Acta Paediatrica

WILEY

ACTA PÆDIATRICA
NURTURING THE CHILD

ORIGINAL ARTICLE OPEN ACCESS

Blood Pressure Reference Values in Infants Under 1 Year of Age. Oscillometric and Auscultatory Parameters

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Received: 19 October 2024 | **Revised:** 22 April 2025 | **Accepted:** 27 May 2025

Funding: The authors received no specific funding for this work.

Keywords: auscultatory | blood pressure | infant | oscilometric

ABSTRACT

Aim: Blood pressure values in infants are an understudied topic. It is a complex problem in routine care. We only have reference charts obtained using oscillometric devices, which are not up to date and were measured more than 30 years ago. The usual reference standard for blood pressure is the values obtained by auscultation, and there are no published reference figures for this age group.

Methods: In our study we present the normal values of 228 healthy children, recruited in our centre, aged between 14 days and 364 days of life, with auscultatory and oscillometric values taken in each patient.

Results: Divided into four large quarterly groups, the results obtained confirm significantly greater differences in the oscillometric figures with respect to the auscultatory ones. No significant differences were found between the same blood pressure modalities when age, sex or the finding of minor conditions were assessed in the study of the patients.

Conclusions: Previously undescribed oscillometric and auscultatory reference values for paediatric blood pressure are available and can be applied in daily practice in infants. Auscultatory measurements should be taken into account, especially to confirm the values, as we would do if the patient's age were different.

1 | Introduction

Blood pressure values in infants are an insufficiently studied subject. In fact, the clinical guidelines on the management of hypertension in children and adolescents of the American Academy of Paediatrics refer to those published in 1987 as reference values [1]. These values are taken using Doppler methods [2] and have never been compared with the gold standard, based on auscultatory measurement of blood pressure [3].

The diagnosis of blood pressure abnormalities is made by comparing blood pressure (BP) with normative values of the same measure. This is challenging in infants because there is a lack of such robust normative data and BP is not routinely measured in healthy infants due to technical difficulties. This poses a problem for us in terms of delving into relatively frequent clinical situations in this age range that require good blood pressure management, such as renal disorders, congenital heart diseases or certain medical treatments [4].

Abbreviations: BP, blood pressure; DBP, diastolic blood pressure; SBP, systolic blood pressure.

Summary

- There are no published reference values for auscultatory blood pressure in infants.
- We present reference values for auscultatory and oscillometric blood pressure in this population.
- At this age, confirmatory auscultatory measurements should be considered.

It is noteworthy that the blood pressure figures published by the American Academy of Paediatrics in the latest major guideline about the management of high blood pressure in 2017 refer to normality curves in this age group dating back to 1987, due to the lack of new data to contribute. These measurements were obtained using oscillometric devices. These are recommended until infants and young children can collaborate to take auscultatory blood pressure [1, 2, 5].

Oscillometric blood pressure measurements are generally higher than those obtained by manual or direct methods. Because accurate auscultatory measurement in young infants is often difficult, initial BP measurement in this age group is usually performed using oscillometric devices. The figures obtained should be verified by auscultatory methods [4]. And here we are confronted again with the absence of tables to check against.

The guidelines of the European Society of Hypertension in Children and Adolescents (ESH), those of the American Academy of Paediatrics (AAP) for the management of hypertension, the Canadian guidelines and, recently, the paediatric consensus guidelines published by the ESC (European Society of Cardiology) indicate that the method of choice for the diagnosis of high blood pressure is the auscultatory method [2, 3, 6, 7].

2 | Material and Methods

This is a cross-sectional observational study with 228 children, 129 males and 99 females. The selected patients were recruited from the paediatric cardiology unit of our hospital, where they were referred as outpatients, asymptomatic and with normal growth. The most common reason for consultation was auscultation of a murmur on routine examination. Aged between 14 days and 364 days, we included those children with a diagnosis of normality (without evidence of alterations), or very minor clinical conditions that mimic normality, without any haemodynamic repercussions (such as a minimal foramen ovale as the most frequent cause). Following the established reference standards for blood pressure measurement [2, 3, 8] as a criterion to be followed, patients who were nervous, crying and uncooperative were excluded. Figure 1 shows our study graphically.

The study followed the ethical principles of the Declaration of Helsinki. It has been approved by the Ethics Committee of our hospital.

