for ADL disability starting at age 50 and continuing to age 90. The analyses of change in the prevalence of disability show that both IADL and ADL disability increase over time in the obese compared to normal-weight individuals. Taken together these results do not show disability to be simply obesity's price of longevity,³⁹ but suggest that obesity is accompanied by disability, starting in midlife, and it affects a greater proportion of individuals who are obese with the passage of time. These findings highlight the public health importance of tackling the obesity epidemic.

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Conflicts of Interest We declare no conflicts of interest.

Table 1. Cross-sectional association between BMI categories and activities of daily living (ADL) disability at age 50, 60, 70, 80, and 90 years

BMI categories	Model 1 ^{a, b}		Model 2 ^{a, c}	
	Difference in probability (95 % CI)	Odds Ratio (95 % CI)	Difference in probability (95 % CI)	Odds Ratio (95 % CI)
Age 50				
Underweight	0.04 (0.01, 0.06)**	4.08 (2.00, 8.34)**	0.04 (0.01, 0.07)**	3.18 (1.64, 6.17)**
Normal weight	0 (Reference)	1 (Reference)	0 (Reference)	1 (Reference)
Overweight	0.01 (0.00, 0.01)**	1.41 (1.12, 1.79)**	0.01 (-0.00, 0.01)	1.20 (0.96, 1.49)
Obese class I	0.03 (0.02, 0.04)**	3.71 (2.74, 5.04)**	0.03 (0.02, 0.04)**	2.37 (1.79, 3.13)**
Obese class II & III	0.07 (0.05, 0.08)**	10.15 (6.55, 15.74)**	0.06 (0.04, 0.08)**	5.03 (3.38, 7.48)**
Age 60				
Underweight	0.05 (0.03, 0.07)**	3.82 (2.34, 6.24)**	0.05 (0.02, 0.07)**	2.94 (1.86, 4.64)**
Normal weight	0 (Reference)	1 (Reference)	0 (Reference)	1 (Reference)
Overweight	0.01 (0.00, 0.01)**	1.29 (1.11, 1.51)**	0.01 (-0.00, 0.01)	1.15 (1.00, 1.33)
Obese class I	0.04 (0.03, 0.04)**	3.04 (2.50, 3.70)**	0.03 (0.02, 0.04)**	2.12 (1.77, 2.53)**
Obese class II & III	0.08 (0.07, 0.10)**	7.64 (5.81, 10.04)**	0.07 (0.05, 0.08)**	4.09 (3.18, 5.24)**
Age 70				
Underweight	0.08 (0.06, 0.10)**	3.58 (2.62, 4.88)**	0.06 (0.04, 0.09)**	2.71 (2.03, 3.63)**
Normal weight	0 (Reference)	1 (Reference)	0 (Reference)	1 (Reference)
Overweight	0.01 (0.00, 0.01)**	1.18 (1.07, 1.30)**	0.01 (0.00, 0.01)*	1.11 (1.01, 1.21)*
Obese class I	0.05 (0.05, 0.06)**	2.49 (2.20, 2.82)**	0.04 (0.03, 0.04)**	1.89 (1.69, 2.12)**
Obese class II & III	0.12 (0.10, 0.14)**	5.75 (4.79, 6.89)**	0.08 (0.07, 0.09)**	3.32 (2.81, 3.92)**
Age 80				
Underweight	0.13 (0.10, 0.16)**	3.35 (2.53, 4.42)**	0.09 (0.06, 0.12)**	2.51 (1.94, 3.24)**
Normal weight	0 (Reference)	1 (Reference)	0 (Reference)	1 (Reference)
Overweight	0.01 (-0.00, 0.02)	1.08 (0.97, 1.20)	0.01 (-0.00, 0.01)	1.07 (0.97, 1.18)
Obese class I	0.07 (0.06, 0.09)**	2.04 (1.75, 2.38)**	0.05 (0.03, 0.06)**	1.69 (1.47, 1.94)**
Obese class II & III	0.16 (0.13, 0.20)**	4.32 (3.34, 5.60)**	0.10 (0.07, 0.13)**	2.70 (2.13, 3.41)**
Age 90				
Underweight	0.13 (0.08, 0.18)**	3.13 (2.04, 4.81)**	0.11 (0.05, 0.16)**	2.32 (1.57, 3.42)**
Normal weight	0 (Reference)	1 (Reference)	0 (Reference)	1 (Reference)
Overweight	-0.00 (-0.02, 0.02)	0.99 (0.83, 1.18)	0.00 (-0.02, 0.02)	1.03 (0.88, 1.20)
Obese class I	0.06 (0.03, 0.09)**	1.67 (1.30, 2.15)**	0.05 (0.02, 0.08)**	1.51 (1.20, 1.89)**
Obese class II & III	0.14 (0.09, 0.19)**	3.25 (2.14, 4.95)**	0.10 (0.05, 0.15)**	2.19 (1.50, 3.21)**
P for difference by age^d				
Underweight	<0.001	0.61	<0.001	0.50
Normal weight	Reference	Reference	Reference	Reference
Overweight	0.02	0.06	0.29	0.37
Obese class I	<0.001	0.002	<0.001	0.05
Obese class II & III	<0.001	0.004	<0.001	0.02

*P<0.05; **P<0.01.

Abbreviations: BMI, body mass index; CI, confidence interval.

^a Estimates were extracted from logistic mixed models including age, BMI categories, and interaction between BMI categories and age.

^b Model 1 is adjusted for country, sex, education, marital status and their interactions with age.

^c Model 2 is Model 1 additionally adjusted for smoking, alcohol, physical activity and multimorbidity and their interactions with age.

^d P-value from a Wald test to evaluate whether differences in ADL disability by BMI categories differed at age 50, 60, 70, 80, and 90 years.

All variables were time-varying apart for country, sex, and education.

Table 2. Association between baseline BMI at age 50, 60, 70, and 80 years and subsequent 14-year change in activities of daily living (ADL) disability

