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Body mass index and the risk of incident functional disability in elderly Japanese
The OHSAKI Cohort 2006 Study

Shu Zhang, MB*, Yasutake Tomata, PhD, Kemmyo Sugiyama, MD, Yu Kaiho, MD, Kenji Honkura, MD, PhD, Takashi Watanabe, MD, Fumiya Tanji, MSc, Yumi Sugawara, PhD, Ichiro Tsuji, MD, PhD

Abstract

The relationship between the body mass index (BMI) and the incidence of cause-specific disability remains unclear.

We conducted a prospective cohort study of 12,376 Japanese individuals aged ≥65 years who were followed up for 5.7 years. Information on BMI and other lifestyle factors was collected via a questionnaire in 2006. Functional disability data were retrieved from the public Long-term Care Insurance database. BMI was divided into 6 groups (<21, 21–<23, 23–<25, 25–<27[reference], 27–<29 and ≥29). Hazard ratios and 95% confidence intervals for cause-specific disability were estimated using Cox proportional hazards regression models.

A U-shaped relationship between BMI and functional disability was observed, with a nadir at 26. The nadir BMI values with the lowest disability risk were 28 for dementia, 25 for stroke, and 23 for joint disease. A low BMI (<23) was a risk factor for disability due to dementia, the HR values (95% CI) being 2.48 (1.70–3.63) for BMI <21 and 2.25 (1.54–3.27) for BMI 21 to <23; a high BMI (≥29) was a risk factor for disability due to joint disease, the HR value (95% CI) being 2.17 (1.40–3.35). There was no significant relationship between BMI and disability due to stroke.

The BMI nadirs for cause-specific disability differed: a low BMI (<23) was a risk factor for disability due to dementia, and a high BMI (≥29) was a risk factor for disability due to joint disease. Because BMI values of 23 to <29 did not pose a significantly higher risk for each cause of disability, this range should be regarded as the optimal one for the elderly population.

Abbreviations: ADL = activities of daily living, BMI = body mass index, ICD-10 = International Classification of Diseases and Related Health Problems, Tenth Revision, LTCI = Long-term Care Insurance.

Keywords: body mass index, cause-specific disability, elderly people, ideal BMI range, incident disability

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Division of Epidemiology, Tohoku University School of Public Health, Graduate School of Medicine, Sendai, Miyagi, Japan.

** Correspondence: Shu Zhang, Division of Epidemiology, Tohoku University School of Public Health, Graduate School of Medicine, Seiryo-machi, Aoba-ku, Sendai, Miyagi, Japan (e-mail: zhangshu@med.tohoku.ac.jp).*

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1. Introduction

Nutritional status such as being obese or underweight is a major risk factor for disability in elderly people.[1–4] Because the burden of disability is increasing due to ageing of the population,[5] it has been suggested that health policies aimed at prolongation of disability-free life expectancy should be implemented.

As the fundamental cause of abnormal nutritional status is an energy imbalance between calories consumed and calories expended, researchers in Japan,[6] Queensland,[7] and the USA[8] have proposed that, for elderly people, the body mass index (BMI) should be a major indicator of energy balance for maximization of healthy life expectancy.

Joint disease, stroke, and dementia have been documented as the major causes of disability in elderly populations.[9,10] Many studies have suggested that the optimal BMI ranges for avoidance of these 3 diseases are discrepant,[11–16] suggesting that the optimal BMI values for cause-specific disability might also vary. On the other hand, development of a disease does not necessarily mean that disability will result. Therefore, the optimal BMI for cause-specific disability might differ from that for the corresponding disabling disease, making it inadvisable to apply the optimal BMIs for specific diseases in order to prevent disability.

In the field of disability research, several studies[1,17–19] have reported inconsistent desirable BMI ranges for the elderly population, and these ranges were higher than the WHO standard (18.50–<25). As for federal guidelines relating to overweight and obesity as applied to elderly persons, an evidence-based assessment has also indicated that federal guideline standards for ideal weight (BMI 18.7–<25) may be overly restrictive when applied to the elderly population.[20] As existing evidence has been based on the relationship between BMI and all-cause disability, it is unknown whether the optimal BMI range for all-cause disability is suitable for each major form of cause-specific disability. If this is not the case, adoption of these ranges would not help the elderly to avoid the most likely forms of disability, and it would not be appropriate to apply these desirable BMI ranges for maximization of disability-free life expectancy. Accordingly, it is important to examine whether there is an ideal BMI range that might be suitable for avoidance of cause-specific disability and would not be incompatible with all-cause disability. Nevertheless, to our knowledge, the relationship between BMI and cause-specific disability has not been investigated.

