Mother-offspring aggregation in home versus conventional blood pressure in the Tohoku Study of Child Development (TSCD)

Kei ASAYAMA^{1,2}, MD, PhD; Jan A. STAESSEN^{1,3}, MD, PhD; Katsuhisa HAYASHI⁴, MS; Miki HOSAKA², MS; Nozomi TATSUTA⁵, MS; Naoyuki KUROKAWA⁵, PhD; Michihiro SATOH², MS; Takanao HASHIMOTO⁶, PhD; Takuo HIROSE², PhD; Taku OBARA⁷, PhD; Hirohito METOKI⁷, MD, PhD; Ryusuke INOUE⁸, MD, PhD; Masahiro KIKUYA², MD, PhD; Takayoshi OHKUBO^{2,9}, MD, PhD; Kunihiko NAKAI^{5,7}, PhD; Yutaka IMAI², MD, PhD; Hiroshi SATOH⁵, MD, PhD

¹Studies Coordinating Centre, Division of Hypertension and Cardiovascular Rehabilitation, Dept. of Cardiovascular Diseases, University of Leuven, Leuven, Belgium; ²Dept. of Planning for Drug Development and Clinical Evaluation, Tohoku University Graduate School of Pharmaceutical Sciences, Sendai, Japan; ³Dept. of Epidemiology, Maastricht University, Maastricht, The Netherlands; ⁴Cancer Molecular Biology, Miyagi Cancer Centre, Natori, Japan; ⁵Dept. of Environmental Health Sciences, Tohoku University Graduate School of Medicine, Sendai, Japan; ⁶Dept. of Clinical Pharmacology and Therapeutics, Tohoku University Graduate School of Pharmaceutical Sciences Sendai, Japan; ⁷Dept. of Development and Environmental Medicine, Tohoku University Graduate School of Medicine, Sendai, Japan; ⁸Dept. of Medical Informatics, Tohoku University Graduate School of Medicine, Sendai, Japan; ⁹Dept. of Health Science, Shiga University of Medical Science, Otsu, Japan.

Objective Few studies described the home blood pressure (HBP) in young children. Using intrafamilial correlations of blood pressure as research focus, we assessed the feasibility of HBP monitoring in this age group.

Methods We enrolled 382 mothers (mean age 38.8 years) and singletons (7.0 years) in the Tohoku Study of Child Development. We measured their conventional blood pressure (CBP; single reading) at an examination centre. Participants monitored HBP in the morning. We used the OMRON HEM-7080IC for CBP and HBP measurement. In a separate group of 84 children (mean age 7.7 years), we compared blood pressure readings obtained by the OMRON monitor and the Dinamap Pro 100, a device approved by FDA for use in children. We used correlation coefficients as measure of intrafamilial aggregation, while accounting for the mothers' age, body mass index, heart rate and smoking and drinking habits and the children's age, height, and heart rate.

Results Mother-offspring correlations were closer ($P \leq 0.003$) for HBP than CBP for systolic pressure [0.28 ($P < 0.0001$) vs 0.06 ($P = 0.26$)] and diastolic pressure [0.28 ($P < 0.0001$) vs 0.02 ($P = 0.65$)]. The between-device differences (OMRON minus Dinamap) averaged 7.8 ± 6.0 mmHg systolic and 5.8 ± 5.5 mmHg diastolic.

Conclusions HBP monitoring is an easily applicable method to assess intrafamilial blood pressure aggregation in young children and outperforms CBP. Validation protocols for HBP devices in young children need revision, because the Korotkoff method is not practicable at this age and there is no agreed alternative reference method.

Keywords Home blood pressure – intrafamilial aggregation – Korotkoff method – self-measurement – TSCD – young children.

Address for correspondence:

Hiroshi Satoh, MD, PhD, Dept. of Environmental Health Sciences, Tohoku University Graduate School of Medicine, 2-1 Seiryō-cho, Aoba-ku, Sendai, 980-8575, Japan.
E-mail: h.satoh@nies.go.jp

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INTRODUCTION

In adults, self-measurement of blood pressure at home is widely used in clinical practice, because compared with conventional blood pressure measurement it has higher reproducibility and provides more accurate risk stratification based on a large consensus about

diagnostic thresholds¹⁻³. Measurement or self-measurement of blood pressure in children by means of semi-automatic or automatic devices is feasible. However, only few studies described blood pressure as measured by automated devices in young children⁴.