BMI categories	Model 1 ^{a, b}		Model 2 ^{a, c}	
	Absolute difference in 14-year change in probability (95 % CI)	Relative difference (OR) in 14-year change in probability (95 % CI)	Absolute difference in 14-year change in probability (95 % CI)	Relative difference (OR) in 14-year change in probability (95 % CI)
Age 50				
Underweight	-0.03 (-0.09, 0.04)	0.29 (0.04, 2.25)	-0.03 (-0.10, 0.03)	0.34 (0.04, 2.62)
Normal weight	0 (Reference)	1 (Reference)	0 (Reference)	1 (Reference)
Overweight	0.01 (-0.00, 0.02)	1.17 (0.66, 2.08)	0.01 (-0.01, 0.02)	1.28 (0.73, 2.23)
Obese class I	0.00 (-0.02, 0.02)	0.73 (0.36, 1.50)	0.00 (-0.02, 0.03)	0.97 (0.48, 1.95)
Obese class II & III	0.07 (0.01, 0.13)*	2.09 (0.75, 5.82)	0.08 (0.02, 0.14)**	3.61 (1.31, 9.97)*
Age 60				
Underweight	-0.04 (-0.12, 0.04)	0.29 (0.08, 1.07)	-0.04 (-0.12, 0.03)	0.34 (0.09, 1.28)
Normal weight	0 (Reference)	1 (Reference)	0 (Reference)	1 (Reference)
Overweight	0.02 (0.00, 0.03)*	1.10 (0.78, 1.56)	0.02 (-0.00, 0.03)	1.18 (0.84, 1.66)
Obese class I	0.02 (-0.00, 0.05)	0.83 (0.54, 1.27)	0.03 (0.00, 0.05)*	1.05 (0.69, 1.60)
Obese class II & III	0.10 (0.05, 0.15)**	1.45 (0.81, 2.62)	0.11 (0.07, 0.15)**	2.23 (1.24, 4.00)**
Age 70				
Underweight	-0.07 (-0.18, 0.04)	0.29 (0.09, 0.96)*	-0.05 (-0.16, 0.05)	0.35 (0.11, 1.18)
Normal weight	0 (Reference)	1 (Reference)	0 (Reference)	1 (Reference)
Overweight	0.01 (-0.01, 0.04)	1.03 (0.77, 1.38)	0.01 (-0.01, 0.04)	1.09 (0.82, 1.46)
Obese class I	0.04 (0.00, 0.07)*	0.94 (0.63, 1.39)	0.04 (0.01, 0.08)*	1.14 (0.77, 1.69)
Obese class II & III	0.07 (-0.00, 0.14)	1.01 (0.49, 2.10)	0.09 (0.02, 0.16)*	1.37 (0.67, 2.83)
Age 80				
Underweight	-0.11 (-0.30, 0.09)	0.29 (0.05, 1.84)	-0.07 (-0.27, 0.12)	0.36 (0.06, 2.31)
Normal weight	0 (Reference)	1 (Reference)	0 (Reference)	1 (Reference)
Overweight	0.00 (-0.05, 0.05)	0.97 (0.61, 1.55)	0.00 (-0.04, 0.05)	1.01 (0.64, 1.62)
Obese class I	0.02 (-0.04, 0.09)	1.06 (0.55, 2.06)	0.04 (-0.02, 0.10)	1.24 (0.64, 2.39)
Obese class II & III	-0.02 (-0.14, 0.10)	0.71 (0.20, 2.50)	0.02 (-0.11, 0.14)	0.85 (0.24, 2.98)
P for difference by age^d				
Underweight	0.29	0.99	0.65	0.96
Normal weight	Reference	Reference	Reference	Reference
Overweight	0.04	0.67	0.02	0.60
Obese class I	<0.001	0.54	<0.001	0.67
Obese class II & III	<0.001	0.29	<0.001	0.15

*P<0.05; **P<0.01.

Abbreviations: BMI, body mass index; OR, odds ratio; CI, confidence interval.

^a Estimates were extracted from logistic mixed models including time (per 14 years), BMI categories, age, their interactions with time, interactions between BMI categories and age, and between BMI categories, age, and time.

Estimates at age 90 were not computed due to insufficient number of participants with 14-year follow-up.

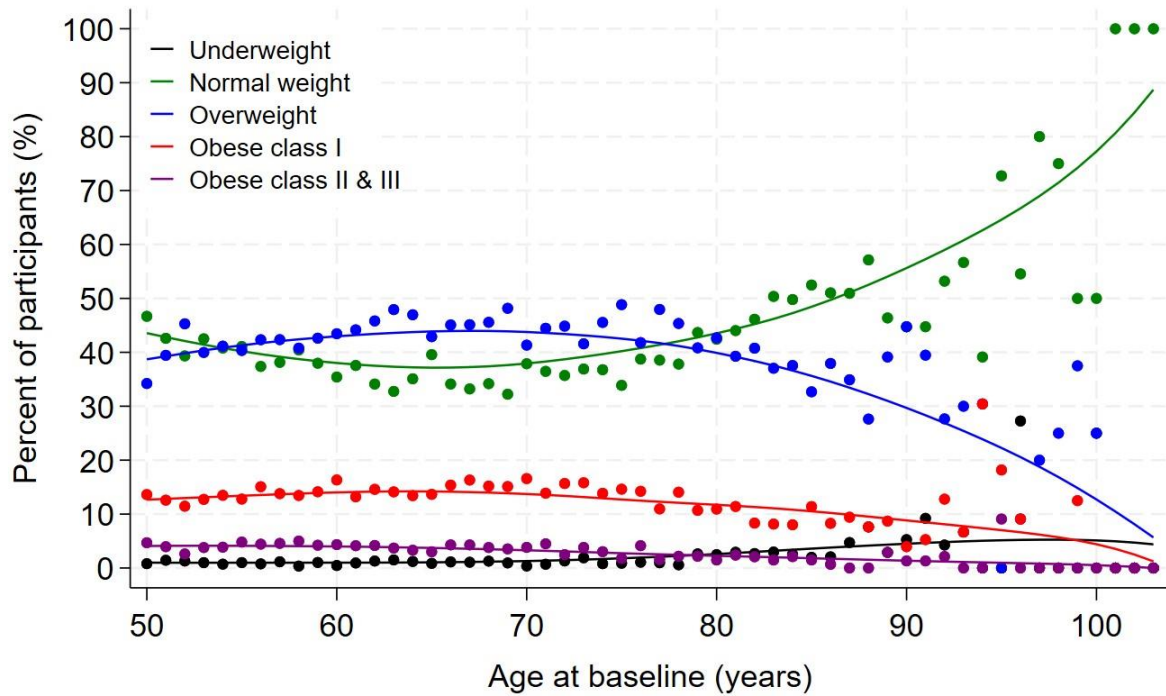
^b Model 1 is adjusted for country, sex, education and baseline marital status and their interactions with time.

^c Model 2 is Model 1 additionally adjusted for baseline smoking, alcohol, physical activity, multimorbidity and their interactions with time.

^d P-value from a Wald test to evaluate whether differences in 14-year change in ADL disability by BMI categories differed at age 50, 60, 70, and 80 years.

All variables apart from time were drawn from baseline.

