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REGULAR ARTICLE

Association of hypertension with changes in the body mass index of university students

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Abstract
Background There are few longitudinal studies on the associations of obesity with hypertension in young adults.
Objectives To analyze longitudinally to what extent weight gain associates with hypertension in young adults.
Methods The subjects of this study consisted of 6,178 university students (male 4,098; female 2,080). The associations of hypertension with body type change were longitudinally examined by using the records of health examinations while at university. The prevalence ratios (PRs) for hypertension in their senior year were calculated on groups that changed toward obese against those that changed toward underweight. The logistic regression analyses were used to estimate odds ratios (ORs) for hypertension in their senior year of each factor. The analyses were conducted on (i) all subjects, (ii) non-hypertensive subjects in their freshman year, and (iii) by schools, in order to take into account physical activities.
Results The PRs of hypertension in subjects changed toward obese from their freshmen to seniors against ones toward underweight were 1.47 (95% CI; 1.00–2.15) for males and 3.50 (0.93–13.22) for females. In analyses limited to non-hypertensive subjects in their freshman year, results were similar to those of all subjects. The analyses by school also showed similar results to those including all subjects. In logistic regression analyses, although the factor most strongly associated with hypertension was body type in their senior year, the body type in their freshman still showed significant association with hypertension after the adjustment of senior year body type and hypertension in freshman year. The ORs for hypertension in obese subjects to normal weight ones in their senior year were 9.13 (95% CI; 5.77–14.45) for males and 22.59 (5.69–89.67) for females after adjusted by hypertension in freshman, body type in freshman and school.
Conclusions These data suggest that the increase of BMI is linked to hypertension in university students.

Keywords BMI · Hypertension · University students · Weight change · Weight gain

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Introduction

The 2001 National Nutrition Survey of Japan (NNS-J) estimated that, among Japanese populations over 20 years of age, 28.0% of males and 21.6% of females were obese [1]. Recently, the proportion of obese male adults older than 20 years has increased from 12.0 to 18.1% in the 20- to 29-year age category and from 13.1 to 21.0% in the 30- to 39-year age category; the trends for females were either parallel or lower. Most obesity is due to poor lifestyles, such as the excessive intake of energy, the lack of physical activity, among others. Obesity is frequently combined with hypertension, hyperlipidemia and diabetes. The 1996 NNS-J [2] reported the occurrences of hypertension and abnormal blood test by body mass index (BMI) strata. According to the report, the obese group (BMI $\geq$26.4) had 3.4-fold higher chance of hypertension, 1.8-fold higher chance of hyperglycemia and 1.6-fold higher chance of hypercholesterolemia compared to the underweight group (BMI <19.8).

To date, most of the studies that have linked body weight with blood pressure have been conducted on

middle-aged subjects [3–19] because age is positively related with blood pressure [3–5], and the occurrence of hypertension, one of lifestyle-related disease, has been observed to increase markedly from approximately 40 years of age [2]. These studies have consistently reported that increases in weight or BMI are related to rising blood pressure. On the other hand, there are few such reports conducted on young adults [20–26]. Okasha et al. [20] reported that BMI and body weight were positively associated with blood pressure in both males and females of a study cohort consisting of 14,775 university students (male 11,284; female 3,491). Hirose et al. [22] reported the presence of close positive correlations between changes in body weight and changes in blood pressure in 4976 university students (male 3558; female 1418) during a 3-year follow-up period. Moreover, in a large nation-wide survey of health states on 323,517 university students (male 202,536; female 120,981) in Japan, Kitamura et al. [25] reported that BMI was positively correlated with systolic and diastolic blood pressure. In an earlier study on 3686 university students (male 2394; female 1,292), we also found that changes in body weight were positively correlated with changes in blood pressure [26]. These findings were in accordance with those found on middle-aged individuals.

