Factors Affecting Tracking of Blood Pressure from Childhood to Adulthood: The Childhood Determinants of Adult Health Study

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Objectives To examine the modifiable factors that alter the trajectory of blood pressure (BP) from childhood to adulthood.

Study design This study investigated the BP of 798 participants (53% female) from the Childhood Determinants of Adult Health Study who had BP measured when aged 9, 12, or 15 years, and at follow-up 20 years later. BP was classified as normal or elevated (prehypertensive or hypertensive) in childhood and adulthood. BP trajectory groups (persistently normal, resolution, incident elevated, persistently elevated) were established according to these classifications. Potentially modifiable factors measured at both examinations included body mass index, fruit and vegetable intake, physical activity, cardiorespiratory fitness, alcohol consumption, smoking, and socioeconomic status.

Results Spearman correlation coefficients for BP tracking from childhood to adulthood were 0.31 ($P < .001$) for systolic BP and 0.16 ($P < .001$) for diastolic BP. Children with elevated BP had a 35% increased risk of elevated BP in adulthood compared with those with normal BP (relative risk 1.35, 95% CI 1.18-1.55, $P < .001$). Relative to those with persistently elevated BP, participants in the resolution group significantly decreased their body mass index z-score, decreased their alcohol consumption z-score, and increased their vegetable consumption z-score between childhood and adulthood. The proportion of participants with upwardly mobile socioeconomic status was significantly higher in the resolution group (41.2%) compared with the persistently elevated group (27.5%).

Conclusions Resolution of elevated BP in the transition from childhood to adulthood appeared to be partially determined by modifiable factors associated with a healthy lifestyle. *(J Pediatr 2015;167:1422-28)*.

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Elevated blood pressure (BP) is known to be a leading contributor to cardiovascular disease and continues to be a major concern despite recent developments in treatment and prevention.[1] Moreover, there is evidence to suggest the incidence of elevated BP in children and adolescents is increasing and is tied to the childhood obesity epidemic.[2]

In the past, the presence of elevated BP in childhood was considered to be relatively benign unless secondary to a diagnosis such as renovascular disease.[3] However, data now demonstrate that higher levels of BP in childhood are associated with concurrent and future pathologic changes, including early atherosclerosis and changes in left ventricular morphology.[4,5] In a previous international collaboration, we found that children with elevated BP are not destined to an increased future atherosclerotic burden if they are able to normalize their BP in the time between childhood and adulthood.[6] This reversal has not been demonstrated to the same extent in those who normalize their BP during adulthood and, thus, confirms the importance of identifying elevated BP in childhood.[7] Although BP levels track from childhood to adulthood,[8,9] it is possible that intervention in childhood might prevent progression to adult prehypertension and hypertension.

Despite these findings, few studies have examined the behavioral factors that affect tracking from childhood to adulthood,[3] especially those factors that may lead to the resolution of elevated child BP by adulthood. Such studies might provide useful information for prevention strategies in childhood with the aim of reducing the proportion of children who maintain elevated BP into adulthood. Therefore, the aims of this study were to investigate the tracking

BMI	Body mass index
BP	Blood pressure
CDAH	Childhood Determinants of Adult Health
DBP	Diastolic BP
RR	Relative risk
SBP	Systolic BP
SES	Socioeconomic status

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of BP from childhood to adulthood and investigate the potentially modifiable factors that affect tracking from childhood to adulthood.

Methods

The Childhood Determinants of Adult Health (CDAH) Study is a longitudinal investigation of the child factors that associate with adult cardiovascular disease. The baseline cohort consisted of 8498 participants aged 7-15 years who participated in the 1985 Australian Schools Health and Fitness Survey. The CDAH first follow-up was conducted 20 years later in 2004-2006 with 2410 (28%) of the original Australian Schools Health and Fitness Survey participants returning for clinical assessments, then aged 26-36 years. Owing to time and economic constraints, BP measures in childhood were only performed among those aged 9, 12, and 15 years. Of the 2678 participants who had BP measured in childhood, 798 participated at follow-up and were included in this investigation (**Figure 1**; available at www.jpeds.com).

