

Ambulatory blood pressure in schoolchildren

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Abstract

Objective—To define the range and variability of ambulatory blood pressure in normal schoolchildren.

Design—Prospective study.

Methods—Resting blood pressure of 1121 schoolchildren from Newcastle upon Tyne was recorded. An ambulatory blood pressure device, which uses both auscultatory (Korotkoff) and oscillometric methods of blood pressure measurement, was then put in place for 24 hours.

Results—The day was divided into three time periods: school, home, and night time. Normal centiles for blood pressure for each of these time periods were obtained and many daytime readings were outside reported normal resting levels. The normal variation of blood pressure was quantified by comparing each of these time periods with the resting readings. Resting systolic blood pressure did not predict 24 hour mean systolic blood pressure.

Conclusions—The availability of normal ambulatory blood pressure data on the level and variation of blood pressure in children may facilitate the early identification of hypertension in this age group.

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Keywords: ambulatory blood pressure; Korotkoff; blood pressure variation

The diagnosis of hypertension in adults is made when blood pressure exceeds a defined level. The diagnosis of hypertension in children is more difficult and the use of absolute values is inappropriate. Hypertension in children is diagnosed when resting blood pressure consistently exceeds the 95th centile.¹ Experience in adults has shown ambulatory blood pressure is a better predictor of end organ damage than casual readings.² It is possible that ambulatory blood pressure in children could provide the basis for easier and earlier recognition of abnormal blood pressure behaviour, but interpretation depends on knowledge of normal ranges. In this study we aimed to define the range and variability of ambulatory blood pressure in normal school children.

Methods

POPULATION STUDIED

Twenty six of the 28 schools approached in Newcastle upon Tyne agreed to participate in the study. Seventeen were primary schools and 11 were secondary schools. Because it was envisaged that the study would cause some disruption to the running of the school, each was asked to participate for no more than a few

weeks. Certain age groups were targeted within each school and a doctor (JOS) visited the chosen class to explain the study to the children. The participation rate of the target years varied from 7-75%.

AMBULATORY BLOOD PRESSURE MONITORING DEVICE

The ambulatory blood pressure monitoring device used was the TM 2421 (A & D, Japan), weighing 390 g. In a previous study its predecessor, the TM 2420 model, was found to be acceptable to children over the age of 6 years.³ Each inflation gives both an oscillometric and a Korotkoff reading. Arm measurements were taken to ensure that the bladder length was at least 80% of the arm circumference and the bladder width about 40% of the arm circumference. A Doppler probe was used to aid optimal placement of the lower microphone. The microphones were kept in place using rings with double sided adhesive.

In a validation study done when the device was being put on,⁴ the Korotkoff systolic and diastolic (phase V) readings received satisfactory British Hypertension Society grades. Studies in adults have found the oscillometric method used by this device to be accurate; however, we have excluded the oscillometric readings because of the poor British Hypertension Society grades obtained using this method in our study in children.⁴

PROTOCOL

Seven children were studied each day and the devices were placed between 0900 and 1030. The children were allowed breakfast and sat quietly for at least 10 minutes before the resting readings. The left arm was used in all children as this is how the cuffs were designed. The recorder measured blood pressure every 30 minutes during the day and every hour between 2200 and 0700. Children were asked to keep their arm still during each inflation and received a 10 second warning from the device before each measurement. They were asked to avoid activities that might displace the microphone but otherwise to lead as normal a day as possible.

STATISTICS AND DATA ANALYSIS

The data from each monitor were downloaded the following morning to a laptop computer with software that was specifically designed by one of the research team (GD). All readings were accepted unless: systolic blood pressure was ≥ 200 or ≤ 50 mm Hg; diastolic blood pressure was ≥ 100 or ≤ 30 mm Hg; and heart rate was ≥ 200 or ≤ 30 beats per minute. If more than 25% of any individual recordings were errors then that individual was excluded.