Many investigators have also reported on the risk of hypertension from increasing body weight [4–11, 23–25]. The studies examining the association between hypertension and body weight have been conducted on various age groups, especially middle-aged individuals, and have shown that body weight or BMI are positively associated with the risk for hypertension. However, most of these studies were cross-sectional [4, 6–10, 23–25]. Among the few longitudinal studies [8, 9, 11], Huang et al. [8] reported that weight gain dramatically increased the risk for hypertension in study of 82,473 female registered nurses who were 30–55 years of age at study entry. Field et al. [9] described that for each 10 lb (4.5 kg) gain in weight, the risk of hypertension increased 30% in 46,224 females (the mean age of 39 years) who were participants in the Nurses Health Study II. Nakanishi et al. [11] studied in 949 hypertension-free Japanese male office workers aged 35–54 years and described that age, alcohol intake, BMI and hours of work were independent factors associated with the development of hypertension. However, these studies were conducted in middle-aged individuals, and there are few longitudinal studies in young adults. As such, the aim of our study was to investigate the association of hypertension with weight change in university students in order to analyze longitudinally to what extent weight gain associates with hypertension in this age category adults.

Subjects and methods

Subjects

The eligible participants of this study consisted of 8294 students (males 5628; females 2666) who had been admitted to a university [School of Sociology (SS), School of Computer and Cognitive Sciences (SCCS), School of Health and Sport Sciences (SHSS)] between 1991 and 1998 who became seniors between 1994 and 2001. We excluded subjects over the age of 30 years during their senior year, those with an unknown date of birth, and those with missing height, body weight, systolic blood pressure (SBP) or diastolic blood pressure (DBP) data in their university healthcare records. The final study cohort comprised 4098 male and 2,080 female students. The investigators received the approval of the student office of the university to use the health examination records. In addition, we explained the purpose of survey to all the subjects at the beginning of the new academic year counseling session held by the student office that was conducted before the health examinations. We also explained about the survey to the subjects in writing and informed them about the survey with their acceptance to participate in the examinations by means of a poster (by writing).

Measurements of blood pressure and body weight

We used the records of health examinations conducted annually at the university. With regard to the measurements, body weight was taken with the student as lightly dressed as possible. Blood pressure was measured using a standard mercury sphygmomanometer. The procedures involved with taking these measurements have been described in detail elsewhere [26].

Analytic methods

The schools were categorized as SS and SCCS (SS&SCCS), and SHSS based on the difference in physical activities. We analyzed the association of hypertension with change of body types classified using the BMI as follows:

1. The means and standard deviations were calculated for the age of seniors, BMI and blood pressure. The means between SS&SCCS and SHSS were compared.
2. The distributions of body types and blood pressure categories were examined. Each distribution was compared between SS&SCCS and SHSS.
3. The prevalence ratios (PRs) and 95% confidence intervals (95% CIs) for hypertension were calculated on each body type and compared with that for the

normal weight. The PRs for hypertension were calculated for SS&SCCS against SHSS.

4. The proportions and 95% CIs for hypertension in the senior year were calculated by changes in body type patterns. The PRs for hypertension in the senior year were calculated on groups that changed in the direction of obesity against those that changed towards underweight.
5. In all subjects and non-hypertensive subjects in their freshman year, the logistic regression analyses were applied to estimate odds ratios (ORs) for hypertension in the senior year of each factor: hypertension in freshman year, body type in freshman year, body type in senior year and school.

The body types were categorized as underweight (BMI <18.5), normal weight (18.5–24.9), overweight (25.0–29.9) and obese (30.0 ≤) using the criteria of the World Health Organization (WHO) and the Japan Society for the Study of Obesity. The BMI was calculated as weight (kg)/height (m^2). According to the WHO and International Society of Hypertension (ISH) [27], blood pressure can be divided into three categories: normotensive (SBP <130 mmHg and DBP < 85 mmHg), high normotensive (SBP 130–139 mmHg and/or DBP 85–90 mmHg except for hypertensive), and hypertensive (SBP ≥140 mmHg and/or DBP ≥90 mmHg). The analyses were conducted on all subjects, non-hypertensive subjects in their freshman year (male 3757; female 2058), and subjects categorized into SS&SCCS (male 2003; female 1029) and SHSS (male 2095; female 1051) in order to take into account physical activities. With regard to the difference in participating in physical activities between the schools, SS&SCCS students were required to take a sports class for two credits for graduation, while SHHS were required to earn 12–13 credits for sports. All of the analyses conducted were sex specific.

Statistical methods

The statistical analyses were performed using SPSS FOR WINDOWS (SPSS, Chicago, IL). To compare SS&SCCS students with the SHSS ones, we used *t* tests for comparing the means of age, BMI and blood pressure, and chi-square tests for comparing the distribution of body types and blood pressure categories. In logistic regression analyses, hypertension in their senior year was used as the dependent variable, and hypertension in their freshman year, the body types in their freshman and senior years, and the schools were used as independent variables. In the logistic regression analyses, blood pressure was divided into two categories: normotensive (<140 mmHg for SBP and <90 mmHg for DBP) and hypertensive(≥140 mmHg for SBP and/or ≥ 90 mmHg for DBP). In all analyses, P values of < 0.05 were regarded as statistically significant.