Measurements were taken on the right arm [8] using a cuff with an inflatable bladder with a width of approximately 50% of the mid-arm circumference [9] and the length of the bladder should cover 80%–100% of the arm circumference. In case of doubt, the larger size is chosen [4].

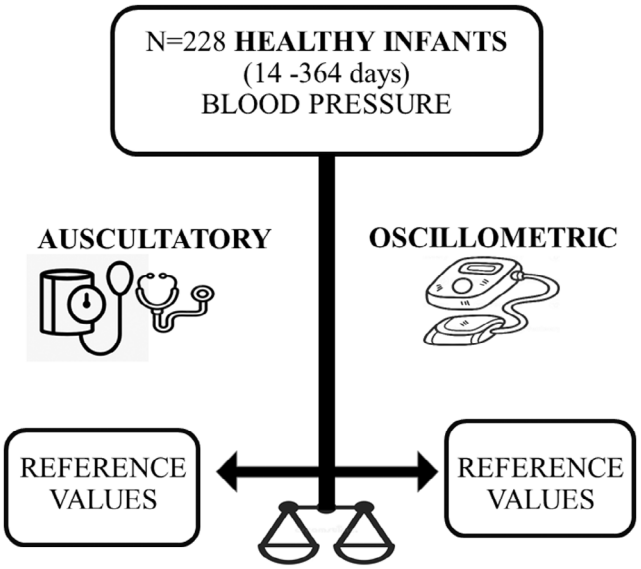


FIGURE 1 | Graphical summary of our study.

In a comfortable and quiet environment, all patients underwent three measurements on the right arm, 3 to 5 min apart; the first two were oscillometric measurements, computing their average value, and the last one was auscultatory. Measurements have been performed by a nurse with extensive experience in the paediatric area.

In the auditory recording, the stethoscope bell was placed at the level of the brachial artery in the right antecubital fossa. The first audible sound (phase I Korotkoff) and the last audible sound (phase V Korotkoff) are taken as systolic blood pressure (SBP) and diastolic blood pressure (DBP), respectively [3].

The oscillometric blood pressure measuring device is a paediatric validated Drager Dinamap monitor. Regularly calibrated aneroid sphygmomanometers were used for auscultation.

The variables to be measured in the study, in addition to blood pressure, are heart rate, age (with date of birth), sex, weight, height and body mass index (BMI). History, number of history, basic diagnoses and treatment intake were recorded.

Descriptive statistics were performed on the data, dividing the groups into 4 quarterly age groups (0–3, 4–6, 7–9, 10–12), showing their percentile values (5, 10, 25, 50, 75, 90, 95). Statistical analysis of the results was carried out using SPSS software version 23. Comparisons of means were carried out using Student's *t*-test. The Mann–Whitney *U* test was used to compare variables.

2.1 | Compliance With Ethical Standards

The study followed the ethical principles of the Declaration of Helsinki. It has been approved by the Ethics Committee of the Hospital San Cecilio.

3 | Results

The blood pressure data obtained are shown by grouping the different percentile values, divided into 4 large age groups from 3 months to 1 year. The largest group was made up of children under 3 months, with 92 patients, from 4 to 6 months 73, and 7 to 9 months 40. The group with the smallest number of children was from 9 to 12 months with 23. 56% of the sample was male, with 44% of the sample being female. Likewise, 40% of the sample had no echocardiographic findings compared to 60% who presented situations that mimic complete haemodynamic normality but constitute minor diagnoses.

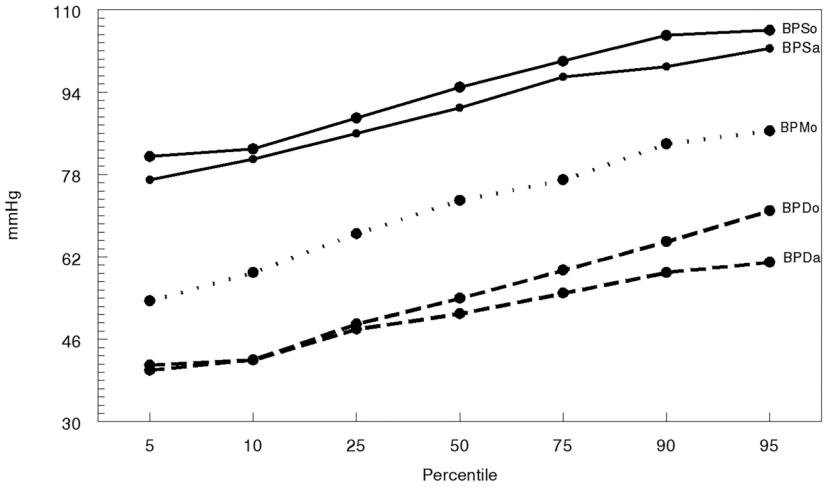
The different values of normality detailed by groups are presented in graphs [1–4].