In order to clarify the ideal BMI range for maximizing disability-free life expectancy, we conducted a 5.7-year cohort study of the relationship between BMI and risk of cause-specific disability in elderly people. We hypothesized that the optimal BMI range for various forms of major cause-specific disability would differ. From the data related to cause-specific disability, we then derived an ideal generalized BMI range that did not impose a significantly higher risk for each specific cause of disability. Finally, we compared the ideal BMI range with the optimal BMI range for all-cause disability to see whether any inconsistency was evident. In view of the huge burden of disability among the increasing elderly population worldwide, it is essential to gain a comprehensive understanding of the relationship between BMI and disability for formulation of public health policy.

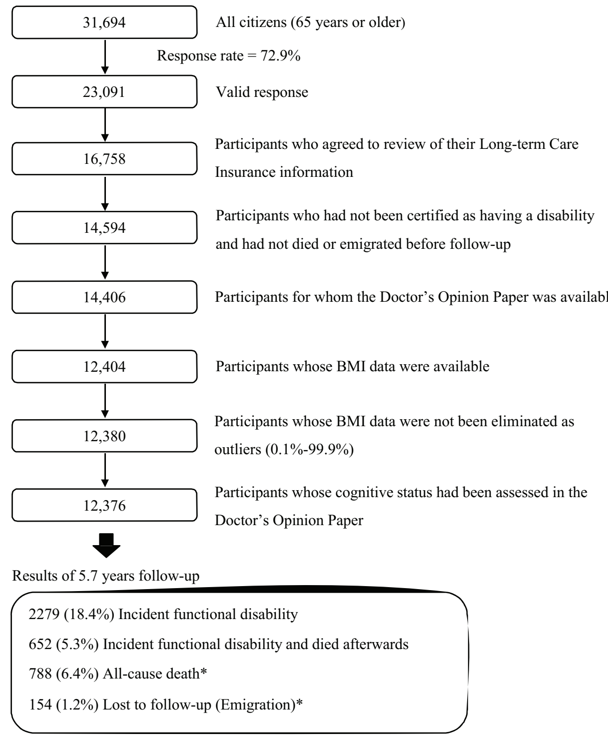

Figure 1. Flowchart of the study participants: the Ohsaki Cohort 2006 Study. *Without experiencing incident functional disability.

2. Subjects and methods

2.1. Study cohort

The design of the Ohsaki Cohort 2006 Study has been described in detail elsewhere.[21] In brief, the source population for the baseline survey comprised 31,694 men and women aged ≥65 y who were living in Ohsaki City, northeastern Japan, on 1 December 2006.

The baseline survey was conducted between 1 December and 15 December 2006. A questionnaire was distributed by the heads of individual administrative districts to individual households and then collected by mail. In this analysis, 23,091 persons who provided valid responses formed the study cohort (Fig. 1). We excluded 6333 persons who did not provide written consent for review of their Long-term Care Insurance (LTCI) information, 2102 persons who had already been certified as having disability by the LTCI before follow-up, 62 persons who had died or moved out of the district during the period of the baseline survey, 188 persons whose Doctor's Opinion Paper was unavailable, 2002 persons whose BMI data were missing, 24 persons whose BMI value fell outside the 0.1% to 99.9% total BMI range, and 4 persons who had already been certified as having disability by the LTCI at the time of the baseline survey. Thus, 12,376 responses were analyzed for the purposes of this study. During the 5.7-year period, only 154 persons were lost to follow-up because of migration from the study area, without developing incident functional disability, which provided a follow-up rate of 98.8%. Among 61,803 person-years, incident functional disability was determined for 2931 persons and the number of all-cause deaths without incident functional disability was 788.

2.2. Exposure data

The survey included questions about body weight (currently and 1 year ago) and height, as well as items on history of disease, education level, smoking, alcohol drinking, cognitive activity score,[22] psychological distress score (K6),[23,24] motor function score according to the Kihon Checklist,[25] body pain, having been confined to bed or not for over 1 week in the last 3 months, time spent walking per day, social support, and participation in community activities.