Results

Characteristics of population

When male SS&SCCS students were compared with their SHSS counterparts, the mean values of age, SBP and DBP in their freshman year were significantly higher in the former than the later, and BMI in their freshman and senior years was significantly higher in the latter. In the female students, age and DBP in the freshman year were significantly higher in SS&SCCS students, and BMI in the freshman and senior years was higher in SHSS students (Table 1).

Distributions of body types and comparisons between schools

Among all of the subjects and non-hypertensive subjects in their freshman year, the body types in both freshmen and seniors were categorized as normal weight in more than 80% of both males and females (Table 2). In all subjects, the proportions of overweight and obese subjects (BMI ≥ 25.0) were 11.6% of males and 6.2% of females in their freshman year, and 13.7% of males and 6.6% of females in their senior year.

The distributions of body types displayed significant differences between SS&SCCS and SHSS in both male and female subjects ($P < 0.001$). The proportion of underweight students was higher among SS&SCCS students: in males, 12.0% in their freshman year and 9.9% in their senior year. Among SHSS male students, these were 1.6 and 1.7%, respectively. The proportions of underweight female students were 12.1% in their freshman year and 16.3% in their senior year among SS&SCCS students, compared to 4.0 and 5.6%, respectively, among SHSS students.

Distributions of blood pressure categorized and comparisons between schools

In all subjects, the proportions of hypertensive subjects were 8.3% in males and 1.1% in females in their freshman year, 14.4% in males and 2.1% in females in their senior year (Table 3). In non-hypertensive subjects in their freshman year, the distributions of blood pressure in their senior year differed very little from those in all subjects.

In both male and female subjects, the distributions of blood pressure showed significant difference between SS&SCCS and SHSS in their freshman year ($P < 0.001$ for males and $P < 0.01$ for females), but did not show significance in their senior year.

Table 1 Characteristics of subjects

Sex	Academic year	Variables	All subjects	Non-hypertensive subjects in freshmen	SS&SCCS	SHSS	Significance
Male	Senior year	Number of subjects	4,098	3,757	2,003	2,095	–
		Age (years)	21.2 ± 0.5	21.2 ± 0.5	21.3 ± 0.6	21.2 ± 0.4	***
	Freshman year	BMI (kg/m^2)	22.1 ± 2.9	21.9 ± 2.7	21.5 ± 3.1	22.5 ± 2.6	***
		SBP (mmHg)	120.9 ± 13.0	118.7 ± 11.1	121.7 ± 13.4	120.1 ± 12.6	***
		DBP (mmHg)	67.1 ± 9.7	66.1 ± 8.9	67.7 ± 9.9	66.6 ± 9.6	***
	Senior year	BMI (kg/m^2)	22.2 ± 2.9	22.1 ± 2.7	21.6 ± 3.0	22.8 ± 2.7	***
		SBP (mmHg)	124.9 ± 13.1	124.2 ± 12.8	124.9 ± 13.4	125.0 ± 12.9	NS
		DBP (mmHg)	69.8 ± 9.9	69.4 ± 9.8	69.6 ± 10.0	70.0 ± 9.9	NS
Female	Senior year	Number of subjects	2,080	2,058	1,029	1,051	–
		Age (years)	21.1 ± 0.4	21.1 ± 0.4	21.2 ± 0.5	21.1 ± 0.3	***
	Freshman year	BMI (kg/m^2)	21.4 ± 2.4	21.4 ± 2.3	21.0 ± 2.6	21.8 ± 2.1	***
		SBP (mmHg)	108.5 ± 12.1	108.1 ± 11.7	108.8 ± 12.6	108.1 ± 11.7	NS
		DBP (mmHg)	61.5 ± 8.8	61.3 ± 8.5	62.1 ± 8.9	60.9 ± 8.6	**
	Senior year	BMI (kg/m^2)	21.2 ± 2.5	21.2 ± 2.5	20.7 ± 2.6	21.7 ± 2.3	***
		SBP (mmHg)	112.0 ± 12.5	111.9 ± 12.5	112.1 ± 12.8	111.9 ± 12.3	NS
		DBP (mmHg)	63.6 ± 9.2	63.5 ± 9.2	63.9 ± 9.3	63.2 ± 9.1	NS