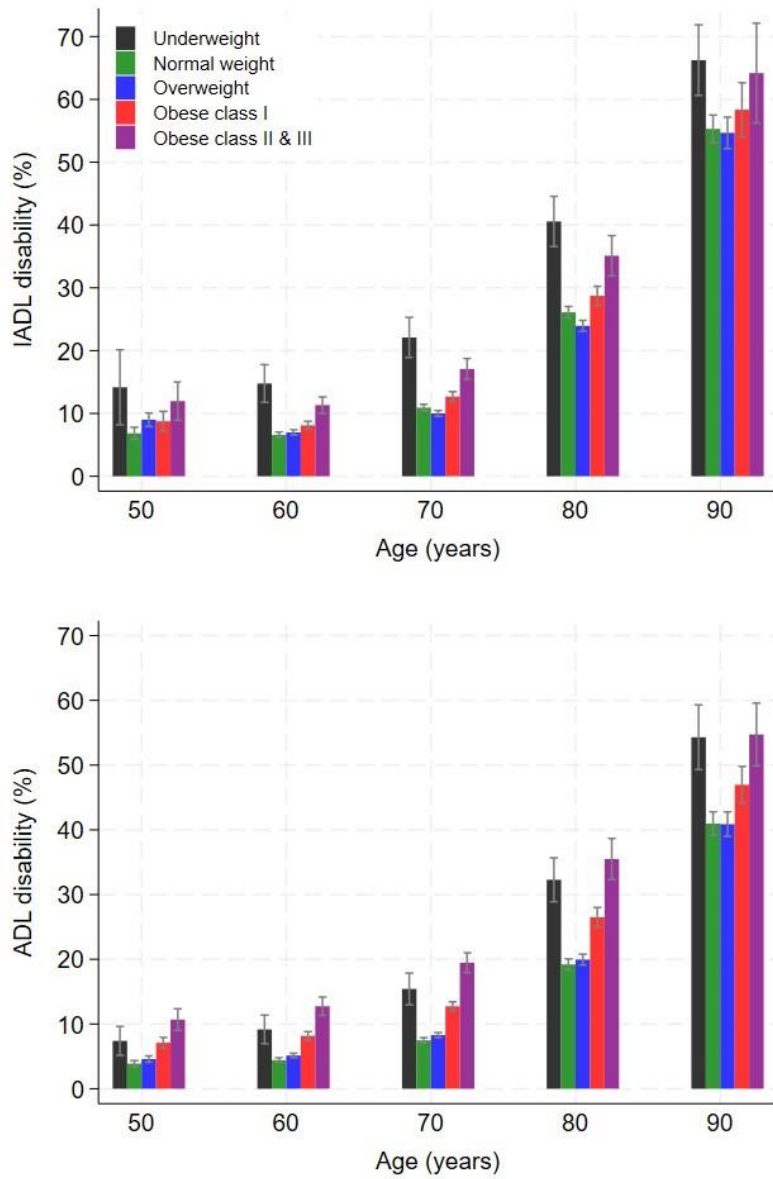
Figure 1. Raw data showing participants who were underweight, normal-weight, overweight, and obese at baseline, as a function of age-group.*



<i>N in BMI categories</i>	50-59	60-69	70-79	80-89	90-99	≥100
Underweight	103	95	66	66	18	1
Normal weight	4369	3160	2279	1072	144	6
Overweight	4411	4112	2687	860	99	1
Obese class I	1433	1333	869	215	26	0
Obese class II & III	451	350	186	37	4	0

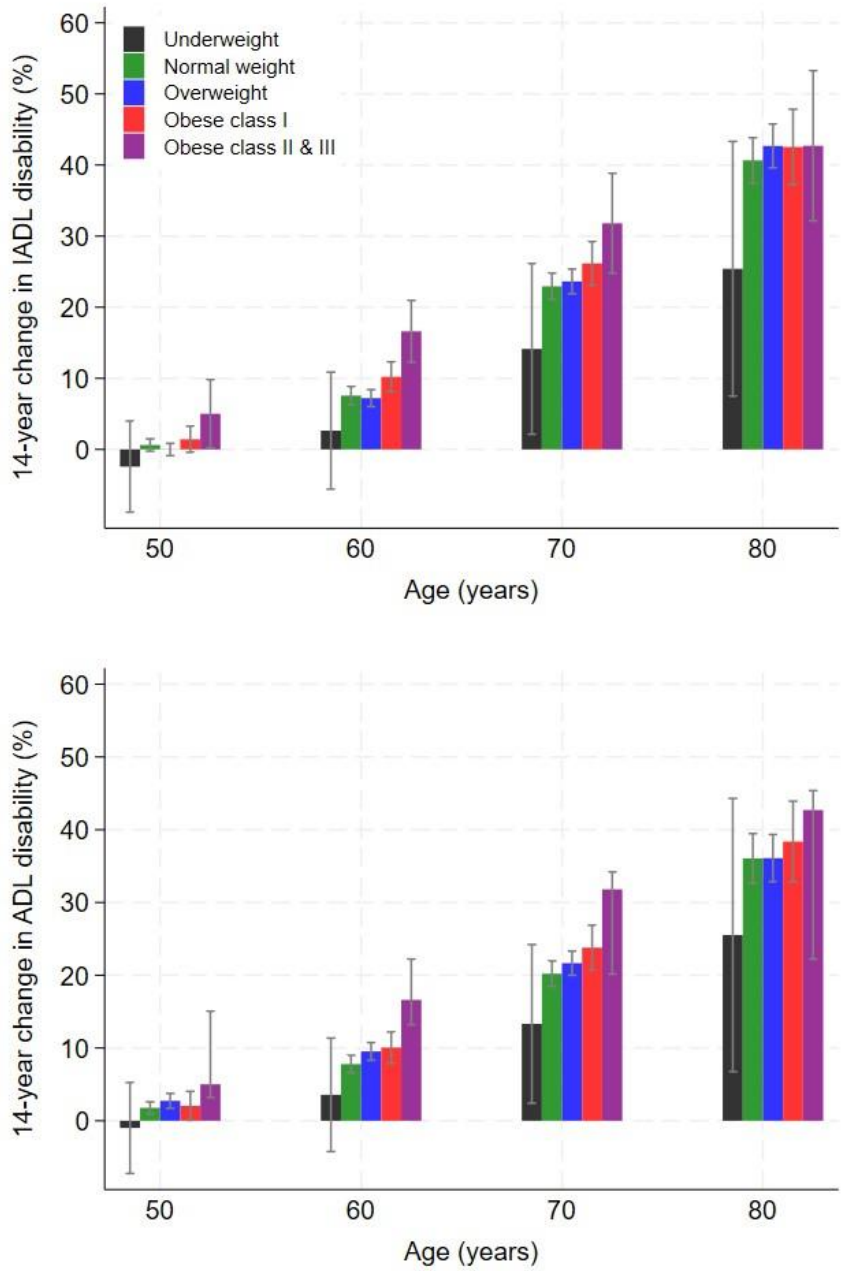
*Data shown in the figure are percentages, the smoothed line shows trends with age, and the tabulated data under the figure are number of participants.

Figure 2. Rates (%) of IADL and ADL disability as a function of BMI categories at age 50, 60, 70, 80, and 90 years (cross-sectional associations)*



*Rates are drawn from logistic mixed models including age (and age² for IADL), BMI categories, BMI categories by age (and age² for IADL) in analyses adjusted for country and sociodemographic factors (sex, education, marital status), and their interactions with age (and age² for IADL). All variables were used as time-varying variables apart from country, sex, and education. Associated estimates are provided in **e-table 2**.