BMI was calculated as the self-reported body weight (in kilogram) divided by the square of the self-reported body height (in meter). The options for the degree of body pain in the last month included: (1) none, (2) slight, (3) mild, (4) moderate, (5) strong, and (6) severe. Weight fluctuation was calculated by (1) subtracting the self-reported current body weight (in kilogram) from the self-reported body weight (in kilogram) 1 year previously, (2) dividing the difference by the self-reported body weight (in kilogram) 1 year previously, and (3) changing the quotient into an absolute value and multiplying it by 100%. The degree of social support available to each individual was assessed by asking the following questions[26]: Do you have someone (1) with whom you can talk when you are in trouble, (2) whom you can consult when you do not feel well, (3) who can help you with your daily housework, (4) who can take you to a hospital when you feel ill, and (5) who can take care of you if you become bedridden? This social support questionnaire consisted of 5 questions, each requiring a "yes" or "no" answer. The validity and reliability of the questionnaire had not been evaluated. We also assessed participation in community activities. We asked how often each respondent participated in the following activities: (1) neighborhood associations; (2) sports, exercise, or hobbies; (3) volunteering for activities related to nonprofit organizations; and (4) any other type of social gatherings. The frequency of these activities was assessed as never, a few times each year, monthly, 2 to 3 times/month, 1 time/wk, 2 to 3 times/

wk, and ≥4 times/wk. The Kihon Checklist motor function score has been previously evaluated and has shown to have predictive validity for functional disability.[25] This questionnaire was available only in Japanese.

2.3. The LTCI system in Japan

In this study, we defined incident functional disability as certification for the LTCI in Japan, which uses a nationally uniform standard of functional disability. The LTCI is a form of mandatory social insurance to assist the frail and the elderly in their daily activities.[27,28] Everyone aged ≥40 year pays a premium, and everyone aged ≥65 year is eligible for formal caregiving services. When a person applies to the municipal government for benefits, a care manager visits his or her home and assesses the degree of functional disability by using a questionnaire developed by the Ministry of Health, Labor, and Welfare. Then, the municipal government calculates the standardized scores for physical and mental function on the basis of the questionnaire and classifies the applicant as being eligible or ineligible for LTCI benefits (certification). If a person is judged to be eligible for benefits, the Municipal Certification Committee decides on 1 of 7 levels of support, ranging from Support Level 1, Support Level 2, and Care Level 1 to Care Level 5. In brief, LTCI certification levels are defined as follows: Support Level 1 is defined as "limited in instrumental activities of daily living but independent in basic activities of daily living (ADLs)," Care Level 2 is defined as "requiring assistance in at least 1 basic ADL task," and Care Level 5 is defined as "requiring care in all ADL tasks." A community-based study has shown that the level of LTCI certification is well correlated with ability to perform ADLs, and with the Mini Mental State Examination score.[29] A prospective study has also indicated that the level of LTCI certification is significantly associated with mortality risk.[30] LTCI certification has been used as a measure of incident functional disability in the elderly.[31,32]

2.4. Follow-up and case ascertainment

Incident functional disability was set as our endpoint, which was defined as LTCI certification. The primary outcome was LTCI certification (Support Level 1 or higher), and deaths without LTCI certification were treated as censored. We obtained information on the date of LTCI certification, death, or emigration from Ohsaki City. With regard to LTCI certification, information on care level was also provided. All data were transferred from the Ohsaki City Government under the agreement related to Epidemiologic Research and Privacy Protection yearly each December.

2.5. Cause of disability

To determine the cause of functional disability, diagnosis related to disability was investigated by reference to the LTCI doctor's opinion paper, in accordance with a standardized physicians' manual issued by the Ministry of Health, Labor and Welfare.[33] Primary diagnosis was coded using the International Classification of Diseases and Related Health Problems, Tenth Revision (ICD-10).

In our research, 3 major functional disabling diseases in Japanese elderly[34,35] were defined as the primary outcomes: dementia (codes F00-03, G30), stroke (codes I60-69) and joint disease (codes M00-25, M40-54).

2.6. Ethical issues

We considered the return of completed questionnaires to imply consent to participate in the study involving the baseline survey data and subsequent follow-up of death and emigration. We also confirmed information regarding LTCI certification status after obtaining written consent from the subjects. The Ethics Committee of Tohoku University Graduate School of Medicine (Sendai, Japan) reviewed and approved the study protocol.

2.7. Statistical analysis

We counted the person-years of follow-up for each subject from 16 December 2006 until the date of incident functional disability, date of emigration from Ohsaki City, date of death, or the end of the study period (30 November 2011), whichever occurred first. Baseline characteristics were evaluated by using ANOVA for continuous variables and the chi-squared test for categorical variables. We used the multiple adjusted Cox proportional hazards model to calculate HRs and 95% CIs for incidence of functional disability and cause-specific disability according to various categories of BMI range.

