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 (1.40–3.53). 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

1. Introduction

Nutritional status such as being obese or underweight is a major risk factor for disability in elderly people.[1,14] Because the burden of disability is increasing due to ageing of the population,[15] 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.[9,14] 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[11,17–19] 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. 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.

2. Subjects and methods
2.1. Study cohort
The design of the Ohsaki Cohort 2006 Study has been described in detail elsewhere. In brief, the source population for the baseline survey comprised 31,694 men and women aged ≥65 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, psychological distress score (K6), motor function score according to the Kihon Checklist, 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:

| Education level | Smoking | Alcohol drinking | Cognitive activity score | Psychological distress score (K6) | Motor function score according to the Kihon Checklist | Body pain | Social support | Participation in community activities |
|-----------------|---------|----------------|-------------------------|-------------------------------|---------------------------------|----------|----------------|-----------------------------------|
| Low | Yes | Yes | High | Low | Moderate | None | None | None |
| High | No | No | Low | High | Low | None | None | None |

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

| BMI <21 | 21–23 | 23–25 | 25–27 | 27–29 | ≥29 |
|--------|-------|-------|-------|-------|-----|
| 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 | 15.2 | 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 | <0.001 |
| 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 you are in trouble | 90.3 | 91.3 | 90.6 | 89.9 | 90.7 | 91.4 | 0.57 |
| To consult 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, the HR values (95% CI) for model 2 were 1.56 (1.36–1.80) for BMI <21, 1.22 (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).^1

| BMI (range) | <21 | 21–23 | 23–25 | 25–27 | 27–29 | ≥29 |
|-------------|-----|-------|-------|-------|-------|-----|
| No. of all participants | 2509 | 3020 | 3057 | 2050 | 1089 | 651 |
| Median of BMI | 19.6 | 22.1 | 23.9 | 25.9 | 27.8 | 30.3 |
| Male | | | | | | |
| Crude | 1.99 (1.74–2.29)^1 | 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.

Table 3

Relationships between the body mass index (BMI) and cause-specific disability (n = 12,376).^1

| Cause of Disability | <21 | 21–23 | 23–25 | 25–27 | 27–29 | ≥29 |
|---------------------|-----|-------|-------|-------|-------|-----|
| No. of events (562) | 80 | 82 | 79 | 54 | 30 | 14 |
| Male | | | | | | |
| 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 | 1.20 (0.85–1.70) | 1.01 (0.71–1.42) | 0.95 (0.67–1.34) | 1.00 (Reference) | 1.02 (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) |
| Female | 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) |
| Dementia | | | | | | |
| No. of events (562) | 122 | 123 | 63 | 35 | 16 | 14 |
| Male | | | | | | |
| Crude | 3.24 (2.23–4.72)^2 | 2.48 (1.70–3.61) | 0.81 (0.71–1.48) | 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) |
| Stroke | | | | | | |
| No. of events (562) | 80 | 82 | 79 | 54 | 30 | 14 |
| Male | | | | | | |
| 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 | 1.20 (0.85–1.70) | 1.01 (0.71–1.42) | 0.95 (0.67–1.34) | 1.00 (Reference) | 1.02 (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) |
| Female | 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) |

BMI = body mass index.

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 [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), the results also did not change substantially. The multiple-adjusted HR values (95% CI) 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.
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, whereas cohort studies 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. 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. 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, 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. Al Snih et al considered that the BMI range posing the lowest risk of disability was 25 to <30 in elderly Americans, and Kumar et al drew the same conclusion for elderly Mexicans. Racial differences could account for subtle

---

**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.
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 were clear, (4) this was not used as an adjustment factor in our analysis, (5) 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,[146,147] 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,[158,159] such as promotion of physical activities,,[160] regulation of the food environment,[161,162] and elimination of social inequality[163] based on research evidence.[154–158] 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.

