Blood Pressure Measurement in Paediatric Patients: State of the Art

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Accurate blood pressure determination is crucial in the management of critically ill infants and children, in detecting secondary hypertension amenable to surgical correction, and in the early detection of essential hypertension. However, the paediatric literature consists of contradictory methodology and marked variations in the 'limits of normal'. Blood pressure measured in the arm or leg does not necessarily reflect the central aortic pressure because of a phenomenon known as the peripheral amplification of systolic pressure. Indirect blood pressure measurements are affected by multiple variables. Selection of blood pressure cuff size is the major source of this variance. The laws of physics, supported by intra-arterial pressure measurements, indicate that the correct cuff size should be based on the circumference (or diameter) of the limb, not the length. Using the length may produce adequate readings if the subject is of normal weight/height relationship, but will result in hypertensive readings in obese subjects who are actually normotensive and in mildly low readings for thin subjects. The correct cuff width is 40-50% of the circumference (or 125-155% of the diameter) of the limb, whether arm or leg. Most available blood pressure standards have been obtained by the length-based cuff. A tentative guide to normal blood pressure values using the recently recommended circumference-based cuff is provided, which was derived from the San Antonio (Texas, USA) Biethnic Children's Blood Pressure Study.

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Blood pressure (BP) measurement in paediatric patients is recommended to be a routine procedure except in infants and small children. For these young subjects, an automated device, such as the oscillometric method, is being used in an increasing frequency because of the difficulties with the auscultatory method. However, many if not most paediatricians are confused about the methodology and normative BP standards because there are disparate recommendations as to the correct technique of measuring BP and unacceptably wide variations in normative data[1,2]. Normative BP value recommended by the National Institute of Health (NIH) Task Force-1987[3] is quite different from that published 10 years ago by an earlier NIH Task Force[4]. Such wide variations reported in the literature are, for the most part, secondary to different methodologies[5,6]. The use of different BP cuff selection method is the main source of the variance. BP cuff width recommended by the NIH Task Force-1987[3] is different from that recently recommended by the American Heart Association (AHA)[7] and the working group of the National High Blood Pressure Education Programme (NHBPEP)[8].

In this communication, the authors wish to review briefly problems in obtaining reliable BP readings in children, to offer suggestions to improve paediatric BP determinations, and to present new normal BP standards for children which have been obtained by a validated BP cuff selection method. Specifically we will (a) review the significance of BP recorded in the arm or leg, including the important concept of peripheral amplification of systolic pressures; (b) review the popular methods of indirect BP measurement with their advantages and shortcoming; (c) present published normative values with discrepancies among them and discuss reasons for the difference, (d) discuss procedures which help to control certain variables, with emphasis on the selection of the BP cuff, and (e) present a tentative normative BP standard using the most recently recommended circumference-based BP cuff selection method.

A. Significance of Arm and Leg BP Readings

Direct BP in this review refers to the BP obtained through an intra-arterial cannulation and indirect BP refers to that obtained by a non-invasive method such as sphygmomanometry or electronic device. When a BP measurement is obtained using a correct BP cuff in the arm (or other extremity sites), the indirect BP measured at a peripheral site should logically reflect and is close to intra-arterial BP at that particular site. However, BP obtained in the arm does not necessarily agree with the central aortic pressure that is more important than the peripheral pressure. This is due to a phenomenon known as the peripheral amplification of systolic pressure[9]. Although it is widely accepted that the 'gold standard' of BP is that obtained through an intra-arterial line, even direct intra-arterial BP readings from peripheral sites may be quite different from the central aortic pressure because of the above phenomenon. This phenomenon bears some important clinical implications (see below). If a BP cuff of incorrect size is used for the arm BP measurement, the BP reading may not reflect either the peripheral or central pressure.

It is well established, although not widely recognised, that there is an increase in amplitude of the pressure wave as it propagates peripherally. The systolic pressure is the lowest