In an effort to obtain more specific data that would better define the optimum BMI range, BMI was divided into 6 groups (<21, 21–<23, 23–<25, 25–<27, 27–<29, and ≥29). Several previous studies have indicated that BMI 25 to <27 was associated with the lowest risk of total disability[3,17] and mortality[1,36] in elderly people. Respondents whose BMI was 25 to <27 were used as a reference group. We examined the relationship between BMI and incident functional disability using the following models. Model 1 was sex- and age-adjusted. To examine whether the association between BMI and incident disability risk could be explained as resulting from healthy physical status or other lifestyle factors, model 2 was further adjusted for history of stroke, myocardial infarction, diabetes, digestive system diseases or cancer, education level, smoking status, and tertile categories of the cognitive activity score and psychological distress score. Cause-specific disability was also examined in models using the same set of covariates as that used in the all-cause disability models.

We estimated the shape of the continuous relationship between BMI and disability endpoints using penalized splines (P-splines)[37] in which automatic selection criteria for deciding the optimal degree of smoothing (or equivalently, the optimal degrees of freedom) with P-splines were implemented.

All data were analyzed using SAS version 9.1 (SAS Institute Inc.), and P-splines were drawn by R version 3.2.1. All statistical tests described here were 2-sided, and differences at $P < 0.05$ were accepted as significant.

3. Results

3.1. Association of BMI with healthy physical status and lifestyle factors

The baseline characteristics of the 12,376 participants according to BMI category are shown in Table 1. Subjects with higher BMI were less likely to have a history of gastric and duodenal ulcer or cancer, to be current smokers, and to have better motor function. Subjects with lower BMI were less likely to have a history of diabetes or arthritis and to have body pain.

Table 1

Characteristics of participants divided into 6 body mass index (BMI) groups (n = 12,376).

	Six groups of BMI (range)						
	<21	21–23	23–25	25–27	27–29	≥29	*P*[*]
No. of all participants	2509	3020	3057	2050	1089	651	
Age, y	74.8 ± 6.2[†]	73.7 ± 5.8	73.1 ± 5.6	72.9 ± 5.4	72.6 ± 5.1	73.1 ± 5.6	<0.001
Sex, males, %	43.9	45.9	50.4	45.3	39.1	35.3	<0.001
Past history of (%)							
Stroke	2.4	2.3	3.0	3.0	2.4	3.4	0.28
Myocardial infarction	5.0	4.0	4.7	5.7	4.8	6.1	0.05
Diabetes	8.9	11.9	11.8	12.2	15.0	18.3	<0.001
Gastric and duodenal ulcer	20.6	15.9	15.1	14.9	13.2	9.4	<0.001
Osteoarthritis	11.8	13.8	15.0	19.0	22.1	24.7	<0.001
Cancer	13.2	8.3	8.1	7.4	6.2	5.2	<0.001
Educational level <16 y (%)	28.9	27.3	25.7	26.2	26.3	30.6	<0.01
Current smoker (%)	15.8	13.3	12.1	9.5	8.6	6.8	<0.001
Current alcohol drinker (%)	31.5	34.9	39.4	35.5	32.5	30.6	<0.001
Frequent cognitive activity (%) [‡]	20.7	24.7	27.9	26.0	22.4	18.6	<0.001
Psychological distress (%)[§]	4.6	3.8	3.5	3.6	3.9	3.7	0.22
Better motor function (%)[||]	74.4	80.0	78.1	75.5	69.5	58.7	<0.001
Body pain (%)[¶]	26.7	24.3	24.6	27.4	32.7	37.5	<0.001
Been in bed for >1 week (%)	4.4	3.4	2.9	2.9	2.5	3.7	<0.01
Time spent walking ≥1 h/d (%)	26.5	27.9	28.5	26.7	22.7	24.4	<0.01
Weight fluctuation ≥5% (%)[#]	20.2	14.3	13.7	14.3	15.0	19.2	<0.001
Social support (%)							
To consult when you are in trouble	90.3	91.3	90.6	89.9	90.7	91.4	0.57
To consult when you are in poor physical condition	94.0	94.2	93.9	93.9	94.2	95.5	0.75
To help with your daily housework	86.3	85.1	85.4	84.9	84.4	86.1	0.67
To take you to a hospital	92.6	92.9	92.6	92.1	92.7	92.3	0.96
To take care of you	86.5	86.7	87.6	86.5	86.3	84.0	0.28
Participation in community activities (%)							
Activities in neighborhood association	36.8	46.1	48.3	48.4	45.6	43.0	<0.001
Sports or exercise	36.0	44.9	47.5	46.7	44.7	38.7	<0.001
Volunteering	22.6	30.7	31.4	31.5	31.0	23.2	<0.001
Social gathering	35.6	43.9	47.7	47.9	45.9	39.2	<0.001