The Tohoku Study of Child Development (TSCD) is a cohort study on the potential effects of perinatal exposure to environmental pollutants on the neurobehavioural development of Japanese children^{5,6}. This study offered the opportunity to start a new line of longitudinal research into the blood pressure as measured by conventional and automated methods in children growing up from childhood to adolescence. In this first report, we assessed the feasibility of automated oscillometric blood pressure measurement in 7-year-old children. We also compared the intrafamilial aggregation of blood pressure as assessed by an oscillometric technique in an examination centre or by repeated measurements at home.

METHODS

Study population

The present study is nested within the longitudinal TSCD. Previous reports describe the study design in detail⁶ as well as eligibility criteria of participants at enrolment⁵. Briefly, mothers in the second trimester of pregnancy and living in Sendai city (from 2001 until 2003, $n = 599$) or in a geographically defined rural area of the Pacific coast (from 2003 until 2005, $n = 749$) were enrolled in TSCD. Mother-offspring pairs qualified for inclusion in TSCD if the following conditions were met: singleton pregnancy in nulliparous or multiparous women in good health having Japanese as native language and neonates born at term (36-42 weeks of gestation) with birth weight of more than 2400 g and without congenital anomalies or diseases. The study protocol was approved by the Ethics Committee of the Tohoku University Graduate School of Medicine. Mothers gave written informed consent.

Because the earthquake of 11 March 2011 disrupted data collection in the rural coastal area, the present analysis is confined to mothers recruited in Sendai city. Of the 599 mother-neonate pairs originally recruited, 53 were lost to follow-up and 546 participated in a follow-up examination in March 2008 – March 2011, when offspring were approximately 7 years old. Of the 546 mother-offspring pairs followed up, 454 participated in the study of the home blood pressure. We excluded 72 mother-offspring pairs from analysis, because either the conventional or home blood pressure was unavailable in mothers or offspring ($n = 20$),

because the home blood pressure had been measured for less than 3 days ($n = 33$), because mothers were taking antihypertensive medication during the survey ($n = 3$), or because not all required characteristics were available for analysis ($n = 16$). Thus, the number of mother-offspring pairs statistically analysed totalled 382.

Blood pressure measurements

Trained staff measured the conventional blood pressure (one reading) at the examination centre after mothers and offspring had rested for at least 2 minutes in the sitting position. The staff also instructed mothers and offspring how to measure blood pressure at home for two weeks according to the guidelines of the Japanese Society of Hypertension⁷. After having rested in the sitting position for 2 minutes or longer, study participants measured blood pressure at home holding the cuffed arm at the heart level, once in the morning within one hour of waking (after micturition and before breakfast) and once in the evening before going to sleep.

Mothers assisted their children in measuring their home blood pressure. The home blood pressure was the average of the readings obtained over a period of up to 2 weeks.

For blood pressure measurement at the examination centre and at home, we used the OMRON *HEM-7080IC* (Omron Healthcare Co., Ltd., Kyoto Japan) cuff-oscillometric device⁸. Standard and small cuffs had inflatable bladders of 22 × 12 cm and 16 × 9 cm, respectively, and were used in mothers and offspring depending on upper arm circumference (22-32 cm vs under 22 cm). The OMRON *HEM-7080IC* device is equivalent to the OMRON *HEM-705IT*. This device passed validation for use in adults⁹ and in children aged from 6 to 16 years¹⁰. However, to our knowledge, no specific validation studies of the OMRON *HEM-7080IC* in 7-year-old children are currently available. We therefore compared in a separate group ($n = 86$) of 7- to 8-year-old children the OMRON *HEM-7080IC* with the Dinamap Pro 100 (GE Healthcare, Chalfont St Giles, Buckinghamshire, UK), which is an oscillometric device approved by the Food and Drug Administration (FDA) (http://www.accessdata.fda.gov/cdrh_docs/pdf/k992638.pdf) to monitor the blood pressure in infants and children, and which is commonly used in Japanese hospitals. We applied the protocol of the Japan International Organization for Standardization (ISO) Working Group¹¹. The method consists of 4 comparisons between simultaneous readings obtained by the reference and tested device at opposite arms, switching sides each time with the order randomised.