***$P < 0.001$, **$P < 0.01$ comparison of SS&SCCS and SHSS students by the t test. NS, Not significant

BMI, Body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure

Values are given as the mean ± standard deviation

Table 2 Body types in their freshman and senior years

Sex	Academic year	Body types	All subjects	Non-hypertensive subjects in freshmen	SS&SCCS	SHSS	Significance
Male	Freshman year	Underweight	275 (6.7)	259 (6.9)	241 (12.0)	34 (1.6)	***
		Normal weight	3348 (81.7)	3111 (82.8)	1537 (76.4)	1817 (86.7)	
		Overweight	397 (9.7)	335 (8.9)	188 (9.4)	209 (10.0)	
		Obese	78 (1.9)	52 (1.4)	43 (2.2)	35 (1.7)	
	Senior year	Underweight	233 (5.7)	218 (5.8)	198 (9.9)	35 (1.7)	***
		Normal weight	3302 (80.6)	3067 (81.6)	1577 (78.7)	1725 (82.3)	
		Overweight	485 (11.8)	420 (11.2)	196 (9.8)	289 (13.8)	
		Obese	78 (1.9)	52 (1.4)	32 (1.6)	46 (2.2)	
Female	Freshman year	Underweight	167 (8.0)	166 (8.1)	125 (12.1)	42 (4.0)	***
		Normal weight	1784 (85.8)	1770 (86.0)	845 (82.1)	939 (89.3)	
		Overweight	116 (5.6)	110 (5.3)	48 (4.7)	68 (6.5)	
		Obese	13 (0.6)	12 (0.6)	11 (1.1)	2 (0.2)	
	Senior year	Underweight	227 (10.9)	226 (11.0)	168 (16.3)	59 (5.6)	***
		Normal weight	1715 (82.5)	1702 (82.7)	804 (78.1)	911 (86.7)	
		Overweight	127 (6.1)	119 (5.8)	50 (4.9)	77 (7.3)	
		Obese	11 (0.5)	11 (0.5)	7 (0.7)	4 (0.4)	

***$P < 0.001$ comparison of SS&SCCS and SHSS by chi-square test

Values are given as the number of subjects, with the percentage in parenthesis

Associations of body types with hypertension

In all subjects, the PRs for hypertension tended to rise as body types changed to becoming more obese (Table 4). When compared to normal male weight, the PRs were 2.21 (95% CI 1.70–2.86) for overweight and 4.71 (95% CI 3.36–6.60) for obese male students in their freshman year, and 2.03 (95% CI 1.70–2.42) for overweight and 4.54 (95% CI 3.66–5.63) for obese male students in their senior year. In the senior year, the PR in the underweight category was

Table 3 Blood pressure categorized in the freshman and senior years

Sex	Academic year	Blood pressure categorized	All subjects	Non-hypertensive subjects in freshmen	SS&SCCS	SHSS	Significance
Male	Freshman year	Normotensive	2966 (72.4)	2966 (78.9)	1371 (68.5)	1595 (76.1)	***
		High normotensive	791 (19.3)	791 (21.1)	437 (21.8)	354 (16.9)	
		Hypertensive	341 (8.3)	–	195 (9.7)	146 (7.0)	
	Senior year	Normotensive	2507 (61.2)	2373 (63.2)	1229 (61.4)	1278 (61.0)	NS
		High normotensive	999 (24.4)	903 (24.0)	475 (23.7)	524 (25.0)	
		Hypertensive	592 (14.4)	481 (12.8)	299 (14.9)	293 (14.0)	
Female	Freshman year	Normotensive	1967 (94.5)	1967 (95.6)	956 (92.9)	1011 (96.2)	**
		High normotensive	91 (4.4)	91 (4.4)	58 (5.6)	33 (3.1)	
		Hypertensive	22 (1.1)	–	15 (1.5)	7 (0.7)	
	Senior year	Normotensive	1863 (89.5)	1849 (89.9)	910 (88.5)	953 (90.7)	NS
		High normotensive	174 (8.4)	167 (8.1)	100 (9.7)	74 (7.0)	
		Hypertensive	43 (2.1)	42 (2.0)	19 (1.8)	24 (2.3)	

