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Association between Height and Hypertension: A Retrospective Study

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Abstract: Height loss starting in middle age is reported to be an independent risk factor for cardiovascular mortality. Recent studies have revealed an inverse association between height and hypertension, but the influence of hypertension on height loss is unknown. Since hypertension is an established cardiovascular risk factor, clarifying the association between baseline hypertension and height loss could lead to an efficient tool to estimate the risk of mortality. A retrospective study of 11,154 Japanese aged 40–74 years was conducted. Height loss was defined as being in the highest quintile of annual height decrease (≥2.015 mm/year for men and ≥1.756 mm/year). Baseline height was significantly inversely associated with incident hypertension for men only. The adjusted odds ratio (OR) and 95% confidence interval (CI) for incident hypertension for each 1 standard deviation increment of height (5.9 cm for men and 5.6 cm for women) was 0.90 (0.84, 0.97) for men and 1.07 (0.91, 1.26) for women, respectively. We also found that baseline hypertension is independently positively associated with height loss for men only. The adjusted OR was 1.25 (1.11, 1.42) for men and 0.93 (0.71, 1.21) for women. These results might lead to an efficient tool for estimating the risk of height loss, which has been reported to be associated with a higher risk of mortality in adults.

Keywords: height; height loss; hypertension; retrospective study

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1. Introduction

Recently, adult height was revealed to be inversely associated with hypertension [1–3]. Presumably, early-life conditions related to the development of height also play a role in later life. Presence of low grade chronic inflammation, productivity of hematopoietic stem cells, and genetic factors are potential candidates that explain the inverse association between height and hypertension [4,5]. However, the mechanisms underlying this inverse association have not yet been clarified.

Although adult height could act as a risk marker for hypertension, no studies have reported an association between baseline hypertension and height loss among adults. Aging is a process that is associated with height loss [6]. Height loss starting in middle age is a risk factor for mortality from cardiovascular disease and respiratory disease among the elderly [7].

Since hypertension is an established cardiovascular risk factor, clarifying the association between baseline hypertension and height loss could lead to an efficient tool to estimate the risk of mortality.

To clarify the association between baseline height and incident hypertension and the association between baseline hypertension and height loss, we conducted a retrospective study of 11,154 Japanese individuals aged 40–75 years who underwent an occupational medical examination at least twice between 2000 to 2010 at the Osaka Center for Cancer and Cardiovascular Diseases Prevention.

2. Materials and Methods

2.1. Study Population

The study population comprised 15,199 individuals aged 40–74 years who participated in a general occupational medical examination that involved a medical interview, physical examination, blood pressure measurement, and blood tests between 2000 and 2009 at Osaka Center for Cancer and Cardiovascular Diseases Prevention. Subjects who participated in this general health examination only once between 2000 and 2010 were excluded from present study population (n = 4045). The remaining 11,154 subjects with a mean age of 49.2 years (standard deviation [SD], 7.4; range 40–74) at baseline were enrolled in the study. Mean follow-up of this study was 4.2 years (SD, 3.0). Since the participants of this study were current workers who had the capacity to work, they might be relatively healthier than the general population. Furthermore, compared to the general population, the proportion of men might be higher because more men than women tend to became workers in Japanese society.

This study was approved by the ethics committee of Osaka Center for Cancer and Cardiovascular Diseases Prevention (Project registration code: R2-Rinri-7). To obtain consent on this study, opt-out method was performed by using the poster description and institutional website later. This website is available at: www.osaka-ganjun.jp/effort/cvd/r-and-d/ (accessed on 20 July 2022).

2.2. Data Collection and Laboratory Measurements

Trained medical staff conducted interviews to obtain information about medications and habits. Systolic blood pressure and diastolic blood pressure were recorded at rest. Hypertension was defined as systolic blood pressure $\geq$140 mmHg, diastolic blood pressure $\geq$90 mmHg, or use of an anti-hypertensive medication. Height loss was defined as being the highest quintile of annual height decrease ($\geq$2.015 mm/year for men and $\geq$1.756 mm/year for women) as in our previous study [8]. Median annual height decrease [interquartile range] was 3.486 [2.563, 5.276] mm/year for men and 2.903 [2.145, 4.451] mm/year for women, respectively. A fasting blood sample was collected. Hemoglobin A1c (HbA1c) and total cholesterol were measured using standard procedures at Osaka Center for Cancer and Cardiovascular Diseases Prevention.