References

[1] Al Snih S, Ottenbacher KJ, Markides KS, et al. The effect of obesity on disability vs mortality in older Americans. Arch Intern Med 2007;167: 774–80.
[2] Nam S, Kuo YF, Markides KS, et al. Waist circumference (WC), body mass index (BMI), and disability among older adults in Latin American and the Caribbean (LAC). Arch Gerontol Geriatr 2012;55:40–7.
[3] Marsh AP, Keipski WJ, Espeland MA, et al. Muscle strength and BMI as predictors of major mobility disability in the Lifestyle Interventions and Independence for Elders pilot (LIFE-P). J Gerontol A Biol Sci Med Sci 2011;66:1376–83.
[4] Sharkey JR, Branch LG, Giuliani C, et al. Nutrient intake and BMI as predictors of severity of ADL disability over 1 year in homebound elders. J Nutr Health Aging 2004;8:131–9.
[5] Global Burden of Disease Study CGlobal, regional, and national incidence, prevalence, and years lived with disability for 301 acute and chronic diseases and injuries in 188 countries, 1990–2013: a systematic analysis for the Global Burden of Disease Study 2013. Lancet 2015; 386:743–800.
[6] Nutrition NfoHa. Overview of Dietary Reference Intakes for Japanese (2013), 2nd ed. http://www.nhbro.go.jp/files/06-seisakushou-109000000-kemkoukyokuoverview.pdf. Accessed February 2, 2015.
[7] Government Q, Using Body Mass Index. 2014; https://www.health.qld. gov.au/nutrition/resourcens/gqa/nutrition-bmi.html. Accessed January 3, 2015.
[8] Health NRC/CoDaDiet and Health: Implications for Reducing Chronic Disease Risk. Washington (DC): National Academies Press (US); 1989.
[9] Vos T, Flaxman AD, Naghavi M, et al. Years lived with disability (YLDs) for 1160 sequelae of 293 diseases and injuries 1990–2010: a systematic analysis for the Global Burden of Disease Study 2010. Lancet 2012; 380:2163–96.
[10] Murray CJ, Vos T, Lozano R, et al. Disability-adjusted life years (DALYs) for 291 diseases and injuries in 21 regions, 1990–2010: a systematic analysis for the Global Burden of Disease Study 2010. Lancet 2012;380:2197–223.
[11] Jiang L, Tian W, Wang Y, et al. Body mass index and susceptibility to knee osteoarthritis: a systematic review and meta-analysis. Joint Bone Spine 2012;79:291–7.
[12] Yusuf E, Nelsen RG, Ioann-Fasianu A, et al. Association between weight or body mass index and hand osteoarthritis: a systematic review. Ann Rheum Dis 2010;69:761–5.
[13] Arbabshahi S, Busnegy D, Subasanti AK, et al. Adiposity has a greater impact on hypertension in lean than not-lean populations: a systematic review and meta-analysis. Eur J Epidemiol 2014;29:311–24.
[14] Lu Y, Hajifathalian K, et al. Global Burden of Metabolic Risk Factors for Chronic Diseases CMetabolic mediators of the effects of body-mass index, overweight, and obesity on coronary heart disease and stroke: a pooled analysis of 97 prospective cohorts with 1.8 million participants. Lancet 2014;385:970–83.
[15] Blom K, Emmolar-Vonk MH, Koek HL. The influence of vascular risk factors on cognitive decline in patients with dementia: a systematic review. Maturitas 2013;76:113–7.
[16] Tolpanen AM, Ntanda T, Karelhotel I, et al. Midlife and late-life body mass index and late-life dementia: results from a prospective population-based cohort. J Alzheimers Dis 2014;38:201–9.
[17] Kumar A, Karmarkar AM, Tan A, et al. The effect of obesity on incidence of disability and mortality in Mexicans aged 50 years and older. Salud Publica Mex 2015;57(suppl 1):S31–8.
[18] Wee CC, Huskey KW, Ngo LH, et al. Obesity, race, and risk for death or functional decline among Medicare beneficiaries: a cohort study. Ann Intern Med 2011;154:640–55.
[19] Goya Wannamethee S, Gerald Shaper A, Whincup PH, et al. Overweight and obesity and the burden of disease and disability in elderly men. Int J Obes Relat Metab Disord 2004;5:1374–82.
[20] Heit A, Vacarino V, Krumholz HM. An evidence-based assessment of federal guidelines for overweight and obesity as they apply to elderly persons. Arch Int Med 2001;161:1194–203.
[21] Kuriyama S, Nakaya N, Ohmori-Matsuda K, et al. The Ohsaki Cohort 2006 Study: design of study and profile of participants at baseline. J Epidemiol 2010;20:253–8.
[22] Wilson RS, Mendes De Leon CF, Barnes LL, et al. Participation in cognitively stimulating activities and risk of incident Alzheimer disease. JAMA 2002;287:742–8.
[23] Kessler RC, Barker PR, Colpe LJ, et al. Screening for serious mental illness in the general population. Arch Gen Psychiatry 2003;60:184–9.
[24] Kessler RC, Andrews G, Colpe LJ, et al. Short screening scales to monitor population prevalences and trends in non-specific psychological distress. Psychol Med 2002;32:959–76.
[25] Tomata Y, Hozawa A, Ohmori-Matsuda K, et al. Validation of the Kihon Checklist for predicting the risk of 1-year incident long-term care insurance certification: the Ohsaki Cohort 2006 Study: design of study and profile of participants at baseline. J Epidemiol 2010;20:253–8.
[26] Wilson RS, Mendes De Leon CF, Barnes LL, et al. Participation in cognitively stimulating activities and risk of incident Alzheimer disease. JAMA 2002;287:742–8.