Anthropometric measurements and other information

We obtained information on obstetrical data and lifestyle from hospital records and questionnaires administered to mothers. We measured the height and weight of the offspring at follow-up, using a KS-502Gp automatic analyser (Kansai Seiki Co., Ltd., Kusatsu, Japan) with the children wearing light indoor clothes and no shoes. Body mass index was weight in kilogram divided by height in meters squared.

Statistical methods

For statistical analysis, we used SAS software, version 9.2 (SAS Institute, Cary, NC). We represented the central tendency and spread of continuously distributed variables by the mean and standard deviation. Significance was a 2-sided *P*-value of 0.05 or less. In the study comparing the OMRON *HEM-7080IC* and the Dinamap Pro 100, we applied the Bland and Altman's method.

The current study only included singleton pregnancies and unique mother-offspring pairs. We therefore computed simple product-moment correlation coefficients to express the degree of concordance (positive correlations) or discordance (negative correlations) between mothers and offspring. These analyses were done first without adjustment and next using residuals, in which the contribution of confounders and covariables to the variance of the trait under study was removed. We applied multiple linear regression separately in mothers and offspring to compute the residuals. For the comparison of means and correlation coefficients, we

used the Student *t* test and Fisher *Z* transformation, respectively.

RESULTS

Characteristics of study participants

Gestational weeks at birth (2001-2003) averaged 39.5 ± 1.2 with no difference between 182 girls and 200 boys ($P=0.90$). Length (48.7 ± 1.8 vs 49.3 ± 1.7 cm) and weight (3013 ± 332 vs 3120 ± 343 gram) were significantly lower ($P \leq 0.003$) in female than male neonates.

The characteristics of mothers and offspring at follow-up (2008-2011) appear in table 1. The mothers' age averaged 38.8 years. Of 382 mothers, 11 (2.9%) had a history of hypertension, 100 (26.2%) reported regular alcohol intake, and 34 (8.9%) were smokers. The blood pressure of mothers averaged 109.4 mmHg systolic and 70.2 mmHg on conventional measurement and 109.2 mmHg and 68.0 mmHg on self-measurement in the morning at home [median number of readings 13; interquartile range (IQR), 12-14].

Girls and boys had similar age and anthropometric characteristics ($P \geq 0.43$). In offspring the median number of readings at home was 13 (IQR, 11-14). The systolic and diastolic blood pressures measured in the examination centre and the diastolic home blood pressure were similar ($P \geq 0.13$) in girls and boys, averaging 91.6 ± 9.3 mmHg, 55.5 ± 9.2 mmHg and 55.7 ± 5.8 mmHg, respectively. In girls compared with boys ($P \leq 0.002$), systolic home blood pressure was lower (92.6 vs 94.7 mm

Table 1 Characteristics of mothers and offspring

Variables	Mothers	Offspring		<i>P</i>
		Girls	Boys	
Number (n)	382	182	200	
Age (years)	38.8 ± 4.2	7.0 ± 0.2	7.0 ± 0.1	0.79
Height (cm)	158.2 ± 4.5	120.0 ± 4.6	120.2 ± 4.8	0.62
Weight (kg)	52.8 ± 7.3	22.8 ± 3.1	23.1 ± 3.0	0.43
Body mass index (kg/m ²)	21.1 ± 2.7	15.8 ± 1.5	15.9 ± 1.3	0.49
Conventional measurement				
Systolic (mmHg)	109.4 ± 12.3	91.1 ± 10.1	91.9 ± 8.4	0.40
Diastolic (mmHg)	70.2 ± 9.0	55.8 ± 9.3	55.3 ± 9.2	0.65
Heart rate (bpm)	67.8 ± 9.9	82.8 ± 10.2	78.0 ± 10.1	< 0.0001
Home measurement				
Systolic (mmHg)	109.2 ± 9.9	$92.6 \pm 7.1^*$	$94.7 \pm 6.1^\dagger$	0.002
Diastolic (mmHg)	$68.0 \pm 7.8^\dagger$	55.2 ± 5.9	56.1 ± 5.7	0.13
Heart rate (bpm)	68.5 ± 7.6	$86.8 \pm 7.0^\dagger$	$82.5 \pm 7.8^\dagger$	< 0.0001