BMI = body mass index.
[*] Obtained by using the chi-square test for variables of proportion and 1-factor ANOVA for continuous variables.
[†] Mean ± SD (all such values).
[‡] Cognitive activity score ≥23.
[§] Kessler 6-item psychological distress scale score ≥13.
[||] Motor function score of the Kihon Checklist <3.
[¶] Body pain degree in the past month belonged to moderate, strong, or severe.
[#] The absolute weight change compared with 1 y ago divided by the weight 1 y ago ≥5%

3.2. BMI and incident functional disability

The relationship between BMI and incident functional disability with HRs and associated 95% CIs is shown in Table 2. After multivariate adjustment for potential confounders, the HR values (95% CI) for model 2 were 1.56 (1.36–1.80) for BMI <21, 1.22 1.23 (1.07–1.41) for BMI 21 to <23, and 1.47 (1.20–1.80) for BMI ≥29. This association was significant for both sexes (P = 0.08 for interaction with sex).

3.3. BMI and cause-specific disability

The relationship between BMI and cause-specific disability with HRs and associated 95% CIs is shown in Table 3. After multivariate adjustment, the cause-specific disability HR values (95% CI) for dementia were 2.48 (1.70–3.63) (2.27 [1.23–4.21] in men and 2.66 [1.64–4.31] in women) for BMI <21, 2.25 (1.54–3.27) (2.15 [1.18–3.91] in men and 2.30 [1.41–3.74] in women) for BMI 21 to <23; those for joint disease were 2.17 (1.40–3.35) (2.86 [1.14–7.14] in men and 2.04 [1.24–3.34] in women) for BMI ≥29. There was no significant relationship between BMI and disability due to stroke.

Figure 2 shows plots of the estimated continuous associations of BMI with all-cause and cause-specific disability. A U-shaped relationship between BMI and all-cause disability was observed, the risk of disability being significantly higher for participants with lower and higher BMIs, with a nadir at 26. For cause-specific disability, the risk of dementia disability was significantly higher for participants with lower BMIs, with a nadir at 28, whereas the risk of joint disease disability was elevated only among those with higher BMIs, with a nadir at 23. Although the risk of stroke disability was not significant for any BMI values, the trend and nadir were similar to those for all-cause disability.

3.4. Sensitivity analysis

To examine possible reverse causality, we analyzed whether the association would change by excluding participants whose disability event occurred in the first 2 years of follow-up. After we had excluded 655 such participants, the results did not change substantially. The multiple-adjusted HR values (95% CI) (model 2) were 1.51 (1.28–1.79) for BMI <21, 1.29 (1.09–1.53) for BMI 21 to <23, and 1.59 (1.25–2.02) for BMI ≥29 (Supplementary

Table 2

Relationships between the body mass index (BMI) and incident functional disability (n=12,376)[*].

	Six groups of BMI (range)					
	<21	21–23	23–25	25–27	27–29	≥29
No. of all participants	2509	3020	3057	2050	1089	651
(Person-years)	(11601)	(15102)	(15674)	(10582)	(5637)	(3207)
Primary outcome events	639	566	472	298	167	137
Median of BMI	19.6	22.1	23.9	25.9	27.8	30.3
Crude	1.99 (1.74–2.29)[§]	1.34 (1.16–1.54)	1.07 (0.93–1.24)	1.00 (Reference)	1.05 (0.87–1.27)	1.53 (1.25–1.88)
Model 1[†]	1.59 (1.38–1.82)	1.23 (1.07–1.42)	1.04 (0.90–1.20)	1.00 (Reference)	1.08 (0.89–1.31)	1.58 (1.29–1.93)
Model 2[‡]	1.56 (1.36–1.80)	1.23 (1.07–1.41)	1.04 (0.90–1.20)	1.00 (Reference)	1.04 (0.86–1.26)	1.47 (1.20–1.80)

BMI = body mass index.
[*] Analysis by Cox proportional hazards model.
[†] Model 1 was adjusted for age (65–69, 70–74, 75–79, 80–84, or ≥85 y) and sex.
[‡] Model 2 was adjusted as for model 1 plus history of disease (stroke, myocardial infarction, diabetes, digestive system diseases or cancer [yes, no]), educational level (age at last school graduation: <16 y, 16–18 y, ≥19 y, or missing), smoking (never, former, current, or missing), cognitive activity score (<20, 20–23, ≥23, or missing), psychological distress score (<13, ≥13, or missing).
[§] Adjusted hazard ratios (95% confidence interval) (all such values).