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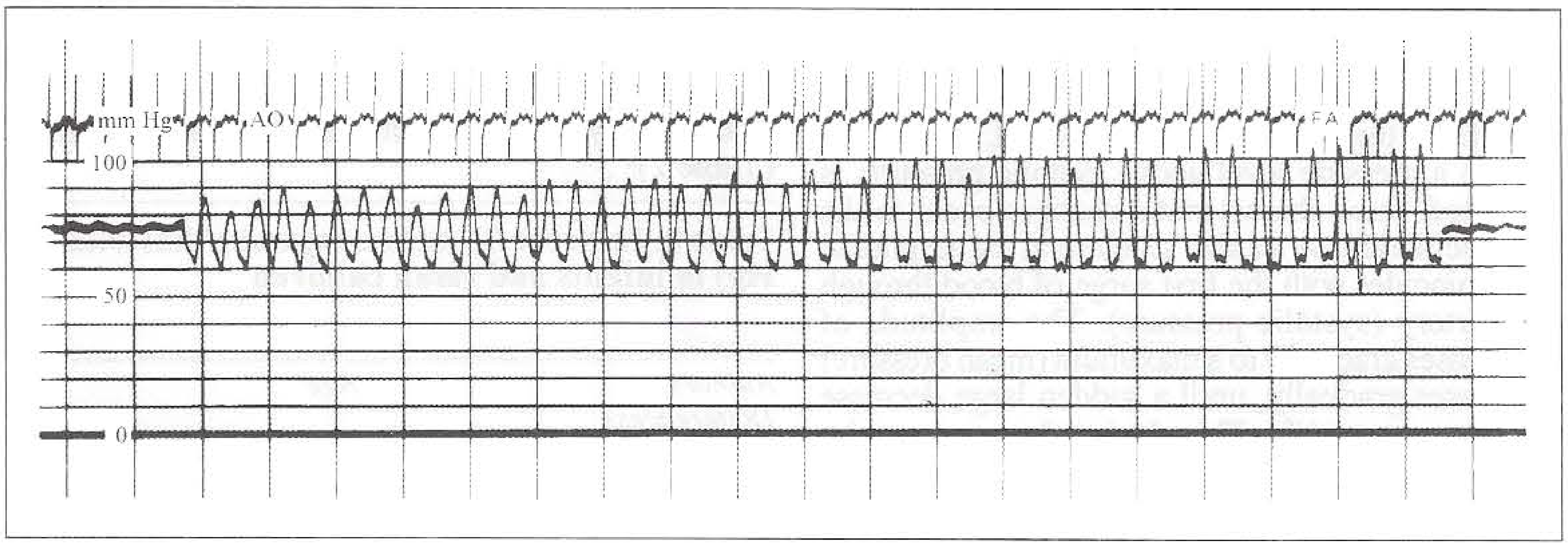

Figure 1. Peripheral amplification of systolic pressure. Intra-arterial BP tracing from a 5 year old child during cardiac catheterization. The catheter was withdrawn from the ascending aorta (AO) to the femoral artery (FA) with continuous recording of pressure. Note that the femoral artery systolic pressure is higher than the aortic systolic pressure by approximately 20 mm Hg. There is no significant difference in diastolic and mean pressures between the two sites.

in the ascending aorta and tends to increase as the site of recording moves farther from the heart (peripheral amplification of systolic pressure)[9]. In figure 1, the catheter was withdrawn from the ascending aorta to the femoral artery, while continuously recording the BP. The systolic pressure in the femoral artery is 15-20 mm Hg higher than that in the ascending aorta, while the diastolic and mean pressures are equal or slightly lower in the femoral artery; the peripheral amplification of the BP is limited to systolic pressure. Reflected waves from the terminal arterioles are widely accepted as the major mechanism for the phenomenon[9]. In normal children and young adults the systolic pressure in the brachial artery is about 10 mm Hg higher than that in the central aorta[9,10] and there is little or no further amplification in the radial artery[11]. The amplification in the femoral artery is about the same as that seen in the brachial artery[10], but a further amplification is observed in the pedal arteries in children[11], an average of 20 mm Hg as opposed to 13 mm Hg reported in an adult population[12]. In premature and full-term newborn infants, no difference was reported between the direct umbilical artery pressure and the direct radial or posterior tibial artery pressure[13].

The amplification is greatest in the arteries with high vascular tone and less in arteries with degenerative diseases or those in dilated state[9-12]. Therefore, systolic amplification is more marked in children and young adults and in those patients with increased vascular tone such as seen in congestive heart failure, circulatory shock, or during the administration of catecholamines or other vasoconstrictor agents. This consideration is important in evaluation of BP taken in the peripheral sites (either arm or leg), either direct or indirect, especially in patients with congestive heart failure or impending circulatory shock with increased sympathetic tone.Under these conditions, the systolic pressure in the peripheral artery may be still in the 'acceptable' normal range, even though the central aortic pressure might indicate circulatory shock[11].

B. Methods and Techniques

Three popular methods; auscultatory, oscillometric and Doppler methods; will be briefly reviewed. In all indirect BP determinations, an arterial occluding cuff is used. The importance of the width of the cuff will be presented under the heading of Control of Variables.

b-1. ***Auscultation***: This is the most widely used method of BP determination in clinical medicine. An appropriate-sized BP cuff is applied, and the cuff is inflated above the level at which the radial pulse disappears[7,14,15]. The correct width of the cuff is 40-50% of the arm circumference and the cuff should be long enough to completely or nearly completely encircle the extremity (see below for further discussion)[7,10,14]. The cuff should be at heart level[7]. There are no significant differences in the BP, whether recorded in the supine or sitting position, as long as the cuff is at the heart level[16]. The cuff pressure is deflated at a rate of 2-3 mm Hg/Sec. Korotkoff sounds (Table 1) are detected by the use of the bell of a stethoscope over an artery just distal to the cuff. The sphygomanometer reading at the onset, or phase 1, of Korotkoff sounds is universally accepted as the systolic pressure. There are, however, historical and persistent controversies about the diastolic level[17]. At the present time, the adult literature favours phase V (disappearance) for diastolic pressure, while the paediatric literature favours phase IV (muffing) for children (up to 12 years of age) and phase V for those 13 years and older[3,7]. It is advisable to record both K4 and K5; eg. 120/70/40, reflecting systolic, K4 and K5 values. These controversies may indicate that an accurate diastolic pressure cannot always be obtained with auscultation method[17].