Values are mean $\pm$ SD. *P* values are for the comparison between girls and boys. Significance of the difference between conventional and home measurement:

* $P < 0.05$, $^\dagger P < 0.0001$.

Hg), whereas the opposite was the case for heart rate as measured at the examination centre (82.8 vs 78.0 beats per minute) or at home (86.8 vs 82.5 beats per minute).

Mother-offspring correlations for blood pressure

Table 2 lists the mother-offspring correlations for the conventional and home blood pressures without adjustment and with stepwise adjustment. Adjusted estimates accounted for the mothers' age and body mass index

Fig. 1 Flow diagram of study participants. BP indicates blood pressure.

and the children's age and height. Fully adjusted estimates accounted for the same covariables plus smoking and drinking status in mothers and heart rate corresponding with the conventional or home blood pressure (and *vice versa*) in both mothers and offspring.

In general, unadjusted and adjusted mother-offspring correlations were similar (table 2). With full adjustments applied, the mother-offspring correlations in the conventional systolic and diastolic blood pressures were weak and non-significant ($P \geq 0.39$), whereas the correlation coefficient for the conventionally measured heart rate was 0.14 ($P=0.006$). The fully adjusted mother-offspring correlations for the measurements at home were 0.28 and 0.25 for systolic and diastolic blood pressure ($P < 0.0001$) and 0.17 for heart rate ($P=0.001$). Mother-offspring correlations in systolic pressure ($P \leq 0.003$) and diastolic pressure ($P \leq 0.002$), but not heart rate ($P \geq 0.69$) were significantly tighter on home than conventional measurement.

Figure 2 shows the mother-offspring correlations for the home measurements stratified by the sex of offspring. For diastolic blood pressure and heart rate, the mother-daughter correlations tended to be higher than the mother-son correlations, but none of the differences between mother-daughter and mother-son correlations reached significance ($P \geq 0.32$).

Mother-offspring correlations for anthropometric measurements

The mother-offspring correlations were 0.35 [95 % confidence interval (CI), 0.24–0.42; $P < 0.0001$] for height, 0.29 (CI, 0.19–0.37; $P < 0.0001$) for weight, and 0.34 (CI, 0.24–0.41; $P < 0.0001$) body mass index. Results were similar with adjustments applied for the mothers' age and the children's sex.

Table 2 Intrafamilial mother-offspring correlations

Variables	Unadjusted			Adjusted*			Fully adjusted†		
	r	(95 % CI)	P	r	(95 % CI)	P	r	(95 % CI)	P
Conventional measurement									
Systolic pressure	0.06	(−0.04, 0.16)	0.26	0.05	(−0.05, 0.15)	0.36	0.04	(−0.06, 0.14)	0.39
Diastolic pressure	0.02	(−0.08, 0.12)	0.65	0.03	(−0.07, 0.13)	0.57	0.03	(−0.07, 0.13)	0.58
Heart rate	0.17	(0.07, 0.27)	0.0007	0.13	(0.03, 0.23)	0.01	0.14	(0.04, 0.24)	0.006
Home measurement									
Systolic pressure	0.28	(0.17, 0.36)	<0.0001	0.29	(0.19, 0.37)	<0.0001	0.28	(0.17, 0.36)	<0.0001
Diastolic pressure	0.28	(0.18, 0.36)	<0.0001	0.28	(0.18, 0.37)	<0.0001	0.25	(0.15, 0.34)	<0.0001
Heart rate	0.20	(0.10, 0.29)	<0.0001	0.16	(0.06, 0.25)	0.002	0.17	(0.07, 0.26)	0.001

Values are correlation coefficients (95 % confidence interval). *Adjusted estimates accounted for the mothers' age and body mass index and the children's age and height. †Fully adjusted estimates accounted for the same covariables plus smoking and drinking status in mothers and heart rate corresponding with the conventional or home blood pressure (and *vice versa*) in both mothers and offspring.

