Impact of Obesity, Overweight and Underweight on Life Expectancy and Lifetime Medical Expenditures: The Ohsaki Cohort Study

Journal:	*BMJ Open*
Manuscript ID:	bmjopen-2012-000940
Article Type:	Research
Date Submitted by the Author:	25-Jan-2012
Complete List of Authors:	Nagai, Masato; Tohoku University Graduate School of Medicine, Division of Epidemiology, Department of Public Health and Forensic Medicine Kuriyama, Shinichi; Tohoku University Graduate School of Medicine, Department of Molecular Epidemiology, Environment and Genome Research Center; Tohoku University Graduate School of Medicine, Division of Epidemiology, Department of Public Health and Forensic Medicine Kakizaki, Masako; Tohoku University Graduate School of Medicine, Division of Epidemiology, Department of Public Health and Forensic Medicine Ohmori-Matsuda, Kaori; Tohoku University Graduate School of Medicine, Division of Epidemiology, Department of Public Health and Forensic Medicine Sone, Toshimasa; Tohoku University Graduate School of Medicine, Division of Epidemiology, Department of Public Health and Forensic Medicine Hozawa, Atsushi; Yamagata University Graduate School of Medical Science, Department of Public Health; Tohoku University Graduate School of Medicine, Division of Epidemiology, Department of Public Health and Forensic Medicine Kawado, Miyuki; Fujita Health University School of Medicine, Department of Hygiene Hashimoto, Shuji; Fujita Health University School of Medicine, Department of Hygiene
Primary Subject Heading:	Epidemiology
Secondary Subject Heading:	Health economics, Public health
Keywords:	Body mass index, Life expectancy, Lifetime medical expenditure, Longevity, Obesity

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Research

Impact of Obesity, Overweight and Underweight on Life Expectancy and Lifetime Medical Expenditures: The Ohsaki Cohort Study

Running Title: BMI, Life Expectancy, and Lifetime Medical Cost

Masato Nagai, PhD[1], Shinichi Kuriyama, MD, PhD[1, 2], Masako Kakizaki, PhD[1], Kaori Ohmori-Matsuda, MD, PhD[1], Toshimasa Sone, MSc[1], Atsushi Hozawa, MD, PhD[1, 3], Miyuki Kawado, PhD[4], Shuji Hashimoto, PhD[4], and Ichiro Tsuji, MD, PhD[1]

[1] Division of Epidemiology, Department of Public Health and Forensic Medicine, Tohoku University Graduate School of Medicine, Sendai, Japan

[2] Department of Molecular Epidemiology, Environment and Genome Research Center, Tohoku University Graduate School of Medicine, Sendai, Japan

[3] Department of Public Health, Yamagata University Graduate School of Medical Science, Yamagata, Japan

[4] Department of Hygiene, Fujita Health University School of Medicine, Toyoake, Japan

Address for correspondence:

Masato Nagai, PhD.

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Division of Epidemiology, Department of Public Health and Forensic Medicine, Tohoku University Graduate School of Medicine, Sendai, Japan

2-1 Seiryo-machi, Aoba-ku, Sendai, Miyagi, 980-8575, Japan

Phone: +81-22-717-8123

Fax: +81-22-717-8125

E-mail: m-nagai@med.tohoku.ac.jp

Manuscript information:

#Financial support: This study was supported by a Health Sciences Research Grant for Health Services (H21-Choju-Ippan-001, H20-Junkankitou (Seisyu)-Ippan-013, H22-Junkankitou (Seisyu)-Ippan-012), Ministry of Health, Labour and Welfare, Japan. Masato Nagai is a recipient of a Research Fellowships of the Japan Society for the Promotion of Science for Young Scientists.

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#Word counts: 2,985

#References: 34

#Tables: 3

#Figures: 2

#Page: 3

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Abstract

Objective

People who are obese have higher demands for medical care than those of normal weight. However, in view of their shorter life expectancy, it is unclear whether obese people have higher lifetime medical expenditure. We examined the association between body mass index (BMI), life expectancy, and lifetime medical expenditure.

Method

We followed up 41,965 participants aged 40-79 years and prospectively collected data on their medical expenditure and survival covering a 13-year period. Participants were classified the following BMI categories: <18.5, 18.5-24.9 (normal weight), 25.0-29.9 (overweight), ≥30.0 kg/m^2 (obesity). We constructed life tables, and estimated the life expectancy and lifetime medical expenditure from 40 years of age using estimate of multiadjusted mortality and medical expenditure by Poisson regression model and linear regression model, respectively.

Results

In spite of their shorter life expectancy, obese participants required higher medical expenditure than normal weight participants. In men aged 40 years, multiadjusted life expectancy for those who were obese participants was 41.4 years, which was 1.7 years shorter than that for normal weight participants (*p*=0.3184). Multiadjusted lifetime medical expenditure for obese participants was £112,858.9, being 14.7% higher than

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that for normal weight participants (*p*=0.1141). In women aged 40 years, multiadjusted life expectancy for those who were obese participants was 49.2 years, which was 3.1 years shorter than for normal weight participants (*p*=0.0724), and multiadjusted lifetime medical expenditure was £137,765.9, being 21.6% higher (*p*=0.0005).

Discussion

Lifetime medical expenditure appears to be higher for obese participants, despite their short life expectancy. With weight control, more people would enjoy their longevity with lower demands for medical care.

(260 words)

Key Words: Body mass index; Life expectancy; Lifetime medical expenditure; Longevity; Obesity;

Introduction

Obesity is closely associated with an increased risk of cardiovascular disease (CVD), cancer, hypertension, diabetes mellitus, and other medical problems. Previous studies have reported that obese and overweight people have higher needs and demands for medical care than normal weight people. [1-5] However, it is unclear whether obese people have higher lifetime medical expenditure than those of normal weight, because the former have a comparatively shorter life expectancy. [6-10] Additionally, underweight people have a higher risk of mortality, and thus also tend to have higher medical expenditure per month or per person, based on a 10-year follow-up. [1 4]

Although four previous studies have examined the association between obesity and lifetime medical expenditure, [10-13] the results were inconsistent. One study showed that obese people had lower lifetime medical expenditure than those of normal weight, [11] whereas the others indicated that obese people had higher lifetime medical expenditure. [10 12 13] In addition, two of the four studies estimated lifetime medical expenditure from excess risk of cause-specific mortality and mean medical expenditure for the index disease. [10 11] Only the other two studies calculated lifetime medical expenditure on the basis of individual medical expenditure and mortality. [12 13] However, one of those studies followed up the participants for only 2 years, [12] and the

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other calculated lifetime medical expenditure for elderly participants aged 70 years or over.[13] Therefore, the association between body mass index (BMI) and lifetime medical expenditure remains to be fully clarified.

We therefore conducted a 13-year prospective observation of 41,965 Japanese adults aged 40-79 years living in the community, which accrued 392,860 person-years. We examined the association between BMI and lifetime medical expenditure, based on individual medical expenditure and life table analysis.[1 14-17] For all participants, this cohort study collected data for survival and all medical-care utilization and costs, excluding home care services provided home health aides, nursing home care, and preventive health services.

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Materials and methods

Study cohort

We used data from the Ohsaki National Health Insurance (NHI) Cohort Study.[1 14 16-18] In brief, we sent a self-administered questionnaire on various lifestyle habits between October and December 1994 to all NHI beneficiaries living in the catchment area of Ohsaki Public Health Center, Miyagi Prefecture, northeastern Japan. A survey was conducted of NHI beneficiaries aged 40 to 79 years. Among 54,996 eligible individuals, 52,029 (95%) responded.

We excluded 776 participants who had withdrawn from the NHI before January 1, 1995, when we started the prospective collection of NHI claim files. Thus, 51,253 participants formed the study cohort. The study protocol was approved by the Ethics Committee of Tohoku University School of Medicine. The participants who had returned the self-administered questionnaires and had signed them were considered to have consented to participate in this study.

For the current analysis, we also excluded participants who did not provide information about body weight and height (n=3,543), were at both extremes of the BMI range: lower than the 0.05th percentile for BMI (below 14.41 for men; below 13.67 for women) or higher than the 99.95th percentile for BMI (above 58.46 for men; above 62.00 for women; n=48), those who died within the first year (n=454), or those who had

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a history of cancer (n=1,533), myocardial infarction (n=1,233), stroke (n=831), or kidney disease (n=1,646). Thus, a total of 41,965 participants (20,066 men and 21,899 women) participated.

Body mass index

The self-administered questionnaire included questions on weight and height, and BMI was calculated as weight divided by the square of height (kg/m²). We divided the participants into groups according to the following BMI categories: <18.5 (underweight), 18.5-24.9 (normal weight), 25.0-29.9 (overweight), and ≥30.0 kg/m² (obesity). These BMI categories correspond to the cut-off points proposed by the World Health Organization (WHO): normal BMI range (18.5-24.9 kg/m²), grade 1 overweight (25.0-29.9 kg/m²), grade 2 overweight (30.0-39.9 kg/m²), and grade 3 overweight (≥40.0 kg/m²). [19]

The validity of self-reported body weight and height has been reported earlier [1]. Briefly, the weight and height of 14,883 participants, who were a subsample of the cohort, were measured during basic health examinations provided by local governments in 1995. The Pearson correlation coefficient (r) and weighted kappa (κ) between the self-reported values and measured values was r=0.96 (p<.01) for weight, r=0.93 (p<.01) for height, and r=0.88 (p<.01) and κ=0.72 for BMI categories. Thus, the self-reported heights and weights were considered to be sufficiently valid.

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Health insurance system in Japan

The details of the NHI system have been described previously.[1 4 14 16 18] Briefly, everyone living in Japan is required to enroll in one health insurance system. The NHI covers 35% of the Japanese population for almost all medical treatment, including diagnostic tests, medication, surgery, supplies and materials, physicians and other personnel costs, and most dental treatment. It also covers home care services provided by physicians and nurses but not those by other professionals such as home health aides. The NHI covers inpatient care but not nursing home care. Also, it does not cover preventive health services such as mass screening and health education. Payment to medical providers is made on a fee-for-service basis, where the price of each service is determined by a uniform national fee schedule.

If a participant withdrew from the NHI system because of death, emigration, or employment, the withdrawal date and the reason for withdrawal were coded in the NHI withdrawal history files. We recorded any mortality or migration by reviewing the NHI withdrawal history files and collected data on the death of participants by reviewing the death certificates filed at Ohsaki Public Health Center. We then followed up the participants and prospectively collected data on medical care utilization and its costs for all participants in the cohort from January 1, 1995 through December 31, 2007.

