Blood pressure centiles for Great Britain

Lisa V Jackson, Nandu K S Thalange, Tim J Cole

Objective: To produce representative cross-sectional blood pressure reference centiles for children and young people living in Great Britain.


Methods: Blood pressure was measured using the Dinamap 8100 with the same protocol throughout. Weight and height were also measured. Data for 11 364 males and 11 537 females aged 4–23 years were included in the analysis, after excluding 0.3% missing or outlying data. Centiles were derived for systolic, diastolic, mean arterial and pulse pressure using the latent moderated structural (LMS) equations method.

Results: Blood pressure in the two sexes was similar in childhood, rising progressively with age and more rapidly during puberty. Systolic pressure rose faster and was appreciably higher in adult men than in adult women. After adjustment for age, blood pressure was related more to weight than height, the effect being stronger for systolic blood pressure. Pulse pressure peaked at 18 years in males and 16 years in females.

Conclusions: These centiles increase our knowledge of blood pressure norms in contemporary British children and young people. High blood pressure for age should be defined as blood pressure above the 98th centile, and high-normal blood pressure for age as blood pressure between the 91st and 98th centiles. The centiles identify children and young people with increased blood pressure, and will be of benefit to both clinical practice and research.

METHODS

Blood pressure data from seven national health and social surveys carried out between 1995 and 1998 were obtained from the UK Data Archive (http://www.data-archive.ac.uk/)(table 1). The data were originally collected on behalf of the Departments of Health and the Ministry of Agriculture Fisheries and Food, by the Joint Health Surveys Unit of Social and Community Planning Research and University College London, London, UK and the Social Survey Division of the Office for National Statistics and Medical Research Council, Human Nutrition Research, Cambridge, UK.

The survey samples were obtained by stratified multistage sampling techniques to ensure that there was a proportional representation of the population at large by sex, age, geographical region and social class. In brief, the demographic characteristics of a geographical area are known from census and other data. Using this information, a representative sample of individuals from the target age groups for each survey was obtained. Households in geographical areas selected by postcode were contacted and asked to fill in a questionnaire to identify eligible young people. A subset of this initial sample was then contacted by trained interviewers. The demographic characteristics of those agreeing to take part were determined and further targeted sampling undertaken to ensure the study sample remained representative. More information may be found in the published surveys.

Ethical approval was obtained from all areas in which the surveys were carried out. Participation was subject to informed consent. Data for the present analysis were excluded for participants who had eaten, consumed alcohol or smoked in the 30 min before being measured, and for those on antihypertensive drugs.

All seven surveys used the Dinamap 8100 (Critikon, Tampa, Florida, USA) with the same protocol to measure blood pressure. The use of an automatic oscillometric method was necessary for practicality, accuracy and reproducibility.

Briefly, the blood pressure cuff was applied to the right arm. The lower margin of the cuff was placed about 2 cm above the elbow crease, with the arrow marked on the cuff placed over the brachial artery. The cuff was wrapped to a tightness allowing two fingers to be inserted under the top and bottom of the cuff. Four cuff sizes were available, the appropriate cuff size being determined by measurement of the mid-upper arm circumference (child cuff 10–19 cm, small adult cuff 17–25 cm, adult cuff 23–33 cm, large adult cuff 31–40 cm). The participants were comfortably seated, with their feet flat to the floor. Measurements of systolic, mean arterial and diastolic pressure were obtained after a 10–15 min rest period in triplicate, at minute intervals. The first reading was discarded and the mean of the second and third readings was used for analysis, as the first reading of a series of blood pressure measurements is typically higher with oscillometric devices.

Pulse pressure was calculated by subtracting diastolic from systolic pressure.

For 73 (0.3%) participants, the blood pressure data were found to be either outliers or inconsistent with age, lying more than five SD from the median for age and sex. Hence blood...
pressure data for 22,901 participants, 11,364 male and 11,537 female, aged 4–23.9 years were analysed.

Sex-specific smoothed centiles were derived using the latent moderated structural equations (LMS) method for age and sex. The LMS method summarises the age-changing frequency distribution of blood pressure in terms of three curves: the L curve defines the skewness, the M curve the median and the S curve the coefficient of variation as functions of age. Centile charts were drawn with centiles spaced two-thirds of an SD score apart, ranging from the 0.4th centile to the 99.6th centile, consistent with other anthropometric charts in current use in the UK.

The relationship of systolic and diastolic blood pressure, weight and height was investigated through the multiple regression of blood pressure on weight and height, after adjusting the three variables for age and sex by converting them to SDS. The British 1990 reference was used for height and weight, and the internal reference for blood pressure. For measuring weight and height in subjects age ≥23 years was taken as 22.99 (the upper limit of the British reference). Sex effects were tested for in the regression by including sex and its interactions with height and weight.