Fig. 2 Plotted values are correlation coefficients in 182 mother-daughter and 200 mother-son pairs.

M1, M2, and M3 refer to unadjusted, adjusted and fully adjusted estimates, respectively. Adjusted estimates accounted for the mothers' age and body mass index and the children's age and height. Fully adjusted estimates accounted for the same covariables plus smoking and drinking status in mothers and heart rate corresponding with the conventional or home blood pressure (and *vice versa*) in both mothers and offspring. There were no significant differences between mother-daughter and mother-son correlations ($P \geq 0.32$).

Comparison of devices

Mean age of the 40 girls and 46 boys participating in the comparison between the Dinamap and the OMRON was 7.67 ± 0.29 (SD) years. The difference in the blood pressure readings (OMRON minus Dinamap) averaged 7.8 ± 6.0 mmHg systolic and 5.8 ± 5.5 mmHg diastolic. The Bland and Altman plots appear in figure 3.

DISCUSSION

The key finding of the current study was that the mother-offspring correlations in systolic and diastolic blood pressures, but not heart rate, were significantly higher on home than conventional measurement. The mother-offspring correlations in the conventional blood pressure did not reach statistical significance. In addition, the mother-daughter correlations in the diastolic home blood pressure tended to be slightly higher than the mother-son correlations.

Several previous reports described the familial aggregation of blood pressure¹²⁻¹⁵. However, to the best of our knowledge, no previous studies used automated blood pressure measurement. In a Belgian study published in 1985¹⁴, the parent-offspring correlations were significant

for systolic blood pressure in father-son ($r=0.33$) and mother-daughter ($r=0.24$) pairs, whereas this was not the case for the other parent-offspring correlations for systolic and diastolic pressure. In this Belgian study¹⁴, each participant was characterised by the mean of 10 blood pressure readings, 5 readings at each of 2 home visits 2 to 3 weeks apart. As described in detail elsewhere¹⁴, the observers recording the blood pressure at home were especially trained. Training required at least 4 training sessions and an additional test session. Blood pressure of all members of the same household was measured by the same team of observers, which necessitated adjustment of the intrafamilial correlations for observer bias. The similarity in the mother-offspring correlations in systolic blood pressure in our current study and the previous Belgian study (0.28 vs 0.24) shows that to assess the intrafamilial aggregation of blood pressure automated measurement at home is an easily applicable method, which is much less costly and labour intense than conventional measurement.

The Tecumseh Blood Pressure study compared estimates of blood pressure obtained in the clinic-office setting (average of 2 readings) with self-reported home blood pressure readings (average of 14 readings) taken over 1 week¹⁵. A trained technician instructed the

Fig. 3 Bland and Altman plots for the comparison between the OMRON HEM-7080IC and Dinamap Pro 100 devices in 86 7-8 year-old children. Mean differences between paired measurements ± 1.96 SD are represented by full and dotted lines, respectively.

participants in self-measurement of the home blood pressure by the Korotkoff technique. Among 380 siblings (average age, 31.4 years), correlation coefficients for the home readings were of the same magnitude as for office readings ($r=0.23$ vs 0.24). Thus, in contrast to our current findings, home monitoring of blood pressure by a manual method based on auscultation did not improve estimates of intrafamilial aggregation. Taken together, these observations support the use of automated techniques to assess heritability or intrafamilial aggregation of blood pressure.

Our current results demonstrated that intrafamilial correlation of diastolic home blood pressure as well as home heart rate between mothers and daughters tended to be tighter than that between mothers and sons. In 502 Tokelau Island children¹², aged 5-14 years, the mother's systolic pressure was the only predictor of the similarity of systolic blood pressure among 210 sibling pairs. Morrison *et al.* reported that significant mother-daughter correlations in obesity existed regardless of subjects' race¹⁶. Similarly, in the Belgian study¹⁴, the correlation coefficients for body weight and body mass index tended to be higher in mother-offspring than in father-offspring pairs, suggesting a closer maternal influence in setting the balance between calorie intake and expenditure in offspring. To what extent factors related to energy metabolism or body weight might influence the mother-offspring aggregation in blood pressure, remains to be elucidated.