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Statistical analysis

We conducted the same analysis as previous study.[16] Briefly, we divided the age-groups (x) from 40 years according to the following categories: 40-44, 45-49, 50-54, 55-59, 60,64, 65-69, 70-74, 75-79, 80-84, and ≥85 years. Based on person-years and the number of deaths from 1996 until 2007, the multiadjusted mortality rates for each age category were estimated from a Poisson regression model. The dependent variable was mortality and independent variables were age-groups, categories of BMI, and the following covariates: smoking status (current and past smoker, or never smoker), alcohol consumption (current drinker consuming 1-499 g/week, current drinker consuming ≥450 g/week, or never and past drinker), sports and physical exercise (≥3 hours/week or <3 hours/week), time spent walking (≥1 hours/week or <1 hours/week), education (junior high school, high school, or college/university or higher). We did not adjust for hypertension and diabetes mellitus in the multivariate models because these variables are considered to occupy an intermediate position in the etiologic pathway between BMI and mortality.

We separately calculated medical expenditure for participants who survived through the index year and for those who died because of increasing medical expenditure before death. [20] The multiadjusted medical expenditure per year was estimated using a linear regression model adjusted for the above covariates in survivors and decedents.

The estimates of multiadjusted mortality and medical expenditure were used for

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estimating life expectancy and lifetime medical expenditure from 40 years of age. To estimate life expectancy and lifetime medical expenditure, we constructed life tables per100,000 persons using Chiang's analytical method on the basis of the latest published complete life tables of Japan for the year 2000.[21 22] Then, life expectancy (e_x) and lifetime medical expenditure (M_x) for each age-groups (x) were estimated using the numbers of survivors (l_x), deaths (d_x), static population (L_x), multiadjusted medical expenditure for survivors (a_y), and multiadjusted medical expenditure for the deceased (b_y) as follows;

$\sum$ is sum of $y \geq x$

$$e_x = \frac{\sum L_y}{l_x}$$

$$M_x = \frac{\sum (L_y \cdot a_y + d_y \cdot b_y)}{l_x}$$

The 95% confidence intervals (CIs) were estimated using a Monte Carlo simulation based on a Poisson regression model and linear regression model. We repeated 100,000 times and all analysis were used the SAS version 9.1 statistical software package (SAS Institute Inc., 2004). All *p* values were differences at p<.05 were accepted as statistically significant.

We used a purchasing power parity rate of UK£ 1.00=JPN¥ 140.

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Results

After 13 years of follow-up, we observed 5,159 deaths (3,356 men and 1,803 women) among the 41,965 participants (20,066 men and 21,899 women).

The mean medical expenditure per year for survivors in men was £2,392.7 in underweight, £2,055.0 in normal weight, £2,230.7 in overweight, and £2,333.6 in obesity, respectively. In women, it was £2,374.6 in underweight, £1,972.0 in normal weight, £2,316.9 in overweight, and £2,733.0 in obesity, respectively. These differences of mean medical expenditure per year for survivors are statistically significant in men and women (p<.0001). Also, the mean medical expenditure in the year of death for participants in men was £15,445.1 in underweight, £16,973.3 in normal weight, £17,810.6 in overweight, and £17,878.3 in obesity, respectively. In women, it was £12,833.1 in underweight, £15,584.2 in normal weight, £17,058.6 in overweight, and £19,635.8 in obesity, respectively. These differences of mean medical expenditure in the year of death for participants are statistically significant in only women (men; p=0.2241, women; p=0.0059).

Baseline characteristics by BMI category

The baseline characteristics of the study participants according to the BMI categories are shown for men and women (Table 1), among whom 3.3% and 3.9% were

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underweight, 23.6% and 28.4% were overweight, and 2.0% and 3.6% were obese, respectively.

Mean age in men decreased linearly with increasing BMI category. In women, mean age was highest in the underweight category. The proportions of men and women who were current and past smokers decreased with increasing BMI, and this tendency was especially marked in men. The proportions of men who had never and past drinker were highest in the underweight category. The proportions of men who did ≥3 hours sports and physical exercise per week decreased with increasing BMI. The proportions of men and women who walked ≥1 hours per day were the lowest in underweight men and obese women. Educational background increased linearly in men and decreased linearly in women as the BMI category increased. These characteristics showed statistically significant difference.

Mortality in terms of categories for BMI

Figure 1-a for men and Figure 1-b for women show the mortality (per 1,000 person-years) in each of the age-groups according to the categories of BMI.

In underweight participants, there was a tendency that the mortality was the highest in each age-group. Overweight participants showed similar mortality with normal weight participants, especially women. Overweight men showed slightly lower mortality than normal weight men. In obese participants, the mortality curve was not

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described smoothly because of small number of participants.

Table 2 shows the mortality ratio with 95% CIs according to the categories of BMI. In underweight participants, the multiadjusted mortality ratio was significantly higher than that in normal weight participants (men; 1.62, 95%CIs; 1.41-1.86, *p*<.0001, women; 1.46, 1.22-1.76, *p*<.0001). In overweight participants, the multiadjusted mortality ratio was significantly lower in men and non-significantly lower in women than that in normal weight participants (men; 0.91, 0.83-0.99, *p*=0.0260, women; 0.98, 0.88-1.10, *p*=0.7841). In obese participants, the multiadjusted mortality ratio was non-significantly higher than that in normal weight participants (men; 1.14, 0.88-1.49, *p*=0.3177, women; 1.23, 0.98-1.55, *p*=0.0717).

Life expectancy and lifetime medical expenditure by BMI category

Table 3 show life expectancy and lifetime medical expenditure with 95% CIs according to the BMI categories.

By multiadjusted analysis, obese men and women had approximately 1.7 years and 3.1 years shorter life expectancy from the age of 40 years in comparison with men and women of normal weight, respectively. Meanwhile, obese men and women had approximately 14.7% and 21.6% higher lifetime medical expenditure in comparison with normal weight participants, respectively.

In men, multiadjusted life expectancy was greatest for overweight, i.e. 44.34 years

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(95% CI; 43.11-45.54, *p*=0.0264), followed by normal weight (43.03 years, 42.22-43.73), and obesity (41.36 years, 38.28-44.70, *p*=0.3184), and was shortest for underweight (37.40 years, 35.80-38.87, *p*<.0001). The multiadjusted lifetime medical expenditure for overweight was the highest, i.e. £114,766.9 (95% CI; 107,754.1-121,966.6, *p*<.0001), followed by obesity (£112,858.9, 94,954.1-131,840.9, *p*=0.1141) and normal weight (£98,355.0, 93,615.3-103,010.2), and was the lowest for underweight (£93,208.7, 81,704.9-104,706.4, *p*=0.3916).

In women, multiadjusted life expectancy was greatest for overweight, i.e. 52.56 years (50.67-54.46, *p*=0.7797), followed by normal weight (52.31 years, 50.79-53.75), and obesity (49.23 years, 46.14-52.59, *p*=0.0724), and was shortest for underweight (46.98 years, 44.63-49.29, *p*<.0001). The lifetime medical expenditure for obesity was the highest (£137,765.9, 123,672.9-152,970.2, *p*=0.0005), followed by overweight (£129,964.6, 121,845.4-138,577.2, *p*<.0001), and normal weight (£113,282.9, 106,668.0-120,054.6), and was lowest for underweight (£109,382.2, 97,996.6-121,008.6, *p*=0.5174).

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Discussion

The present results indicate that: 1) obese men and women have 14.7% and 21.6% higher multiadjusted lifetime medical expenditure than those of normal weight, even though their life expectancy is shorter by 1.7 years and 3.1 years than those of normal weight participants, respectively; 2) underweight men and women have 5.2% and 3.4% lower lifetime medical expenditure than those of normal weight because men and women live 5.6 years and 5.3 years less than those of normal weight, respectively.

Comparison with other studies

Obese participants had shorter life expectancy than normal weight participants, as has been observed in previous studies.[6-10] Overweight participants had longer life expectancy than normal weight participants. Two of four previous studies have reported that overweight participants had longer life expectancy than normal weight participants.[7 9] These results support our finding of an association between being overweight and life expectancy. Additionally, an association between BMI and all-cause mortality in the Japanese population has been reported by other data sets.[23-29] All seven previous studies showed that among the BMI categories, the lowest one had the highest mortality risk. These results are consistent with the fact that underweight participants have significantly the shortest life expectancy, as was observed in our study.

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Our present results support three of four previous studies of lifetime medical expenditure for obese participants. [10 12 13] In comparison to previous studies, we calculated lifetime medical expenditure from individual medical expenditure and survival data covering longest follow-up period to date. Meanwhile, one study has shown that obese participants have lower lifetime medical expenditure than normal weight participants. [11] However, that study limited the participants to non-smokers, and calculated lifetime medical expenditure from the mortality of a hypothetical cohort and estimated medical expenditure from other cohort. In the present study, overweight participants were found to have higher lifetime medical expenditure than normal weight participants, as had been reported previously. [10 12 13] We consider that this was attributable to the higher medical expenditure per month or per person from the 10-year or 9-year follow-up than for normal weight participants. [1 3 4] On the other hand, with regard to underweight participants, our present findings were inconsistent with those of a previous study that examined the association between being underweight and lifetime medical expenditure. [13] However, that study calculated lifetime medical expenditure for elderly participants aged over 70 years. Elderly underweight participants have high mortality, [30] and medical expenditure increases in the 1 year prior to death. [20] Thus, lifetime medical expenditure from 70 years for underweight participants becomes higher than for participants of normal weight. Our study results are thus inconsistent with those reported previously.

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We previously calculated life expectancy and lifetime medical expenditure for smokers and non-smokers from age 40 years by using the same dataset as that for the present study.[17] The results indicated that lifetime medical expenditure was non-significantly lower in smokers than in non-smokers, reflecting the 3.5 years shorter life expectancy of smokers. On the other hand, the present study indicated that lifetime medical expenditure was higher for obese participants in spite of their shorter life expectancy. This difference would result from the difference in which obesity and smoking affect one's health and longevity. Previous studies of healthy and disability free life expectancy have agreed that smoking shortens life expectancy without affecting the years of life spent with ill-health or disability, while obesity shortens life expectancy and extends the years of life with ill-health or disability.[31] On the basis of these differences, Reuser et al. summarized the situation as "smoking kills, and obesity disables".[7] Extended years with ill-health and/or disability must result in increased lifetime medical expenditure. All of these findings suggest that weight control would bring about not only longer life expectancy but also long-term enhancement of the quality of life and a cost saving.