***$P < 0.001$, **$P < 0.01$ comparison of SS&SCCS and SHSS by chi-square test

Data are given as the number of subjects, with the percentage given in parenthesis

SS&SCCS, School of Sociology (SS), School of Computer and Cognitive Sciences (SCCS); SHSS, School of Health and Sport Sciences

Table 4 Prevalences of hypertension and prevalence ratios for hypertension by body types—all subjects

Sex	Body types	Freshman year			Senior year		
		Hypertensives/ subjects	Prevalences of hypertension (%)	PRs (95% CIs)	Hypertensives/ subjects	Prevalences of hypertension (%)	PRs (95% CIs)
Male	Total	341/4098	8.3	–	592/4098	14.4	–
	Underweight	16/275	5.8	0.82 (0.50–1.34)	16/233	6.9	0.55 (0.34–0.90)*
	Normal weight	237/3348	7.1	1.00	410/3302	12.4	1.00
	Overweight	62/397	15.6	2.21 (1.70–2.86)*	122/485	25.2	2.03 (1.70–2.42)*
	Obese	26/78	33.3	4.71 (3.36–6.60)*	44/78	56.4	4.54 (3.66–5.63)*
Female	Total	22/2080	1.1	–	43/2080	2.1	–
	Underweight	1/167	0.6	0.76 (0.10–5.77)	3/227	1.3	0.81 (0.25–2.64)
	Normal weight	14/1784	0.8	1.00	28/1715	1.6	1.00
	Overweight	6/116	5.2	6.59 (2.58–16.83)*	9/127	7.1	4.34 (2.09–9.00)*
	Obese	1/13	7.7	9.80 (1.33–69.17)*	3/11	27.3	16.70 (5.95–46.91)*

*$P < 0.05$ comparison of normal weight and other body types

PR, Prevalence ratios

significantly lower than that in normal weight (PR 0.55, 95% CI 0.34–0.90). In females, the PRs were significantly higher for overweight (freshmen: PR 6.59, 95% CI 2.58–16.83; seniors: PR 4.34, 95% CI 2.09–9.00) and obese (freshmen: PR 9.80, 95% CI 1.33–69.17; seniors: PR 16.70, 95% CI 5.95–46.91) students when compared with normal weight in both the freshman and senior years.

In analyses by schools, the PRs for hypertension tended to rise as body types changed to becoming obese as did those for all subjects. Compared with normal weight, overweight and obese had significantly high PRs, except for SHSS female students in their freshman year and SS&SCCS female students in their senior year. In SS&SCCS, the PR in underweight male students in their senior year was (PR 0.60, 95% CI 0.37–0.98). Compared with SS&SCCS students, the PRs for hypertension in male SHSS students were 0.72 (95% CI 0.58–0.88) in their freshman year and 0.93 (95% CI 0.81–1.09) in their senior year; those for female SHSS students were 0.46 (95% CI 0.19–1.12) and 1.24 (95% CI 0.68–2.24), respectively.

In non-hypertensive subjects in their freshman year, the PRs for hypertension tended to rise as body types changed to becoming more obese, in both the underweight and all subjects categories. The PRs for hypertension in males were 0.57 (95% CI 0.34–0.96) for underweight, 2.06 (95% CI 1.68–2.52) for overweight and 4.46 (95% CI 3.34–5.95)

for obese compared with normal weight; these differences were statistically significant. The differences in females of the different weight categories were also statistically significant for overweight (PR 4.09, 95% CI 1.90–8.77) and obese (PR 16.58, 95% CI 5.90–46.55).

Proportions of hypertension in their seniors by body type change patterns

In all subjects, the groups that changed towards becoming obese between their freshman and senior years tended to show higher proportions of hypertension when compared with those who changed towards being underweight, in both male and female subjects (Table 5). The proportions of hypertension were high for the group that changed from overweight as freshmen to obese as seniors (54.2%, 95% CI34.3–74.1) and the group that were obese as both freshmen and seniors (56.9%, 43.3–70.5) in males, and the group that changed from being overweight in their freshman year to being obese in their senior year (42.9%, 6.2–79.6) in females. In the subjects that changed towards becoming underweight, 31 of 207 males and three of 156 females were hypertensive in their seniors. On the other hand, in those that changed towards becoming obese, 74 of 337 males and seven of 104 females were hypertensive in as seniors. The PRs for hypertension in groups that changed towards becoming obese from their freshman to senior year were 1.47 (95% CI 1.00–2.15) for males and 3.50 (95% CI 0.93–13.22) for females when compared with those that changed towards becoming underweight.

