BMI and All-cause Mortality Among Japanese Older Adults: Findings From the Japan Collaborative Cohort Study

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The association between BMI and all-cause mortality may vary with gender, age, and ethnic groups. However, few prospective cohort studies have reported the relationship in older Asian populations. We evaluated the association between BMI and all-cause mortality in a cohort comprised 26,747 Japanese subjects aged 65–79 years at baseline (1988–1990). The study participants were followed for an average of 11.2 years. Proportional-hazards regression models were used to estimate mortality hazard ratios (HRs) and 95% confidence intervals. Until 2003, 9,256 deaths occurred. The underweight group was associated with a statistically higher risk of all-cause mortality compared with the mid-normal-range group (BMI: 20.0–22.9); resulting in a 1.78-fold (95% confidence interval: 1.45–2.20) and 2.55-fold (2.13–3.05) increase in mortality risk among severest thin men and women (BMI: <16.0), respectively. Even within the normal-range group, the lower normal-range group (BMI: 18.5–19.9) showed a statistically elevated risk. In contrast, being neither overweight (BMI: 25.0–29.9) nor obese (BMI: ≥30.0) elevated the risk among men; however among women, HR was slightly elevated in the obese group but not in the overweight group compared with the mid-normal-range group. Among Japanese older adults, a low BMI was associated with increased risk of all-cause mortality, even among those with a lower normal BMI range. The wide range of BMI between 20.0 and 29.9 in both older men and women showed the lowest all-cause mortality risk.

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INTRODUCTION

The relationship between high BMI (BMI: weight in kg/height in m^2) and all-cause mortality is well known (1,2). The World Health Organization defines overweight as a BMI of 25.0–29.9 kg/m^2 and obesity as a BMI of ≥30 kg/m^2. These BMI thresholds have been recommended worldwide for all individuals aged ≥18 (3). However, increasing evidence suggests that the association between BMI and mortality varies with age. A 2007 review by Janssen and Mark concluded that BMIs in the overweight range (BMI: 25.0–29.9) were not associated with a significant increase in mortality risk among the older adults (4). Furthermore, some recent studies have revealed that among this age group, being underweight seems to be a better predictor of mortality than obesity (5–7). Thus, it remains to be established whether older adults require different BMI cut-off points from those younger.

Japan has witnessed a rapid growth in its older population in recent years. From a public health perspective, it is important to determine the BMI range associated with a low mortality risk for them. We sought to examine the association between BMI and all-cause mortality among participants in our Japan Collaborative Cohort study.

METHODS AND PROCEDURES

Study subjects and data collection

The study design and methods adopted by the Japan Collaborative Cohort study have been previously described elsewhere (8,9). Briefly, from 1988 to 1990, healthy subjects in 45 areas throughout Japan replied to a self-administered questionnaire. The cohort comprised 110,792 subjects aged 40–79 years old at baseline, among whom those participants aged 65–79 years were enrolled in this study. The ethical board of the Nagoya University School of Medicine, where the central office of the Japan Collaborative Cohort study was located, has approved our complete study design.

Follow-up

The cause and date of death of the study subjects were identified by reviewing all death certificates in each area by each area investigator

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with the permission of the Director-General of the Prime Minister's Office (Ministry of Internal Affairs and Communications). Those who had moved out of a study area were treated as censored. Follow-ups were conducted to the end of 2003, except in four areas where they were discontinued at the end of 1999.

BMI

Information on height and weight as well as lifestyle variables was gathered from self-administered questionnaires. BMI at baseline was calculated based on the height and weight reported. We grouped subjects into the following nine detailed categories according to the World Health Organization classification (10): BMIs <16.0, 16.0–16.9, 17.0–18.4, 18.5–19.9, 20.0–22.9, 23.0–24.9, 25.0–27.4, 27.5–29.9, and ≥30.0. These categories incorporated the current definitions of underweight (BMI: <18.5), normal range (18.5–24.9), overweight (25.0–29.9), and obese (≥30.0) (3). There were 26,747 subjects (11,230 men and 15,517 women) aged 65–79 years who provided information on BMI, all of whom were considered to be eligible for this study.