Table 1, http://links.lww.com/MD/B163). In addition, after we had excluded participants with any history of diseases that could cause functional disability (stroke, myocardial infarction, diabetes, digestive system diseases, or cancer), the results also did not change substantially. The multiple-adjusted HR values (95% CI) (model 2) were 1.60 (1.30–1.97) for BMI <21, 1.33 (1.08–1.64) for BMI 21 to <23, and 1.55 (1.14–2.10) for BMI ≥29 (Supplementary Table 2, http://links.lww.com/MD/B163). To eliminate the possible effect of weight fluctuation, we performed stratified analysis using only 10,083 participants whose weight fluctuation had been <5% of their original weight 1 year before, but the results also did not change substantially. The multiple-adjusted HR values (95% CI) (model 2) were 1.59 (1.36–1.87) for BMI <21, 1.22 (1.04–1.44) for BMI 21 to <23, and 1.62 (1.28–2.04) for BMI ≥29 (Supplementary Table 3, http://links.lww.com/MD/B163).

4. Discussion

The present research was conducted to investigate the relationship between BMI and cause-specific disability in an elderly population to explore the optimum BMI range that would maximize disability-free life expectancy. The BMI nadirs for cause-specific disability differed, lower BMI (<23) being a risk factor for disability due to dementia, whereas a higher BMI (≥29) was a risk factor for disability due to joint disease.

Table 3

Relationships between the body mass index (BMI) and cause-specific disability (n=12,376)[*].

	Six categories of BMI (range)					
	<21	21–23	23–25	25–27	27–29	≥29
Dementia						
No. of events	122	123	63	35	16	14
Crude	3.24 (2.23–4.72)[§]	2.48 (1.70–3.61)	(0.81–1.84)	1.00 (Reference)	0.86 (0.48–1.55)	1.33 (0.72–2.48)
Model 1[†]	2.53 (1.74–3.69)	2.27 (1.56–3.31)	1.19 (0.79–1.81)	1.00 (Reference)	0.88 (0.48–1.58)	1.37 (0.74–2.54)
Model 2[‡]	2.48 (1.70–3.63)	2.25 (1.54–3.27)	1.17 (0.78–1.77)	1.00 (Reference)	0.84 (0.47–1.52)	1.25 (0.67–2.33)
Male	2.27 (1.23–4.21)	2.15 (1.18–3.91)	0.97 (0.50–1.88)	1.00 (Reference)	0.71 (0.25–1.98)	0.99 (0.32–3.02)
Female	2.66 (1.64–4.31)	2.30 (1.41–3.74)	1.34 (0.79–2.28)	1.00 (Reference)	0.94 (0.45–1.94)	1.43 (0.67–3.05)
Stroke						
No. of events	80	82	79	54	30	14
Crude	1.37 (0.97–1.93)	1.07 (0.76–1.51)	0.99 (0.70–1.40)	1.00 (Reference)	1.04 (0.67–1.63)	0.86 (0.48–1.55)
Model 1	1.2 (0.85–1.70)	1.01 (0.71–1.42)	0.95 (0.67–1.34)	1.00 (Reference)	1.09 (0.70–1.71)	0.92 (0.51–1.66)
Model 2	1.22 (0.86–1.73)	1.02 (0.72–1.44)	0.97 (0.69–1.37)	1.00 (Reference)	1.07 (0.69–1.68)	0.85 (0.47–1.53)
Male	1.22 (0.75–1.98)	1.02 (0.64–1.63)	1.12 (0.71–1.75)	1.00 (Reference)	1.04 (0.55–1.97)	0.79 (0.33–1.91)
Female	1.20 (0.72–2.01)	1.02 (0.61–1.72)	0.76 (0.43–1.32)	1.00 (Reference)	1.10 (0.58–2.08)	0.91 (0.41–2.03)
Joint disease						
No. of events	65	77	59	52	24	34
Crude	1.16 (0.81–1.67)	1.04 (0.73–1.48)	0.77 (0.53–1.12)	1.00 (Reference)	0.87 (0.54–1.41)	2.18 (1.42–3.36)
Model 1	0.91 (0.63–1.31)	0.97 (0.68–1.38)	0.77 (0.53–1.13)	1.00 (Reference)	0.86 (0.53–1.39)	2.18 (1.41–3.36)
Model 2	0.91 (0.63–1.32)	0.97 (0.68–1.38)	0.77 (0.53–1.12)	1.00 (Reference)	0.87 (0.54–1.41)	2.17 (1.40–3.35)
Male	1.42 (0.67–2.99)	1.00 (0.47–2.12)	1.05 (0.51–2.20)	1.00 (Reference)	0.40 (0.09–1.81)	2.86 (1.14–7.14)
Female	0.78 (0.51–1.20)	0.97 (0.65–1.46)	0.68 (0.44–1.06)	1.00 (Reference)	0.97 (0.58–1.63)	2.04 (1.24–3.34)

BMI = body mass index.
[*] Analysis by Cox proportional hazards model.
[†] Model 1 was adjusted for age (65–69, 70–74, 75–79, 80–84, or ≥85 y) and sex.
[‡] Model 2 was adjusted as for model 1 plus history of disease [stroke, myocardial infarction, diabetes, digestive system diseases or cancer (yes, no)], educational level (age at last school graduation: <16 y, 16–18 y, ≥19 y, or missing), smoking (never, former, current, or missing), cognitive activity score (<20, 20–23, ≥23, or missing), and psychological distress score (<13, ≥13, or missing).
[§] Adjusted hazard ratios (95% confidence interval) (all such values).