In analyses by schools, the PRs for hypertension in groups changed towards being obese were significantly higher than those changing towards underweight in males: 1.79 (1.09–2.93) for SS&SCCS, 1.95 (1.00–3.79) for SHSS.

In non-hypertensive subjects in their freshman year, the PRs for hypertension in groups that changed towards becoming obese against those that changed towards being underweight were 1.75 (95% CI1.09–2.81) for males and 5.27 (1.12–24.85) for females.

The proportions of hypertension were, on the whole, higher for males when compared with females in the same BMI groups or body type change groups.

Logistic regression analyses

In all subjects, the factors significantly associated with hypertension in their senior year were hypertension in their freshman year and body types in both their freshman and senior year—but not schools (Table 6). Among hypertensive male subjects in their freshman year, the OR for hypertension in their senior year was 3.29 (95% CI 2.57–

Table 5 Numbers and proportions of hypertensive subjects in their senior year by body type change patterns

Academic year	Sex	Body types	Senior year			
			Underweight	Normal weight	Overweight	Obese
Freshman year	Male	Underweight	*7.6 (3.6–11.6)*	9.6 (3.9–15.3)		
			13/171	10/104		
		Normal weight	4.8 (0.0–10.1)	*12.3 (11.1–13.5)*	23.8 (18.0–29.6)	66.7 (13.4–100.0)
			3/62	*379/3,077*	49/206	2/3
		Overweight		16.9 (10.1–23.7)	*25.9 (20.5–31.3)*	54.2 (34.3–74.1)
				20/118	*66/255*	13/24
		Obese		33.3 (0.0–86.6)	29.2 (11.0–47.4)	*56.9 (43.3–70.5)*
				1/3	7/24	*29/51*
	Female	Underweight	*1.7 (0.0–4.0)*	0.0		
			2/120	0/47		
		Normal weight	0.9 (0.0–2.7)	*1.7 (1.1–2.3)*	8.0 (0.5–15.5)	
			1/107	*27/1, 627*	4/50	
		Overweight		2.5 (0.0–7.3)	*5.8 (0.3–11.3)*	42.9 (6.2–79.6)
				1/40	*4/69*	3/7
		Obese		0.0	12.5 (0.0–35.4)	*0.0*
				0/1	1/8	*0/4*

Above (top diagonal row of italics): the proportions of hypertensive subjects in their senior year by body type change groups and 95% confidence intervals. Below (bottom diagonal row of italics) the numbers of hypertensive subjects in their senior year by body type change groups; hypertensives/subjects

PRs for hypertension in groups that changed towards becoming obese compared with those who changed towards becoming underweight: male 1.47 (95% CI 1.00–2.15); female 3.50 (95% CI 0.93–13.22)

Table 6 Odds ratios for hypertension in their senior year according to hypertension in their freshman year, body types in their freshman and senior year, and schools by logistic regression analyses—all subjects

		Male		Female	
		ORs	95% CIs	ORs	95% CIs
Hypertension in freshman year	Normotensive	1.00		1.00	
	Hypertensive	3.29***	2.57–4.20	2.29	0.30–17.39
Body type in freshman year	Underweight	0.61*	0.40–0.95	0.66	0.16–2.79
	Normal weight	1.00		1.00	0.23–6.98
	Overweight	2.24***	1.74–2.87	4.06**	1.83–9.01
	Obese	6.08***	3.85–9.58	4.56	0.58–36.15
Body type in senior year	Underweight	0.52*	0.31–0.87	0.81	0.24–2.68
	Normal weight	1.00		1.00	
	Overweight	2.37***	1.88–2.98	4.60***	2.12–9.96
	Obese	9.13***	5.77–14.45	22.59***	5.69–89.67
Schools	SS&SCCS	1.00		1.00	
	SHSS	0.93	0.78–1.10	1.24	0.68–2.28

Logistic regression analyses: ***$P < 0.001$, **$P < 0.01$, *$P < 0.05$

4.20) as compared with normotensive males in their freshman year. Among obese subjects in their senior year, the ORs for hypertension were 9.13 (95% CI 5.77–14.45) for males and 22.59 (5.69–89.67) for females, as compared with normal-weight subjects in their senior year.