Analysis

To compare the proportions of subject characteristics across BMI categories at baseline, we used the Mantel–Haenszel test. Hazard ratios (HRs) were calculated separately by gender according to Cox's proportional hazard model. Not only in all the subjects combined but also in subcohorts of noncurrent smokers, physically active subjects (engaging in physical exercise ≥1 h per week and/or walking >1 h/day), and those

Table 1 Distribution of some demographic factors according to BMI categories

		BMI category								
		<16.0	16.0–16.9	17.0–18.4	18.5–19.9	20.0–22.9	23.0–24.9	25.0–27.4	27.5–29.9	≥30.0
Men										
Age at baseline										
65–69	%	19.0	31.0	36.5	43.8	47.4	49.5	52.7	51.6	50.6***
70–74	%	34.1	30.6	37.4	32.8	32.1	32.5	32.8	31.2	28.6
75–79	%	46.8	38.4	26.1	23.4	20.5	18.0	14.4	17.2	20.8
Current cigarette smoker	%	50.8	48.7	52.8	47.2	42.6	34.3	34.2	30.8	29.9***
Current alcohol drinker	%	44.4	53.9	56.5	60.7	62.0	61.4	61.8	66.7	50.6***
Sleep 6.5–8.4 h/day	%	49.2	57.3	54.0	57.4	59.8	60.8	57.7	54.8	48.1*
Physically active	%	42.9	47.4	46.7	48.9	49.6	47.6	44.8	40.9	42.9
College or higher education	%	11.1	12.1	11.9	12.6	13.6	14.6	14.8	12.2	9.1
High-mental stress	%	7.9	13.8	9.8	8.7	7.8	8.6	7.7	10.0	11.7*
Married	%	66.7	75.9	70.6	72.6	73.7	76.4	77.3	80.3	75.3*
Eating green vegetables almost daily	%	23.0	31.0	28.1	30.8	29.3	28.8	27.8	23.7	15.6*
No prior disease history (cancer, MI, or stroke)	%	46.0	59.5	59.5	62.7	65.8	63.3	64.8	62.7	66.2***
Number		126	232	871	1,622	4,670	2,217	1,136	279	77
Women										
Age at baseline										
65–69	%	28.1	41.7	43.0	45.4	50.0	54.5	56.7	58.2	53.2***
70–74	%	37.6	32.8	33.4	31.8	31.3	29.8	29.2	28.6	28.4
75–79	%	34.3	25.5	23.5	22.9	18.7	15.7	14.1	13.2	18.4
Current cigarette smoker	%	7.9	9.0	6.0	4.7	3.6	3.5	3.8	5.6	5.1***
Current alcohol drinker	%	11.6	14.2	16.3	16.3	16.3	17.7	15.9	18.1	15.1
Sleep 6.5–8.4 h/day	%	50.0	54.2	55.6	54.7	58.0	56.0	56.6	53.3	54.7*
Physically active	%	29.8	40.9	42.4	43.7	45.4	44.0	42.9	38.9	35.0***
College or higher education	%	9.5	4.9	6.8	6.2	6.2	5.6	5.0	3.8	4.2***
High-mental stress	%	14.5	7.5	10.4	9.4	8.9	10.3	9.6	9.2	11.2*
Married	%	43.8	43.5	54.8	51.8	52.2	53.0	53.4	53.6	51.7**
Eating green vegetables almost daily	%	24.4	33.3	30.9	33.0	32.1	32.2	31.6	30.6	34.4
No prior disease history (cancer, MI, or stroke)	%	61.2	61.4	63.1	64.1	65.4	64.1	66.3	65.4	55.9
Number		242	345	1,062	1,832	5,596	3,107	2,234	768	331

MI, myocardial infarction.
*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$ by Mantel–Haenszel test adjusting for age categories.

without a disease history of cancer, myocardial infarction and/or stroke were analyzed because these factors were known to influence both BMI and mortality (11–14). In addition to age-adjusted HRs, we calculated HRs adjusting for the following potential confounding factors: smoking (current smoker, exsmoker, nonsmoker, or unknown), alcohol consumption (current drinker, exdrinker, nondrinker, or unknown), sleep duration per night (<6.4 h, 6.5–8.4 h, ≥8.5 h, or unknown), physical activity (engaging in physical exercise ≥1 h per week and/or walking >1 h/day, others or unknown), education (attended school up to 15 years of age, 18 years, >18 years or unknown), perceived stress (yes, no, or unknown), marital status (married, single, or unknown), frequency of green vegetables consumed (almost daily, not daily, or unknown), and history of cancer, myocardial infarction or stroke (yes, no, or unknown). Those potential confounding factors were queried in a self-administered questionnaire, and the results of validation studies on the physical activity and food frequency questionnaire were reported previously (15,16). Moreover, additional analyses were conducted to exclude those subjects whose events occurred within 3 years after baseline to avoid reverse-causality bias.