2.3. Statistical Analysis

To clarify the influence of height on body mass index (BMI), simple correlation analysis was performed.

Sex-specific characteristics of the study population were expressed as means $\pm$ SD, except for the prevalence of daily drinker, current smoker, hypertension and medication use as well as height decrease. Since height decrease had a skewed distribution, it was expressed as median [interquartile range]. Significant differences were evaluated using analysis of variance (ANOVA) for continuous variables and the chi-squared test for proportion.

Logistic regression was used to evaluate the association between height and incidence of hypertension among subjects without baseline hypertension. We also used logistic regression to calculate odds ratios (ORs) and 95% confidence intervals (CIs) of incident height loss for baseline hypertension.

Two different approaches were used to make adjustment for confounding factors. First, one model was adjusted only for age (age-adjusted model). BMI is a value derived from the weight and height of a person. Our previous retrospective study with Japanese worker reported positive association between over-weight defined as baseline BMI $\geq$ 25 kg/m^2 and incidence of height loss [8]. Since BMI is strongly associated with hypertension [9], BMI could influence the association between baseline hypertension and height loss. Then, for the second model (multivariable model), we included several other potential confounding factors with BMI (kg/m^2), namely drinking status (none, often, daily), smoking status (never, former, current smoker), BMI, HbA1c (%), total cholesterol (mg/dL), glucose-lowering medication use (no, yes), and use of medication for dyslipidemia (no, yes).

Values of $p < 0.05$ were regarded as statistically significant. All statistical analyses were performed with SAS for Windows (version 9.4; SAS Inc., Cary, NC, USA).

3. Results

3.1. Characteristics the of Study Population

For men, baseline height was not significantly correlated with baseline BMI. However, for women, slightly but significant correlation between baseline height and baseline BMI was observed. The simple correlation coefficient for height and BMI were −0.02 ($p = 0.164$) for men and −0.14 ($p < 0.001$) for women.

Sex-specific characteristics of the study population are shown in Table 1. Among the 11,154 study participants (8342 men and 2812 women), 2639 (23.7%) participants (2223 [26.6%] men and 416 [14.8%] women) had hypertension at baseline.

Table 1. Characteristics of the study population.

	Men	**Women**	***p***
No. of participants at risk	8342	2812	
Age, years	49.3 ± 7.2	49.0 ± 7.9	<0.001
Daily drinker, %	23.3	9.7	<0.001
Current smoker, %	43.6	12.9	<0.001
Hypertension, %	26.6	14.8	<0.001
Body mass index, kg/m^2	23.8 ± 3.1	22.1 ± 3.2	<0.001
Hemoglobin A1c, %	5.0 ± 0.9	4.9 ± 0.6	<0.001
Glucose-lowering medication use, %	3.4	1.0	<0.001
Total cholesterol, mg/dL	205 ± 33	208 ± 34	0.0028
Use of medication for dyslipidemia, %	4.1	3.8	0.4583
Height, cm	169.1 ± 5.9	156.1 ± 5.6	<0.001
Height decrease, mm/year	0.528 [−0.462, 1.662] *[1]	0.429 [−0.593, 1.426] *[1]	<0.001 *[2]

Unless otherwise indicated, continuous values are means ± SD. Regression model for mean values was used for determining *p* values. *[1]: Values are median [the first quartile, third quartile]. *[2]: Logarithmic transformation was used for evaluating *p*.

3.2. Association between Height and Incident Hypertension

Table 2 shows the association between height and incident hypertension among participants without hypertension at baseline (6119 men and 2396 women). During the follow-up period (4.4 ± 3.1 years for men and 3.9 ± 2.7 years for women), 993 men and 201 women developed hypertension. For men, height was significantly inversely associated with incident hypertension, but not for women. Multivariable ORs and 95% CIs for hypertension with each 1 SD increment of height (5.9 cm for men and 5.6 cm for women) were 0.90 (0.84, 0.97) for men and 1.07 (0.91, 1.26) for women, respectively.

