SHORT REPORT

Growth-related disappearance of the childhood relationship between height and blood pressure levels

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Abstract

Context: Although there is a positive relationship between height and blood pressure (BP) levels in children, there are no reports regarding the association between height and BP levels in adolescents and adults.

Objective: This study examined whether there is an association between height and BP levels in Japanese adolescents.

Methods: The source population was all fifth (10 and 11-year-olds) and ninth graders (14 and 15-year-olds) who attended 11 elementary schools and five junior high schools in the Iwata area from 2002–2008. School-based screenings were conducted annually by the local government from April to June. Data obtained from health examinations were analysed, including anthropometric measurements and BP levels, for 11 780 children (98.7% of the source population).

Results: Height showed significant positive relationships with systolic blood pressure (SBP) and diastolic blood pressure (DBP) in childhood and in adolescent males. In contrast, the relationship between height and SBP was significantly weaker in adolescent females than in childhood and there was no significant relationship between height and DBP in adolescent females.

Conclusion: The relationship between height and SBP was attenuated by development in females and the relationship between height and DBP disappeared.

Keywords
Age groups, growth, haemodynamics, Japan

Introduction

Considerable physiological changes occur in childhood and adolescents. As height and body weight change substantially with age (Cole et al., 1998), age-specific standard definitions for children and adolescents have been proposed (Cole et al., 2000). Blood pressure (BP) levels also change with growth (National High Blood Pressure Education Program Working Group on High Blood Pressure in Children and Adolescents 2004). BP levels increase around puberty in the Japanese general population (Kouda et al., 2003) and a cross-sectional analysis showed a positive association between height and BP levels in Japanese elementary school children (Fujita et al., 2010). A cohort study in African-American children showed that peak BP change rates were highly synchronized with peak height velocity (Tu et al., 2009). For children, therefore, BP reference tables by age, sex and height have been proposed (National High Blood Pressure Education Program Working Group on High Blood Pressure in Children and Adolescents 2004). However, there are no reports regarding the association between height and BP levels in adolescents and adults. We speculate that the association between height and BP levels disappears in adolescents and adults. The present study attempts to demonstrate the disappearance of the association between height and BP levels in the Japanese general population.

Methods

Study population

The source population was all fifth (10 and 11-year-olds) and ninth graders (14 and 15-year-olds) who attended 11 elementary schools and five junior high schools in the Iwata area from 2002–2008. We analysed data obtained from health examinations, including anthropometric measurements and BP levels, for 11 780 children (98.7% of the source population). This study was approved by the Ethics Committee of Kinki University Faculty of Medicine and conducted in accordance with the ethical principles of the Declaration of Helsinki.

School examinations

Examinations were conducted annually by local governments at each school from April–June using a standard protocol. Height and body weight measurements were taken in...
accordance with the Japanese School Health Law by special teachers (Yogo teachers) with a Japanese national teaching license who play a role in health education and healthcare at schools. Height was measured to an accuracy of 0.1 cm and body weight to 0.1 kg. The BMI (kg/m²) was then calculated as the weight (kg) divided by the square of the height (m²). Arm circumference was measured midway between the olecranon and acromion process and used to select cuff size. Nurses and medical technologists measured systolic blood pressure (SBP) and diastolic blood pressure (DBP) using an automated device (BP-103i II, Colin Corporation, Komaki, Japan) in accordance with the Yobo Igaku Jigyo Chuokai manual for screening (Ura, 2005). The measurement was taken in the seated position with the right arm supported at heart level after at least 2 minutes of rest. If the value was greater than the cut-off points (SBP ≥ 135 mmHg or DBP ≥ 80 mmHg in fifth graders and ninth-grade females, SBP ≥ 140 mmHg or DBP ≥ 80 mmHg in ninth-grade males), a second reading was taken after at least 2 minutes of rest. If the value from the second reading was also greater than the cut-off points, a third reading was taken after at least 2 minutes of rest. If the value from the third reading was also greater than the cut-off points, the lowest values were used.

Statistical analysis
All analyses were performed using SAS version 9.2 (SAS Institute Japan Ltd., Tokyo, Japan). We used t-tests to compare anthropometric characteristics of males with those of females. To reveal height-specific BP values in more detail, height values were divided into quintile groups that included 20% of the study population in each group. To remove the influence of grade, the BP standard deviation (SD) score was calculated as follows: (BP value – mean value)/SD. Correlation analysis was used to evaluate the relationship between height and SBP in ninth-grade females. Coefficient between height and SBP in ninth-grade females was significantly lower than that in fifth-grade females. The difference in SBP SD score between the lowest and highest quintiles was 0.569 in fifth-grade females and only 0.062 in ninth-grade females. The correlation coefficient between height and SBP in ninth-grade females was significantly lower than that in fifth-grade females. The difference in SBP SD score between the lowest and highest quintiles was 0.813 in fifth-grade females and 0.216 in ninth-grade females. In fifth- and ninth-grade males, a significant relationship was found between height and both SBP and DBP.

Results
Anthropometric characteristics of fifth and ninth graders were shown in Table 1. In fifth graders, height and SBP were significantly higher in females compared to males. In contrast, in ninth graders, height and SBP were significantly lower in females compared to males.