The different values obtained are shown in Table 1.

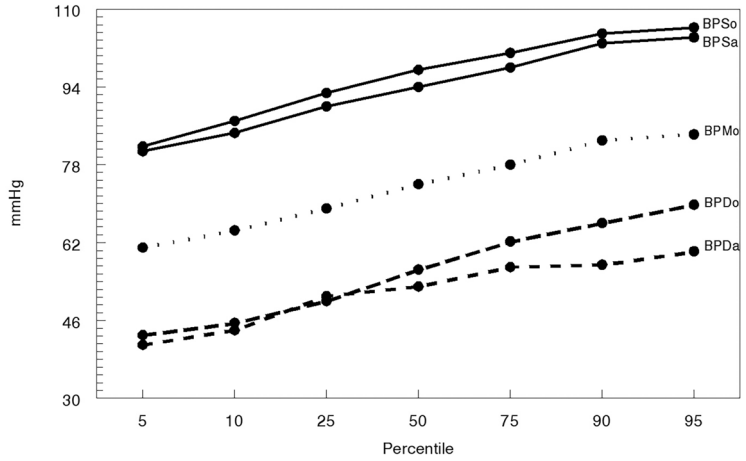
As it can be noticed, both systolic and diastolic oscillometric arterial blood pressures show higher values than the respective values taken audiometrically; this is statistically verified by comparison (Student's t-test for related samples, $p < 0.001$).

As an important aspect to highlight, taking age as the central variable, the different age groups do not show significant differences when compared between them (ANOVA of one factor, NS with $p = 0.54$). Nor are significant differences found when distinguishing the population by sex.

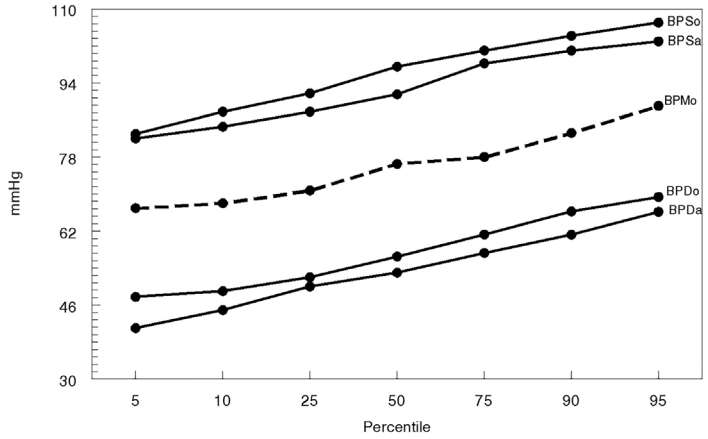
In order to homogenise the population, we compared the children, all of whom were healthy and asymptomatic and had no findings on examination, with what we called non-significant or minor haemodynamic conditions (unimportant exploratory findings such as patent foramen ovale, minimal ventricular septal defects or valvulopathies without alterations in function), and no statistically significant differences were found.