Among non-hypertensive subjects in their freshman year, there were the same tendencies as all subjects. The ORs for hypertension in among seniors were 2.38 (95% CI 1.85–3.06) for overweight and 7.92 (4.54–13.79) for obesity in males, and 4.31 (1.92–9.68) for overweight and 22.42 (5.65–88.98) for obesity in females when compared with normal-weight subjects.

Discussion

Yoshiike et al. [28] examined the prevalence of obesity by 5-year age categories in Japanese adults using the 1990–1994 data set of the NNS-J. They found a prevalence of obesity (BMI $\geq$ 25.0) of approximately 10% in males and 6% in females in subjects aged 15–19 years, which includes the age of university freshmen, and 13% in males and 5% in females in subjects aged 20–24, which includes the age of university seniors. Based on a study of the records of annual health examinations of university students, Yoshimura et al. [23] reported that in their freshman year, 15.4% of males and 11.2% of females were obese, while in their senior year, 9.9% of males and 5.2% of females were obese. Miyazaki et al. [24] reported that the prevalences of obesity were 10.1% in males and 2.2% in females at the time of university entrance. Sato [29] found that 9.1% of male students and 5.0% of female students aged 18 years were obese, and theat 9.2 and 4.0%, respectively, aged 21 years were obese. In our study, the proportions of obese subjects (BMI $\geq$25.0) were 11.6% in males and 6.2% in females in their freshman year, and 13.7% in males and 6.6% in females in their senior year. The proportions of obese subjects in our study were therefore somewhat higher than those reported in previous studies, except for the proportions of obesity in the freshman year reported by Yoshimura et al. This difference may partially have been caused by including the SHSS students in our study. Morita et al. [30 reported that students in the department of physical education had a better physique than those of other departments. In our study, the mean values of BMI were higher in SHSS male and female students than their SS&SCCS counterparts. In terms of body types that were categorized by BMI, the proportions of obese subjects showed little difference between the schools, but there were three- to sevenfold more underweight subjects among the SS&SCCS students. The 1998 NNS-J [31] reported that the proportion of underweight (BMI <18.5) among 15- to 19-year olds was 16.3% of males and 20.4% of females; in the 20- to 29-year olds, this was 8.3 and 20.3%, respectively. The proportions of underweight subjects among the SS&SCCS students were close to those reported in the NNS-J, while those among SHSS students (2% or less in males and 4–6% in females) were lower than those reported by the NNS-J.

In terms of the proportions of hypertension ($\geq$140 mmHg for SBP and/or $\geq$90 mmHg for DBP) in Japanese young adults, Kawasaki et al. [32] reported that approximately 7–20% (average, 14%) of the students at the annual regular health check at a certain university were hypertensive. Ejima et al. [33] reported among university students aged less than 30 years, 13% of males and 3% of females were hypertensive. The proportions of hypertension reported in the 2001 NNS-J [1] were 2.2% of males and 0.7% of females aged 15–19 years, and 11.5% of males and 1.0% of females aged 20–29 years. The respective values from our study were 8.3% of males and 1.1% of females in their freshman year, and 14.4% of

males and 2.1% of females in their senior year. Although the proportions of hypertension from our study were slightly higher than those reported in the 2001 NNS-J, the same tendencies were the same. Yoshimura et al. [23] reported that students in their senior year tended to be more hypertensive than those in their freshmen year. Our study also displayed a similar tendency. Moreover, the proportions of hypertension were different between sexes, being higher in males. Kawabe et al. [21] found that blood pressure in female students was significantly lower than that in their male counterparts, and more males (30–35%) than females (2–5%) had higher than normal blood pressure (≥130 mmHg for SBP and/or ≥85 mmHg for DBP). Uezono [5] reported that the proportions of students with hypertension for SBP (≥ 140 mmHg) were 11.0% of male students and 1.9% of female students, and that the proportions of those with higher than normal blood pressure for SBP (≥ 130 mmHg) were 33.5 and 8.6%, respectively. In our study, 27.6 and 38.8% of male students in their freshman and senior year, respectively, and 5.4 and 10.4% of their female counterparts, respectively, had higher than normal blood pressure. The corresponding proportions for hypertension were 8.3 and 14.4% in male subjects, and 1.1 and 2.1% in female subjects. The proportions of higher than normal blood pressure was also higher in males, as were those of hypertension, and our findings were consistent with those reported by Kawabe et al. [21] and Uezono [5].