Table 2. Odds ratios (ORs) and 95% confidence intervals (CIs) for incident hypertension.

	Height Tertile			***p***	**1SD Increment in Height**
	Low	**Middle**	**High**		
Men					
No. at risk	1931	2041	2147		
No. of cases (%)	369 (19.1)	319 (15.6)	305 (14.2)		
Age-adjusted OR	Ref	0.85 (0.72, 1.00)	0.80 (0.68, 0.95)	0.012	0.90 (0.83, 0.96)
Multivariable OR	Ref	0.85 (0.72, 1.01)	0.80 (0.68, 0.96)	0.013	0.90 (0.84, 0.97)
Women					
No. at risk	740	817	839		

Table 2. *Cont.*

	Height Tertile			*p*	1SD Increment in Height
	Low	**Middle**	**High**		
No. of cases (%)	68 (9.2)	67 (8.2)	66 (7.9)		
Age-adjusted OR	Ref	1.02 (0.71, 1.47)	1.13 (0.78, 1.65)	0.527	0.99 (0.85, 1.16)
Multivariable OR	Ref	1.09 (0.75, 1.58)	1.36 (0.92, 2.00)	0.127	1.07 (0.91, 1.26)

Ref: reference. SD: standard deviation. Multivariable ORs adjusted further for age, drinking status, smoking status, body mass index, hemoglobin A1c, total cholesterol, glucose-lowering medication use, and use of medication for dyslipidemia. Tertiles of height for men and women were <166.7 cm and <153.7 cm for Low, 166.7–171.6 cm and 153.7–158.4 cm for Middle, and ≥171.7 cm and ≥158.5 cm for High, respectively. One standard deviation increment in height was 5.9 cm for men and 5.6 cm for women, respectively.

3.3. Association between Hypertension and Height Loss

Table 3 shows the associations between hypertension and height loss. While significant positive associations were observed for men, no significant associations were observed for women. The multivariable OR for height loss was 1.25 (1.11, 1.42) for men and 0.93 (0.71, 1.21) for women.

Table 3. Odds ratios (ORs) and 95% confidence intervals (CIs) for height loss with respect to hypertension.

	Hypertension		*p*
	(-)	**(+)**	
Men			
No. at risk	6119	2223	
No. of cases (%)	1116 (18.2)	552 (24.8)	
Age-adjusted OR	Ref	1.26 (1.12, 1.42)	<0.001
Multivariable OR	Ref	1.25 (1.11, 1.42)	<0.001
Women			
No. at risk	2396	416	
No. of cases (%)	464 (19.4)	98 (23.6)	
Age-adjusted OR	Ref	0.93 (0.71, 1.21)	0.579
Multivariable OR	Ref	0.93 (0.71, 1.21)	0.572

Ref: reference. Multivariable ORs adjusted further for age, drinking status, smoking status, body mass index, hemoglobin A1c, total cholesterol, glucose-lowering medication use, and use of medications for dyslipidemia. Height loss was defined as being in the highest quintile of annual height decrease (≥2.015 mm/year for men and ≥1.756 mm/year for women).

3.4. Sensitivity Analysis

We performed the analysis between hypertension and height loss again with height loss defined as being in the highest quartile of annual height decrease and obtained essentially the same associations. With the multivariable model, the OR for height loss with respect to hypertension was 1.24 (1.10, 1.39) for men and 0.95 (0.74, 1.22) for women, respectively.

4. Discussion

The major findings of present study are that height is inversely associated with incident hypertension for men but not for women, and baseline hypertension is significantly positively associated with height loss for men but not for women.

Recent epidemiological studies revealed inverse associations between height and hypertension; the results were hypothesized to be due to early-life conditions related to development of height having an influence on later life [1–3]. Those studies are partly compatible with our present study findings, which show that height is significantly inversely associated with incident hypertension among men.