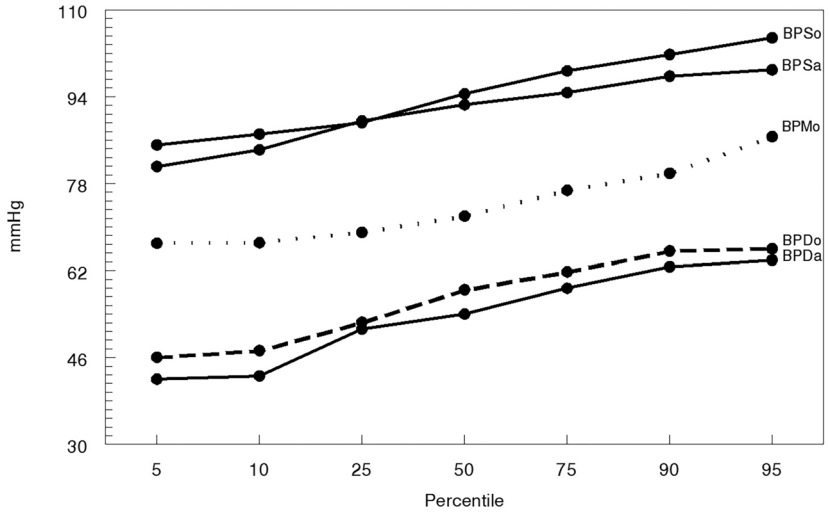
GRAPH 1 | Percentile blood pressures in the group of children aged 14 days to 3 months. BPOs: oscillometric systolic blood pressure, BPSa: auscultatory systolic blood pressure. BPMo: Oscillometric mean arterial blood pressure. BPDo: Oscillometric diastolic blood pressure. BPDa: auscultatory diastolic blood pressure.



GRAPH 2 | Percentile blood pressures in the group of children aged 4 to 6 months. BPOs: oscillometric systolic blood pressure, BPSa: auscultatory systolic blood pressure. BPMo: Oscillometric mean arterial blood pressure. BPDo: Oscillometric diastolic blood pressure. BPDa: auscultatory diastolic blood pressure.



GRAPH 3 | Percentile blood pressures in the group of children aged 7 to 9 months. BPOs: oscillometric systolic blood pressure, BPSa: auscultatory systolic blood pressure. BPMo: Oscillometric mean arterial blood pressure. BPDo: Oscillometric diastolic blood pressure. BPDa: auscultatory diastolic blood pressure.



GRAPH 4 | Percentile blood pressures in the group of children aged 10 to 12 months. BPOs: oscillometric systolic blood pressure, BPSa: auscultatory systolic blood pressure. BPMo: Oscillometric mean arterial blood pressure. BPDo: Oscillometric diastolic blood pressure. BPDa: auscultatory diastolic blood pressure.

TABLE 1 | Mean values of the different blood pressures, in mmHg, obtained by age group. Interquartile range in brackets.

BP (mmHg)	0–3 months	4–6 months	7–9 months	10–12 months
BPSo	95 (89–100)	97,5 (92,75-101,00)	97,5 (91,75-101,00)	94,5 (89,25-98,75)
BPSa	91(86,00-97,00)	94 (90.00–98,00)	95,50 (91,50-98,25)	92,50 (89,50-94,75)
BPMo	73,00 (66,50-77,00)	7f4,00 (69,00-78,00)	76,50(70,75-78,00)	72,00 (69,00-76,75)
BPDo	54,00 (49,00-59,50)	56,50 (50,00-62,25)	56,50 (52,00-61,25)	58,5 (52,50-61,75)
BPDa	51,00 (48,00-55,00)	53,00 (51,00-57,00)	53,00 (50,00-57,25)	54,00 (51,25-58,75)

Abbreviations: BP, Blood pressure; BPDa, Auscultatory diastolic blood pressure; BPDo, Oscillometric diastolic blood pressure; BPMo, Oscillometric mean arterial blood pressure; BPSa, auscultatory systolic blood pressure; BPSo, oscillometric systolic blood pressure.

4 | Discussion

4.1 | Implications for Clinical Practice

Although hypertension in infants is estimated to be rare except in risk groups (such as renal disease, cardiac disease, medical treatment, low birth weight, premature infants) [2], it is challenging to make the diagnosis of hypertension in these patients because of the lack of robust normative data and because BP is not routinely measured in healthy infants due to technical difficulties. Usually, we need a high index of suspicion, based on history or physical examination to make a diagnosis of

hypertension because BP measurements are not routinely performed [4].

This paper provides tables with updated values of normal BP in an age group where it is difficult to obtain, whose reference figures are oscillometric and with technical devices that date back more than 40 years [1]. Above all, comparative data obtained auscultatorily are available, something that has not been described to date. In other paediatric age groups, auscultatory measurement is mandatory for confirmation [2], so we believe that the publication of auscultatory blood pressure charts as a reference is relevant. The auscultatory method, although traditional, is used more in paediatrics for research purposes. It is more accurate under ideal conditions, but requires training to correctly identify sounds in a difficult population such as infants, where collaborative conditions are more difficult. Both of these considerations may encourage observer error. The oscillometric method is the reference standard in routine clinical practice, due to its simplicity and automation, with less risk of human error.