Strengths and limitations

A major strength of our present study is that it is the first in the world to have clarified the association between BMI and lifetime medical expenditure calculated from individual medical expenditure and mortality data over a long period in a general population from the age of 40 years. [1 14 16-18] The NHI covers almost all medical-care utilization. [1 4 14 16 18] Additionally, in order to reduce bias, we adjusted confounders by including various covariates in our Poisson regression model and linear regression mode. [16] On the other hand, several limitations of our study should also be considered. First, we used self-reported BMI which in a source of error. [32 33] We consider this error to be a nondifferential misclassification. This misclassification would lead to attenuation of the true association toward the null. To address this problem, van Dam et al. studied the association between BMI and mortality using lower BMI cutoff points: 24.5 kg/m^2 to reflect a measured BMI of 25.0 kg/m^2, and 29.0 kg/m^2 to reflect a measured BMI of 30.0 kg/m^2. [34] The association showed similar with original cutoff points. Second, the 95% CI was wide, and there was a limit to the accurate estimation of life expectancy and lifetime medical expenditure for obese participants because the Japanese population has a low prevalence of BMI≥30.0 kg/m². However, our results are consistent with those of previous studies. [6-8 10 12 13]

Conclusions and policy implication

In summary, lifetime medical expenditure appears to be higher for obese participants, despite their short life expectancy. With better weight control, more people would enjoy their longevity with lower needs and demands for medical care.

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Article focus

・Obese people have higher needs and demands for medical care.

・Obesity is associated with an increased risk of mortality.

・In view of the decreased life expectancy in obese participants, it is unclear whether lifetime medical expenditure increases or decreases as a result.

Key messages

・In spite of their short life expectancy, obese men and women had approximately 14.7% and 21.6% higher lifetime medical expenditure in comparison with normal weight participants, respectively.

・With better weight control, more people would enjoy their longevity with lower needs and demands for medical care.

Strengths and limitations of this study

・This is the first study to have investigated the association between BMI, life expectancy, and lifetime medical expenditure calculated from individual medical expenditure and mortality data over a long period in a general population.

・There was a limit to the accurate estimation of life expectancy and lifetime medical expenditure for obese participants because the Japanese population has a low prevalence of BMI≥30.0 kg/m².

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Contributions

All authors contributed to the design of the study. Masato Nagai, Shinichi Kuriyama, Masako Kakizaki, Kaori Ohmori-Matsuda, Toshimasa Sone, and Ichiro Tsuji participated in data collection. Masato Nagai, Shinichi Kuriyama, Atsushi Hozawa, Miyuki Kawado, and Shuji Hashimoto participated in data analysis. Masato Nagai, Masako Kakizaki, Kaori Ohmori-Matsuda, Toshimasa Sone, Atsushi Hozawa, Miyuki Kawado, and Shuji Hashimoto participated in the writing of the report. Shinichi Kuriyama and Ichiro Tsuji participated in critical revision of the manuscript. All authors approved the final version of the report for submission.

Funding

This study was supported by a Health Sciences Research Grant for Health Services (H21-Choju-Ippan-001, H20-Junkankitou (Seisyu)-Ippan-013, H22- Junkankitou (Seisyu)-Ippan-012), Ministry of Health, Labour and Welfare, Japan. Masato Nagai is a recipient of a Research Fellowships of the Japan Society for the Promotion of Science for Young Scientists.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Ethical approval

The study protocol was approved by the Ethics Committee of Tohoku University School of Medicine. Participants who had returned the self-administered questionnaires and signed them were considered to have consented to participate.

Data sharing

No additional data available.

Figure legend

Figure 1

Multiadjusted mortality by BMI categories in each age-group in men (a) and women (b).

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Table1 Baseline characteristics by BMI[a] categories in 41,965 participants.

	Men					Women				
	BMI (kg/m^2)				*p* value[b]	BMI (kg/m^2)				*p* value
	<18.5	18.5-24.9	25.0-29.9	≥30.0		<18.5	18.5-24.9	25.0-29.9	≥30.0	
No. of subjects	666	14,278	4,730	392		857	14,031	6,226	785	
Mean age (years)	64.0	59.1	57.4	56.1	<.0001	63.7	59.8	60.7	61.2	<.0001
SD[a]	10.4	10.5	10.2	10.2		10.9	10.1	9.1	9.5	
Smoking status (%)										
Current and Past smoker	87.3	82.5	76.6	74.8	<.0001	18.6	11.2	10.1	10.6	<.0001
Never smoker	12.7	17.5	23.4	25.2		81.4	88.8	90.0	89.4	
Alcohol consumption (%)										
Current drinker, 1-449 g/week	49.2	61.0	61.4	50.8	<.0001	18.2	21.8	21.4	19.3	0.0574
Current drinker, ≥450 g/week	9.6	11.7	12.6	15.0		0.6	0.8	0.5	0.9	
Never and past drinker	41.2	27.3	26.0	34.2		81.2	77.4	78.2	79.8	
Sports and physical exercise (%)										
≥3 hours/week	17.5	16.1	13.8	10.1	<.0001	9.8	11.3	11.0	10.8	0.5993
<3 hour/week	82.5	83.9	86.2	89.9		90.2	88.7	89.0	89.2	
Time spent walking (%)										
≥1 hour/day	41.7	51.4	45.8	42.7	<.0001	37.9	45.1	41.0	35.6	<.0001
<1 hour/day	58.3	48.7	54.2	57.3		62.1	54.9	59.0	64.4	
Education (%)										
Junior high school	64.2	62.2	58.9	58.8	0.0013	58.3	54.2	62.7	71.3	<.0001
High school	27.4	30.5	33.4	33.4		34.0	36.9	31.0	24.6	
College/university or higher	8.4	7.3	7.7	7.8		7.7	8.9	6.3	4.1	

[a] BMI, body mass index; SD, standard deviation.

[b] *p* values were calculated by chi-squared test (categorical variables) or ANOVA (continuous variables).

Table 2. Mortality ratio for BMI[a] categories in 41,965 participants.

	BMI (kg/m^2)	Univariate			Multiadjusted[b]		
		Mortality ratio	95% confidence interval	*p* value	Mortality ratio	95% confidence interval	*p* value
Men	<18.5	1.69	1.47 - 1.93	<.0001	1.62	1.41 - 1.86	<.0001
	18.5-24.9	1.00	Reference		1.00	Reference	
	25.0-29.9	0.90	0.82 - 0.98	0.0163	0.91	0.83 - 0.99	0.0260
	≥30.0	1.13	0.87 - 1.47	0.3712	1.14	0.88 - 1.49	0.3177
Women	<18.5	1.50	1.25 - 1.81	<.0001	1.46	1.22 - 1.76	<.0001
	18.5-24.9	1.00	Reference		1.00	Reference	
	25.0-29.9	1.00	0.89 - 1.11	0.9613	0.98	0.88 - 1.10	0.7841
	≥30.0	1.29	1.03 - 1.62	0.0273	1.23	0.98 - 1.55	0.0717

[a] BMI, body mass index.

[b] Adjusted for age groups, smoking status, alcohol drinking, sports and physical exercise, time spent walking, and education.

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Table 3. Life expectancy and lifetime medical expenditure at age 40 years for BMI[a] categories in 41,965 participants.

	BMI (kg/m^2)	Univariate			Multiadjusted[b]		
		Estimate	95% confidence	*p* value	Estimate	95% confidence	*p* value
Men	Life expectancy at age 40 years (years)						
	<18.5	36.72	35.10 - 38.17	<.0001	37.40	35.80 - 38.87	<.0001
	18.5-24.9	42.70	41.91 - 43.37	Reference	43.03	42.22 - 43.73	Reference
	25.0-29.9	44.09	42.89 - 45.25	0.0157	44.34	43.11 - 45.54	0.0264
	≥30.0	41.23	38.16 - 44.54	0.3733	41.36	38.28 - 44.70	0.3184
	Lifetime medical expenditure at age 40 years (£)						
	<18.5	94,877.5	83,411.4 - 106,275.7	0.6846	93,208.7	81,704.9 - 104,706.4	0.3916
	18.5-24.9	97,244.1	92,662.5 - 101,774.0	Reference	98,355.0	93,615.3 - 103,010.2	Reference
	25.0-29.9	114,398.2	107,490.1 - 121,505.3	<.0001	114,766.9	107,754.1 - 121,966.6	<.0001
	≥30.0	115,362.6	97,361.8 - 134,555.0	0.0501	112,858.9	94,954.1 - 131,840.9	0.1141
Women	Life expectancy at age 40 years (years)						
	<18.5	46.26	43.98 - 48.43	<.0001	46.98	44.63 - 49.29	<.0001
	18.5-24.9	51.70	50.28 - 53.02	Reference	52.31	50.79 - 53.75	Reference
	25.0-29.9	51.74	49.98 - 53.48	0.9582	52.56	50.67 - 54.46	0.7797
	≥30.0	48.13	45.23 - 51.22	0.0272	49.23	46.14 - 52.59	0.0724
	Lifetime medical expenditure at age 40 years (£)						
	<18.5	108,278.3	97,142.8 - 119,593.7	0.5816	109,382.2	97,996.6 - 121,008.6	0.5174
	18.5-24.9	111,512.8	105,303.4 - 117,910.4	Reference	113,282.9	106,668.0 - 120,054.6	Reference
	25.0-29.9	127,869.3	120,236.3 - 135,932.3	<.0001	129,964.6	121,845.4 - 138,577.2	<.0001
	≥30.0	134,887.1	121,318.4 - 149,383.6	0.0007	137,765.9	123,672.9 - 152,970.2	0.0005

[a] BMI, body mass index.

[b] Adjusted for age groups, smoking status, alcohol drinking, sports and physical exercise, time spent walking, and education.