RESULTS

Table 2 summarises the data for 22,901 participants with both systolic and diastolic blood pressure. Mean arterial pressure, height and weight were missing for 8%, 1% and 2% of participants, respectively. By year of age the sample consisted of 114 participants aged 4 years, 1181–1581 per year between 5 and 16 years, and 715–950 per year between 17 and 23 years. Height was very similar to the British 1990 reference (mean SDS 0.0), while weight and body mass index (weight (kg)/height2 (m²)) were slightly increased (mean SDS 0.3–0.4).

The data were used to construct blood pressure centile charts for systolic, diastolic, mean arterial and pulse pressure (figs 1–4). Blood pressure in the two sexes was similar before puberty, but the pubertal rise was more marked in boys. Pulse pressure peaked at 18 years in male participants and at 16 years in female participants, corresponding to the end of puberty.

Table 3 summarises the multiple regression of blood pressure on weight and height, each adjusted for age and sex by

<table>
<thead>
<tr>
<th>Variable</th>
<th>n</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Men (%)</td>
<td>22,901</td>
<td>49.6</td>
<td>—</td>
</tr>
<tr>
<td>Age (years)</td>
<td>22,901</td>
<td>13.1</td>
<td>5.2</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>22,901</td>
<td>148.9</td>
<td>21.3</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>22,485</td>
<td>64.6</td>
<td>19.9</td>
</tr>
<tr>
<td>Height SDS (British 1990)</td>
<td>22,767</td>
<td>0.03</td>
<td>1.08</td>
</tr>
<tr>
<td>Weight SDS (British 1990)</td>
<td>22,485</td>
<td>0.27</td>
<td>1.14</td>
</tr>
<tr>
<td>Body mass index SDS (British 1990)</td>
<td>22,425</td>
<td>0.36</td>
<td>1.11</td>
</tr>
</tbody>
</table>

SDS, standard deviation score.
converting to SDS. This adjustment allowed the data for both sexes and all ages to be combined. Results are also given by sex, although they do not differ significantly; hence the combined results are valid. Weight had a large and positive effect on blood pressure (p < 0.001), whereas height had a smaller negative effect (0.005 < p < 0.001). A 1 SD increase in weight was associated with a 0.3 SD increase in systolic pressure and a 0.08 SD increase in diastolic pressure, whereas a 1 SD increase in height was associated with a 0.03 SD reduction in both systolic and diastolic pressure. Thus, on average, for any given weight, a taller (and hence thinner) individual had lower blood pressure. Analysing the data in separate age groups showed the associations in late puberty to be stronger than before or after.

These results suggest that body size (ie, weight) and obesity (weight adjusted for height) both play a role in raising blood pressure, particularly systolic blood pressure, 8% of the variation of which was explained by weight and height. The effect on diastolic blood pressure (0.5% of variance explained) was much smaller.

Using the British Hypertension Society cut-offs for hypertension, 23% of men and 6% of women exceeded the systolic cut-off, and 1.0% of men and 0.8% of women exceeded the diastolic cut-off by age 24 years.

**DISCUSSION**

The blood pressure centiles presented here are based on data collected using a consistent and rigorous method in representative samples of nearly 23 000 children and young people living in Great Britain. As such, we believe they are the most accurate characterisation of normal blood pressure in any country to date.

It is well recognised that children’s blood pressure tends to “track” over time. Moreover, high blood pressure in children is associated with the development of atherosclerosis, especially in those with additional risk factors, notably obesity. The charts will aid the timely recognition and monitoring of individuals with high blood pressure and hypertension, and facilitate the detection of children with secondary hypertension, consequent on renal, endocrine or other disease.

Blood pressure monitoring is also important in children at risk of hypertension and/or vascular disease, such as those with obesity, diabetes, renal disease, or those receiving
Hypertension is present. Steroids or stimulant drugs and where a family history of hypertension is present.

Pulse pressure rises progressively until the end of puberty and then falls again.

The centiles are spaced two-thirds of a standard deviation score apart.

Figure 4 Pulse pressure centiles in male (A) and female participants (B). The centiles are spaced two-thirds of a standard deviation score apart. Pulse pressure rises progressively until the end of puberty and then falls again.