Figure 3. Fourteen-year change in IADL and ADL disability rates (%) as a function of baseline BMI in participants 50, 60, 70, and 80 years*



*The changes in rates are drawn from logistic mixed models including time since baseline, BMI categories, age, country and sociodemographic factors (sex, education, marital status) and their interactions with time, interactions between BMI categories and age, and between BMI categories, age and time. All variables apart from time were drawn from baseline. Associated estimates are provided in **e-table 4**.

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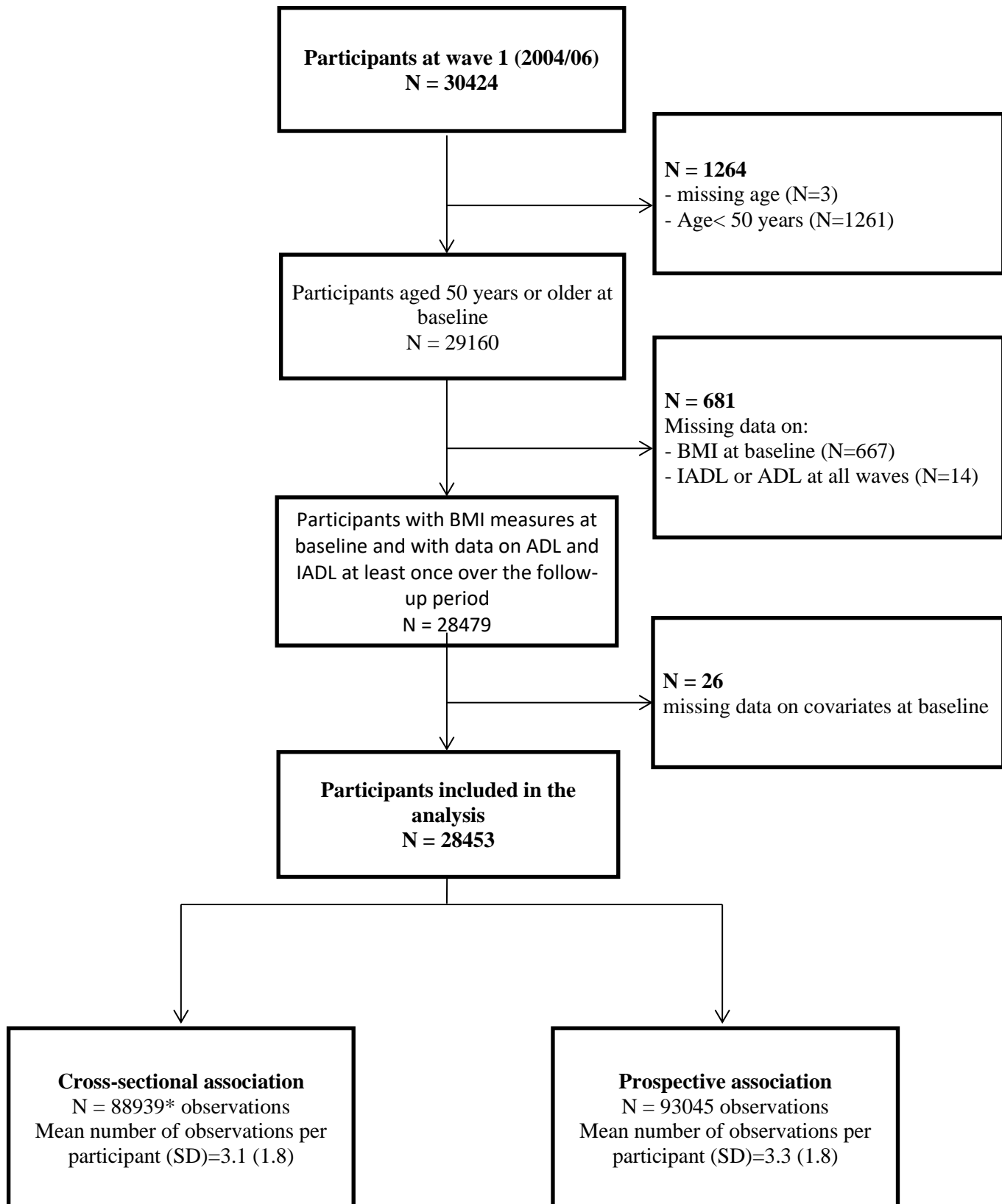
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Supplementary Figure and Tables

1 e-figure 1. Flow chart

2



Abbreviation: SD, standard deviation.

*N = 4106 observations with missing data on BMI or covariates during the follow-up.

3 e-table 1. Baseline characteristics according to categories of BMI

	BMI categories					P ^a
	Underweight N=349	Normal weight N=11030	Overweight N=12170	Obese class I N= 3876	Obese class II & III N= 1028	
Age (years), M (SD)	68.5 (12.4)	64.6 (10.6)	64.5 (9.7)	64.1 (9.3)	62.5 (8.6)	<0.001
Sex, women	287 (82.2)	6601 (59.8)	5642 (46.4)	2104 (54.3)	675 (65.7)	<0.001
Education						<0.001
Primary	142 (40.7)	3169 (28.7)	4227 (34.7)	1613 (41.6)	461 (44.8)	
Secondary	141 (40.4)	5280 (47.9)	5688 (46.7)	1773 (45.7)	452 (44.0)	
Higher	66 (18.9)	2581 (23.4)	2255 (18.5)	490 (12.6)	115 (11.2)	
Marital status						<0.001
Married/cohabiting	194 (55.6)	7770 (70.4)	9128 (75.0)	2810 (72.5)	693 (67.4)	
Other	155 (44.4)	3260 (29.6)	3042 (25.0)	1066 (27.5)	335 (32.6)	
Smoking						<0.001
Never	163 (46.7)	5877 (53.3)	6246 (51.3)	2091 (53.9)	589 (57.3)	
Ex-smoker	71 (20.3)	2790 (25.3)	3764 (30.9)	1164 (30.0)	293 (28.5)	
Current	115 (33.0)	2363 (21.4)	2160 (17.7)	621 (16.0)	146 (14.2)	
Alcohol						<0.001
None	261 (74.8)	6880 (62.4)	7299 (60.0)	2550 (65.8)	753 (73.2)	
1-14 drinks per week	67 (19.2)	3364 (30.5)	3753 (30.8)	1009 (26.0)	224 (21.8)	
>14 drinks per week	21 (6.0)	786 (7.1)	1118 (9.2)	317 (8.2)	51 (5.0)	
Physical activity						<0.001
No	97 (27.8)	1475 (13.4)	1713 (14.1)	749 (19.3)	276 (26.8)	
Intermediate level	39 (11.2)	1132 (10.3)	1444 (11.9)	496 (12.8)	133 (12.9)	
Active	213 (61.0)	8423 (76.4)	9013 (74.1)	2631 (67.9)	619 (60.2)	
Multimorbidity^b	82 (23.5)	2560 (23.2)	3910 (32.1)	1647 (42.5)	507 (49.3)	<0.001
IADL disability^c	117 (33.5)	1321 (12.0)	1489 (12.2)	567 (14.6)	211 (20.5)	<0.001
ADL disability^d	80 (22.9)	914 (8.3)	1100 (9.0)	521 (13.4)	213 (20.7)	<0.001

4 Numbers are N (%), otherwise stated.

5 Abbreviations: BMI, body mass index; SD, standard deviation; IADL, Instrumental Activities of Daily Living;

6 ADL, Activities of Daily Living.

7 ^a P for heterogeneity.