Table 1. **Korotkoff sounds**

Phase	
I	Loud clear-cut snapping tone
II	Succession of bruits
III	Disappearance of bruit and appearance of a tone resembling the first phase
IV	Muffing of the tones
V	Disappearance of all sounds

Although general accuracy and applicability of this method are well accepted for the adult and older children, some reports[18] indicate that the systolic pressure obtained by the auscultatory method is significantly lower than the direct arterial pressure from the radial or brachial artery. This technique is difficult to use in infants and small children and in those with circulatory collapse, because of their faint Korotkoff sounds[7]. Also, hearing difficulties in the observer or high levels or ambient noise as in air evacuation make this method impractical.

b-2. ***Oscillometry***: The oscillometric device detects pressure oscillation in the cuff bladder encircling the extremity which is transmitted from the underlying arterial wall. When the cuff, inflated to a pressure level above systolic pressure, is gradually deflated, three characteristic changes occur in the magnitude of oscillation. A sudden increase in the amplitude of oscillation coincides with the first surge of blood through the occluded artery (systolic pressure). The amplitude of oscillation increases gradually to a maximum (mean pressure) and then decreases gradually, until a sudden large decrease occurs (diastolic pressure)[19]. This device does not require placement of a detection device over the underlying artery as in the Doppler method. The device (marketed as Dinamap and others) reports systolic, diastolic and mean pressures as well as the heart rate. The accuracy of the device in reflecting a direct arterial pressure has been demonstrated in neonates[20], infants and children[19] and adults[21]. However, a study in infants in postoperative status shows less promising accuracy than reported previously and the accuracy of this device has been questioned in premature neonates whose BPs are in low ranges[22]. Certain models of oscillometric device may not provide accurate readings (unpublished data). Therefore, accuracy of each model needs validation.

Despite it's potential problems, there are some advantages of the device over other noninvasive methods of blood pressure determination[19]: (a) since it detects pressure oscillation, not sounds, it can be used in the neonate and small infant in whom Korotkoff sounds are usually too weak to give accurate readings; (b) it can be used in noisy environment or by a person with hearing impairment; (c) the observer-related variation is eliminated; and (d) it also gives mean pressure and heart rate which are not ordinarily provided by other methods. An important disadvantage of this device is its relatively high cost.

b-3. ***Doppler method***: This method is similar to the auscultation, except for the signal detection device. A Doppler device, instead of stethoscope, is placed directly over an artery distal to the BP cuff for the detection of flow. Two types of the device are available; the Parks ultrasound device (parks Electronics, Beaverton, Oregon, USA) and the Arteriosonde (Roche Medical Electronics, Cranbury, NJ, USA). This device can be used in infants and small children on whom the auscultatory method is unsuitable[3,7]. The result obtained by Doppler shift shows a close correlation with intra-arterial determination for the systolic, but not for the diastolic pressure[23].

C. **Published Blood Pressure Values in Children**

c-1. ***Newborn, Infants and small children***: The auscultatory BP measurement is difficult to obtain and is rarely reliable in the newborn, infants and small children less than 2 years of age[3,7]. Thus, statistically reliable normative BP values by the auscultatory method do not exist for this age group. Intra-arterial systolic pressure of premature infants is lower than that of full term neonates and is directly related to the body weight or to the length of gestation[24]. Blood pressure values by Dinamap monitor in the newborn 1-3 days of age were 65 ± 8/41 ± 6 mm Hg (systolic/diastolic; ± SD) with a mean pressure of 50 ± 7.0 (SD) mm Hg[25]. The blood pressure increases rapidly during the first 4 days of life, and thereafter it becomes more stable[26,27]. There is a further rise in BP during the first few months of life, and then it remains relatively constant up to and including 2 years of age[26,28]. Systolic pressure rises gradually from 2 to 5 years of age, approximately 1 mm Hg/year[3,28,29]. Indirect BP values obtained by various methods are summarised in Table 2 for infants and small children. Auscultatory BP values are lower than values obtained by Doppler method[27] and oscillometric devices (Table 2)[28].