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Table 3 Relationship of systolic and diastolic blood pressure with weight and height by sex (all variables expressed as standard deviation score)

<table>
<thead>
<tr>
<th>Outcome measure</th>
<th>Sex</th>
<th>n</th>
<th>Weight (SDS)</th>
<th>Height (SDS)</th>
<th>$R^2$ (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Systolic blood pressure (SDS)</td>
<td>Men</td>
<td>11 153</td>
<td>0.279 (0.011)</td>
<td>-0.033 (0.011)</td>
<td>8.6</td>
</tr>
<tr>
<td></td>
<td>Women</td>
<td>11 272</td>
<td>0.258 (0.010)</td>
<td>-0.039 (0.010)</td>
<td>7.6</td>
</tr>
<tr>
<td></td>
<td>Combined</td>
<td>22 425</td>
<td>0.268 (0.007)</td>
<td>-0.035 (0.008)</td>
<td>8.1</td>
</tr>
<tr>
<td>Diastolic blood pressure (SDS)</td>
<td>Men</td>
<td>11 153</td>
<td>0.070 (0.011)</td>
<td>-0.033 (0.012)</td>
<td>0.4</td>
</tr>
<tr>
<td></td>
<td>Women</td>
<td>11 272</td>
<td>0.081 (0.010)</td>
<td>-0.032 (0.011)</td>
<td>0.6</td>
</tr>
<tr>
<td></td>
<td>Combined</td>
<td>22 425</td>
<td>0.076 (0.008)</td>
<td>-0.033 (0.008)</td>
<td>0.5</td>
</tr>
</tbody>
</table>

SDS, standard deviation score.

The table gives regression coefficients (SEs).
What is already known on this topic

- Blood pressure rises through childhood and childhood blood pressure strongly predicts adult blood pressure.
- This rise in blood pressure is substantially determined by weight.
- As growth, blood pressure is an important parameter of child health.
- Furthermore, atherosclerosis and hypertension may have their origins in childhood, particularly in those with additional risk factors—for example, obesity, renal disease or diabetes.

What this study adds

- These blood pressure centiles compiled from nationally representative data are the most comprehensive attempt to characterise normal blood pressure in childhood in Great Britain.
- The centiles complement existing charts for height, weight and body mass index and other parameters in evaluating the health of children.
- This information will contribute to a better understanding of blood pressure in childhood and aid further research.

inaccuracies but simply reflect the fact that different methods yield different results. However, in view of these differences, blood pressure results recorded with the mercury sphygmomanometer should be referenced to these centiles with caution.

The definition of hypertension in children is problematic. Use of the British Hypertension Society cut-offs in adults is justified by adverse health outcomes in association with hypertension. However, no single cut-off can define hypertension in children owing to the normal rise in blood pressure with age, and the paucity of evidence about what constitutes hypertension in children. Consequently, we suggest that, in children, those above the 98th centile on repeated occasions are stated to have high blood pressure for age, whereas those lying between the 91st and 98th centiles are stated to have high-normal blood pressure for age. These cut-offs are similar to recommendations made in the Taskforce Report on High Blood Pressure in Children and Adolescents in the USA.

Our centile-based definitions predict a prevalence of 2.3% for high blood pressure (>2 SDS) and 6.9% for high-normal blood pressure (>1.33 SDS). These centiles should facilitate ongoing research into the importance of high or high-normal blood pressure in children, and serve as a basis for defining hypertension in childhood.

The strong association between high blood pressure and weight/obesity that we and others have found is of particular concern given the well documented rise in childhood obesity. Childhood obesity, and its health consequences—including hypertension, metabolic syndrome and type 2 diabetes—present a major challenge for the coming years and demand vigilance and concerted action from all healthcare professionals to mitigate the adverse health consequences for children and young people.

ACKNOWLEDGEMENTS

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Authors’ affiliations

Lisa V Jackson, Willow Wood Medical Practice and University of East Anglia School of Medicine, Health Policy and Practice, Norwich, UK

Nandu K S Thalange, Norfolk and Norwich University Hospital, Norwich, UK

Tim J Cole, Centre for Paediatric Epidemiology and Biostatistics, Institute of Child Health, University College London, London, UK

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Competing interests: Subsequent to the presentation of data at the Spring Meeting in April 2003, blood pressure centile charts using these data were published commercially.

Previous publication: Some of this work was presented as an oral presentation at the Royal College of Paediatrics & Child Health Spring Meeting, April 2003. G203. Blood pressure centiles for children and young people aged 4–24 years in Great Britain. Arch Dis Child 2003; 88:A66.

Contributors: all authors contributed to the design, analysis and writing up of the paper. LVJ is guarantor.

REFERENCES


A 7-year-old boy presented to paediatrics with a 3-week history of a worsening facial rash, which was intermittently itchy. He was otherwise well. He had two guinea pigs as pets. On examination, an extensive scaling erythema was noticed with a definite edge involving the upper eyelids, the bridge of the nose and extending onto both cheeks (see fig 1). A provisional diagnosis of tinea faciei was made; however, cutaneous lupus was also considered. While mycology results were awaited, topical terbinafine was given, with little effect. Microscopy revealed a dermatophyte infection with *Trichophyton mentagrophytes*, and a 3-week course of oral terbinafine (125 mg oral dosage once daily) was given. The rash resolved completely, leaving post-inflammatory hyperpigmentation only.