Table 2 shows the relationship between height and BP levels. In females, there was a significant relationship between height and DBP in the fifth-grade, while there was no significant relationship between height and DBP in the ninth-grade. The difference in DBP SD score between the lowest and highest quintiles was 0.569 in fifth-grade females and only 0.062 in ninth-grade females. The correlation coefficient between height and SBP in ninth-grade females was significantly lower than that in fifth-grade females. The difference in SBP SD score between the lowest and highest quintiles was 0.813 in fifth-grade females and 0.216 in ninth-grade females. In fifth- and ninth-grade males, a significant relationship was found between height and both SBP and DBP.

Discussion
This is the first study to examine the growth-related disappearance of the relationship between height and BP levels from a large sample of the general population. In childhood, represented by fifth graders in the present study, there were significant positive relationships between height and BP levels in both males and females. In contrast, the relationship of height with SBP was significantly weaker in adolescent females (ninth graders) than in childhood, and there was no significant relationship between height and DBP. Thus, in females, the relationship between height and SBP was attenuated by development and the relationship between height and DBP disappeared.

A cohort study of African-American children reported that increases in BP were highly synchronized with peak height velocity (Tu et al., 2009). Height is positively related to pubertal stage (Tanner & Whitehouse, 1976) and pubertal status is also positively related to BP (Shankar et al., 2005; Tu et al., 2009). A longitudinal study in American children reported that increments of BP changes during puberty were larger than during pre-pubescence (Shankar et al., 2005). Therefore, the relationship between height and BP levels might be remarkable during periods of rapid growth and puberty. The relationship between increasing height and increasing BP in children may be explained by their requirement for maintaining homeostasis during somatic growth. Growth of the renal or cardiovascular systems is hypothesized to be necessary for maintaining homeostasis during somatic growth. Growth of the renal or cardiovascular systems is hypothesized to be necessary for maintaining homeostasis during somatic growth. Growth of the renal or cardiovascular systems is hypothesized to be necessary for maintaining homeostasis during somatic growth.

In the present study, relationships between height and BP levels disappeared in females but not in males. This sex difference might be explained by the difference in the average age at which height growth stops in males and females. Our results showed that height was significantly higher in females than males in the fifth grade and was significantly lower in females than males in the ninth grade (Table 1). Data from Japanese children showed that the mean ages (minimum–maximum) of peak height velocity are 12.80 (10.47–15.66) for males and 11.12 (8.09–13.58) for females (Kato et al., 1993). Other data from Japanese children also showed similar mean ages (13.5 for males and 11.5 for
females) (Suwa et al., 1992). Pubic hair appeared earlier in females than in males in a Japanese cross-sectional study (Kouda et al., 2012). A prospective study in the US reported that onset of pubertal growth occurs earlier in females than in males (Shankar et al., 2005). Thus, sex differences in the present study may be explained by sex differences in the age of growth ceasing.

The study has some potential limitations. The data are from only one area in Japan and might not be a representative sample of the Japanese population. However, the mean height and weight of the study population were consistent with those reported in the National Nutrition Survey in Japan (Matsushita et al., 2004). In addition, the participants’ ages were limited to 10–11 years old and 14–15 years old. Adolescents at 14–15 years of age might be too young to demonstrate the growth-related disappearance of the relationship, especially males, since their pubertal development is later than that of females. Thus, to demonstrate the growth-related disappearance of the association between height and BP in males, further studies using older individuals are needed.

### Conclusion

The present study showed growth-related disappearance of the childhood relationship between height and BP levels in a large sample of the Japanese general population. In females, a positive association between height and SBP in childhood was attenuated by development and the association between height and DBP disappeared.

### Acknowledgements

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### Declaration of interest

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

### References


### Table 2. Effect of growth on the relationship between height and BP levels.

<table>
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<tr>
<th></th>
<th>Systolic blood pressure</th>
<th>Diastolic blood pressure</th>
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<tbody>
<tr>
<td></td>
<td>Males</td>
<td>Females</td>
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<tr>
<td></td>
<td>Fifth grade</td>
<td>Ninth grade</td>
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<td></td>
<td>Females</td>
<td>Fifth grade</td>
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### Table 2: Effect of growth on the relationship between height and BP levels.

<table>
<thead>
<tr>
<th></th>
<th>BP SD score* (standardized distance from mean value)</th>
<th>Correlation between height and BP</th>
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<tr>
<td></td>
<td>Q1</td>
<td>Q2</td>
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<tr>
<td>Systolic blood pressure</td>
<td>Males</td>
<td></td>
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<tr>
<td>Fifth grade</td>
<td>−0.267</td>
<td>−0.192</td>
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<td>Ninth grade</td>
<td>−0.330</td>
<td>−0.066</td>
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<tr>
<td>Diastolic blood pressure</td>
<td>Males</td>
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</tr>
<tr>
<td>Fifth grade</td>
<td>−0.371</td>
<td>−0.203</td>
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<tr>
<td>Ninth grade</td>
<td>−0.123</td>
<td>−0.006</td>
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*BP SD score = (BP value – mean of BP value)/SD of BP value.

1p < 0.0001 compared with correlation coefficient of fifth graders.