Table 2. **Indirect BP values (systolic/diastolic; ± SD mm Hg) in infants and small children**

Authors [References]	*Age*				*Method*
	6 months	*1 year*	*2 years*	*4 years*	
Kirschsieper and Rutenfranz[30]	84 ± 4/ 64 ± 4	89 ± 2/ 68 ± 1	91 ± 7/ 63 ± 7	95 ± 7/ 59 ± 9	Auscul-tation
De Sweiet et al [27]	93 ± 13/ (no diastolic)	94 ± 11/	94 ± 11/	98 ± 9/	Doppler
Zinner et al [26]	92 ± 9/ 55 ± 9	95 ± 8/ 56 ± 8	99 ± 8/ 58 ± 7		Arterio-sonde
Park and Menard [28]	94 ± 9/ 60 ± 9 (mean 74 ± 10)	94 ± 8/ 58 ± 8 (mean 73 ± 7)	96 ± 8/ 56 ± 7 (mean 71 ± 7)	101 ± 8/ 102 57 ± 7 (mean 73±7)	Dinamap (model 1846SX)

c-2. ***Older children***: A large number of epidemiological studies have provided data on the normal distribution of BP in children by the auscultatory method. Comparison of these observations reveal a wide variation in BP values [1-4,6,16, 31-36] (see Figure 2). The difference between the highest and lowest mean systolic pressure is as much as 30 mm Hg in certain age groups. The values reported by the 1977 NIH Task Force[4] are much higher than those reported in many other studies including the report of the 1987 NIH Task Force[3] (Figure 2). The main reason for this discrepancy is most likely the methodology, although the observations are on different populations[1,5,6]. Some studies used Korotkoff phase IV and others used phase V as the diastolic signal. Many studies selected the occluding cuff based solely on the length of the arm. Most studies took only one measurement while others used the average of multiple readings as many as nine. Some studies carried out complete physical examination, exercise test or even venipuncture as part of the blood pressure survey[6]. Nevertheless, most studies show a consistent increase in BP with increasing age.

c-3. ***Factors reported to affect blood pressure levels***: Various factors for BP patterns have been investigated with inconsistent results. In adults, except for young adults, both systolic and diastolic pressures were higher in blacks than in whites[37]. In children the racial difference in BP levels varies from study to study. A higher systolic BP was reported in black than white children[35]. Other studies[2,16,31] show higher BP levels in adolescent white boys and girls than in black counterparts, and still other studies[38,39] show no differences between white and black children. However, a recent report of a meta-analysis of previously published data suggests that BP levels of black children and adolescents, especially females, are higher than those of other racial group[40]. Similarly inconsistent findings were reported between boys and girls. Among the age group of 6-11 years, the BP of girls was generally higher than that of boys, particularly for systolic pressure[32], but others found no consistent difference[39]. After 13 to 14 years, the systolic pressure was higher in boys than in girls[31] while no difference was noted for diastolic pressure[16]. For diastolic pressure, higher reading was reported in blacks than whites[32], but this finding has not been confirmed by others[16].