The reproducibility of home blood pressure in children, like that in adults, is better than that of conventional blood pressure¹⁷. Our current results are in keeping with the Arsakeion study, in which the home blood pressure

of healthy young children aged 6-12 years was higher than the conventional blood pressure⁴. In the Arsakeion study, the difference between home and conventional blood pressure disappeared in older children and adolescents⁴. Physical activity in children is probably one of the major determinants of blood pressure. In addition, young children might be less likely to follow the instructions for home blood pressure monitoring, in particular observing a resting period before the actual measurement⁴. The observation that girls had lower blood pressure and faster heart rate than boys is in line with the observations in adults^{18,19} and represents a validation of our measurements in children. The mother-offspring correlations in the anthropometric measurements are also in line with those reported in the literature^{16,20}.

The present study identified an important issue in the validation of automated devices for home blood pressure measurement in young children. The OMRON 705IT passed validation for use in children¹⁰ according to the AAMI²¹ and ESH-IP²² criteria. Validation involved simultaneous blood pressure measurements taken by 2 observers (Y-tube connected mercury sphygmomanometers) 4 times in sequence with 3 measurements by the OMRON device. Systolic blood pressure was determined at the first appearance of Korotkoff sounds (phase I) and diastolic blood pressure at the disappearance of sounds (phase V). The study included 197 children. Mean age was 10.6 ± 2.4 (SD) years, but ranged from 6 to 16 years. Validation of devices across such a wide age range should probably not be extrapolated to children aged 7 years as enrolled in our current study. Furthermore, the mean height of our study participants was 120.1 ± 4.7 (SD) cm. Height in the published validation study¹⁰ ranged from

123 cm to 186 cm. A crucial issue is that validation requires phase V diastolic blood pressure to be recorded, which is often impossible in young children, because Korotkoff sounds are often audible until zero cuff pressure²³. In another validation study, children whose Korotkoff sounds were still audible at a cuff pressure below 10 mm Hg were excluded from analysis²⁴. Validating diastolic blood pressure against Korotkoff phase IV sounds is not an alternative, because it leads to inconsistencies between and within observers. Lip *et al.* reported that there was considerable variation on the choice of auscultatory end points for measuring diastolic blood pressure in clinical practice²⁵. The current protocols for validation make little provision to address or circumvent these problems.

For the reasons outlined above, we compared, in a separate study, the blood pressure values between OMRON HEM-7080IC and the Dinamap Pro 100, which is widely used in infants²⁶ and prepubertal children²⁷. The Dinamap is a stationary device approved by FDA. The computational algorithm embedded in the Dinamap was tested against the intra-arterial blood pressure²⁸. The bias between the 2 devices averaged 7.8 mm Hg systolic and 5.8 mm Hg diastolic. However, the difference between the 2 devices was not dependent on level, and it had probably little influence on the estimates of the mother-offspring correlations.

The present study has to be interpreted within the context of its limitations. First, we included only 7-year-old children in our study. Second, we enrolled only one child per family. We did not assess sib-sib or father-offspring correlations. Third, we obtained only a single reading of the conventional blood pressure in each participant. Notwithstanding these limitations, our study proved that home monitoring of blood pressure in young children is feasible. Approximately 20% of children diagnosed as hypertensive by conventional blood pressure measurement at the age of junior high school remain hypertensive 20 years later²⁹. We propose that home blood pressure monitoring should become part of the

diagnostic work-up and management of children suspected to be hypertensive.

In conclusion, home monitoring of blood pressure is an easily applicable method to assess heritability and intrafamilial aggregation of blood pressure and outperforms conventional blood pressure in this regard. The intrafamilial correlation of blood pressure might be higher in mother-daughter than mother-son pairs, although sufficiently powered studies are necessary to consolidate this observation. Current protocols for the validation of devices for home monitoring of blood pressure in young children need revision.