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Table 1 Age and sex distribution of the children studied

Age (years)	Male	Female	Total
6	1	1	2
7	41	38	79
8	70	88	158
9	46	75	211
10	54	77	131
11	39	57	96
12	55	56	111
13	59	46	105
14	62	83	145
15	25	57	82
16	0	4	4

A two level variance component analysis was carried out using a macro in the statistical package GLIM. This analysis supported the hypothesis of there being four relatively homogenous time periods: resting, school, home, and sleep. The statistical package S-Plus was used to extract summary statistics such as centiles and means.

ETHICAL APPROVAL

Approval to place ambulatory blood pressure monitors on over 1000 school children in Newcastle was approved by the joint ethics committee of Newcastle and North Tyneside health authority. Signed consent was obtained from the parent/guardian.

Results

Of the 1129 children recruited, five children fainted during the validation procedure and did not wear the monitor. Three of the 1124 who wore the monitor were excluded because not enough valid systolic readings were obtained. The total number of readings in 1121 children was 45 822, giving an average per child of 41 readings. The age and sex distribution is given in table 1.

NORMAL RESTING BLOOD PRESSURE

The readings taken by the monitor during validation (which was after at least 10 minutes rest) are called "resting" readings and there was an average of four readings per child (fig 1). The median for each height range was plotted and joined by straight lines to aid comparison with the normal sitting "casual" blood pressure from data pooled from six European studies.⁵ The lower readings in our study probably reflect the fact that the children sat quietly for at least 10 minutes before measurement. It may be surprising that blood pressure does not seem to rise consistently with height. This is because smaller cuffs give a higher reading of systolic pressure than a larger cuff, and a slight "step" in recorded blood pressure may be seen when cuff size changes. The change in cuff in our study tended to occur between ages 10 and 12 years, accounting for the slight dip in fig 1. This problem of blood pressure measurement in childhood epidemiological studies has been highlighted by Gillman and Cook.⁶

NORMAL CENTILES FOR THE 24 HOUR DAY

The 24 hour day was divided into three main time periods for the purpose of analysis. The mean of all readings for each child within each period was used for analysis. School readings were the non-validation readings between 0900 and 1600 (inclusive), home readings between 1630 and 2100, and overnight readings from 0000 to 0600. The median (and 95th centile) for systolic and diastolic pressure for the different heights, measured using the Korotkoff method, are shown in fig 2. For graphical presentation the heights were put into 10 cm groups so that 120 cm represents children in the height range 115–124.9 cm, and so on. The rise and fall in blood pressure seems to mirror the change in heart rate, suggesting a strong autonomic influence on blood pressure. The

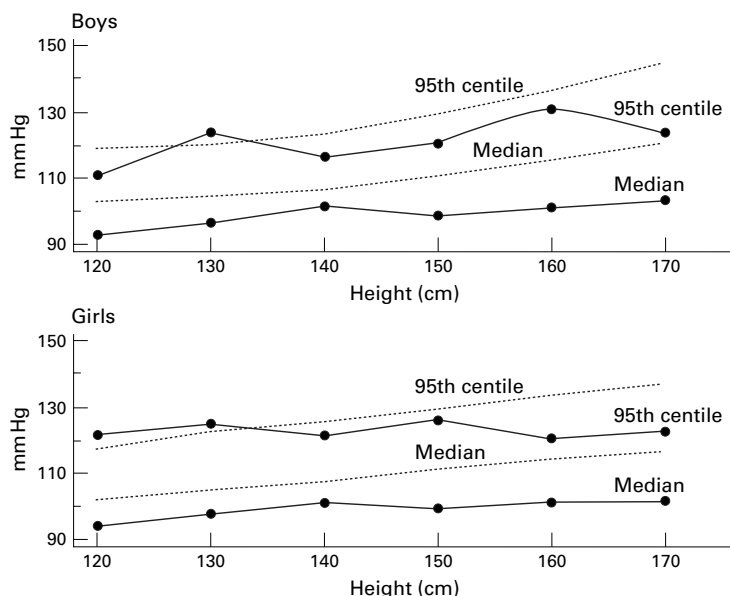


Figure 1 Relation between resting blood pressure and height. Shown are the median (and 95th centile) of resting systolic blood pressure for boys and girls of different height (solid lines). Also included (dotted lines) are the median (and 95th centile) of casual systolic blood pressure as reported from six European studies.⁵