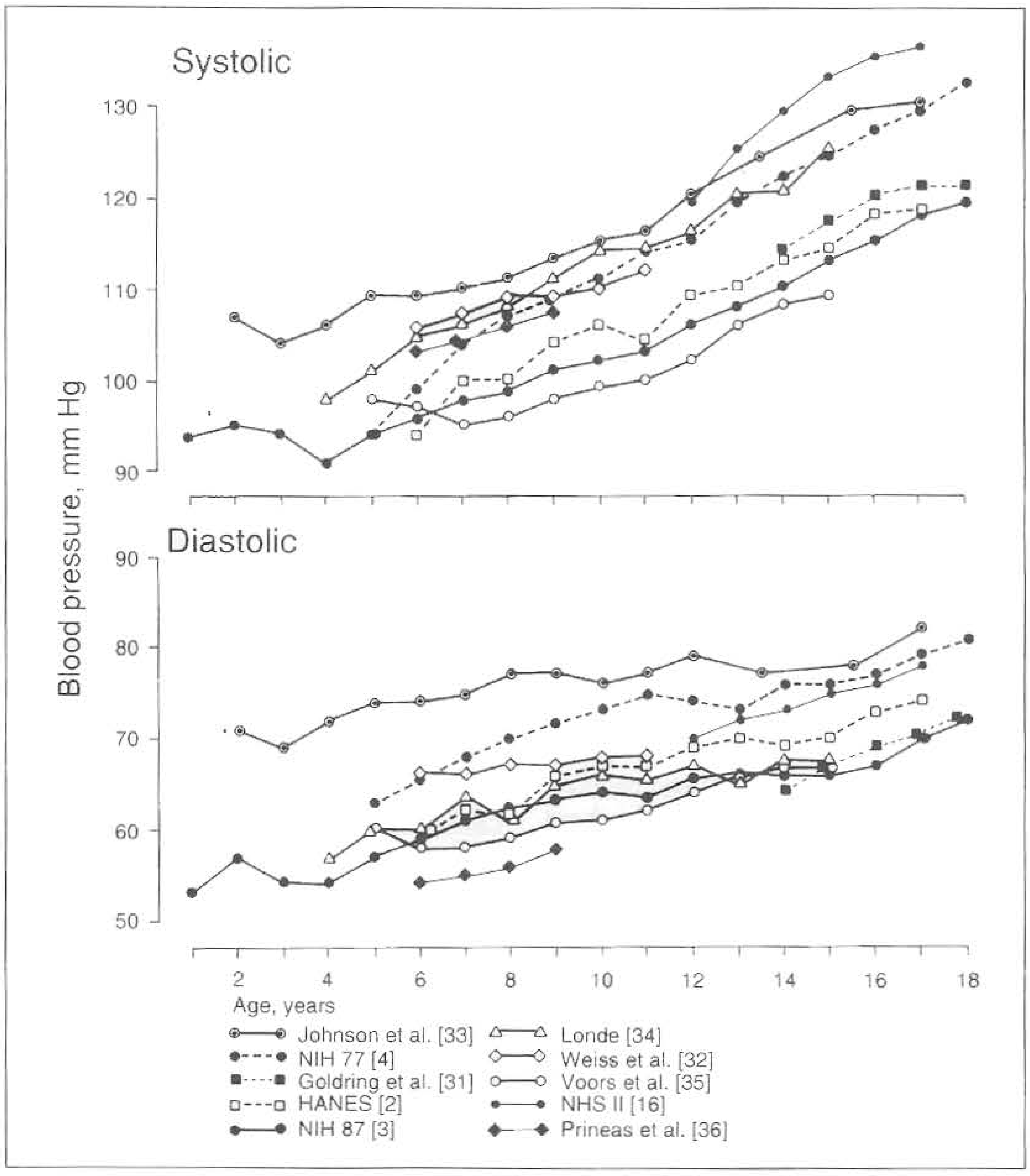

Figure 2. Comparison of mean (or 50th percentile) values of indirect BP levels of boys from ten large epidemiological surveys. When racial differences were present, values for white children were illustrated. Note that more than 20 mm Hg difference exists between the highest and the lowest values for certain age groups for both systolic and diastolic pressures

The averages of repeated measurements are lower than those of 'casual' measurements and may be better estimates of the 'basal' BP[5,29,41]. The first reading is higher than the subsequent ones for both systolic and diastolic pressures[5,32,41]. Mean systolic pressures in children 12-17 years of age were slightly higher (2-3 mm Hg) in the prone position than in the supine position, but for the mean diastolic pressure, the relationship was the opposite[19]. Studies which investigated the effects on BP of different regions of the United States, seasonal variations, urban versus rural living, socioeconomic status and education level of parents did not reveal consistent findings[2,16,31,32]. BP values tend to be slightly higher in the afternoon than in the morning, especially for systolic, but not for diastolic pressures[32]. A number of studies in adult population indicate that obesity is highly correlated with hypertension[42]. Similar trends have been reported in children[3,5]. However, no reliable data known to us separate the possible contribution of undercuffing (using too small a cuff selected by the length of the arm) to these elevated pressures in the obese. Blood pressure in children seemed to be positively related to weight, height, triceps skin fold thickness and arm circumference[6,39,43]. Among these variables weight shows the highest correlation with BP levels[43].

Table 3. **Sources of variance in blood pressure measurements**

A. Patient variables
- Levels of cooperation and/or anxiety
- Fever, recent exercise or meals
- Medications (nose drops, antiasthmatic agents, etc)

B. Instrument
- Inadequately tested device
- Calibration of the system, particularly the aneroid manometer
- Intact bladder and air tight tubing system, including the rubber bulb
- Cuff size

C. Examiner and technique
- Hearing ability of the examiner
- Full understanding of measuring technique, including Korotkoff sounds (K1, K4, K5 etc), auscultatory gap, correct selection and application of the cuff, position of the arm (at heart level), and rate of bladder deflation.
- Examiner preference of certain numbers

D. Circumstances
- Quietness, relaxed, non-threatening situation, and briefly approach to patients
- Temperature of the room
- Avoidance of other procedures (exercise, venipuncture, etc)

D. Control of Variables in Indirect BP Measurement

Indirect BP measurement by any technique is affected by multiple variables, including the patient, the method used, observer-related variables, and circumstances under which the measurement is obtained[5,7,14]. Physicians should be aware of these variables (Table 3) and make every effort to eliminate or minimise their effects on BP measurement. These variables will be briefly discussed in this section. In all direct methods, an occluding BP cuff is employed. The only difference among various methods is the difference in the device used for detection of systolic and diastolic signals. Thus, the accuracy of the indirect BP measurement is greatly influenced by correct selection and application of the BP cuff and the sensitivity and reliability of the detection device.

d-1. ***Patient variables***: The level of cooperation and of anxiety and other physical factors including fever determine the level of BP by affecting the actual BP level. Medications such as vasoconstrictor agents (nose drops, antiasthmatic agents, etc) or corticosteroids may cause high BP. Recent exercise and even a distended urinary bladder may cause high BP readings[7]. BP values taken in the resting and relaxed state appear to be most reproducible and provide the best opportunity to observe trends over time[5].

d-2. ***Instrument***: The instrument that measures and/or records BPs should be reliable and accurate. The bladder and the tubing system including the rubber bulb should be airtight. The pressure gauge in the instrument should accurately reflect the pressure in the occluding cuff, whether a mercury or an aneroid manometer or a digital readout device is used. The mercury manometer is the reference standard, any other form of pressure gauge should be calibrated against this at regular intervals[7].