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REFERENCES

- Ohkubo T, Imai Y, Tsuji I, Nagai K, Kato J, Kikuchi N, Nishiyama A, Aihara A, Sekino M, Kikuya M, Ito S, Satoh H, Hisamichi S. Home blood pressure measurement has a stronger predictive power for mortality than does screening blood pressure measurement: A population-based observation in Ohasama, Japan. *J Hypertens* 1998; **16**: 971-5.
- Asayama K, Ohkubo T, Kikuya M, Metoki H, Hoshi H, Hashimoto J, Totsune K, Satoh H, Imai Y. Prediction of stroke by self-measurement of blood pressure at home versus casual screening blood pressure measurement in relation to the Joint National Committee 7 classification: the Ohasama study. *Stroke* 2004; **35**: 2356-61.
- Asayama K, Ohkubo T, Kikuya M, Metoki H, Obara T, Hoshi H, Hashimoto J, Totsune K, Satoh H, Imai Y. Use of 2003 European Society of Hypertension-European Society of Cardiology guidelines for predicting stroke using self-measured blood pressure at home: the Ohasama study. *Eur Heart J* 2005; **26**: 2026-31.
- Stergiou GS, Rarra VC, Yiannes NG. Changing relationship between home and office blood pressure with increasing age in children: the Arsakeion School study. *Am J Hypertens* 2008; **21**: 41-6.
- Suzuki K, Nakai K, Sugawara T, Nakamura T, Ohba T, Shimada M, Hosokawa T, Okamura K, Sakai T, Kurokawa N, Murata K, Satoh C, Satoh H. Neurobehavioral effects of prenatal exposure to methylmercury and PCBs, and seafood intake: neonatal behavioral assessment scale results of Tohoku study of