We used the SAS program version 9.1 (SAS Institute, Cary, NC) for analyses conducted at the Aichi Medical University Computation Center.

RESULTS

Mean value of BMI was 21.9 among men and 22.5 among women. Proportions of those underweight (BMI: <18.5), overweight (BMI: 25.0–29.9) and obese (BMI: ≥30.0) were 10.9, 12.6, and 0.7% among men, and 10.6, 19.3, and 2.1% among women at baseline, respectively. Compared to those with normal-range BMI, both underweight and overweight/obese men and women were less likely to be drinkers, to sleep for the normal duration, and to be physically active, while they were more likely to suffer from high levels of mental stress (Table 1). Underweight and overweight/obese men were less likely to eat green vegetables, and corresponding women were more likely to be current smokers. However, among men, the proportion of current smokers decreased with increasing BMI. Among both men and women, subjects who were young, married, and free from prior disease history (cancer, myocardial infarction, or stroke) increased according to increasing BMI. Highly educated subjects showed different trends by gender,

Table 2 Cause of mortality according to BMI categories

	BMI category									
	<16.0	16.0–16.9	17.0–18.4	18.5–19.9	20.0–22.9	23.0–24.9	25.0–27.4	27.5–29.9	≥30.0	Total
Men										
Number at baseline	126	232	871	1,622	4,670	2,217	1,136	279	77	11,230
Number of deaths										
All causes	94	157	500	831	2,149	936	473	115	37	5,292
%	74.6	67.7	57.4	51.2	46.0	42.2	41.6	41.2	48.1	47.1
Malignant neoplasms	13	42	139	252	762	320	151	35	11	1,725
%[a]	13.8	26.8	27.8	30.3	35.5	34.2	31.9	30.4	29.7	32.6
Diseases of the circulatory system	23	31	150	244	681	329	179	44	15	1,696
%[a]	24.5	19.7	30.0	29.4	31.7	35.1	37.8	38.3	40.5	32.0
Pneumonia	18	27	63	98	219	73	33	9	5	545
%[a]	19.1	17.2	12.6	11.8	10.2	7.8	7.0	7.8	13.5	10.3
Senility	3	2	17	16	40	10	6	0	1	95
%[a]	3.2	1.3	3.4	1.9	1.9	1.1	1.3	0.0	2.7	1.8
Women										
Number at baseline	242	345	1,062	1,832	5,596	3,107	2,234	768	331	15,517
Number of deaths										
All causes	132	121	362	536	1,322	690	519	179	103	3,964
%	54.5	35.1	34.1	29.3	23.6	22.2	23.2	23.3	31.1	25.5
Malignant neoplasms	21	26	65	132	359	213	161	45	24	1,046
%[a]	15.9	21.5	18.0	24.6	27.2	30.9	31.0	25.1	23.3	26.4
Diseases of the circulatory system	48	42	151	210	488	272	199	87	48	1,545
%[a]	36.4	34.7	41.7	39.2	36.9	39.4	38.3	48.6	46.6	39.0
Pneumonia	17	17	39	54	91	49	30	7	3	307
%[a]	12.9	14.0	10.8	10.1	6.9	7.1	5.8	3.9	2.9	7.7
Senility	3	4	15	15	50	15	16	2	0	120
%[a]	2.3	3.3	4.1	2.8	3.8	2.2	3.1	1.1	0.0	3.0

[a]Percentage of deaths per all causes.

increasing among men and decreasing among women with increasing BMI.