Figure 1-a

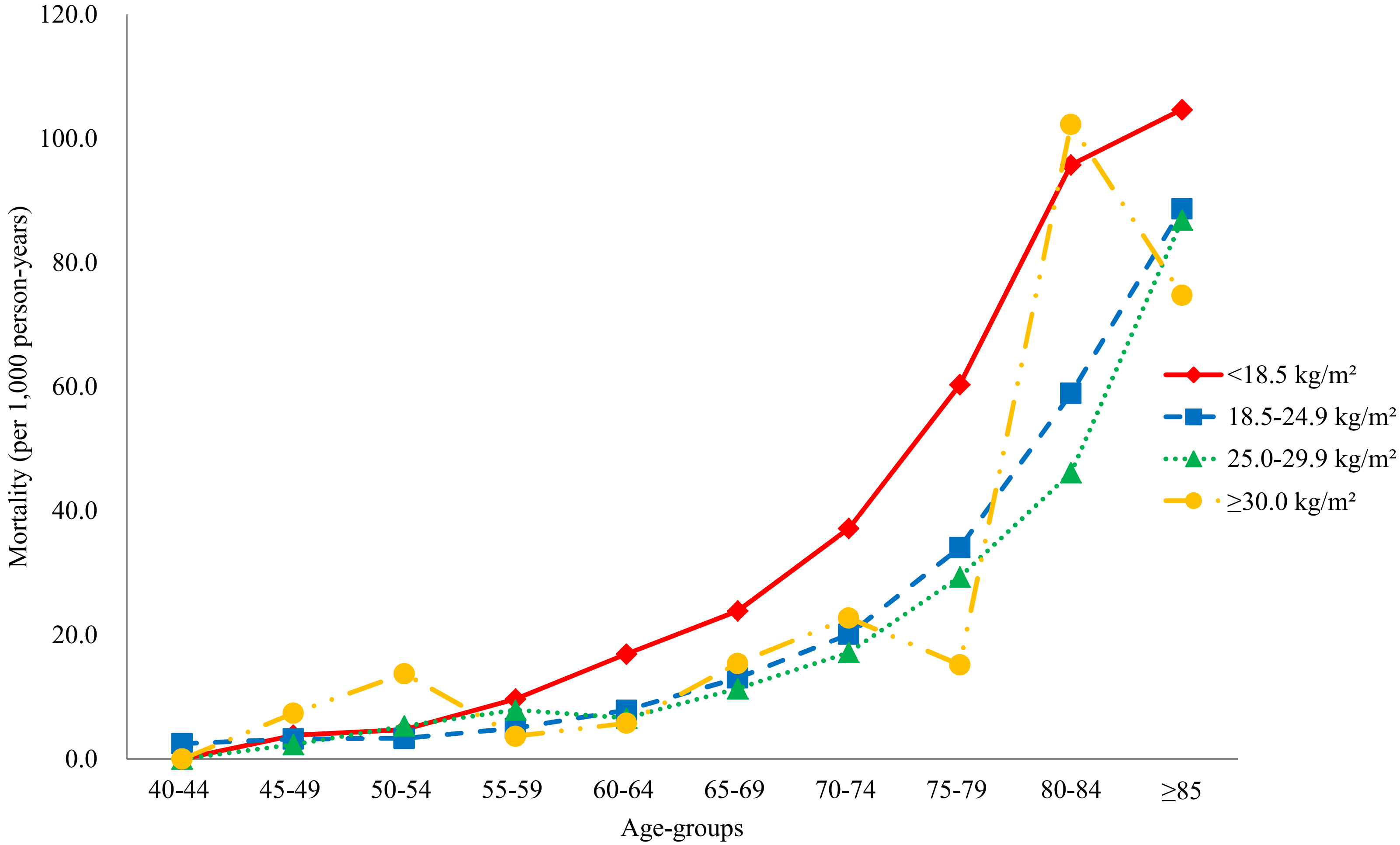
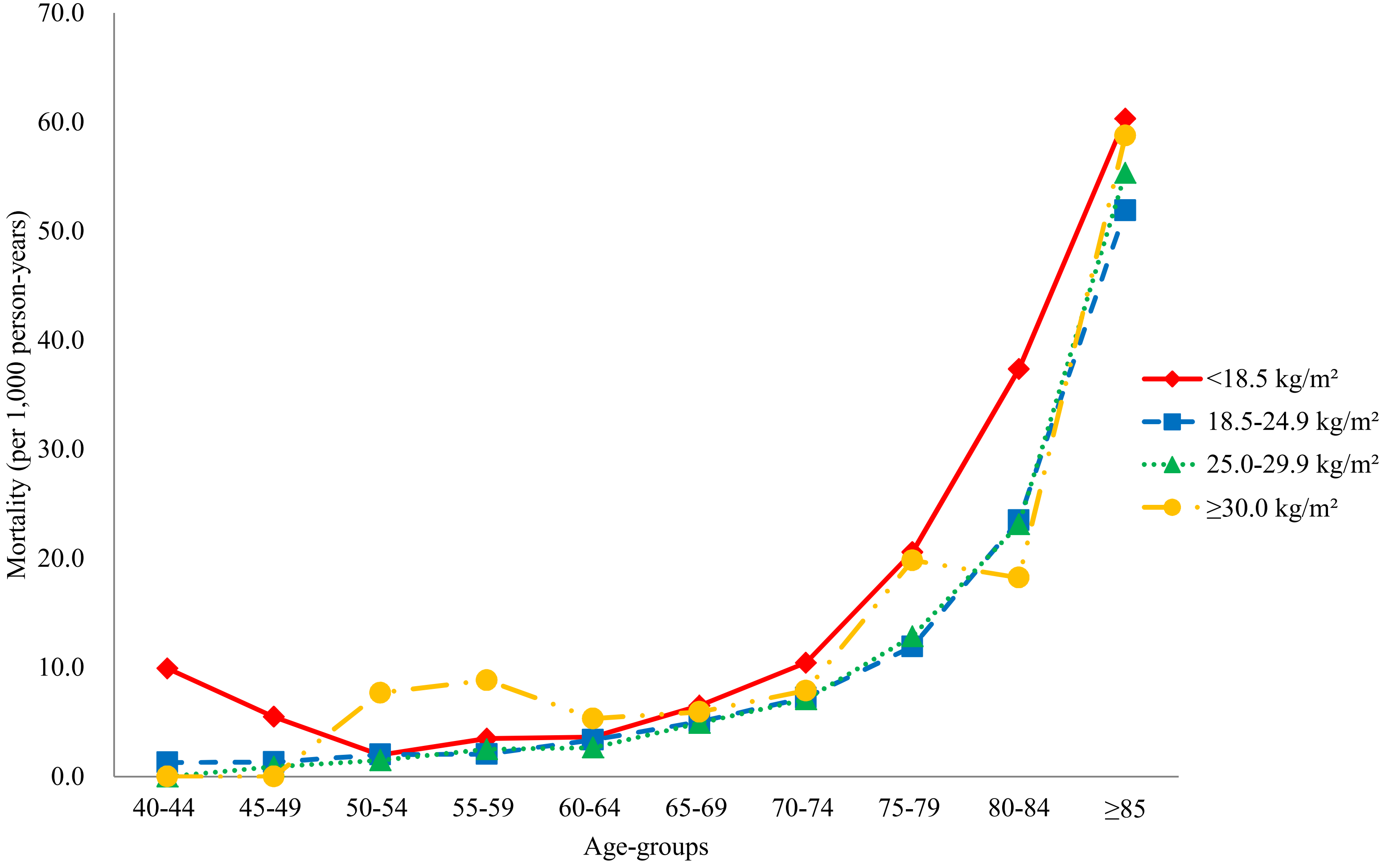

120.0
100.0
80.0
60.0
40.0
20.0
0.0
Mortality (per 1,000 person-years)
40-44
45-49
50-54
55-59
60-64
65-69
70-74
75-79
80-84
≥85
Age-groups
<18.5 kg/m²
18.5-24.9 kg/m²
25.0-29.9 kg/m²
≥30.0 kg/m²

Figure 1-b


70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
Mortality (per 1,000 person-years)
40-44
45-49
50-54
55-59
60-64
65-69
70-74
75-79
80-84
≥85
Age-groups
<18.5 kg/m²
18.5-24.9 kg/m²
25.0-29.9 kg/m²
≥30.0 kg/m²

deemed to be important to include in checklists for each type of study. A provisional list of items prepared in advance (available from our website) was used to facilitate discussions. The three draft checklists were then discussed by all participants and, where possible, items were revised to make them applicable to all three study designs. In a final plenary session, the group decided on the strategy for finalising and disseminating the STROBE statement.

After the workshop we drafted a combined checklist including all three designs and made it available on our website. We invited participants and additional scientists

STROBE statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation
Title and abstract		
	1	*(a)* Indicate the study's design with a commonly used term in the title or the abstract
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported
Objectives	3	State specific objectives, including any prespecified hypotheses
Methods		
Study design	4	Present key elements of study design early in the paper
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection
Participants	6	*(a) Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants
		(b) Cohort study—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group
Bias	9	Describe any efforts to address potential sources of bias
Study size	10	Explain how the study size was arrived at
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why
Statistical methods	12	*(a)* Describe all statistical methods, including those used to control for confounding
		(b) Describe any methods used to examine subgroups and interactions
		(c) Explain how missing data were addressed
		(d) Cohort study—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross sectional study*—If applicable, describe analytical methods taking account of sampling strategy
		(e) Describe any sensitivity analyses
Results		
Participants	13*	*(a)* Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed
		(b) Give reasons for non-participation at each stage
		(c) Consider use of a flow diagram
Descriptive data	14*	*(a)* Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders
		(b) Indicate number of participants with missing data for each variable of interest
		(c) Cohort study—Summarise follow-up time (eg average and total amount)
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time
		Case-control study—Report numbers in each exposure category, or summary measures of exposure
		Cross sectional study—Report numbers of outcome events or summary measures
Main results	16	*(a)* Report the numbers of individuals at each stage of the study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed
		(b) Give reasons for non-participation at each stage
		(c) Consider use of a flow diagram
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses
Discussion		
Key results	18	Summarise key results with reference to study objectives
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence
Generalisability	21	Discuss the generalisability (external validity) of the study results
Other information		
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross sectional studies.
The STROBE checklist is best used in conjunction with the explanation and elaboration article.[18-20] This article and separate versions of the checklist for cohort, case-control, and cross sectional studies are available at www.strobe-statement.org.