8 ^b Defined as having 2 or more of the following 9 conditions: coronary heart disease, hypertension, high cholesterol, stroke, diabetes, chronic lung disease, arthritis, cancer and hip fracture.

10 ^c Corresponds to “having difficulties” in at least one IADL.

11 ^d Corresponds to “having difficulties” in at least one ADL.

12

13 **e-table 2. Probability of IADL and ADL disability as a function of BMI categories at age 50, 60,**
 14 **70, 80, and 90 years (cross-sectional associations)^a**

BMI categories	IADL	ADL	15
	Probability (95 % CI)	Probability (95 % CI)	
Age 50			
Underweight	0.14 (0.08, 0.20)**	0.07 (0.05, 0.10)**	
Normal weight	0.07 (0.06, 0.08)**	0.04 (0.03, 0.04)**	
Overweight	0.09 (0.08, 0.10)**	0.05 (0.04, 0.05)**	
Obese class I	0.09 (0.07, 0.10)**	0.07 (0.06, 0.08)**	
Obese class II & III	0.12 (0.09, 0.15)**	0.11 (0.09, 0.12)**	
Age 60			
Underweight	0.15 (0.12, 0.18)**	0.09 (0.07, 0.11)**	
Normal weight	0.07 (0.06, 0.07)**	0.04 (0.04, 0.05)**	
Overweight	0.07 (0.07, 0.07)**	0.05 (0.05, 0.05)**	
Obese class I	0.08 (0.07, 0.09)**	0.08 (0.08, 0.09)**	
Obese class II & III	0.11 (0.10, 0.13)**	0.13 (0.11, 0.14)**	
Age 70			
Underweight	0.22 (0.19, 0.25)**	0.15 (0.13, 0.18)**	
Normal weight	0.11 (0.10, 0.11)**	0.07 (0.07, 0.08)**	
Overweight	0.10 (0.10, 0.11)**	0.08 (0.08, 0.09)**	
Obese class I	0.13 (0.12, 0.13)**	0.13 (0.12, 0.13)**	
Obese class II & III	0.17 (0.15, 0.19)**	0.19 (0.18, 0.21)**	
Age 80			
Underweight	0.41 (0.37, 0.45)**	0.32 (0.29, 0.36)**	
Normal weight	0.26 (0.25, 0.27)**	0.19 (0.18, 0.20)**	
Overweight	0.24 (0.23, 0.25)**	0.20 (0.19, 0.21)**	
Obese class I	0.29 (0.27, 0.30)**	0.26 (0.25, 0.28)**	
Obese class II & III	0.35 (0.32, 0.38)**	0.35 (0.32, 0.39)**	
Age 90			
Underweight	0.66 (0.61, 0.72)**	0.54 (0.49, 0.59)**	
Normal weight	0.55 (0.53, 0.58)**	0.41 (0.39, 0.43)**	
Overweight	0.55 (0.52, 0.57)**	0.41 (0.39, 0.43)**	
Obese class I	0.58 (0.54, 0.63)**	0.47 (0.44, 0.50)**	
Obese class II & III	0.64 (0.56, 0.72)**	0.55 (0.50, 0.60)**	

16 *P<0.05; **P<0.01.

17 Abbreviations: BMI, body mass index; CI, confidence interval.

18 ^aProbabilities are drawn from logistic mixed models including age (and age² for IADL), BMI categories in
 19 analyses adjusted for country and sociodemographic factors (sex, education, marital status), and their
 20 interactions with age (and age² for IADL). All variables were used as time-varying variables apart from country,
 21 sex, and education.

22

23 **e-table 3. Cross-sectional association between BMI categories and instrumental activities of daily**
 24 **living (IADL) disability at age 50, 60, 70, 80, and 90 years**

BMI categories	Model 1 ^{a, b}		Model 2 ^{a, c}	
	Difference in probability (95 % CI)	Odds Ratio (95 % CI)	Difference in probability (95 % CI)	Odds Ratio (95 % CI)
Age 50				
Underweight	0.07 (0.01, 0.13)*	4.47 (1.69, 11.83)**	0.07 (0.01, 0.14)*	3.77 (1.49, 9.59)**
Normal weight	0 (Reference)	1 (Reference)	0 (Reference)	1 (Reference)
Overweight	0.02 (0.01, 0.03)**	1.71 (1.24, 2.34)**	0.02 (0.01, 0.03)**	1.51 (1.12, 2.05)**
Obese class I	0.02 (0.00, 0.04)*	1.61 (1.05, 2.46)*	0.01 (-0.01, 0.03)	1.27 (0.84, 1.91)
Obese class II & III	0.05 (0.02, 0.08)**	3.08 (1.69, 5.59)**	0.04 (0.01, 0.07)*	2.29 (1.29, 4.06)**
Age 60				
Underweight	0.08 (0.05, 0.11)**	4.31 (2.84, 6.53)**	0.08 (0.05, 0.11)**	3.53 (2.37, 5.26)**
Normal weight	0 (Reference)	1 (Reference)	0 (Reference)	1 (Reference)
Overweight	0.00 (-0.00, 0.01)	1.10 (0.96, 1.25)	0.00 (-0.01, 0.01)	1.01 (0.89, 1.14)
Obese class I	0.02 (0.01, 0.02)**	1.41 (1.19, 1.67)**	0.01 (-0.00, 0.01)	1.10 (0.94, 1.30)
Obese class II & III	0.05 (0.03, 0.06)**	2.58 (2.03, 3.27)**	0.03 (0.01, 0.04)**	1.66 (1.32, 2.08)**
Age 70				
Underweight	0.11 (0.08, 0.14)**	3.85 (2.81, 5.30)**	0.10 (0.07, 0.13)**	3.12 (2.30, 4.21)**
Normal weight	0 (Reference)	1 (Reference)	0 (Reference)	1 (Reference)
Overweight	-0.01 (-0.02, -0.00)**	0.86 (0.78, 0.95)**	-0.01 (-0.02, -0.01)**	0.81 (0.74, 0.90)**
Obese class I	0.02 (0.01, 0.03)**	1.30 (1.14, 1.49)**	0.00 (-0.01, 0.01)	1.03 (0.90, 1.17)
Obese class II & III	0.06 (0.04, 0.08)**	2.27 (1.85, 2.79)**	0.02 (0.01, 0.04)**	1.38 (1.13, 1.68)**
Age 80				
Underweight	0.14 (0.11, 0.18)**	3.20 (2.37, 4.32)**	0.11 (0.08, 0.15)**	2.59 (1.95, 3.43)**
Normal weight	0 (Reference)	1 (Reference)	0 (Reference)	1 (Reference)
Overweight	-0.02 (-0.03, -0.01)**	0.82 (0.74, 0.91)**	-0.02 (-0.03, -0.01)**	0.80 (0.72, 0.87)**
Obese class I	0.03 (0.01, 0.04)**	1.26 (1.09, 1.45)**	0.00 (-0.01, 0.02)	1.02 (0.89, 1.16)
Obese class II & III	0.09 (0.06, 0.12)**	2.11 (1.63, 2.73)**	0.03 (0.00, 0.06)*	1.32 (1.04, 1.68)*
Age 90				
Underweight	0.11 (0.05, 0.17)**	2.47 (1.51, 4.02)**	0.10 (0.03, 0.16)**	2.02 (1.28, 3.20)**
Normal weight	0 (Reference)	1 (Reference)	0 (Reference)	1 (Reference)
Overweight	-0.01 (-0.03, 0.02)	0.95 (0.76, 1.18)	-0.01 (-0.04, 0.02)	0.94 (0.76, 1.15)
Obese class I	0.03 (-0.01, 0.08)	1.28 (0.89, 1.83)	0.01 (-0.04, 0.06)	1.07 (0.77, 1.50)
Obese class II & III	0.09 (0.01, 0.17)*	2.07 (1.05, 4.07)*	0.05 (-0.04, 0.14)	1.45 (0.76, 2.74)
P for difference by age^d				
Underweight	<0.001	0.26	<0.001	0.22
Normal weight	Reference	Reference	Reference	Reference
Overweight	<0.001	<0.001	<0.001	0.001
Obese class I	<0.001	0.56	0.80	0.64
Obese class II & III	<0.001	0.50	0.02	0.24