A total of 5,292 (47.1%) and 3,964 (25.5%) deaths occurred prior to 2003 among men and women, respectively. Those who had moved out of the study areas numbered 1,208 (4.5%), and they were more likely to be women and older than those who were successfully followed. The average follow-up period was 11.2 years (10.6 years for men, 11.7 years for women). Deaths from malignant neoplasms (ICD10: C00–C97), diseases of the circulatory system (I00–I99), pneumonia (J12–J18), and senility (R54) accounted for 32.6, 32.0, 10.3, and 1.8% of total deaths among men and 26.4, 39.0, 7.7, and 3.0% among women, respectively (**Table 2**). The proportion of those who died from malignant neoplasms was highest in the normal-range BMI group, but diminished as the BMI fluctuated above or below normal. Mortality from diseases of the circulatory system

Table 3 Hazard ratios and 95% CI of all-cause mortality according to BMI among men aged 65–79

	BMI category								
	<16.0	16.0–16.9	17.0–18.4	18.5–19.9	20.0–22.9	23.0–24.9	25.0–27.4	27.5–29.9	≥30.0
Total									
Person-years at risk	967	1,962	8,565	16,699	50,471	24,168	12,720	3,142	842
Number of deaths	94	157	500	831	2,149	936	473	115	37
Age-adjusted HR	1.99	1.74	1.27	1.16	1.00	0.94	0.91	0.87	1.02
Age-adjusted 95% CI	(1.62–2.45)	(1.48–2.05)	(1.16–1.40)	(1.07–1.25)		(0.87–1.01)	(0.83–1.01)	(0.72–1.05)	(0.74–1.42)
Multivariate HR[a]	1.78	1.66	1.16	1.12	1.00	0.94	0.92	0.89	0.93
Multivariate 95% CI[a]	(1.45–2.20)	(1.41–1.96)	(1.06–1.28)	(1.04–1.22)		(0.87–1.02)	(0.83–1.01)	(0.73–1.07)	(0.67–1.29)
Not current smokers									
Person-years at risk	404	1,024	3,529	7,706	26,355	14,217	7,359	2,050	552
Number of deaths	45	70	203	371	1,008	503	260	66	21
Age-adjusted HR	2.54	1.70	1.41	1.22	1.00	0.98	1.01	0.87	1.04
Age-adjusted 95% CI	(1.88–3.43)	(1.33–2.16)	(1.21–1.64)	(1.08–1.37)		(0.88–1.09)	(0.88–1.16)	(0.67–1.11)	(0.67–1.59)
Multivariate HR[a]	2.24	1.72	1.29	1.20	1.00	0.98	1.01	0.82	0.87
Multivariate 95% CI[a]	(1.66–3.03)	(1.35–2.20)	(1.11–1.50)	(1.07–1.36)		(0.88–1.09)	(0.88–1.16)	(0.64–1.05)	(0.56–1.34)
Physically active									
Person-years at risk	480	992	4,241	8,529	25,511	11,590	5,658	1,303	385
Number of deaths	34	69	201	345	934	399	189	39	11
Age-adjusted HR	1.57	1.84	1.22	1.08	1.00	0.98	0.95	0.83	0.69
Age-adjusted 95% CI	(1.12–2.22)	(1.44–2.35)	(1.04–1.42)	(0.95–1.22)		(0.87–1.10)	(0.81–1.11)	(0.60–1.14)	(0.38–1.25)
Multivariate HR[a]	1.46	1.76	1.11	1.04	1.00	1.00	0.98	0.83	0.65
Multivariate 95% CI[a]	(1.03–2.06)	(1.37–2.25)	(0.95–1.29)	(0.92–1.18)		(0.89–1.13)	(0.84–1.15)	(0.60–1.15)	(0.36–1.19)
No history of cancer, MI or stroke									
Person-years at risk	484	1,236	5,231	10,750	33,931	15,849	8,331	2,069	548
Number of deaths	40	91	282	483	1,323	524	289	64	21
Age-adjusted HR	1.78	1.77	1.29	1.15	1.00	0.87	0.93	0.82	1.04
Age-adjusted 95% CI	(1.30–2.44)	(1.43–2.19)	(1.13–1.47)	(1.04–1.28)		(0.79–0.97)	(0.82–1.06)	(0.63–1.05)	(0.68–1.60)
Multivariate HR[a]	1.68	1.80	1.20	1.14	1.00	0.91	0.93	0.84	0.99
Multivariate 95% CI[a]	(1.22–2.30)	(1.45–2.23)	(1.05–1.36)	(1.03–1.26)		(0.82–1.00)	(0.82–1.06)	(0.66–1.09)	(0.64–1.53)
Excluded those who died within 3 years									
Person-years at risk	920	1,209	8,407	16,472	49,949	23,952	12,612	3,104	840
Number of deaths	65	124	406	708	1,869	818	424	96	36
Age-adjusted HR	1.72	1.68	1.21	1.15	1.00	0.94	0.93	0.83	1.15
Age-adjusted 95% CI	(1.34–2.20)	(1.40–2.01)	(1.09–1.35)	(1.05–1.25)		(0.86–1.02)	(0.84–1.04)	(0.67–1.01)	(0.83–1.60)
Multivariate HR[a]	1.56	1.62	1.11	1.11	1.00	0.95	0.94	0.84	1.07
Multivariate 95% CI[a]	(1.22–2.00)	(1.35–1.94)	(0.99–1.23)	(1.02–1.21)		(0.88–1.03)	(0.84–1.04)	(0.69–1.04)	(0.77–1.49)