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Impact of Obesity, Overweight and Underweight on Life Expectancy and Lifetime Medical Expenditures: The Ohsaki Cohort Study

Journal:	*BMJ Open*
Manuscript ID:	bmjopen-2012-000940.R1
Article Type:	Research
Date Submitted by the Author:	27-Mar-2012
Complete List of Authors:	Nagai, Masato; Tohoku University Graduate School of Medicine, Division of Epidemiology, Department of Public Health and Forensic Medicine Kuriyama, Shinichi; Tohoku University Graduate School of Medicine, Division of Epidemiology, Department of Public Health and Forensic Medicine; Tohoku University Graduate School of Medicine, Department of Molecular Epidemiology, Environment and Genome Research Center Kakizaki, Masako; Tohoku University Graduate School of Medicine, Division of Epidemiology, Department of Public Health and Forensic Medicine Ohmori-Matsuda, Kaori; Tohoku University Graduate School of Medicine, Division of Epidemiology, Department of Public Health and Forensic Medicine Sone, Toshimasa; Tohoku University Graduate School of Medicine, Division of Epidemiology, Department of Public Health and Forensic Medicine Hozawa, Atsushi; Tohoku University Graduate School of Medicine, Division of Epidemiology, Department of Public Health and Forensic Medicine; Yamagata University Graduate School of Medical Science, Department of Public Health Kawado, Miyuki; Fujita Health University School of Medicine, Department of Hygiene Hashimoto, Shuji; Fujita Health University School of Medicine, Department of Hygiene Tsuji, Ichiro; Tohoku University Graduate School of Medicine, Division of Epidemiology, Department of Public Health and Forensic Medicine
Primary Subject Heading:	Epidemiology
Secondary Subject Heading:	Health economics, Public health, Cardiovascular medicine, Nutrition and metabolism
Keywords:	Body mass index, Life expectancy, Lifetime medical expenditure, Longevity, Obesity

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Research

Impact of Obesity, Overweight and Underweight on Life Expectancy and Lifetime Medical Expenditures: The Ohsaki Cohort Study

Running Title: BMI, Life Expectancy, and Lifetime Medical Cost

Masato Nagai, PhD[1], Shinichi Kuriyama, MD, PhD[1, 2], Masako Kakizaki, PhD[1], Kaori Ohmori-Matsuda, MD, PhD[1], Toshimasa Sone, MSc[1], Atsushi Hozawa, MD, PhD[1, 3], Miyuki Kawado, PhD[4], Shuji Hashimoto, PhD[4], and Ichiro Tsuji, MD, PhD[1]

[1] Division of Epidemiology, Department of Public Health and Forensic Medicine, Tohoku University Graduate School of Medicine, Sendai, Japan

[2] Department of Molecular Epidemiology, Environment and Genome Research Center, Tohoku University Graduate School of Medicine, Sendai, Japan

[3] Department of Public Health, Yamagata University Graduate School of Medical Science, Yamagata, Japan

[4] Department of Hygiene, Fujita Health University School of Medicine, Toyoake, Japan

Address for correspondence:

Masato Nagai, PhD.

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Division of Epidemiology, Department of Public Health and Forensic Medicine, Tohoku University Graduate School of Medicine, Sendai, Japan

2-1 Seiryo-machi, Aoba-ku, Sendai, Miyagi, 980-8575, Japan

Phone: +81-22-717-8123

Fax: +81-22-717-8125

E-mail: m-nagai@med.tohoku.ac.jp

Manuscript information:

#Financial support: This study was supported by a Health Sciences Research Grant for Health Services (H21-Choju-Ippan-001, H20-Junkankitou (Seisyu)-Ippan-013, H22-Junkankitou (Seisyu)-Ippan-012), Ministry of Health, Labour and Welfare, Japan.

Masato Nagai is a recipient of a Research Fellowships of the Japan Society for the Promotion of Science for Young Scientists.

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#Word counts: 3,110

#References: 37

#Tables: 3

#Figures: 2

#Page: 33

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Abstract

Objectives

People who are obese have higher demands for medical care than those of normal weight. However, in view of their shorter life expectancy, it is unclear whether obese people have higher lifetime medical expenditure. We examined the association between body mass index (BMI), life expectancy, and lifetime medical expenditure.

Design

Prospective cohort study using individual data from the Ohsaki Cohort Study.

Setting

Miyagi Prefecture, northeastern Japan.

Participants

The 41,965 participants aged 40-79 years.

Primary and secondary outcome measures

The life expectancy and lifetime medical expenditure aged from 40 years.

Results

In spite of their shorter life expectancy, obese participants might require higher medical expenditure than normal weight participants. In men aged 40 years, multiadjusted life expectancy for those who were obese participants was 41.4 years (95%CIs; 38.28-44.70), which was 1.7 years non-significantly shorter than that for normal weight participants (p=0.3184). Multiadjusted lifetime medical expenditure for obese

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participants was £112,858.9 (94,954.1-131,840.9), being 14.7% non-significantly higher than that for normal weight participants (*p*=0.1141). In women aged 40 years, multiadjusted life expectancy for those who were obese participants was 49.2 years (46.14-52.59), which was 3.1 years non-significantly shorter than for normal weight participants (*p*=0.0724), and multiadjusted lifetime medical expenditure was £137,765.9 (123,672.9-152,970.2), being 21.6% significantly higher (*p*=0.0005).

Conclusions

According to the point estimate, lifetime medical expenditure might appear to be higher for obese participants, despite their short life expectancy. With weight control, more people would enjoy their longevity with lower demands for medical care.

(242 words)

Key Words: Body mass index; Life expectancy; Lifetime medical expenditure; Longevity; Obesity;

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Introduction

Obesity is closely associated with an increased risk of cardiovascular disease (CVD), cancer, hypertension, diabetes mellitus, and other medical problems. Previous studies have reported that obese and overweight people have higher needs and demands for medical care than normal weight people. [1-5] However, it is unclear whether obese people have higher lifetime medical expenditure than those of normal weight, because the former have a comparatively shorter life expectancy. [6-10] Additionally, underweight people have a higher risk of mortality, and thus also tend to have higher medical expenditure per month or per person, based on a 10-year follow-up. [1 4]

Although four previous studies have examined the association between obesity and lifetime medical expenditure, [10-13] the results were inconsistent. One study showed that obese people had lower lifetime medical expenditure than those of normal weight, [11] whereas the others indicated that obese people had higher lifetime medical expenditure. [10 12 13] In addition, two of the four studies estimated lifetime medical expenditure from excess risk of cause-specific mortality and mean medical expenditure for the index disease. [10 11] Only the other two studies calculated lifetime medical expenditure on the basis of individual medical expenditure and mortality. [12 13] However, one of those studies followed up the participants for only 2 years, [12] and the

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other calculated lifetime medical expenditure for elderly participants aged 70 years or over.[13] Therefore, the association between body mass index (BMI) and lifetime medical expenditure remains to be fully clarified.

We therefore conducted a 13-year prospective observation of 41,965 Japanese adults aged 40-79 years living in the community, which accrued 392,860 person-years. We examined the association between BMI and lifetime medical expenditure, based on individual medical expenditure and life table analysis.[1 14-17] For all participants, this cohort study collected data for survival and all medical-care utilization and costs, excluding home care services provided home health aides, nursing home care, and preventive health services.

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Materials and methods

Study cohort

We used data from the Ohsaki National Health Insurance (NHI) Cohort Study.[1 14 16-18] In brief, we sent a self-administered questionnaire on various lifestyle habits between October and December 1994 to all NHI beneficiaries living in the catchment area of Ohsaki Public Health Center, Miyagi Prefecture, northeastern Japan. A survey was conducted of NHI beneficiaries aged 40 to 79 years. Among 54,996 eligible individuals, 52,029 (95%) responded.

We excluded 776 participants who had withdrawn from the NHI before January 1, 1995, when we started the prospective collection of NHI claim files. Thus, 51,253 participants formed the study cohort. The study protocol was approved by the Ethics Committee of Tohoku University School of Medicine. The participants who had returned the self-administered questionnaires and had signed them were considered to have consented to participate in this study.

For the current analysis, we also excluded participants who did not provide information about body weight and height (n=3,543), were at both extremes of the BMI range: lower than the 0.05th percentile for BMI (below 14.41 for men; below 13.67 for women) or higher than the 99.95th percentile for BMI (above 58.46 for men; above 62.00 for women; n=48), those who died within the first year (n=454), or those who had

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a history of cancer (n=1,533), myocardial infarction (n=1,233), stroke (n=831), or kidney disease (n=1,646). Thus, a total of 41,965 participants (20,066 men and 21,899 women) participated.

Body mass index

The self-administered questionnaire included questions on weight and height, and BMI was calculated as weight divided by the square of height (kg/m²). We divided the participants into groups according to the following BMI categories: <18.5 (underweight), 18.5-24.9 (normal weight), 25.0-29.9 (overweight), and ≥30.0 kg/m² (obesity). These BMI categories correspond to the cut-off points proposed by the World Health Organization (WHO): normal BMI range (18.5-24.9 kg/m²), grade 1 overweight (25.0-29.9 kg/m²), grade 2 overweight (30.0-39.9 kg/m²), and grade 3 overweight (≥40.0 kg/m²). [19]

The validity of self-reported body weight and height has been reported earlier [1]. Briefly, the weight and height of 14,883 participants, who were a subsample of the cohort, were measured during basic health examinations provided by local governments in 1995. The Pearson correlation coefficient (r) and weighted kappa (κ) between the self-reported values and measured values was r=0.96 (p<.01) for weight, r=0.93 (p<.01) for height, and r=0.88 (p<.01) and κ=0.72 for BMI categories.

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Health insurance system in Japan

The details of the NHI system have been described previously.[1 4 14 16 18] Briefly, everyone living in Japan is required to enroll in one health insurance system. The NHI covers 35% of the Japanese population for almost all medical treatment, including diagnostic tests, medication, surgery, supplies and materials, physicians and other personnel costs, and most dental treatment. It also covers home care services provided by physicians and nurses but not those by other professionals such as home health aides. The NHI covers inpatient care but not nursing home care. Also, it does not cover preventive health services such as mass screening and health education. Payment to medical providers is made on a fee-for-service basis, where the price of each service is determined by a uniform national fee schedule.

If a participant withdrew from the NHI system because of death, emigration, or employment, the withdrawal date and the reason for withdrawal were coded in the NHI withdrawal history files. We recorded any mortality or migration by reviewing the NHI withdrawal history files and collected data on the death of participants by reviewing the death certificates filed at Ohsaki Public Health Center. We then followed up the participants and prospectively collected data on medical care utilization and its costs for all participants in the cohort from January 1, 1995 through December 31, 2007.

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Statistical analysis

We conducted the same analysis as previous study about the association between walking, life expectancy, and lifetime medical expenditure.[16] Briefly, we divided the age-groups (x) from 40 years according to the following categories: 40-44, 45-49, 50-54, 55-59, 60,64, 65-69, 70-74, 75-79, 80-84, and ≥85 years. Based on person-years and the number of deaths from 1996 until 2007, the multiadjusted mortality rates for each age category were estimated from a Poisson regression model. The dependent variable was mortality and independent variables were age-groups, categories of BMI, and the following covariates: smoking status (current and past smoker, or never smoker), alcohol consumption (current drinker consuming 1-499 g/week, current drinker consuming ≥450 g/week, or never and past drinker), sports and physical exercise (≥3 hours/week or <3 hours/week), time spent walking (≥1 hours/week or <1 hours/week), education (junior high school, high school, or college/university or higher). We did not adjust for hypertension and diabetes mellitus in the multivariate models because these variables are considered to occupy an intermediate position in the etiologic pathway between BMI and mortality.