The sensitivity of the detection device plays an important role in the final BP level. The Doppler device is more sensitive than the auscultation method and, therefore, the reading by the Doppler method may be higher than by the auscultation method[7]. Significantly higher (6-7 mm Hg) systolic and slightly lower (2-4 mm Hg) diastolic readings than in the auscultatory method were found with the Dinamap method (model 1846SX)[41].

d-3. ***Operator***: While the auscultation method enjoys a wide acceptance, this method is subject to a substantial observer variation, as it relies on normal hearing in the observer and requires understanding of each phase of Korotkoff sounds[7,15,44], including auscultatory gap (see below). Variability in detection of Korotkoff sound is a common source of observer variation. An interobserver variation of systolic pressure can be as high as 40 mm Hg[32,44]. Such an interobserver variation can be a problem in epidemiological studies. A given observer may unconsciously have a preference for a certain terminal digit, such as 5 or 0, or even or odd number, resulting in a serious over-or underestimation of true BP[32,44]. Attempts to minimise observer variation have been made by the use of Hawksley zero muddler[45] with variable success, but this device is impractical for clinical use. Certain automatic BP instruments are immune to operator variations[5,19] and others such as the Doppler device are less subject to the operator variability.

Occasionally, auscultatory gap (or pause) is a cause of error. During deflation of the cuff the sounds appear (phase 1), disappear, and reappear and disappear (phase V), leaving a fairly large gap without sounds between the systolic and diastolic pressures[15]. If the cuff pressure is increased only to levels within the range of the auscultatory gap, the pressure at the lower end of this silent range may be mistaken for a systolic pressure when, in fact, the true systolic pressure is much higher. The auscultatory gap appears to be caused by venous congestion and is more likely to occur if the cuff pressure is raised and deflated excessively slowly[15]. Palpation of pulse distal to the cuff during inflation or before starting deflation of the cuff will help detect the auscultatory gap. excessive pressure from the leading edge of the stethoscope bell will compress the artery directly and may lower the diastolic pressure by creating artefactual Korotkoff sounds beyond the true diastolic pressure[7].

d-4. ***Occluding cuff***: No matter which noninvasive BP measuring technique is used, proper selection and application of the occluding cuff is essential for accurate results[7,14,15]. The cuff must be of the correct size to transmit (or exert) the same pressure on the underlying arterial wall as the pressure registered on the manometer[4,15]. The cuff selection must be based on the thickness of the extremity in which the BP is being measured[7,10,14]; the length of the extremity is not as important (see below). In addition, the cuff should be long enough to completely or nearly completely encircle the extremity[7], and it should be applied snuggly. Loose application causes a ballooning of the bag with narrowing of the effective cuff surface. This results in a manometer reading which is greater than the pressure around the artery[7,15].

Too small a cuff results in artificially high BP readings[7,14,15,46]. Conversely, too large a cuff may result in lower than true intra-arterial pressure[14,15,46], although the magnitude of deviation from the true pressure is less with a larger cuff than with a small cuff. When BPs were taken using a cuff one size smaller than the cuff size determined from criteria of the AHA[7], systolic and diastolic pressure were greater than the reference pressures by 6-15 and 4-11 mm Hg, respectively[14,46]. BP values obtained with the next larger cuff were 3-6 mm Hg lower than reference pressures for both systolic and diastolic pressures[14,46]. The excessive cuff width affects a greater length of artery, dampening the flow pulse throughout the cuff length, and the resulting energy loss is perceived as a lower systolic pressure[15]. This effect should be less for Doppler determination compared to auscultation.

Importance of cuff selection based on the thickness of the extremity has long been recognised in th adult literature, as early as the turn of the century[15], but paediatricians were slow to accept this principle and kept using the cuff criterion based on the length of the arm. As early as 1901, Von Rechlinghausen recognised the importance of the width of the cuff in relation to the arm circumference and showed that a cuff 10-12 cm wide gave accurate occluding pressures in the adult arm with a circumference of 24 cm. This corresponds to 40-50% of the arm circumference as currently recommended in the adult[7,15]. More recent studies have shown that when the width of the bladder was 40-50% of the circumference, the same as in the adult, indirect BPs accurately reflected intra-arterial pressures in newborns, infants and children[10,19,47]. Forty percent to 50% of the arm circumference is equal to 125% to 155% of the arm diameter (Figure 3). Despite the well-known physical principle[7,15] and above studies which relate cuff selection to the thickness of the arm[10,19,47,48], paediatric textbooks and the NIH Task Forces repeatedly recommended cuff selection based on the length of the arm, either two third[4] or three quarter[3] of the length of the arm. The width of the cuff recommended by both NIH Task Forces[3,4] has not been shown accurately reflect intra-arterial BP measurement. The 3/4 length criteria may be too wide an occluding cuff for the inner length of the arm and may underestimate true BP. Fortunately, the AHA[7] and the working group of the NHBPEP[8]