Tinea facialis/faciei is a dermatophytosis of the glabrous facial skin, characterised by a well-circumscribed, often asymptomatic, erythematous patch with an elevated border and central regression. It may be asymptomatic or present with pruritus, or, occasionally, photosensitivity that may lead to diagnostic confusion with cutaneous lupus. It is the most commonly misdiagnosed dermatophytosis. Other differential diagnoses include eczema, sebhorrhoic dermatitis* and rosacea.

It is most common in children, with predisposing factors including exposure to animals, chronic topical steroid use and spread from tinea capitis. The most frequent organisms involved are *T mentagrophytes*, *T rubrum* and *T tonsurans*. However, cases caused by *Microsporum audouinii* and *M canis* occur worldwide. Most cases are given short-term oral antifungal treatment, but milder cases may respond to topical imidazoles. Affected animals and family members should also be treated.

**REFERENCES**


**IMAGES IN PAEDIATRICS**

An interesting facial rash

7-year-old boy presented to paediatrics with a 3-week history of a worsening facial rash, which was intermittently itchy. He was otherwise well. He had two guinea pigs as pets. On examination, an extensive scaling erythema was noticed with a definite edge involving the upper eyelids, the bridge of the nose and extending onto both cheeks (see fig 1). A provisional diagnosis of tinea faciei was made; however, cutaneous lupus was also considered.

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Correspondence to: Dr C A Love, Department of Dermatology, Rowan House, Whiston Hospital, Merseyside L35 5DR, UK; drcalove@hotmail.com

Competing interests: None declared.

www.archdischild.com

Figure 1 Informed consent was obtained for publication of this figure.
to date. An infant had presented with increased work of breathing from birth, and tracheomalacia had been found on flexible bronchoscopy. The section on tracheomalacia was again succinct and pragmatic. The chapter on bronchoscopy is by the undisputed king of this investigation, and there was a nice section on interpretation of bronchoalveolar lavage. We had a teenager with a pleural effusion from likely auto-immune disease; there was a solid 23 page chapter on pulmonary involvement in rheumatic disorders. I was therefore very quickly sold on this book – I had confidence that it would deliver what I needed to know and point to further reading.

Sometimes a large specialist textbook like this is not so good on more common conditions, especially where a clear and pragmatic guide is needed. There are five chapters in the section on asthma, and in fact the advice on the management of chronic and acute asthma was still pretty good. Although more accessible guidance on acute severe asthma might be found elsewhere, it did give brief up-to-date reviews of the use of intravenous bronchodilators and magnesium sulphate. However, this is not what this book is primarily for; its real strength is the ability to provide highly readable but comprehensive information on the whole range of paediatric respiratory problems. I am going to keep this book right on my desk. I would consider it the best textbook in paediatric respiratory medicine and therefore a vital resource for specialist paediatric pulmonologists, trainees and paediatricians with an interest in respiratory medicine. While I don’t think I can recommend to our trainees that they should keep it by their bed and read a daily passage, this is as close to a bible as it gets....

Neil Harrower

Management of brain injured children, 2nd edition


The concept of multi-disciplinary working in child health is frequently paid lip-service by professionals but is less frequently achieved in practice. This important book on the management of brain injured children is a truly multi-disciplinary production from the head injury rehabilitation team led by Richard Appleton at Alder Hey, Liverpool. The book is now in its second edition; the first edition, published in 1998, has been revised to provide a comprehensive guide for professionals managing brain injured children. New information on long-term effects of acquired brain injury (ABI) and resuscitation advances has been included.

The 15 contributors cover acute treatment of brain injury, through nursing and therapy needs to the assessment of cognitive problems and re-integration into the home and educational environments. There is an excellent personal contribution by a survivor of ABI and her mother, which gives some insight into the effect on individuals and their families.

Advances in the management of children with ABI have meant improved survival rates but consequently higher morbidity in survivors, ranging from transient memory deficits to complex, multiple difficulties.

The book discusses the issues around giving long-term prognostic information to families following ABI and highlights problems such as the “sleeper effect”, where an individual who has apparently made a good recovery presents years later with cognitive difficulties or school failure.

The book is well-referenced with good quality neuro-imaging examples, but it could have benefited from more diagrams, particularly to help explain the chapter on cognitive assessment, and the images in the feeding assessment chapter are of disappointing quality.

ABI is an important subject – the average district general hospital can expect to see 10 children each year who will need rehabilitation – and this book is an excellent guide for the paediatrician and other professionals in the team. It deserves to be widely read.

Tom Hilliard

CORRECTION

doi: 10.1136/archdischild-2005-008126corr1

Jackson L V, Thalange N K S, Cole T J. Arch Dis Child 2007;92:298–303. Blood pressure centiles for Great Britain. In the Abstract and in the Methods sections of this paper the expansion of the abbreviation “LMS” was published incorrectly. The correct expansion is “lambda-mu-sigma.” We apologise for this error.