25 *P<0.05; **P<0.01.

26 Abbreviations: BMI, body mass index; CI, confidence interval.

27 ^a Estimates were extracted from logistic mixed models including BMI categories, age, age², and interactions of
 28 BMI categories with age and age².

29 ^b Model 1 is adjusted for country, sex, education, marital status and their interactions with age and age².

30 ^c Model 2 is Model 1 additionally adjusted for smoking, alcohol, physical activity and multimorbidity and their
 31 interactions with age and age².

32 ^d P-value from a Wald test to evaluate whether differences in IADL disability by BMI categories differed at age
 33 50, 60, 70, 80, and 90 years.

34 All variables were time-varying apart for country, sex, and education.

35 **e-table 4. Fourteen-year change in probability of IADL and ADL disability rates as a function of**
 36 **baseline BMI in participants 50, 60, 70, and 80 years^a**

BMI categories	IADL	ADL
	Absolute 14-year change in probability (95 % CI)	Absolute 14-year change in probability (95 % CI)
Age 50		
Underweight	-0.02 (-0.09, 0.04)	-0.01 (-0.07, 0.05)
Normal weight	0.01 (-0.00, 0.01)	0.02 (0.01, 0.03)**
Overweight	-0.00 (-0.01, 0.01)	0.03 (0.02, 0.04)**
Obese class I	0.01 (-0.00, 0.03)	0.02 (0.00, 0.04)*
Obese class II & III	0.05 (0.00, 0.10)*	0.09 (0.03, 0.15)**
Age 60		
Underweight	0.03 (-0.06, 0.11)	0.04 (-0.04, 0.11)
Normal weight	0.08 (0.06, 0.09)**	0.08 (0.07, 0.09)**
Overweight	0.07 (0.06, 0.08)**	0.10 (0.08, 0.11)**
Obese class I	0.10 (0.08, 0.12)**	0.10 (0.08, 0.12)**
Obese class II & III	0.17 (0.12, 0.21)**	0.18 (0.13, 0.22)**
Age 70		
Underweight	0.14 (0.02, 0.26)*	0.13 (0.02, 0.24)*
Normal weight	0.23 (0.21, 0.25)**	0.20 (0.18, 0.22)**
Overweight	0.24 (0.22, 0.25)**	0.22 (0.20, 0.23)**
Obese class I	0.26 (0.23, 0.29)**	0.24 (0.21, 0.27)**
Obese class II & III	0.32 (0.25, 0.39)**	0.27 (0.20, 0.34)**
Age 80		
Underweight	0.25 (0.07, 0.43)**	0.26 (0.07, 0.44)**
Normal weight	0.41 (0.37, 0.44)**	0.36 (0.33, 0.39)**
Overweight	0.43 (0.40, 0.46)**	0.36 (0.33, 0.39)**
Obese class I	0.43 (0.37, 0.48)**	0.38 (0.33, 0.44)**
Obese class II & III	0.43 (0.32, 0.53)**	0.34 (0.22, 0.45)**

37 *P<0.05; **P<0.01.

38 Abbreviations: BMI, body mass index; OR, odds ratio; CI, confidence interval,.

39 ^aThe change in rates are drawn from logistic mixed models including time since baseline, BMI categories, age,
 40 country and sociodemographic factors (sex, education, marital status) and their interactions with time,
 41 interactions between BMI categories and age, and between BMI categories, age and time. All variables apart
 42 from time were drawn from baseline.

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46 **e-table 5. Association between baseline BMI at age 50, 60, 70, 80 years and subsequent 14-year**
 47 **change in instrumental activities of daily living (IADL) disability**