- child development. *Environ Res* 2010; **110**: 699-704.
6. Nakai K, Suzuki K, Oka T, Murata K, Sakamoto M, Okamura K, Hosokawa T, Sakai T, Nakamura T, Saito Y, Kurokawa N, Kameo S, Satoh H. The Tohoku Study of Child Development: A cohort study of effects of perinatal exposures to methylmercury and environmentally persistent organic pollutants on neurobehavioral development in Japanese children. *Tohoku J Exp Med* 2004; **202**: 227-37.
 7. Ogiwara T, Kikuchi K, Matsuoka H, Fujita T, Higaki J, Horiuchi M, Imai Y, Imaizumi T, Ito S, Iwao H, Kario K, Kawano Y, Kim-Mitsuyama S, Kimura G, Matsubara H, Matsuura H, Naruse M, Saito I, Shimada K, Shimamoto K, Suzuki H, Takishita S, Tanahashi N, Tsuchihashi T, Uchiyama M, Ueda S, Ueshima H, Umemura S, Ishimitsu T, Rakugi H. The Japanese Society of Hypertension Guidelines for the Management of Hypertension (JSH 2009). *Hypertens Res* 2009; **32**: 3-107.
 8. Coleman A, Steel S, Freeman P, de Greeff A, Shennan A. Validation of the Omron M7 (HEM-780-E) oscillometric blood pressure monitoring device according to the British Hypertension Society protocol. *Blood Press Monit* 2008; **13**: 49-54.
 9. El Assaad MA, Topouchian JA, Asmar RG. Evaluation of two devices for self-measurement of blood pressure according to the international protocol: the Omron m5-I and the Omron 705IT. *Blood Press Monit* 2003; **8**: 127-33.
 10. Stergiou GS, Yiannes NG, Rarra VC. Validation of the Omron 705 IT oscillometric device for home blood pressure measurement in children and adolescents: the Arsakion School Study. *Blood Press Monit* 2006; **11**: 229-34.
 11. Shirasaki O, Asou Y, Takahashi Y. New clinical validation method for automated sphygmomanometer: a proposal by Japan ISO-WG for sphygmomanometer standard. *Blood Press Monit* 2007; **12**: 381-3.
 12. Beaglehole R, Salmond CE, Prior IA. A family study of blood pressure in Polynesians. *Int J Epidemiol* 1975; **4**: 217-20.
 13. Biron P, Mongeau JG, Bertrand D. Familial aggregation of blood pressure in 558 adopted children. *Can Med Assoc J* 1976; **115**: 773-4.
 14. Staessen J, Bulpitt CJ, Fagard R, Joossens JV, Lijnen P, Amery A. Familial aggregation of blood pressure, anthropometric characteristics and urinary excretion of sodium and potassium--a population study in two Belgian towns. *J Chronic Dis* 1985; **38**: 397-407.
 15. Jamerson KA, Schork N, Julius S. Effect of home blood pressure and gender on estimates of the familial aggregation of blood pressure. The Tecumseh Blood Pressure Study. *Hypertension* 1992; **20**: 314-8.
 16. Morrison JA, Payne G, Barton BA, Khoury PR, Crawford P. Mother-daughter correlations of obesity and cardiovascular disease risk factors in black and white households: the NHLBI Growth and Health Study. *Am J Public Health* 1994; **84**: 1761-7.
 17. Stergiou GS, Nasothimiou EG, Giovvas PP, Rarra VC. Long-term reproducibility of home vs. office blood pressure in children and adolescents: the Arsakeion school study. *Hypertens Res* 2009; **32**: 311-5.
 18. Ueshima H. Explanation for the Japanese paradox: prevention of increase in coronary heart disease and reduction in stroke. *J Atheroscler Thromb* 2007; **14**: 278-86.
 19. Morcet JF, Safar M, Thomas F, Guize L, Benetos A. Associations between heart rate and other risk factors in a large French population. *J Hypertens* 1999; **17**: 1671-6.
 20. Fuentes RM, Nottola IL, Shemeikka S, Tuomilehto J, Nissinen A. Familial aggregation of body mass index: a population-based family study in eastern Finland. *Horm Metab Res* 2002; **34**: 406-10.
 21. White WB. National standard for measurement of resting and ambulatory blood pressures with automated sphygmomanometers. *Hypertension* 1993; **21**: 504-9.
 22. O'Brien E, Pickering T, Asmar R, Myers M, Parati G, Staessen J, Mengden T, Imai Y, Waebler B, Palatini P, Gerin W; Working Group on Blood Pressure Monitoring of the European Society of Hypertension. Working Group on Blood Pressure Monitoring of the European Society of Hypertension International Protocol for validation of blood pressure measuring devices in adults. *Blood Press Monit* 2002; **7**: 3-17.
 23. Hammond IW, Urbina EM, Wattigney WA, Bao W, Steinmann WC, Berenson GS. Comparison of fourth and fifth Korotkoff diastolic blood pressures in 5 to 30 year old individuals. The Bogalusa Heart Study. *Am J Hypertens* 1995; **8**: 1083-9.
 24. Wong SN, Tz Sung RY, Leung LC. Validation of three oscillometric blood pressure devices against auscultatory mercury sphygmomanometer in children. *Blood Press Monit* 2006; **11**: 281-91.
 25. Lip GY, Beevers M, Beevers DG, Dillon MJ. The measurement of blood pressure and the detection of hypertension in children and adolescents. *J Hum Hypertens* 2001; **15**: 419-23.
 26. Lurbe E, Garcia-Vicent C, Torro I, Fayos JL, Aguilar F, de Llano JM, Fuertes G, Redon J. First-year blood pressure increase steepest in low birthweight newborns. *J Hypertens* 2007; **25**: 81-6.
 27. Jin RZ, Donaghue KC, Fairchild J, Chan A, Silink M. Comparison of Dinamap 8100 with sphygmomanometer blood pressure measurement in a prepubertal diabetes cohort. *J Paediatr Child Health* 2001; **37**: 545-9.
 28. Ni H, Wu C, Prineas R, Shea S, Liu K, Kronmal R, Bild D. Comparison of Dinamap PRO-100 and mercury sphygmomanometer blood pressure measurements in a population-based study. *Am J Hypertens* 2006; **19**: 353-60.
 29. Uchiyama M. Risk factors for the development of essential hypertension: Long-term follow-up study in junior high school students in Niigata, Japan. *J Hum Hypertens* 1994; **8**: 323-5.