We separately calculated medical expenditure for participants who survived through the index year and for those who died because previous study showed that medical expenditure increased before death. [20] The multiadjusted medical expenditure per year was estimated using a linear regression model adjusted for the above covariates in

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survivors and decedents.

The estimates of multiadjusted mortality and medical expenditure were used for estimating life expectancy and lifetime medical expenditure from 40 years of age. To estimate life expectancy and lifetime medical expenditure, we constructed life tables per100,000 persons using Chiang's analytical method on the basis of the latest published complete life tables of Japan for the year 2000. [21 22] Then, life expectancy (e_x) and lifetime medical expenditure (M_x) for each age-groups (x) were estimated using the numbers of survivors (l_x), deaths (d_x), static population (L_x), multiadjusted medical expenditure for survivors (a_y), and multiadjusted medical expenditure for the deceased (b_y) as follows;

$\sum$ is sum of y≥x

$$e_x = \frac{\sum L_y}{l_x}$$

$$M_x = \frac{\sum(L_y \cdot a_y + d_y \cdot b_y)}{l_x}$$

The 95% confidence intervals (CIs) were estimated using a Monte Carlo simulation based on a Poisson regression model and linear regression model. We repeated 100,000 times and all analysis were used the SAS version 9.1 statistical software package (SAS Institute Inc., 2004). All *p* values were differences at p<.05 were accepted as statistically significant.

We used a purchasing power parity rate of UK£ 1.00=JPN¥ 140. [16]

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Results

After 13 years of follow-up, we observed 5,159 deaths (3,356 men and 1,803 women) among the 41,965 participants (20,066 men and 21,899 women).

The mean medical expenditure per year for survivors in men was £2,393 in underweight, £2,055 in normal weight, £2,231 in overweight, and £2,334 in obesity, respectively. In women, it was £2,375 in underweight, £1,972 in normal weight, £2,317 in overweight, and £2,733 in obesity, respectively. These differences of mean medical expenditure per year for survivors are statistically significant in men and women (ANOVA; p<0.0001). Also, the mean medical expenditure in the year of death for participants in men was £15,445 in underweight, £16,973 in normal weight, £17,811 in overweight, and £17,878 in obesity, respectively. In women, it was £12,833 in underweight, £15,584 in normal weight, £17,059 in overweight, and £19,635 in obesity, respectively. These differences of mean medical expenditure in the year of death for participants are statistically significant in only women (men; p=0.2241, women; p=0.0059).

Baseline characteristics by BMI category

The baseline characteristics of the study participants according to the BMI categories are shown for men and women (Table 1), among whom 3.3% and 3.9% were underweight, 23.6% and 28.4% were overweight, and 2.0% and 3.6% were obese, respectively.

Mean age in men decreased linearly with increasing BMI category. In women, mean age was highest in the underweight category. The proportions of men and women who were current and past smokers decreased with increasing BMI, and this tendency was especially marked in men. The proportions of men who had never and past drinker were highest in the underweight category. The proportions of men who did ≥3 hours sports and physical exercise per week decreased with increasing BMI. The proportions of men and women who walked ≥1 hours per day were the lowest in underweight men and obese women. Educational background increased linearly in men and decreased linearly in women as the BMI category increased. These characteristics showed statistically significant difference.

Mortality in terms of categories for BMI

Figure 1-a for men and Figure 1-b for women show the mortality (per 1,000 person-years) in each of the age-groups according to the categories of BMI.

In underweight participants, there was a tendency that the mortality was the highest in each age-group. Overweight participants showed similar mortality with normal weight participants, especially women. Overweight men showed slightly lower mortality than normal weight men. In obese participants, the mortality curve was not

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described smoothly because of small number of participants.

Table 2 shows the mortality ratio with 95% CIs according to the categories of BMI. In underweight participants, the multiadjusted mortality ratio was significantly higher than that in normal weight participants (men; 1.62, 95%CIs; 1.41-1.86, *p*<0.0001, women; 1.46, 1.22-1.76, *p*<0.0001). In overweight participants, the multiadjusted mortality ratio was significantly lower in men and non-significantly lower in women than that in normal weight participants (men; 0.91, 0.83-0.99, *p*=0.0260, women; 0.98, 0.88-1.10, *p*=0.7841). In obese participants, the multiadjusted mortality ratio was non-significantly higher than that in normal weight participants (men; 1.14, 0.88-1.49, *p*=0.3177, women; 1.23, 0.98-1.55, *p*=0.0717).

Life expectancy and lifetime medical expenditure by BMI category

Table 3 show life expectancy and lifetime medical expenditure with 95% CIs according to the BMI categories.

By multiadjusted analysis, obese men and women had approximately 1.7 years and 3.1 years non-significantly shorter life expectancy from the age of 40 years in comparison with men and women of normal weight, respectively (men; *p*=0.3184, women; *p*=0.0724). Meanwhile, obese men and women had approximately 14.7% non-significantly higher and 21.6% significantly higher lifetime medical expenditure in comparison with normal weight participants, respectively (men; *p*=0.1141, women;

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p=0.0005).

In men, multiadjusted life expectancy was greatest for overweight, i.e. 44.34 years (95% CI; 43.11-45.54, *p*=0.0264), followed by normal weight (43.03 years, 42.22-43.73), and obesity (41.36 years, 38.28-44.70, *p*=0.3184), and was shortest for underweight (37.40 years, 35.80-38.87, *p*<.0001). The multiadjusted lifetime medical expenditure for overweight was the highest, i.e. £114,766.9 (95% CI; 107,754.1-121,966.6, *p*<.0001), followed by obesity (£112,858.9, 94,954.1-131,840.9, *p*=0.1141) and normal weight (£98,355.0, 93,615.3-103,010.2), and was the lowest for underweight (£93,208.7, 81,704.9-104,706.4, *p*=0.3916).

In women, multiadjusted life expectancy was greatest for overweight, i.e. 52.56 years (50.67-54.46, *p*=0.7797), followed by normal weight (52.31 years, 50.79-53.75), and obesity (49.23 years, 46.14-52.59, *p*=0.0724), and was shortest for underweight (46.98 years, 44.63-49.29, *p*<.0001). The lifetime medical expenditure for obesity was the highest (£137,765.9, 123,672.9-152,970.2, *p*=0.0005), followed by overweight (£129,964.6, 121,845.4-138,577.2, *p*<.0001), and normal weight (£113,282.9, 106,668.0-120,054.6), and was lowest for underweight (£109,382.2, 97,996.6-121,008.6, *p*=0.5174).

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Discussion

The present results indicate that: 1) obese men and women have 14.7% non-significantly higher and 21.6% significantly higher multiadjusted lifetime medical expenditure than those of normal weight (men; *p*=0.1141, women; *p*=0.0005), even though their life expectancy is non-significantly shorter by 1.7 years and 3.1 years than those of normal weight participants, respectively (men; *p*=0.3184, women; *p*=0.0724); 2) underweight men and women have 5.2% and 3.4% non-significantly lower lifetime medical expenditure than those of normal weight (men; *p*=0.5174, women; *p*=0.3916) because men and women live 5.6 years and 5.3 years significantly less than those of normal weight, respectively (men; *p*<.0001, women; *p*<.0001).

Comparison with other studies

Obese participants had shorter life expectancy than normal weight participants, as has been observed in previous studies.[6-10] Overweight participants had longer life expectancy than normal weight participants. Two of four previous studies have reported that overweight participants had longer life expectancy than normal weight participants.[7 9] These results support our finding of an association between being overweight and life expectancy. Additionally, an association between BMI and all-cause mortality in the Japanese population has been reported by other data sets.[23-29]

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All seven previous studies showed that among the BMI categories, the lowest one had the highest mortality risk. These results are consistent with the fact that underweight participants have significantly the shortest life expectancy, as was observed in our study. Thus the association between BMI and life expectancy showed same trend with the pooled analyses of the association between BMI and all-cause mortality in Asia and Japan. [30 31]

Our present results support three of four previous studies of lifetime medical expenditure for obese participants. [10 12 13] In comparison to previous studies, we calculated lifetime medical expenditure from individual medical expenditure and survival data covering longest follow-up period to date. Meanwhile, one study has shown that obese participants have lower lifetime medical expenditure than normal weight participants. [11] However, that study limited the participants to non-smokers, and calculated lifetime medical expenditure from the mortality of a hypothetical cohort and estimated medical expenditure from other cohort. In the present study, overweight participants were found to have higher lifetime medical expenditure than normal weight participants, as had been reported previously. [10 12 13] We consider that this was attributable to the higher medical expenditure per month or per person from the 10-year or 9-year follow-up than for normal weight participants. [1 3 4] On the other hand, with regard to underweight participants, our present findings were inconsistent with those of a previous study that examined the association between being underweight and lifetime medical expenditure.[13] However, that study calculated lifetime medical expenditure for elderly participants aged over 70 years. Elderly underweight participants have high mortality,[32] and medical expenditure increases in the 1 year prior to death.[20] Thus, lifetime medical expenditure from 70 years for underweight participants becomes higher than for participants of normal weight. Our study results are thus inconsistent with those reported previously.

We previously calculated life expectancy and lifetime medical expenditure for smokers and non-smokers from age 40 years by using the same dataset as that for the present study.[17] The results indicated that lifetime medical expenditure was non-significantly lower in smokers than in non-smokers, reflecting the 3.5 years shorter life expectancy of smokers. On the other hand, the present study indicated that lifetime medical expenditure was higher for obese participants in spite of their shorter life expectancy. This difference would result from the difference in which obesity and smoking affect one's health and longevity. Previous studies of healthy and disability free life expectancy have agreed that smoking shortens life expectancy without affecting the years of life spent with ill-health or disability, while obesity shortens life expectancy and extends the years of life with ill-health or disability.[33] On the basis of these differences, Reuser et al. summarized the situation as "smoking kills, and obesity disables".[7] Extended years with ill-health and/or disability must result in increased lifetime medical expenditure. All of these findings suggest that weight control would bring about not only longer life expectancy but also long-term enhancement of the quality of life and a cost saving.