BMI categories	Model 1 ^{a, b}		Model 2 ^{a, c}	
	Absolute difference in 14-year change in probability (95 % CI)	Relative difference (OR) in 14-year change in probability (95 % CI)	Absolute difference in 14-year change in probability (95 % CI)	Relative difference (OR) in 14-year change in probability (95 % CI)
Age 50				
Underweight	-0.03 (-0.09, 0.03)	0.46 (0.07, 2.93)	-0.04 (-0.10, 0.03)	0.47 (0.07, 2.96)
Normal weight	0 (Reference)	1 (Reference)	0 (Reference)	1 (Reference)
Overweight	-0.01 (-0.02, 0.01)	0.77 (0.46, 1.28)	-0.01 (-0.02, 0.01)	0.79 (0.48, 1.31)
Obese class I	0.01 (-0.01, 0.03)	1.29 (0.67, 2.51)	0.01 (-0.01, 0.03)	1.49 (0.77, 2.87)
Obese class II & III	0.04 (-0.01, 0.09)	2.56 (0.97, 6.78)	0.05 (0.01, 0.10)*	3.67 (1.40, 9.63)**
Age 60				
Underweight	-0.05 (-0.13, 0.03)	0.39 (0.12, 1.21)	-0.05 (-0.13, 0.03)	0.42 (0.13, 1.31)
Normal weight	0 (Reference)	1 (Reference)	0 (Reference)	1 (Reference)
Overweight	-0.00 (-0.02, 0.01)	0.90 (0.66, 1.22)	-0.00 (-0.02, 0.01)	0.92 (0.68, 1.24)
Obese class I	0.03 (0.00, 0.05)*	1.26 (0.86, 1.86)	0.03 (0.00, 0.05)*	1.43 (0.97, 2.10)
Obese class II & III	0.09 (0.05, 0.14)**	2.13 (1.22, 3.71)**	0.09 (0.05, 0.14)**	2.72 (1.56, 4.73)**
Age 70				
Underweight	-0.09 (-0.21, 0.03)	0.32 (0.10, 1.03)	-0.07 (-0.19, 0.05)	0.37 (0.12, 1.19)
Normal weight	0 (Reference)	1 (Reference)	0 (Reference)	1 (Reference)
Overweight	0.01 (-0.02, 0.03)	1.05 (0.81, 1.37)	0.01 (-0.02, 0.03)	1.07 (0.82, 1.39)
Obese class I	0.03 (-0.00, 0.07)	1.24 (0.86, 1.79)	0.03 (-0.00, 0.07)	1.37 (0.95, 1.98)
Obese class II & III	0.09 (0.02, 0.16)*	1.77 (0.87, 3.60)	0.09 (0.02, 0.16)*	2.01 (0.99, 4.09)
Age 80				
Underweight	-0.15 (-0.33, 0.03)	0.27 (0.04, 1.76)	-0.11 (-0.30, 0.07)	0.33 (0.05, 2.18)
Normal weight	0 (Reference)	1 (Reference)	0 (Reference)	1 (Reference)
Overweight	0.02 (-0.02, 0.06)	1.23 (0.79, 1.91)	0.02 (-0.02, 0.06)	1.24 (0.80, 1.91)
Obese	0.02 (-0.04, 0.08)	1.21 (0.64, 2.27)	0.03 (-0.03, 0.09)	1.32 (0.70, 2.46)
Obese	0.02 (-0.09, 0.13)	1.47 (0.43, 5.07)	0.04 (-0.07, 0.15)	1.49 (0.44, 5.11)
P for difference by age^d				
Underweight	0.002	0.73	0.04	0.83
Normal weight	Reference	Reference	Reference	Reference
Overweight	0.66	0.25	0.50	0.27
Obese class I	0.007	0.91	0.01	0.83
Obese class II & III	<0.001	0.57	<0.001	0.36

48 *P<0.05; **P<0.01.

49 Abbreviations: BMI, body mass index; OR, odds ratio; CI, confidence interval.

50 ^a Estimates were extracted from logistic mixed models including time (per 14 years), BMI categories, age, their interactions with time, interactions between BMI categories and age, and between BMI categories, age, and time. Estimates at age 90 were not computed due to insufficient number of participants with 14-year follow-up.

53 ^b Model 1 is adjusted for country, sex, education and baseline marital status and their interactions with time.

54 ^c Model 2 is Model 1 additionally adjusted for baseline smoking, alcohol, physical activity, multimorbidity and their interactions with time.

56 ^d P-value from a Wald test to evaluate whether differences in 14-year change in IADL disability by BMI categories differed at age 50, 60, 70, and 80 years.

58 All variables apart from time were drawn from baseline.

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60 **e-Table 6. Cross-sectional association between BMI categories and activities of daily living**
61 **(ADL) and instrumental activities of daily living (IADL) disabilities at age 50, 60, 70, 80, and 90**
62 **years, defined using having difficulties in at least 2 items of the ADL/IADL scale.**

BMI categories	ADL ^{a, b}		IADL ^{a, b}	
	Difference in probability (95 % CI)	Odds Ratio (95 % CI)	Difference in probability (95 % CI)	Odds Ratio (95 % CI)
Age 50				
Underweight	0.02 (0.00, 0.04)*	3.69 (1.58, 8.61)**	0.04 (-0.00, 0.09)	5.97 (1.35, 26.41)*
Normal weight	0 (Reference)	1 (Reference)	0 (Reference)	1 (Reference)
Overweight	-0.00 (-0.00, 0.00)	0.99 (0.72, 1.37)	-0.01 (-0.01, 0.00)	0.73 (0.41, 1.32)
Obese class I	0.00 (-0.00, 0.01)	1.37 (0.91, 2.07)	-0.00 (-0.02, 0.01)	0.76 (0.35, 1.64)
Obese class II & III	0.01 (0.00, 0.02)*	2.02 (1.15, 3.56)*	0.00 (-0.02, 0.02)	1.14 (0.39, 3.34)
Age 60				
Underweight	0.03 (0.01, 0.04)**	3.42 (1.88, 6.20)**	0.04 (0.02, 0.06)**	4.88 (2.52, 9.45)**
Normal weight	0 (Reference)	1 (Reference)	0 (Reference)	1 (Reference)
Overweight	-0.00 (-0.00, 0.00)	0.96 (0.78, 1.20)	-0.01 (-0.01, -0.00)**	0.68 (0.53, 0.87)**
Obese class I	0.01 (0.00, 0.01)*	1.39 (1.06, 1.83)*	-0.00 (-0.01, 0.00)	0.77 (0.56, 1.06)
Obese class II & III	0.01 (0.01, 0.02)**	2.00 (1.39, 2.89)**	0.00 (-0.01, 0.01)	1.08 (0.71, 1.65)
Age 70				
Underweight	0.04 (0.02, 0.05)**	3.17 (2.17, 4.63)**	0.05 (0.03, 0.07)**	3.99 (2.61, 6.09)**
Normal weight	0 (Reference)	1 (Reference)	0 (Reference)	1 (Reference)
Overweight	-0.00 (-0.01, 0.00)	0.94 (0.82, 1.07)	-0.01 (-0.01, -0.01)**	0.70 (0.60, 0.82)**
Obese class I	0.01 (0.01, 0.01)**	1.42 (1.20, 1.67)**	-0.00 (-0.01, 0.00)	0.84 (0.68, 1.03)
Obese class II & III	0.02 (0.01, 0.03)**	1.99 (1.58, 2.51)**	0.00 (-0.00, 0.01)	1.18 (0.87, 1.60)
Age 80				
Underweight	0.06 (0.04, 0.08)**	2.94 (2.19, 3.94)**	0.08 (0.05, 0.10)**	3.25 (2.24, 4.72)**
Normal weight	0 (Reference)	1 (Reference)	0 (Reference)	1 (Reference)
Overweight	-0.00 (-0.01, 0.00)	0.91 (0.81, 1.03)	-0.01 (-0.02, -0.00)**	0.81 (0.71, 0.93)**
Obese class I	0.02 (0.01, 0.03)**	1.44 (1.22, 1.71)**	-0.00 (-0.01, 0.01)	0.97 (0.81, 1.17)
Obese class II & III	0.03 (0.02, 0.05)**	1.97 (1.49, 2.61)**	0.02 (0.00, 0.04)*	1.48 (1.09, 2.00)*
Age 90				
Underweight	0.09 (0.05, 0.13)**	2.72 (1.78, 4.17)**	0.10 (0.05, 0.16)**	2.65 (1.60, 4.37)**
Normal weight	0 (Reference)	1 (Reference)	0 (Reference)	1 (Reference)
Overweight	-0.01 (-0.02, 0.01)	0.89 (0.73, 1.07)	0.01 (-0.02, 0.03)	1.06 (0.83, 1.36)
Obese class I	0.03 (0.01, 0.05)*	1.47 (1.11, 1.94)**	0.02 (-0.02, 0.06)	1.19 (0.79, 1.80)
Obese class II & III	0.06 (0.01, 0.10)**	1.95 (1.24, 3.08)**	0.08 (-0.01, 0.16)	2.12 (0.98, 4.56)
P for difference by age^d				
Underweight	<0.001	0.59	<0.001	0.37
Normal weight	Reference	Reference	Reference	Reference
Overweight	0.69	0.62	<0.001	0.03
Obese class I	<0.001	0.83	0.46	0.28
Obese class II & III	<0.001	0.94	0.11	0.33