Mean arterial pressure is most often used in intensive care to direct treatment of hypotension because it is a more stable and representative indicator of blood flow to vital organs. It also tends to be less susceptible to rapid blood pressure variations. Its value is less affected by interindividual variability. This value is best estimated by oscillometry; it is more directly and reliably estimated than systolic (SBP) and diastolic (DBP) pressures. This difference lies in the fundamental principle of the oscillometric method, as it measures it directly. Systolic and diastolic pressures are extrapolated from algorithms from mean arterial blood pressure. As there is no universal standard for these algorithms, two different oscillometric devices may give slightly different values for SBP and DBP in the same patient.

As has been described at different ages, there are significant differences between oscillometric and auscultatory values [2]. These studies showed that oscillometric devices systematically overestimate SBP and DBP compared to values obtained by auscultation [2, 9, 10]. The overreading obtained by oscillometric methods is of relative importance and needs to be contextualised. Each individual has physiological variations; what may be normal for one may be considered hypertension for another. This is the difference between statistical normality and pathology, and it must be appreciated. In fact, in recent years, several studies in adults (such as the SPRINT study, ACC/AHA 2017 guidelines or ESC/ESH 2018) have questioned the traditional thresholds for the diagnosis and treatment of hypertension, proposing more individualised approaches. The oscillometer is practical, but repeated measurement, corroboration with auscultatory methods if feasible, and thorough clinical assessment remain essential for a reliable diagnosis [11].

We observed, by comparison, that there are no significant differences at these ages by sex, as well as when differentiating children with no findings versus the presence of minimal findings with no haemodynamic repercussions.

The data obtained could allow us to establish auscultatory reference values, which are the ideal values of choice. Some previous authors state that they are reliable determinations of blood pressure in children as young as 6 months, although not in newborns [12]. They state that, mostly, the problem of measurement with infants and children has to do with their smaller body size. We think that this is possible as we objectively see with our data obtained. These could be used as a confirmatory reference in selected cases. It is a tool compared to the values obtained with oscillometry, the only reference to date [3]. Although laborious, with the right equipment, training and family collaboration, it would be possible to try to obtain blood pressure readings in the outpatient clinic.

The lack of comparative significance of blood pressure values between different age groups might lead us to believe that a common approximation using values obtained from 1 year of age onwards is adequate. However, it would be inaccurate; we already have specific values available.

The selection of patients for the study was made from those attending the paediatric cardiology service. Referral of asymptomatic infants with a murmur for screening for heart disease is a frequent occurrence; it is an agreed reason for referral and very often no pathology or minor conditions are found, with no haemodynamic repercussions.

Patient selection did not include neonates younger than 14 days, nor did it focus on relevant neonatal data such as gestational age. The absence of this age group means that our data does not cover this population, and therefore is not assessed in our study.

The limitations of our study could be due to the sample size; although it is large, it could be considered insufficient. Another limitation could be due to the fact that it was not carried out in a multicentre setting. Both drawbacks are absolutely avoidable and an invitation for further studies. Special mention should be made to the group of older children (9–12 months), the one with the smallest sample size and the one in which it is most difficult to obtain collaboration.

5 | Conclusions

We have updated, previously undescribed, oscillometric and auscultatory reference values for paediatric blood pressure that can be applied in daily practice in children of this age group. They are useful in children of this age who require blood pressure measurement, as necessary as at other ages. We should consider auscultatory measurements, especially to confirm values, as we would do if the patient's age were different.

Author Contributions

Enrique Blanca-Jover: conceptualization, investigation, writing – original draft, methodology, validation, writing – review and editing, supervision, formal analysis, data curation, project administration, software, resources. **Andrea Villanueva-Garcia:** conceptualization, investigation, writing – original draft, data curation, validation, methodology, resources. **Francisco Contreras-Chova:** conceptualization, investigation, methodology, writing – original draft, writing – review and editing, resources. **Antonio Jerez-Calero:** conceptualization, investigation, writing – original draft, writing – review and editing. **Jose Uberos-Fernandez:** conceptualization, methodology, formal analysis, supervision, data curation, software, writing – review and editing, investigation, validation, writing – original draft.

Acknowledgements

Funding for open access charge: University of Granada/CBUA.

Conflicts of Interest

The authors declare no conflicts of interest.

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