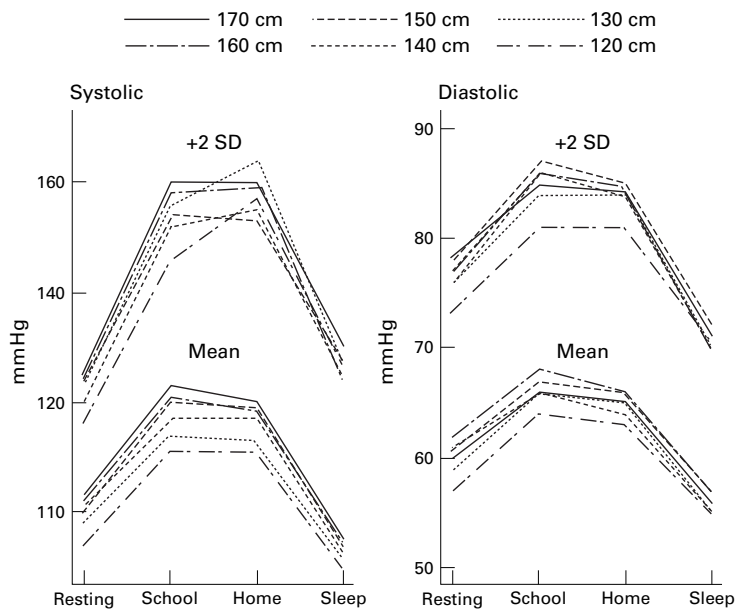


Figure 2 Change in systolic and diastolic blood pressure during various time periods for children of different height. Shown are the median (and 95th centile) of systolic and diastolic blood pressure (measured using the Korotkoff method) when resting, when at school, while at home, and at night time.

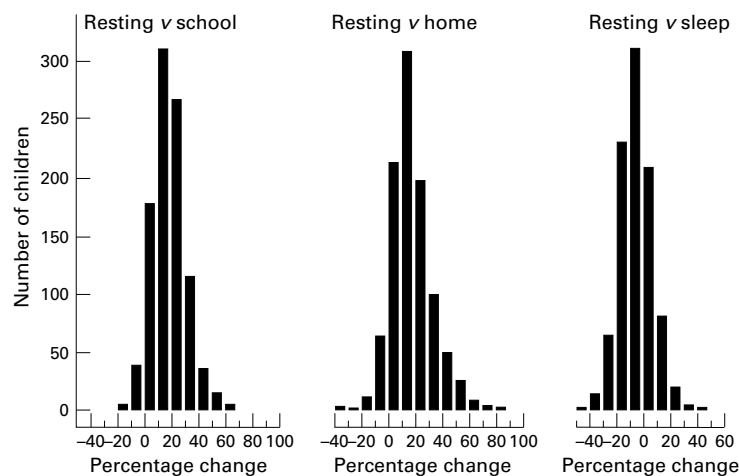


Figure 3 Percentage change from resting mean systolic blood pressure to mean systolic blood pressure at school, at home, and at night time. All children are included.

Table 2 Correlation of resting blood pressure within individuals to their 24 hour mean blood pressure at school, home, and night time

	24 hour	School	Home	Night time
Systolic	0.46	0.48	0.28	0.26
Diastolic	0.49	0.49	0.34	0.22

data obtained using the oscillometric method were similar to those obtained using the Korotkoff method if the resting readings were excluded, but they are not reproduced here because of the poor static validation of that method.⁴

WHAT IS THE NORMAL VARIATION OF BLOOD PRESSURE BETWEEN REST, SCHOOL, HOME, AND SLEEP?