[27] Kessler RC, Barker PR, Colpe LJ, et al. Screening for serious mental illness in the general population. Arch Gen Psychiatry 2003;60:184–9.
[28] Tomata Y, Hozawa A, Ohmori-Matsuda K, et al. Validation of the Kihon Checklist for predicting the risk of 1-year incident long-term care insurance certification: the Ohsaki Cohort 2006 Study. Jpn J Health Psychol 2011;26:13–13.
[29] Muraoa K, Ichiba A, Ibana K. The physical and psychological and social background factor of elderly depression in the community. Ronen Seshin Igaku Zasshi 1996;7:97–407.
[30] Imai H, Fuji Y, Fukuda Y, et al. Health-related quality of life and beneficiaries of long-term care insurance in Japan. Health Policy 2008; 85:349–55.
[31] Ministry of Health LaW. Long-term care insurance in Japan. 2008; http://www.mhlw.go.jp/english/topics/elderlycare/index.html. Accessed October 7, 2015.
[32] Ariai Y, Zarit SH, Kumamoto K, et al. Are there inequities in the assessment of dementia under Japan’s LTC insurance system? Int J Geriatr Psychiatry 2003;18:346–52.
[33] Takeda S. Two-year survival and changes in the level of care for the elderly patients recognized as in need of long-term care in the public nursing-care insurance scheme. Nippon Kosu Eisei Zasshi 2004;51: 157–67.
[34] Hozawa A, Sugawara Y, Tomata Y, et al. Relationships between N-terminal pro-B-type natriuretic peptide and incident disability and
mortality in older community-dwelling adults: the Tsurugaya study. J Am Geriatr Soc 2010;58:2439–41.
[32] Nitta A, Hozawa A, Kaminoh A, et al. Relationship between peripheral arterial disease and incident disability among elderly Japanese: the Tsurugaya project. J Atherosclerosis Thromb 2010;17:1290–6.
[33] Moriyama Y, Tamiya N, Kamimur A, et al. Doctors’ opinion papers in long-term care need certification in Japan: comparison between clinic and advanced treatment hospital settings. Public Policy Admin Res 2014; 4:31–7.
[34] Yoshida D, Nimonya T, Doi Y, et al. Prevalence and causes of functional disability in an elderly general population of Japan: the Hisayama study. J Epidemiol 2012;22:222–9.
[35] Ministry of Health LaW. The outline of the results of National Livelihood Survey 2013, 2013; http://www.mhlw.go.jp/toukei/saikin/hw/k-tyosa/k-tyosa13/index.html. Accessed April 9, 2015.
[36] de Hollander EL, Van Zutphen M, Bogers RP, et al. The impact of body mass index in old age on cause-specific mortality. J Nutr Health Aging 2012;16:100–6.
[37] Meira-Machado L, Cadarso-Suarez C, Gude F, et al. smoothHR: an R package for pointwise nonparametric estimation of hazard ratio curves of continuous predictors. Comput Math Methods Med 2013;2013: 745742.
[38] Gustafson DR, Backman K, Joas E, et al. 37 years of body mass index and disability in an elderly general population of Japanese: the Hisayama study. J Epidemiol 2012;22:222–9.
[39] Qizilbash N, Gregson J, Johnson ME, et al. BMI and risk of dementia in old age on cause-specific mortality. J Nutr Health Aging 2012;16:100–6.
[40] Organisation WH. Healthy Cities. 2016; http://www.euro.who.int/en/health-topics/environment-and-health/urban-health/activities/healthy-cities. Accessed May 5, 2016.
[41] Perlsdtt H. Fritz MJ, Rhaume J. The healthy cities/communities movement: the global diffusion of local initiatives. Community Intervention: Clinical Sociology Perspectives.. New York, NY:Springer New York; 2014. 73–93.
[42] London Mo. SPORT RELIEF RETURNS TO QUEEN ELIZABETH OLYMPIC PARK FOR 2016. 2016; http://queenelizabetholympicpark.co.uk/news/news-articles/2016/1/sport-relief-returns-to-queen-elizabeth-olympic-park-for-2016. Accessed April 5, 2016.
[43] Flint SW. Are we selling our souls? Novel aspects of the presence in academic conferences of brands linked to ill health. J Epidemiol Commun Health 2016. 1–2.
[44] Barquera S, Campos I, Rivera JA. Mexico attempts to tackle obesity: the process, results, push backs and future challenges. Obes Rev 2013;14 (suppl 2):69–78.
[45] Leischik R, Dvorrak B, Strauss M, et al. Plasticity of health. German J Med 2016;1:1–7.
[46] Lavie CJ, Parto P, Archer E. Obesity, fitness, hypertension, and prognosis: is physical activity the common denominator? JAMA Int Med 2016;176:217–8.
[47] Leischik R, Dvorrak B, Strauss M, et al. Physical activity/fitness peaks during perimenopause and BMI change patterns are not associated with baseline activity/fitness in women: a longitudinal study with a median 7-year follow-up. Brit J Sports Med 2013;47:77–82.
[48] Parker ED, Saxiko AR, Kharbanda EO, et al. Change in weight status and development of hypertension. Pediatrics 2016;137:1–9.
[49] Leischik R, Foshag P, Strauss M, et al. Physical activity, cardiorespiratory fitness and carotid intima thickness: sedentary occupation as risk factor for atherosclerosis and obesity. Eur Rev Med Pharmacol Sci 2015;19: 3137–68.
[50] Fiuza-Luces C, Garatachea N, Berger NA, et al. Exercise is the real polypill. Physiology 2013;28:330–58.