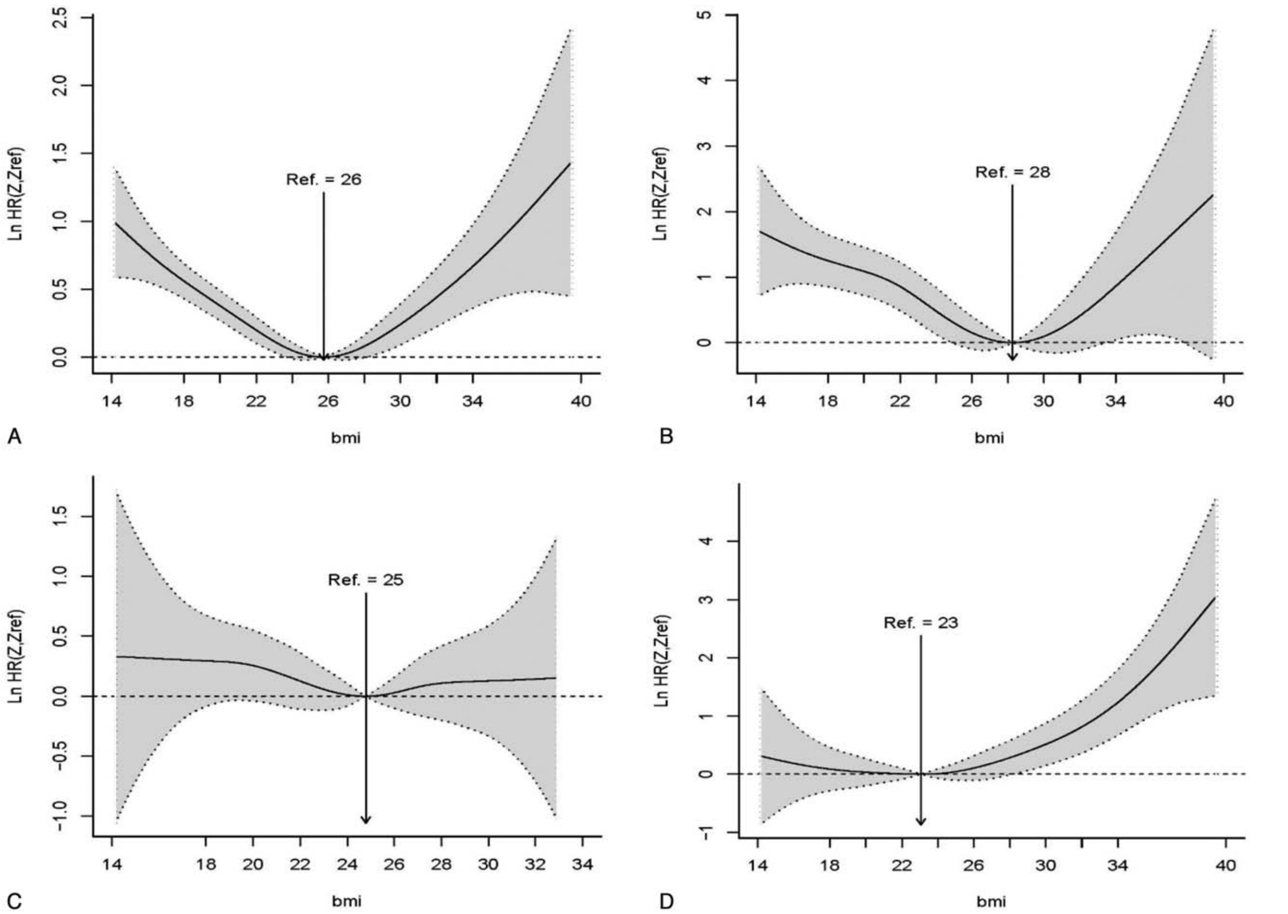

Figure 2. Nonparametric estimates of the association between the body mass index (BMI) in elderly people (age ≥65 years) and all-cause disability (A) and cause-specific disability (dementia (B), stroke (C) and joint disease (D)), for the Ohsaki Cohort 2006 Study. The P-spline reflects the fully adjusted natural log hazard ratios with 95% confidence interval and the nadirs of curves (the reference). *(C) The BMI upper limit on the *x* axis was 34, because no participant with a BMI over 34 suffered stroke during follow-up. BMI = body mass index.