63 *P<0.05; **P<0.01; Abbreviations: BMI, body mass index; CI, confidence interval.

64 ^a Estimates were extracted from logistic mixed models including age, BMI categories, and interaction between
65 BMI categories and age.

66 ^b Models are adjusted for country, sex, education, marital status, smoking, alcohol, physical activity and
67 multimorbidity and their interactions with age.

68 ^c P-value from a Wald test to examine whether differences in ADL disability by BMI categories differed at age
69 50, 60, 70, 80, and 90 years.

70 All variables were time-varying apart for country, sex, and education.

71 **e-Table 7. Association between baseline BMI at age 50, 60, 70, and 80 years and subsequent 14-**
72 **year change in activities of daily living (ADL) and instrumental activities of daily living (IADL)**
73 **disabilities, defined using having difficulties in at least 2 items of the ADL/IADL scale.**

BMI categories	ADL ^{a, b}		IADL ^{a, b}	
	Absolute difference in 14-year change in probability (95 % CI)	Relative difference (OR) in 14-year change in probability (95 % CI)	Absolute difference in 14-year change in probability (95 % CI)	Relative difference (OR) in 14-year change in probability (95 % CI)
Age 50				
Underweight	0.01 (-0.04, 0.05)	1.72 (0.09, 32.50)	-0.01 (-0.04, 0.01)	0.19 (0.01, 4.60)
Normal weight	0 (Reference)	1 (Reference)	0 (Reference)	1 (Reference)
Overweight	-0.00 (-0.01, 0.01)	0.75 (0.31, 1.80)	0.01 (0.00, 0.01)*	2.78 (1.11, 6.95)*
Obese class I	0.00 (-0.01, 0.01)	1.01 (0.36, 3.34)	0.01 (0.00, 0.02)*	4.77 (1.46, 15.57)*
Obese class II & III	0.03 (-0.00, 0.07)	4.55 (1.03, 20.20)*	0.02 (-0.00, 0.04)	4.70 (0.87, 25.52)
Age 60				
Underweight	0.02 (-0.04, 0.09)	1.35 (0.20, 9.07)	-0.01 (-0.07, 0.05)	0.44 (0.06, 3.36)
Normal weight	0 (Reference)	1 (Reference)	0 (Reference)	1 (Reference)
Overweight	-0.00 (-0.02, 0.01)	0.88 (0.51, 1.51)	0.01 (-0.00, 0.02)	1.66 (0.94, 2.93)
Obese class I	0.01 (-0.01, 0.02)	0.98 (0.50, 1.91)	0.02 (0.00, 0.04)*	2.43 (1.19, 4.96)*
Obese class II & III	0.07 (0.04, 0.11)**	3.39 (1.42, 8.10)**	0.06 (0.02, 0.09)**	3.37 (1.28, 8.89)*
Age 70				
Underweight	0.04 (-0.06, 0.14)	1.07 (0.21, 5.28)	0.06 (-0.06, 0.17)	1.06 (0.21, 5.22)
Normal weight	0 (Reference)	1 (Reference)	0 (Reference)	1 (Reference)
Overweight	-0.00 (-0.02, 0.02)	1.03 (0.68, 1.56)	-0.01 (-0.03, 0.02)	0.99 (0.67, 1.48)
Obese class I	0.01 (-0.02, 0.04)	0.88 (0.51, 1.50)	0.01 (-0.03, 0.04)	1.24 (0.72, 2.12)
Obese class II & III	0.10 (0.04, 0.17)**	2.52 (0.97, 6.55)	0.09 (0.03, 0.16)**	2.41 (0.94, 6.20)
Age 80				
Underweight	0.04 (-0.15, 0.22)	0.84 (0.08, 8.70)	0.11 (-0.05, 0.27)	2.51 (0.23, 26.92)
Normal weight	0 (Reference)	1 (Reference)	0 (Reference)	1 (Reference)
Overweight	0.00 (-0.04, 0.05)	1.21 (0.64, 2.29)	-0.04 (-0.09, 0.00)	0.60 (0.33, 1.09)
Obese class I	0.01 (-0.06, 0.07)	0.78 (0.33, 1.88)	-0.04 (-0.11, 0.02)	0.63 (0.26, 1.50)
Obese class II & III	0.09 (-0.03, 0.22)	1.88 (0.37, 9.66)	0.07 (-0.05, 0.18)	1.73 (0.33, 8.96)
P for difference by age^d				
Underweight	0.09	0.74	0.52	0.26
Normal weight	Reference	Reference	Reference	Reference
Overweight	0.30	0.46	0.19	0.02
Obese class I	0.06	0.69	0.10	0.02
Obese class II & III	<0.001	0.52	<0.001	0.50

74 *P<0.05; **P<0.01.

75 Abbreviations: BMI, body mass index; OR, odds ratio; CI, confidence interval.

76 ^a Estimates were extracted from logistic mixed models including time (per 14 years), BMI categories, age, their interactions with time, interactions between BMI categories and age, and between BMI categories, age, and time.

78 Estimates at age 90 were not computed due to insufficient number of participants with 14-year follow-up.

79 ^b Models are adjusted for country, sex, education, baseline marital status, smoking, alcohol, physical activity, multimorbidity and their interactions with time.

81 ^c P-value from a Wald test to evaluate whether differences in 14-year change in ADL disability by BMI categories differed at age 50, 60, 70, and 80 years.

83 All variables apart from time were drawn from baseline.

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