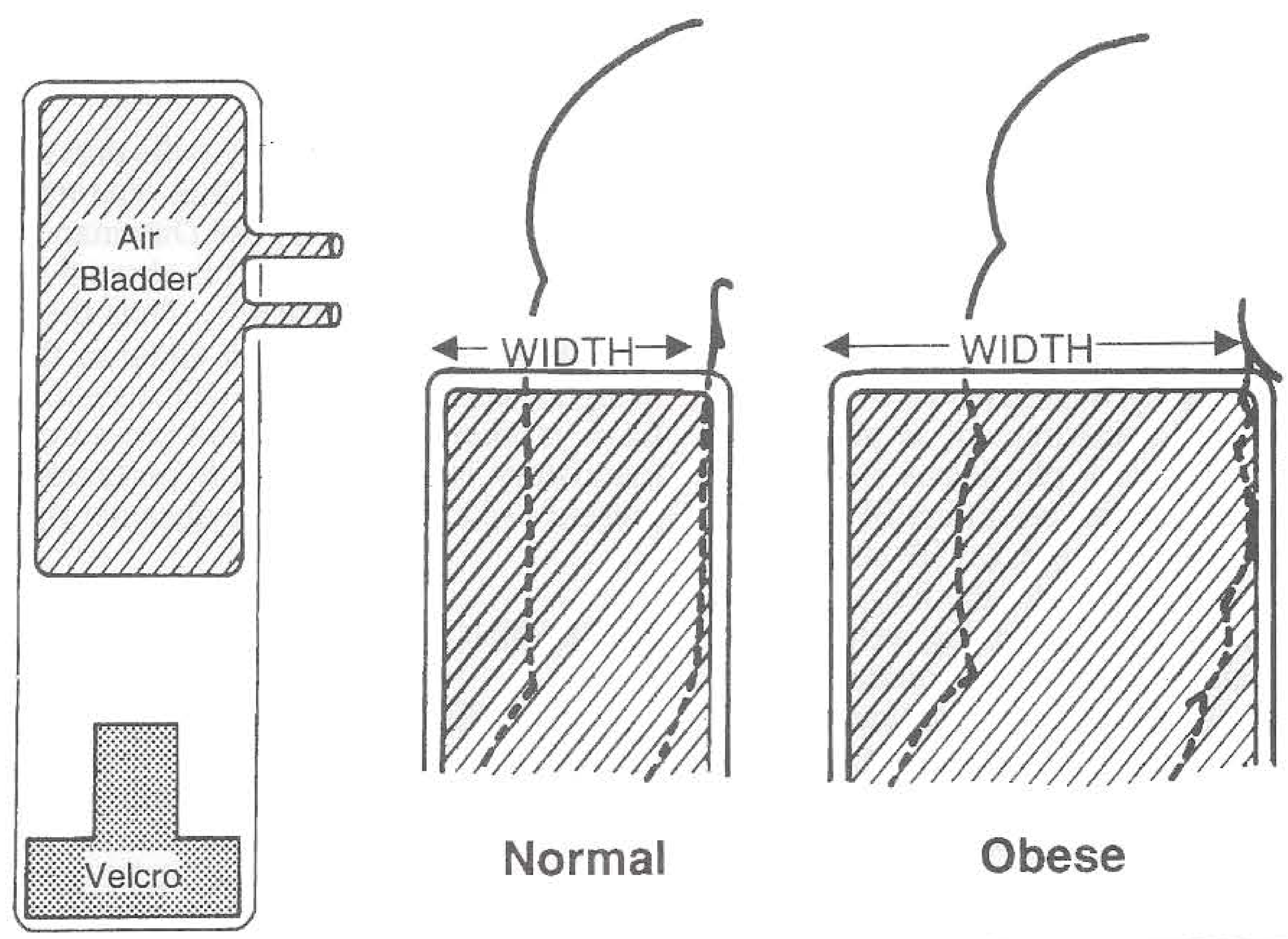

Figure 3. Diagram showing a method of selecting an appropriate-sized BP cuff for children with different thickness of the arm. An obese child (right) requires a wider cuff than a normal child does even when the arm length is the same. The width of the inflatable part of the cuff (bladder, cross-hatched areas) should be 40% to 50% of the

have recently supported earlier recommendations by the authors group[6,10,14,19,28,41] on the selection of BP cuff based on the thickness of the extremities in children, the same as is recommended for the adult.

d-5. ***Circumstances***: Every attempt should be made to obtain BP in a relaxed, nonthreatening situation; basal BP values predict subsequent pressures in the same individual better than do casual pressures[5]. Averaging of several BP measurements provides a more reproducible value[5]; anxiety that accompanies the actual measurement may disappear after several measurements. The environment for BP measurement should be quiet and the temperature maintained at a comfortable level. Other procedures such as blood sampling and exercise tolerance test should not be planned or performed prior to the BP reading.