CI, confidence interval; HR, hazard ratio; MI, myocardial infarction.
[a]Adjusted for smoking, drinking, physical activity, sleep duration, stress, education, marital status, green vegetables, stroke, MI, cancer (includes unknown groups).

seemed to increase as the BMI increased, except for a minor increase in the severely thin group. Mortality from pneumonia showed an obvious inverse association with BMI, and senility was rare among overweight/obese groups.

Tables 3 and 4 showed the HRs by gender of all-cause mortality by BMI categories. Compared with the mid-normal-range group (BMI: 20.0–22.9), multiple-adjusted HRs of all-cause mortality for underweight groups were statistically higher among both men and women, with the highest mortality risk found in the severely thin group (BMI: <16.0) as 1.78 (95% confidence interval: 1.45–2.20) in men, and 2.55 (2.13–3.05) in women. Even within the normal-range group, the lower normal range (BMI: 18.5–19.9) showed a statistically elevated risk compared with the mid normal range (HR: 1.12 in men and 1.22 in women). In contrast, overweight subjects showed no relation with risk elevation among either men or women.

Table 4 Hazard ratios and 95% CI of all-cause mortality according to BMI among women aged 65–79

	BMI category								
	<16.0	16.0–16.9	17.0–18.4	18.5–19.9	20.0–22.9	23.0–24.9	25.0–27.4	27.5–29.9	≥30.0
Total									
Person-years at risk	2,301	3,729	11,814	20,849	65,923	37,144	26,483	9,218	3,844
Number of deaths	132	121	362	536	1,322	690	519	179	103
Age-adjusted HR	2.66	1.52	1.45	1.23	1.00	0.98	1.06	1.07	1.37
Age-adjusted 95% CI	(2.22–3.18)	(1.26–1.83)	(1.29–1.63)	(1.11–1.36)		(0.90–1.08)	(0.96–1.17)	(0.91–1.25)	(1.12–1.68)
Multivariate HR[a]	2.55	1.47	1.42	1.22	1.00	0.96	1.01	0.98	1.24
Multivariate 95% CI[a]	(2.13–3.05)	(1.22–1.77)	(1.26–1.59)	(1.11–1.35)		(0.88–1.06)	(0.92–1.12)	(0.84–1.14)	(1.01–1.52)
Not current smokers									
Person-years at risk	1,631	2,678	9,147	16,306	52,259	29,950	21,359	7,410	3,086
Number of deaths	99	88	273	418	1,033	544	406	145	75
Age-adjusted HR	2.89	1.53	1.43	1.23	1.00	0.98	1.06	1.09	1.24
Age-adjusted 95% CI	(2.35–3.55)	(1.23–1.90)	(1.25–1.63)	(1.10–1.38)		(0.89–1.09)	(0.94–1.18)	(0.92–1.30)	(0.98–1.57)
Multivariate HR[a]	2.72	1.48	1.40	1.24	1.00	0.97	1.02	1.00	1.14
Multivariate 95% CI[a]	(2.21–3.35)	(1.19–1.84)	(1.22–1.60)	(1.10–1.39)		(0.87–1.07)	(0.91–1.14)	(0.84–1.19)	(0.90–1.44)
Physically active									
Person-years at risk	726	1,605	5,078	9,141	29,875	16,085	11,503	3,578	1,325
Number of deaths	32	41	126	200	518	253	171	57	30
Age-adjusted HR	2.32	1.45	1.46	1.25	1.00	1.01	1.00	1.10	1.37
Age-adjusted 95% CI	(1.62–3.31)	(1.05–1.99)	(1.21–1.78)	(1.06–1.47)		(0.87–1.17)	(0.84–1.19)	(0.84–1.45)	(0.95–1.99)
Multivariate HR[a]	2.17	1.41	1.42	1.23	1.00	0.99	0.97	1.02	1.37
Multivariate 95% CI[a]	(1.52–3.11)	(1.02–1.94)	(1.17–1.73)	(1.05–1.45)		(0.85–1.15)	(0.82–1.16)	(0.77–1.34)	(0.95–1.98)
No history of cancer, MI or stroke									
Person-years at risk	1,477	2,327	7,659	13,739	43,948	24,071	17,939	6,164	2,233
Number of deaths	77	75	225	327	835	439	322	111	53
Age-adjusted HR	2.53	1.57	1.49	1.22	1.00	1.03	1.05	1.09	1.32
Age-adjusted 95% CI	(2.01–3.20)	(1.24–1.99)	(1.28–1.72)	(1.07–1.38)		(0.92–1.15)	(0.93–1.20)	(0.89–1.33)	(1.00–1.74)
Multivariate HR[a]	2.38	1.52	1.44	1.21	1.00	1.02	1.02	1.01	1.21
Multivariate 95% CI[a]	(1.88–3.01)	(1.20–1.92)	(1.24–1.67)	(1.06–1.37)		(0.90–1.14)	(0.89–1.16)	(0.83–1.23)	(0.92–1.60)
Excluded those who died within 3 years									
Person-years at risk	2,269	3,697	11,722	20,709	65,577	36,995	26,351	9,164	3,825
Number of deaths	111	101	319	465	1,177	626	464	157	94
Age-adjusted HR	2.63	1.45	1.45	1.20	1.00	1.00	1.06	1.05	1.41
Age-adjusted 95% CI	(2.16–3.19)	(1.18–1.77)	(1.28–1.64)	(1.08–1.34)		(0.91–1.10)	(0.95–1.18)	(0.89–1.24)	(1.14–1.74)
Multivariate HR[a]	2.52	1.40	1.42	1.20	1.00	0.98	1.02	0.97	1.28
Multivariate 95% CI[a]	(2.07–3.06)	(1.14–1.72)	(1.25–1.61)	(1.08–1.34)		(0.89–1.08)	(0.92–1.14)	(0.82–1.15)	(1.04–1.59)