Based on a study of 8302 and 9139 male and female students, respectively, aged 25–64 years,Hu et al. [34] reported that regular physical activities can reduce the risk of hypertension. One of the underlying premises of our study was that students at the SHSS are more physically active as group than those students at the SS&SCCS because the former are more active in sports club activities more than the latter. When we compared the distributions of blood pressure categorized between the schools, there were significant differences in both male and female subjects in their freshman year. The proportions of hypertensive subjects were higher among the SS&SCCS students. However, these differences had disappeared by the senior year. The PR for hypertension was significantly lower for SHSS students than for SS&SCCS students only in males during the freshman year. No significant relationship was found between schools and hypertension among students in their senior year in the logistic regression analyses. Therefore, our study did not seem to indicate an obvious relationship between physical activities and hypertension by adjusting for body types.

There are many reports that obesity are associated with hypertension in middle-aged individuals [4, 6–11], but there have been only a few reports on young adults. Yoshimura et al. [23] reported 45.6% of all male obese university students and 21.7% of all female obese university students were hypertensive; the proportions in our study were 18.5 and 20% among males in their freshman and senior year, respectively, and 5.3 and 9.3% among females, respectively. These are were lower than those reported by Yoshimura et al. [23].

There are many reports of an association between hypertension and increased BMI or weight gain in middle-aged individuals or various age groups [4, 6, 7, 10]. Miyazaki et al. [24] and Kitamura et al. [25] concluded that the appearance of hypertension tended to increase as body types changed to the obese type, even in young adults. The results from our study are consistent with those reported previously.

Huang et al. [8] reported that multivariate relative risks for hypertension were 1.74 for a gain of 5.0–9.9 kg and 5.21 for a gain ≥ 25.0 kg when compared with weight change ≤2 kg in cohort of 82,473 U.S. female nurses aged 30–55 years. Field et al. [9] reported that BMI and weight gain were independently associated with the development of hypertension in 46,224 females aged 33–51 years who were participants in the Nurse Health Study II. Our study has been conducted in young adults of both male and female subjects. However, the PRs for hypertension in groups that changed towards being obese between their freshman and senior year were higher than those in groups that changed towards being underweight, in both male and female subjects. These results showed similar tendencies to those found in middle-aged female individuals [8, 9].

We conducted analyses that separated the subjects into a SS&SCCS subgroup and a SHSS one in order to take into account physical activities in association with hypertension with obesity. As mentioned above, Hu et al. [34] reported that physical activity was negatively associated with hypertension and that these associations were not varied in overweight and obese subjects. In our study, the mean values of blood pressure and proportions of hypertension in students in their freshman year tended to be higher among the SS&SCCS students. However, the associations of hypertension with body type change pattern showed little difference between schools, and schools were not significantly associated with hypertension in their senior year in the logistic regression analyses. Therefore, the results did not show clear findings that physical activities reduced the risk of hypertension.

We also conducted analyses limited to non-hypertensive subjects in their freshman year in order to examine whether the weight change while at university was associated with the appearance of hypertension. Our analyses showed almost the same findings as those in the whole group of subjects. Nakanishi et al. [11] reported that adjusted hazard ratios of hypertension for five increases in BMI were 1.79 in 949 hypertension-free Japanese male office workers

aged 35–54 years. In our study, the prevalences of hypertension tended to rise as body types changed towards being obese. The ORs for hypertension were significantly higher in overweight and obese subjects, in comparison to normal-weight subjects, in the logistic regression analyses. These results were not inconsistent with the findings that were obtained from studies conducted in middle-aged individuals. As a result, our data suggest that obesity is linked to hypertension and that the increase of BMI increases the risk of hypertension, even in individuals of a university age.

There are some limitations in our study. Hypertension in this study was evaluated by a blood pressure measure only once, at the health examination. Although it is different from the diagnostic procedure of hypertension commonly used, it does not seem to have caused different measurement errors among the subgroups. Therefore, it is unlikely to have biased the results systematically. Second, the same width cuff was used for the measurement of blood pressure, regardless of the thickness of the arm. This may have resulted in a little lower blood pressure among the underweight group than other groups, and a little higher blood pressure among the overweight subjects. Third, because the proportions of hypertension were low in female subjects, the subjects of hypertension were small, especially in females. Therefore, in our study, the statistical power is low among the results pertaining to females.

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