In the present study, we found further evidence that baseline hypertension is significantly positively associated with height loss for men but not for women.

Reduced disc height associated with herniated discs and vertebral compression fractures related to osteoporosis are well-known causes of height loss in adults. There are also reportedly cardiovascular risk factors for disc herniation [10–12] and osteoporosis [13]. Since hypertension is one of the strongest cardiovascular risk factors, hypertension could act as a risk factor of disc herniation [14].

Inflammation is a potential underlying biochemical mechanism that explains the results of the present study. Aging is a process that increases oxidative stress. Oxidative stress causes hypertension and activates inflammation [15]. Since the inflammatory response contributes to the onset of intervertebral disk degeneration [16] and vertebral fractures [17], hypertension could act a risk factor for height loss by indicating inflammatory activity associated with intervertebral disk degeneration and vertebral fractures.

Low productivity of hematopoietic stem cell known as CD34-positive cell also might underlying the association between hypertension and height loss. Previously, our follow-up study of 363 Japanese men aged 60–69 years over 2 years revealed significant inverse association between circulating CD34-positive cell count and height loss [18]. CD34-positive cells contribute to the development of angiogenesis [19]. Since the development of angiogenesis should have a beneficial influence on preventing hypertension by reducing peripheral vascular resistance, participants with a shortage of circulating CD34-postive cell increase the risk of hypertension [20]. Inadequate angiogenesis related to lower adaptability to hypoxia [21] might play an important role in the development of intervertebral disc degeneration [22,23] and osteoporosis [24].

However, in the present study, no significant associations were observed for women. Because of the relatively small number of female study participants, the influence of sex on the association between hypertension and height loss could be not evaluated in depth. In fact, a previous study reported a significant inverse association between height and hypertension both for men and women [2], while in the present study a significant inverse association between height and incident hypertension was only observed among men.

However, elderly women have a higher risk of osteoporotic fractures and lumbar disc space narrowing than men [25]. In the present study, the prevalence of hypertension was higher in men than in women. Therefore, the association between hypertension and osteoporotic fracture or lumbar disc space narrowing might be stronger for men than for women. A study with more participants is necessary to clarify the influence of sex on the association between height and hypertension and the association between hypertension and height loss.

The present study showed that height could act as an indicator of risk for incident hypertension, and hypertension could act as an indicator of height loss among men. Therefore, a bidirectional association between height and hypertension existed among men. Since rapid height loss is associated with higher mortality from all causes and respiratory disease in men but not in women [26], the present findings of a significant association between hypertension and height loss limited to men might lead to an efficient tool for estimating the risk of mortality. Further investigations are required.

Potential limitations of the present study warrant consideration. For analyses of hypertension and height loss, the analysis for women was insufficient because the association between height and incident hypertension was not consistent with associations observed in a previous study [2]. Further investigations with a larger sample of women are necessary. In addition, an efficient cut-off point to define height loss was not available. In the present study, we used the highest quintile of annual height loss. In addition, our sensitivity analysis using quartile of annual height loss leads to essentially the same associations. Because there are many unknown genetic factors that influence angiogenesis and inflammation, further investigation is necessary.

5. Conclusions

In conclusion, for men, height was significantly inversely associated with incident hypertension and baseline hypertension was positively associated with height loss, but

those associations were not observed for women in this study. Our results might lead to an efficient tool for estimating the risk of height loss in adults.

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Informed Consent Statement: To obtain consent on this study, opt-out method was performed by using the poster description and institutional website later. This website is available at: www.osaka-ganjun.jp/effort/cvd/r-and-d/ (accessed on 20 July 2022).

Data Availability Statement: The datasets generated and/or analyzed during the current study are not publicly available due to ethical considerations. Qualified researchers may apply for access a minimal dataset by contacting Dr. Masahiko Kiyama, General Coordinator, at kiyama@osaka-ganjun.jp or data management staff at kenkyu_gyomu@osaka-ganjun.jp. Information regarding data requests is also available at http://www.osaka-ganjun.jp (accessed on 20 July 2022).

Conflicts of Interest: The authors declare no conflict of interest.

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