In view of the possible effects of reverse causality, we investigated the relationship between BMI and incident disability after excluding individuals who had suffered incident functional disability in the first 2 years of follow-up, and participants with any history of disease that could cause functional disability (stroke, myocardial infarction, diabetes, digestive system diseases or cancer), respectively. We also conducted stratified analysis using 10,439 participants whose weight had fluctuated within <5% of their original weight 1 year previously, in order to eliminate any potential effect of weight fluctuation. However, the U-shaped association between BMI and incident disability was not attenuated. All these findings suggested that our results were free of reverse causality and the effects of short-term weight change.

To our knowledge, this is the first reported study to have demonstrated a relationship between BMI and incident cause-specific disability. However, differences in the relationships between BMI and the incidence of various diseases are well documented. Two systematic reviews have indicated that increased BMI is associated with the development of osteoarthritis,[11,12] whereas 2 cohort studies[38,39] have demonstrated that lower BMI is associated with a higher risk of dementia. A pooled analysis of 97 prospective cohorts has also demonstrated an excess risk of stroke associated with high BMI.[14] Likewise, some previous studies have demonstrated different relationships between BMI and cause-specific mortality. A cohort study with a 35-year follow-up revealed that higher BMI was associated with coronary heart disease mortality, but for noncardiovascular, cancer, and respiratory mortality, an excess risk was also associated for individuals with a lower BMI.[40] As BMI has been regarded as a risk factor for disease onset and progression (including disability and death), the effects of BMI at different stages of different diseases differ. These previous studies could be considered to have provided supportive evidence for our present findings.

In the present study, a BMI of 23 to <29 was not associated with a significantly higher risk of either specific disease disability or all-cause disability. As functional disabilities caused by stroke, dementia, and joint disease are common among elderly adults,[41] a BMI range that is not associated with a disability risk caused by these 3 diseases might be helpful for maximization of disability-free life expectancy. Therefore, we suggest that a BMI range of 23 to <29 might be optimal for the elderly population when setting a government BMI target.

In general, the findings reported herein are similar to those of prior studies examining the association between BMI and subsequent disability.[1,17] Al Snih et al[1] considered that the BMI range posing the lowest risk of disability was 25 to <30 in elderly Americans, and Kumar et al[17] drew the same conclusion for elderly Mexicans. Racial differences could account for subtle variations in the optimal BMI cut-off point. Because the incident and mortality risks for various diseases associated with the same BMI values differ according to race,[42–44] further investigations of other ethnic populations will still be needed.

Our study had a number of strengths: (1) it was a large population-based cohort study involving 12,376 persons, (2) it had a follow-up rate of almost 100%, (3) the causative diseases we chose led to high disability risk in the study area, and (4) many confounding factors were taken into account.

Several limitations should also be noted, however. First, as the height and weight data were collected via a self-reported questionnaire, the validity of the derived BMI values might have been influenced by reliance on the accuracy of the reported height. Nevertheless, the accuracy of self-reported height and weight is reasonably high among elderly Japanese, suggesting that the information obtained in this way can be used in epidemiological surveys.[45] Second, the number of participants with BMI values over 35 was small, which would not reflect the real relationship between higher BMI and disability accurately. Third, not all potential confounding factors were considered; a few studies have shown that socio-economic status is associated with the incidence of functional disability among elderly people,[46,47] and this was not used as an adjustment factor in our analysis. Fourth, because not all candidates applied for LTCI certification, this study may not have been completely free from detection bias. The degree of this bias remains to be verified.

When interpreted in the context of public health, our present results suggest that strategies for maintaining an ideal BMI range might contribute to prevention of disability in the elderly. For example, in order to address the issue of obesity, population approaches have been used to establish better social circumstances,[48,49] such as promotion of physical activities,[50] regulation of the food environment,[51,52] and elimination of social inequality,[53] based on research evidence.[54–58] By adopting such approaches, disability prevention in the elderly might be achieved through weight management.

In conclusion, the BMI nadirs for cause-specific disability differed in our study: a low BMI (<23) was a risk factor for disability due to dementia, whereas a high BMI (≥29) was a risk factor for disability due to joint disease. The findings of this cohort study suggest that the optimal BMI range for maximization of disability-free life expectancy in the elderly population is 23 to <29.

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