CI, confidence interval; HR, hazard ratio; MI, myocardial infarction.
[a]Adjusted for smoking, drinking, physical activity, sleep duration, stress, education, marital status, green vegetables, stroke, MI, cancer (includes unknown groups).

In addition, obesity (BMI: ≥30.0) did not elevate the all-cause mortality risk among men, though a slight statistically significant risk was observed among women (HR: 1.24) compared with the mid-normal-range group. Subcohort analyses of noncurrent smokers, physically active subjects, and those without major disease at baseline did not alter the risk estimation dramatically. Excluding events occurring within 3 years also produced no change in the effects on all-cause mortality of the underweight and overweight/obese groups.

DISCUSSION

Using a dataset of a large population-based cohort study of older Japanese subjects aged 65–79 who were followed for >10 years on average, we found that a BMI between 20.0 and 29.9 was associated with a minimum risk of all-cause mortality. This wide range was unchanged when our analysis was limited to subjects who could be followed for at least 3 years from baseline. Moreover, the results were essentially unchanged when subcohort analyses were conducted of those who were not currently smoking, were physically active, or were without a history of cancer, cardiovascular disease, or stroke.

The key advantages of our study were its large-scale cohort with subjects from all over Japan, a long follow-up period of >10 years, and adjustments for known confounders. These advantages allowed us to adopt narrow categories of BMI to examine the association with all-cause mortality among older adults. Moreover, subcohort analyses could be performed considering several factors which influence both body composition and all-cause mortality, especially among the older adults, such as (i) heavy and lengthy periods of smoking (14,17), (ii) physical activity (11), and (iii) subclinical diseases (12).