The mean resting blood pressure measured by the monitor was taken as the baseline and the change from this during the school day, home, and at night time is presented in fig 3. The median change is a 10–20% increase in systolic blood pressure during the school day. As expected there was a fall in blood pressure at night, but the changes followed an approximately normal distribution with a small number of children increasing their blood pressure at night.

DOES RESTING BLOOD PRESSURE PREDICT 24 HOUR BLOOD PRESSURE?

The correlation between resting readings in individuals and those obtained at other times is presented in table 2. Resting systolic readings are poorly predictive of 24 hour mean systolic blood pressure and the correlation was even weaker for readings taken at home and while asleep.

Discussion

The lack of outcome data for blood pressure in children means that the diagnosis of hypertension in childhood is based upon centile rank. The variability observed has led to the recommendation that a diagnosis of hypertension should not be made unless the resting blood pressure level exceeds the 95th centile

for age.¹ This guideline has proved useful in clinical practice but ignores the changes that occur in blood pressure over 24 hours. It is possible that in trying to identify children with hypertension we should not only concentrate on resting readings but also on the variation that occurs during normal activities. In this study resting blood pressure was taken as the baseline and the variation during different time periods was examined.

We found that systolic blood pressure in normal children has a wide range, with the 95th centile approximately 130 mm Hg at rest, 160 mm Hg during the school day, and 130 mm Hg at night. Many children had daytime readings above the reported normal range for casual blood pressure.^{1,5} This emphasises a potential weakness in basing a diagnosis of hypertension on resting or casual readings as blood pressure varies throughout the day. The value of resting readings is further weakened by the poor correlation in individual subjects between resting blood pressure and blood pressure at other times of the day. In studies of adults 24 hour blood pressure recordings are more predictive of end organ damage than casual readings.^{2,7} It has been suggested that in adults the variation of blood pressure in an individual is important.^{8–10} Some authors have highlighted the importance of “hyporeactive” individuals¹¹ and “night dippers”.¹² It is apparent from our data that blood pressure variation follows a near normal distribution and the idea that it is abnormal for children to have no change or an increase in blood pressure at night is incorrect. Our study is unique in quantifying these changes in blood pressure in comparison with the resting readings.

There are many methodological problems involved in ambulatory blood pressure measurement, and even though validation studies have been carried out under static conditions the reliability of the ambulatory readings remains uncertain. Validation of the ambulatory readings would require simultaneous intra-arterial monitoring and such a study is unlikely to be carried out in children. Of the two main types of device in use the Korotkoff method should simulate a clinical reading with a sphygmomanometer, but is prone to microphone errors when used in an ambulatory setting. The oscillometric device is generally more robust and is less prone to the production of errors. However, we found the Korotkoff method much more accurate than the oscillometric one under static conditions,⁴ and for this reason only the Korotkoff results from our study are reported. The fact that there are clinical difficulties with the measurement of diastolic pressure in some children makes it likely that automatic devices will have similar problems. Furthermore, the debate as to whether phase IV or V should be used⁶ means that is difficult to validate clinically the diastolic readings provided by these devices.

The potential inaccuracies inherent in ambulatory measurement suggest that when defining a normal range a single type of device should be used. Studies reporting normal data but combining results from oscillometric and

Korotkoff devices are difficult to interpret.¹³ In order to quantify the variation in blood pressure one could directly compare daytime and night time mean blood pressures,¹⁴ but comparison of blood pressure during various time periods with resting readings as measured by the device is more meaningful.

Hypertension is uncommon in children but is a major problem for some, including those who have undergone heart transplantation, kidney transplantation, repair of coarctation of the aorta, and children with renal impairment. With the normal data on ambulatory pressure provided here it may be easier to recognise abnormal blood pressure in these children, even though their blood pressure at rest may not consistently exceed the 95th centile. This merits further investigation as the benefit of 24 hour blood pressure recordings over resting readings in adult studies cannot be automatically extrapolated to children.

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