At baseline, consent was obtained from both parent and child prior to inclusion in the study. At follow-up, written informed consent was obtained from the participant. The State Directors General of Education approved the baseline study and the Southern Tasmania Health and Medical Human Research Ethics Committee approved the follow-up study.

At both time-points, BP measurements were taken while seated, after resting quietly for 5 minutes, and cuff-size (small, medium, large) was determined using arm circumference. Korotkoff sound I and Korotkoff sound V were interpreted as systolic BP (SBP) and diastolic BP (DBP), respectively. BP measurements at baseline were obtained from the left brachial artery using a standard mercury sphygmomanometer. The mean of 2 readings was recorded. Follow-up BP measurements were taken from the right brachial artery using the Omron HEM907 digital automatic monitor (Omron Healthcare Co, Ltd, Kyoto, Japan). The mean of 3 readings with a 1-minute interval between each was recorded.

In childhood, BP levels were defined as normotensive, prehypertensive, or hypertensive according to age-, sex-, and height-specific cut-offs defined by the National High Blood Pressure Education Program.[10] In adulthood, BP levels were classified as normotensive, prehypertensive (SBP ≥120 mm Hg or DBP ≥80 mm Hg), or hypertensive (SBP ≥140 mm Hg or DBP ≥90 mm Hg or taking antihypertensive medication) by the Eighth Joint National Committee guidelines.[11] Participants that met the prehypertension or hypertension cut-offs were classified as having elevated BP.

At baseline and follow-up, body mass index (BMI) was calculated as: BMI = weight (kg)/height $(m)^2$. Waist circumference was measured to the nearest 0.1 cm at the level of the umbilicus at baseline, and at follow-up at the narrowest point between the lower costal border and iliac crest. Skin fold thickness of tricep, bicep, subscapular, and suprailiac skin folds were measured on the right side of the body to the nearest 0.1 mm. The sum of all skin fold measurements was used in the analyses.

Dietary values were recorded at baseline in the 12- and 15-year age groups using a 24-hour diet record. Servings of fruit and vegetable were recorded in grams, and daily servings were calculated.[12] At follow-up, participants completed 2 short questionnaires on usual daily servings of fruits and vegetables. Examples of serving sizes were given.[13]

Cardiorespiratory fitness at baseline and follow-up was approximated as physical work capacity at 170 bpm heart rate using a bicycle ergometer.[14] Because this test is a function of lean body mass, we regressed the absolute physical work capacity at 170 bpm heart rate value on lean body mass and used the resultant residuals as an index of cardiorespiratory fitness that is not correlated with lean body mass. Methods used to calculate lean body mass are described in detail elsewhere.[14]

Alcohol consumption was estimated using the number of times alcohol was consumed per week in childhood and the number of standard drinks (10 g alcohol) consumed per week in adulthood. Participants were classified as smokers at baseline if they reported smoking at least once per week. At follow-up, participants were classified as current smoker, exsmoker, or nonsmoker. Participants retrospectively reported their mother's and father's smoking status. Exposure to parental smoking was considered to be positive if one or both parents were smokers. In females, information on hormonal contraceptive use (including combined and progesterone only contraceptives and intrauterine progesterone releasing devices) was collected at follow-up. At follow-up, participants indicated their highest level of education and their parent's education when they were aged 12 years. Education was categorized as low (secondary or primary education), medium (trade/vocational), or high (tertiary education). These variables were used as indicators of individual-level socioeconomic status (SES) at baseline (parent's education) and follow-up (own education).

Statistical Analyses

Baseline characteristics are reported as mean (SD) or median (25th-75th percentile) for continuous data or proportions for categorical data. Baseline characteristics of participants and nonparticipants were compared using logistic regression.

Tracking was estimated as Spearman rank-order correlation coefficients, and also as the proportion of participants who remained in elevated BP categories from childhood to adulthood. Partial Spearman correlations were calculated within each sex adjusted for age and across the entire analysis sample adjusted for age and sex. Individuals taking antihypertensive medication (n = 8) were excluded from correlation analysis but were categorized as hypertensive in all subsequent analyses.[15]