Risk elevation among thin older adults with results similar to ours was reported by many other cohort studies (1,18,19). There may be several explanations for this association so commonly observed among older adults. First, because lean mass acts as a nutritional preserve (4), and aging itself results in a decline in immune response, such thin older adults may be less resistant to infection (20). Actually, deaths from pneumonia were more prevalent among underweight subjects compared with normal or overweight subjects in our cohort. Second, preexisting disease may be linked to both thinness and an increased risk of death. As shown in **Table 1**, there were more older adults among low-BMI subjects compared with those in other groups, suggesting that age-related diseases cause weight loss. However, excluding the first 3 years of follow-up did not alter that result. Though the purpose of this article was to examine the association between BMI and all-cause mortality, further investigations into the effects of BMI on cause-specific mortality may help us to better understand the relationship of BMI to lean and/or fat mass, and susceptibility to death among older adults. Third, a confounding influence of smoking may exist, because smokers tend to lose weight more readily than nonsmokers (21), and smoking is known to reduce life expectancy (22). Even if such a confounding effect should exist, subcohort analysis of noncurrent smokers revealed that thin subjects who did not smoke also had a higher risk of all-cause mortality, which suggests that a confounding effect from smoking is not the main explanation. Nevertheless, we cannot rule out the possibility that, even with a careful determination of known confounding variables in the present analysis, other undetected factors related to increased mortality risk among thin older adults might have confounded the association between BMI and mortality.

Overweight/obesity is related to excess mortality among both younger and middle-aged populations (1,23,24), and the cut-off points recommended by World Health Organization (3) are mainly based on them. Though some studies have found that the risk of death among older adults was associated with obesity/overweight (2,12,18), the meta-analysis by Janssen and Mark showed no risk elevation for overweight subjects (estimated risk 1.00 with 95% confidence interval: 0.97–1.03), and a significant though very small risk elevation for obese subjects (1.10, 1.06–1.13) (4). Our study showed no increased risk elevation in overweight/obese subjects (except in obese (BMI: ≥30.0) women), and our results were not altered even among some subcohorts. Although the reason for these inconsistent findings is unclear, explanations of why the weak or absent effect of overweight/obesity on all-cause mortality was observed among the older adults in our study may include the following. First, some individuals who were susceptible to the adverse effects of a high BMI may have already died in youth or middle-age, whereas the older adults with a high BMI who survived may have developed a resistance to the effect of overweight/obesity (4,25). Because obesity in women was found to be associated with increased mortality, it is also possible that severely obese men might have been underrepresented in the present sample (self-selection). Second, the possible protective effects of being overweight reflected by a high BMI (such as nutritional reserve) may have prevailed over its negative effects on all-cause mortality in the elderly population (4). Third, a recent study has shown that the prevalence of a clustering of cardiometabolic risk factors among normal-weight individuals was higher in older age groups compared with that in young and middle-aged subjects (26). Thus, the elevated risk of mortality in the normal-weight group among older adults may have caused a relative risk reduction in the overweight/obese groups. As a result, the BMI in older adults may not be a reliable predictor of mortality risk, especially that from cardiovascular diseases, because the variability of BMI in this age group does not adequately reflect that of other intermediate variables leading to disease.

There are some study limitations we should discuss. First, our data were based on self-reported rather than measured heights and weights. Spencer *et al.* compared self-reported and measured height, weight, and BMI among subjects aged 35–76 years. They found that height was overestimated and weight was underestimated, resulting in underestimation of BMI, especially among heavier men and women (27). Thus, we could not exclude the possibility that overweight/obese older adults underestimated their BMI more often than those with a normal BMI, and consequently, misclassifications leading to an underestimation of overweight/obese risk may have occurred. However, according to the same authors (27), normal BMI category men and women were the least likely to be incorrectly allocated to another BMI category, and underweight participants were also less likely to be misclassified into the normal range than overweight/obese subjects, making it somewhat unlikely that overestimations of underweight risk might occur. Second, we have no information on body fat or its distribution, such as the ratio of waist-to-hip circumferences. Both high-body fat and low fat-free mass are known to be independent predictors of overall mortality (28). Moreover, Simpson *et al*. reported that, among women, central adiposity was a better predictor of mortality than BMI (29). A large-scale cohort study among older adults that includes such information will be required to investigate the relationship between body composition and mortality. Finally, it should be kept in mind that we did not examine any relationships between weight history and mortality. Moreover, a review by Bales and Buhr revealed the benefits of maintaining weight in older persons who become obese after age 65 (30). Therefore, the result of our observational study should not be used to dismiss the necessity of weight reduction among all obese older adults. In addition, we do not recommend that underweight older adults should gain weight based on our results, because ours was not an interventional study.

In conclusion, we found an elevated risk of all-cause mortality among thin Japanese older adults and a wide range of BMI between 20.0 and 29.9 that showed the lowest mortality risk to be among both older men and women.

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DISCLOSURE

The authors declared no conflict of interest.

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