Strengths and limitations

A major strength of our present study is that it is the first in the world to have clarified the association between BMI and lifetime medical expenditure calculated from individual medical expenditure and mortality data over a long period in a general population from the age of 40 years. [1 14 16-18] The NHI covers almost all medical-care utilization. [1 4 14 16 18] Additionally, in order to reduce bias, we adjusted confounders by including various covariates in our Poisson regression model and linear regression mode. [16] On the other hand, several limitations of our study should also be considered. First, we used self-reported BMI which in a source of error. [34 35] We consider this error to be a nondifferential misclassification. This misclassification would lead to attenuation of the true association toward the null. To address this problem, van Dam et al. studied the association between BMI and mortality using lower BMI cutoff points: 24.5 kg/m^2 to reflect a measured BMI of 25.0 kg/m^2, and 29.0 kg/m^2 to reflect a measured BMI of 30.0 kg/m^2. [36] The association showed similar with original cutoff points. Second, the 95% CI was wide, and there was a limit to the accurate estimation of life expectancy and lifetime medical expenditure for obese participants. Additionally, we did not observe significant association in obese participants without lifetime medical expenditure in women. However, our results are consistent with those of previous studies.[6-8 10 12 13] In Japan, prevalence of obesity is only 3%.[37] Thus the reason of non-significant association might be beta error because of lack of statistical power due to small number of obese participants.

Conclusions and policy implication

In summary, even though we observed non-significant association between obesity, life expectancy, and lifetime medical expenditure without lifetime medical expenditure in women, lifetime medical expenditure might appear to be higher for obese participants, despite their short life expectancy. With better weight control, more people would enjoy their longevity with lower needs and demands for medical care.

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Article focus

・Obese people have higher needs and demands for medical care.

・Obesity is associated with an increased risk of mortality.

・In view of the decreased life expectancy in obese participants, it is unclear whether lifetime medical expenditure increases or decreases as a result.

Key messages

・In spite of their short life expectancy, obese men and women had approximately 14.7% and 21.6% higher lifetime medical expenditure in comparison with normal weight participants, respectively.

・With better weight control, more people would enjoy their longevity with lower needs and demands for medical care.

Strengths and limitations of this study

・This is the first study to have investigated the association between BMI, life expectancy, and lifetime medical expenditure calculated from individual medical expenditure and mortality data over a long period in a general population.

・There was a limit to the accurate estimation of life expectancy and lifetime medical expenditure for obese participants because the Japanese population has a low prevalence of BMI≥30.0 kg/m².

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Contributions

All authors contributed to the design of the study. Masato Nagai, Shinichi Kuriyama, Masako Kakizaki, Kaori Ohmori-Matsuda, Toshimasa Sone, and Ichiro Tsuji participated in data collection. Masato Nagai, Shinichi Kuriyama, Atsushi Hozawa, Miyuki Kawado, and Shuji Hashimoto participated in data analysis. Masato Nagai, Masako Kakizaki, Kaori Ohmori-Matsuda, Toshimasa Sone, Atsushi Hozawa, Miyuki Kawado, and Shuji Hashimoto participated in the writing of the report. Shinichi Kuriyama and Ichiro Tsuji participated in critical revision of the manuscript. All authors approved the final version of the report for submission.

Funding

This study was supported by a Health Sciences Research Grant for Health Services (H21-Choju-Ippan-001, H20-Junkankitou (Seisyu)-Ippan-013, H22- Junkankitou (Seisyu)-Ippan-012), Ministry of Health, Labour and Welfare, Japan. Masato Nagai is a recipient of a Research Fellowships of the Japan Society for the Promotion of Science for Young Scientists.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Ethical approval

The study protocol was approved by the Ethics Committee of Tohoku University School of Medicine. Participants who had returned the self-administered questionnaires and signed them were considered to have consented to participate.

Data sharing

No additional data available.

Figure legend

Figure 1

Multiadjusted mortality by BMI categories in each age-group in men (a) and women (b).

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Table1 Baseline characteristics by BMI[a] categories in 41,965 participants.

	Men					Women				
	BMI (kg/m^2)				*p* value[b]	BMI (kg/m^2)				*p* value
	<18.5	18.5-24.9	25.0-29.9	≥30.0		<18.5	18.5-24.9	25.0-29.9	≥30.0	
No. of subjects	666	14,278	4,730	392		857	14,031	6,226	785	
Mean age (years)	64.0	59.1	57.4	56.1	<.0001	63.7	59.8	60.7	61.2	<.0001
SD[a]	10.4	10.5	10.2	10.2		10.9	10.1	9.1	9.5	
Smoking status (%)										
Current and Past smoker	87.3	82.5	76.6	74.8	<.0001	18.6	11.2	10.1	10.6	<.0001
Never smoker	12.7	17.5	23.4	25.2		81.4	88.8	90.0	89.4	
Alcohol consumption (%)										
Current drinker, 1-449 g/week	49.2	61.0	61.4	50.8	<.0001	18.2	21.8	21.4	19.3	0.0574
Current drinker, ≥450 g/week	9.6	11.7	12.6	15.0		0.6	0.8	0.5	0.9	
Never and past drinker	41.2	27.3	26.0	34.2		81.2	77.4	78.2	79.8	
Sports and physical exercise (%)										
≥3 hours/week	17.5	16.1	13.8	10.1	<.0001	9.8	11.3	11.0	10.8	0.5993
<3 hour/week	82.5	83.9	86.2	89.9		90.2	88.7	89.0	89.2	
Time spent walking (%)										
≥1 hour/day	41.7	51.4	45.8	42.7	<.0001	37.9	45.1	41.0	35.6	<.0001
<1 hour/day	58.3	48.7	54.2	57.3		62.1	54.9	59.0	64.4	
Education (%)										
Junior high school	64.2	62.2	58.9	58.8	0.0013	58.3	54.2	62.7	71.3	<.0001
High school	27.4	30.5	33.4	33.4		34.0	36.9	31.0	24.6	
College/university or higher	8.4	7.3	7.7	7.8		7.7	8.9	6.3	4.1	

[a] BMI, body mass index; SD, standard deviation.

[b] *p* values were calculated by chi-squared test (categorical variables) or ANOVA (continuous variables).

Table 2. Mortality ratio for BMI[a] categories in 41,965 participants.

		Univariate			Multiadjusted[b]		
	BMI (kg/m^2)	Mortality ratio	95% confidence interval	*p* value	Mortality ratio	95% confidence interval	*p* value
Men	<18.5	1.69	1.47 - 1.93	<.0001	1.62	1.41 - 1.86	<.0001
	18.5-24.9	1.00	Reference		1.00	Reference	
	25.0-29.9	0.90	0.82 - 0.98	0.0163	0.91	0.83 - 0.99	0.0260
	≥30.0	1.13	0.87 - 1.47	0.3712	1.14	0.88 - 1.49	0.3177
Women	<18.5	1.50	1.25 - 1.81	<.0001	1.46	1.22 - 1.76	<.0001
	18.5-24.9	1.00	Reference		1.00	Reference	
	25.0-29.9	1.00	0.89 - 1.11	0.9613	0.98	0.88 - 1.10	0.7841
	≥30.0	1.29	1.03 - 1.62	0.0273	1.23	0.98 - 1.55	0.0717

[a] BMI, body mass index.

[b] Adjusted for age groups, smoking status, alcohol drinking, sports and physical exercise, time spent walking, and education.

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Table 3. Life expectancy and lifetime medical expenditure at age 40 years for BMI[a] categories in 41,965 participants.

	BMI (kg/m²)	Univariate			Multiadjusted[b]		
		Estimate	95% confidence	*p* value	Estimate	95% confidence	*p* value
Men	Life expectancy at age 40 years (years)						
	<18.5	36.72	35.10 - 38.17	<.0001	37.40	35.80 - 38.87	<.0001
	18.5-24.9	42.70	41.91 - 43.37	Reference	43.03	42.22 - 43.73	Reference
	25.0-29.9	44.09	42.89 - 45.25	0.0157	44.34	43.11 - 45.54	0.0264
	≥30.0	41.23	38.16 - 44.54	0.3733	41.36	38.28 - 44.70	0.3184
	Lifetime medical expenditure at age 40 years (£)						
	<18.5	94,877.5	83,411.4 - 106,275.7	0.6846	93,208.7	81,704.9 - 104,706.4	0.3916
	18.5-24.9	97,244.1	92,662.5 - 101,774.0	Reference	98,355.0	93,615.3 - 103,010.2	Reference
	25.0-29.9	114,398.2	107,490.1 - 121,505.3	<.0001	114,766.9	107,754.1 - 121,966.6	<.0001
	≥30.0	115,362.6	97,361.8 - 134,555.0	0.0501	112,858.9	94,954.1 - 131,840.9	0.1141
Women	Life expectancy at age 40 years (years)						
	<18.5	46.26	43.98 - 48.43	<.0001	46.98	44.63 - 49.29	<.0001
	18.5-24.9	51.70	50.28 - 53.02	Reference	52.31	50.79 - 53.75	Reference
	25.0-29.9	51.74	49.98 - 53.48	0.9582	52.56	50.67 - 54.46	0.7797
	≥30.0	48.13	45.23 - 51.22	0.0272	49.23	46.14 - 52.59	0.0724
	Lifetime medical expenditure at age 40 years (£)						
	<18.5	108,278.3	97,142.8 - 119,593.7	0.5816	109,382.2	97,996.6 - 121,008.6	0.5174
	18.5-24.9	111,512.8	105,303.4 - 117,910.4	Reference	113,282.9	106,668.0 - 120,054.6	Reference
	25.0-29.9	127,869.3	120,236.3 - 135,932.3	<.0001	129,964.6	121,845.4 - 138,577.2	<.0001
	≥30.0	134,887.1	121,318.4 - 149,383.6	0.0007	137,765.9	123,672.9 - 152,970.2	0.0005

[a] BMI, body mass index.

[b] Adjusted for age groups, smoking status, alcohol drinking, sports and physical exercise, time spent walking, and education.

deemed to be important to include in checklists for each type of study. A provisional list of items prepared in advance (available from our website) was used to facilitate discussions. The three draft checklists were then discussed by all participants and, where possible, items were revised to make them applicable to all three study designs. In a final plenary session, the group decided on the strategy for finalising and disseminating the STROBE statement.

After the workshop we drafted a combined checklist including all three designs and made it available on our website. We invited participants and additional scientists

STROBE statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation
Title and abstract		
	1 ✓	*(a)* Indicate the study's design with a commonly used term in the title or the abstract
	✓	*(b)* Provide in the abstract an informative and balanced summary of what was done and what was found
Introduction		
Background/rationale	2 ✓	Explain the scientific background and rationale for the investigation being reported
Objectives	3 ✓	State specific objectives, including any prespecified hypotheses
Methods		
Study design	4 ✓	Present key elements of study design early in the paper
Setting	5 ✓	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection
Participants	6 ✓	*(a) Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants
		(b) Cohort study—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case
Variables	7 ✓	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable
Data sources/ measurement	8* ✓	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group
Bias	9 ✓	Describe any efforts to address potential sources of bias
Study size	10 ✓	Explain how the study size was arrived at
Quantitative variables	11 ✓	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why
Statistical methods	12 ✓	*(a)* Describe all statistical methods, including those used to control for confounding
	✓	*(b)* Describe any methods used to examine subgroups and interactions
	✓	*(c)* Explain how missing data were addressed
	✓	*(d) Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross sectional study*—If applicable, describe analytical methods taking account of sampling strategy
	✓	*(e)* Describe any sensitivity analyses
Results		
Participants	13* ✓	*(a)* Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed
	✓	*(b)* Give reasons for non-participation at each stage
		(c) Consider use of a flow diagram
Descriptive data	14* ✓	*(a)* Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders
		(b) Indicate number of participants with missing data for each variable of interest
	✓	*(c) Cohort study*—Summarise follow-up time (eg average and total amount)
Outcome data	15* ✓	*Cohort study*—Report numbers of outcome events or summary measures over time
		Case-control study—Report numbers in each exposure category, or summary measures of exposure
		Cross sectional study—Report numbers of outcome events or summary measures
Main results	16 ✓	*(a)* Report the numbers of individuals at each stage of the study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed
	✓	*(b)* Give reasons for non-participation at each stage
		(c) Consider use of a flow diagram
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses
Discussion		
Key results	18 ✓	Summarise key results with reference to study objectives
Limitations	19 ✓	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias
Interpretation	20 ✓	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence
Generalisability	21 ✓	Discuss the generalisability (external validity) of the study results
Other information		
Funding	22 ✓	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross sectional studies.
The STROBE checklist is best used in conjunction with the explanation and elaboration article.[18-20] This article and separate versions of the checklist for cohort, case-control, and cross sectional studies are available at www.strobe-statement.org.

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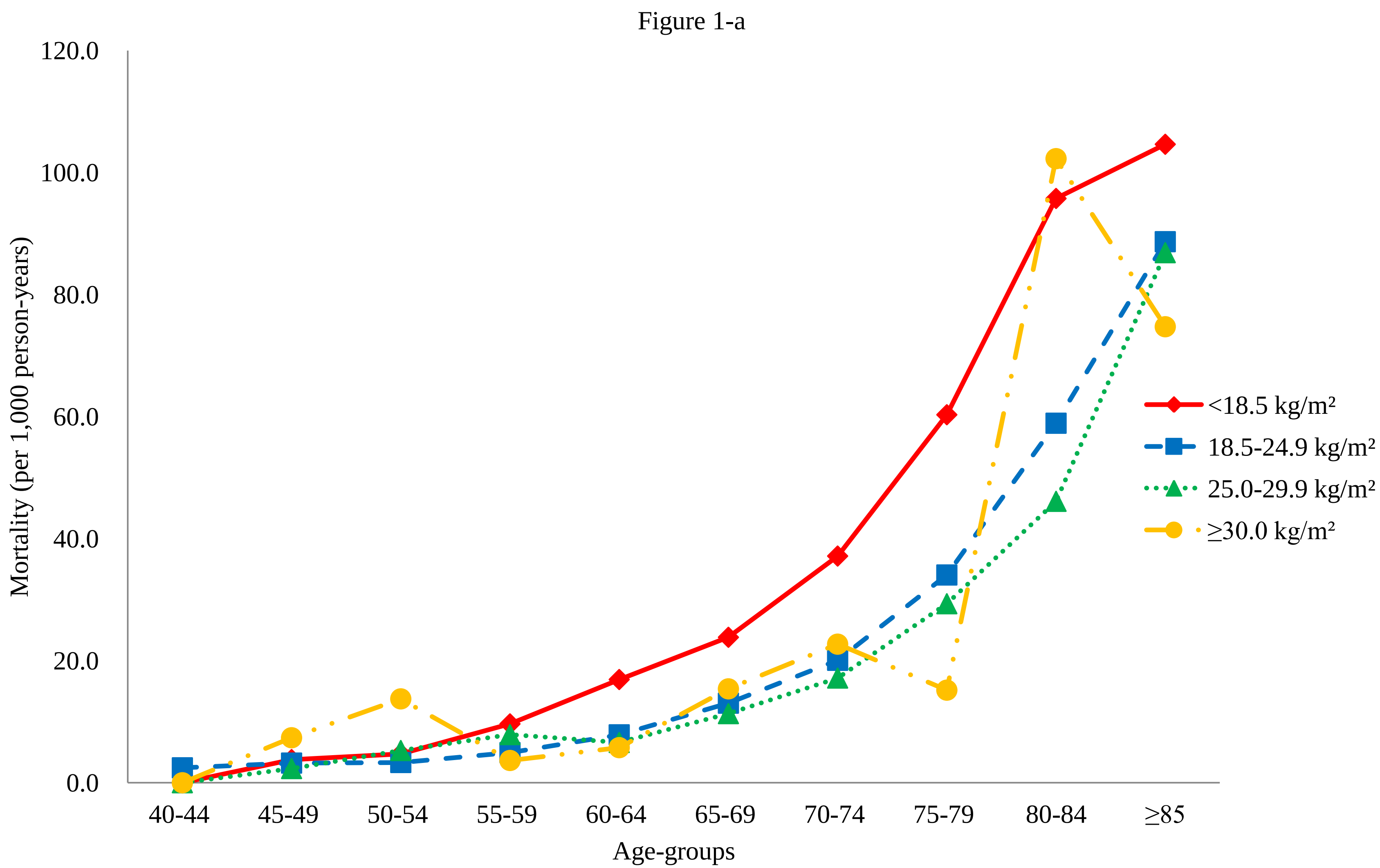

Figure 1-a
Mortality (per 1,000 person-years)
120.0
100.0
80.0
60.0
40.0
20.0
0.0
40-44
45-49
50-54
55-59
60-64
65-69
70-74
75-79
80-84
≥85
Age-groups
<18.5 kg/m²
18.5-24.9 kg/m²
25.0-29.9 kg/m²
≥30.0 kg/m²

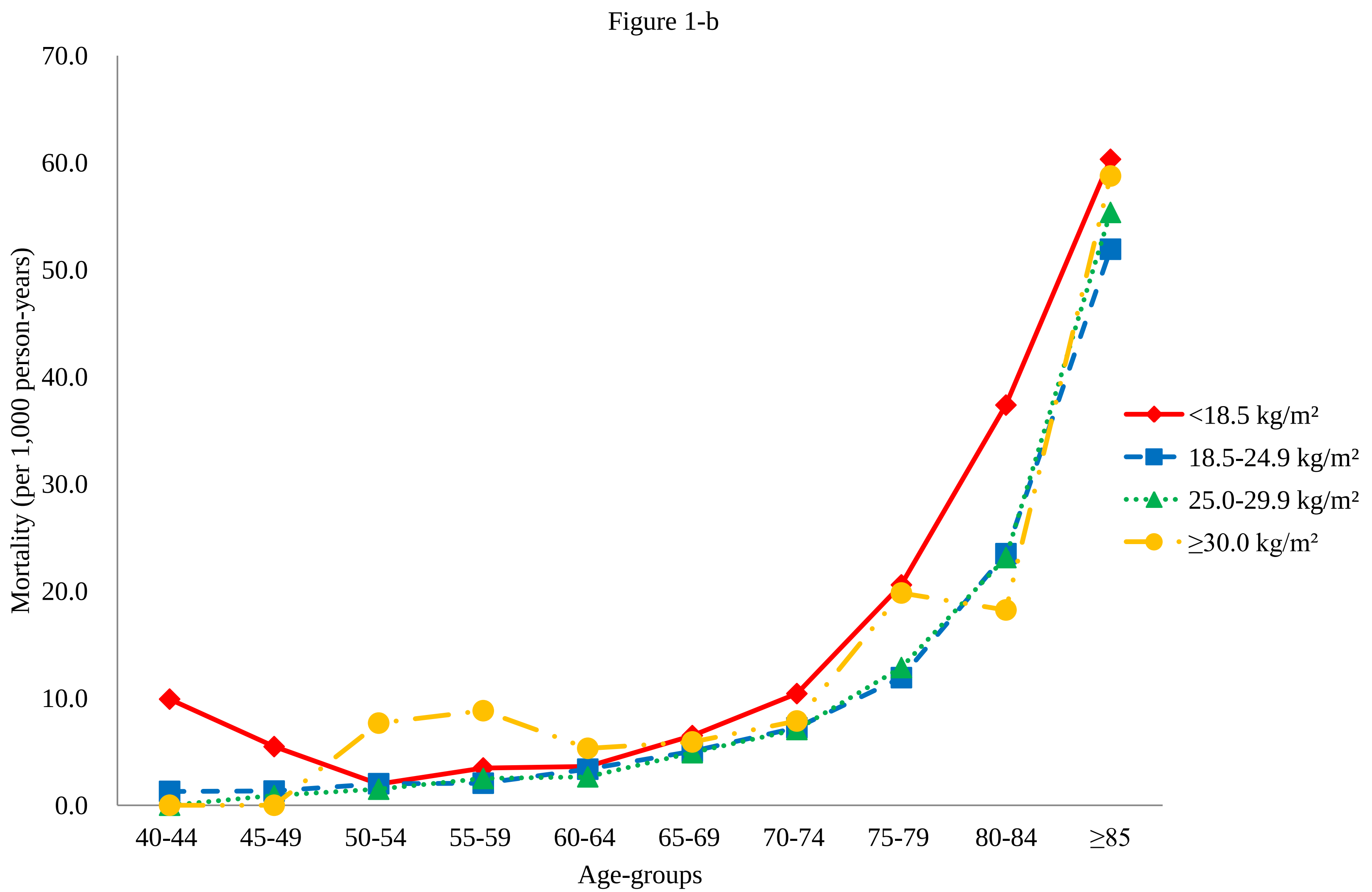
Figure 1-b
Mortality (per 1,000 person-years)
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
40-44
45-49
50-54
55-59
60-64
65-69
70-74
75-79
80-84
≥85
Age-groups
<18.5 kg/m²
18.5-24.9 kg/m²
25.0-29.9 kg/m²
≥30.0 kg/m²