E. Recommended Normative Blood Pressure Standard

The correct method of BP measurement should be one that has been shown to accurately reflect intra-arterial BP and the normative data should have been obtained by the validated methodology. The correct cuff size is that determined by the circumference of the arm, not by the length. The data to be presented here as the tentative normative BP standard is the only set that has been obtained by the circumference-based BP cuff selection method (Table 4)[43]. In the San Antonio (Texas, USA) Biethnic Children's Blood Pressure Study[43], the author's group measured BPs in over seven thousand school children enrolled in kindergarten through 12th grade, using the cuff with 40 to 50% of the circumference of the arm. Thirty three percent were white children and 67% Mexican American children. Fifty two percent were girls and 48% boys. There were no consistent and/or clinically important differences in BP readings between the two ethnic groups. This finding is in agreement with previous studies[49,50]. Therefore, BP data were combined for both ethnic groups. However, a statistically significant ($P<0.05$) and clinically important gender difference was present in systolic pressure readings for children 13 to 17 years of age[43]. The gender difference for diastolic pressure was not consistent. Although the time of appearance of the gender difference was somewhat variable, similar findings were reported by others[8,49,50]. Therefore, normative BP levels are presented according to gender for children 13 years and older (Table 4).

Table 4. Normative auscultatory blood pressure standards in children and adolescents: Mean (and 90th/95th percentiles)*

Age (yr) and sex	*Systolic pressure*		*Diastolic K4 pressure*		*Diastolic K4 pressure*	
5 (M & F)	92	(102/105)	56	(66/69)	50	(61/64)
6 (M & F)	93	(104/107)	58	(68/71)	53	(64/68)
7 (M & F)	95	(105/108)	60	(70/72)	56	(67/69)
8 (M & F)	96	(107/110)	62	(71/74)	57	(68/71)
9 (M & F)	98	(108/111)	63	(72/75)	57	(69/73)
10(M & F)	100	(110/113)	64	(73/76)	58	(69/72)
11(M & F)	102	(112/115)	64	(74/77)	57	(69/72)
12(M & F)	104	(114/117)	65	(74/77)	57	(69/72)
13 (M)	107	(118/121)	64	(74/77)	56	(68/71)
(F)	105	(114/117)	66	(75/78)	58	(69/72)
14 (M)	110	(121/124)	65	(75/78)	57	(68/72)
(F)	106	(115/118)	66	(75/78)	58	(69/72)
15 (M)	113	(124/127)	66	(76/78)	58	(69/72)
(F)	106	(116/119)	66	(76/78)	58	(69/72)
16 (M)	114	(125/128)	67	(77/80)	60	(71/74)
(F)	107	(117/120)	66	(76/78)	59	(70/73)
17 (M)	114	(125/128)	70	(80/82)	62	(74/77)
(F)	108	(117/120)	67	(76/79)	59	(70/73)

* *Averages of three readings*
M = males, F = females, K4 = phase IV Korotkoff sound, K5 = phase V Korotkoff sound

These data in Table 4 are the averages of three readings, taken in sitting position, avoiding physical exercise or recent meals. The mean of the BP data for each age group is close to those reported by the NIH Task Forces - 1987[3]. The mean systolic pressure of this report is 1 to 4 mm Hg lower than the NIH data. The K4 diastolic pressure is 1 mm HG higher to lower and the K5 pressure is 1 to 3 mm Hg lower than the NIH report. Although the population means of the NIH-1987 data[3] and those of the San Antonio study[43] are close, cuff selection by the length-criteria may result in important differences for individual patients[46,51,52], with some normotensive individuals becoming iatrogenically hypertensive and some hypertensive individuals escaping detection.

F. **General Recommendations for BP Measurement**

If the main purpose of measuring BP in ambulatory practice is to detect primary or secondary hypertension, every child should have a blood pressure measurement as part of the physical examination. In doing so, physicians should pay particular attention to variables which can affect BP readings (Table 3), especially the following areas; (a) BP cuff should be based on the thickness of the arm, not the length; (b) the instrument should be accurate and functioning well, and (c0 the measurement must be made under basal condition as far as possible. When uncontrollable variables exist such as lack of cooperation, fever or medications, they should be recorded.

Before taking a blood pressure measurement, the physician must select the correct size of the cuff; ie. 40 to 50% of the circumference (which equals to 125 to 155% of the diameter) of the limb on which the blood pressure is to be measured[7,8]. The cuff selected by the thickness of the arm compensates for variation in arm thickness. This cuff selection standard applies for children and adults, and provides the continuity of blood pressure levels from childhood to adulthood. A cuff length should be 80-100% of the circumference of the extremity and the cuff should be applied snuggly[7].

The cuff should be inflated until the radial pulse disappears to avoid auscultatory gap and deflated slowly at a rate of 2-3 mm/sec. The phase 1 of the Korotkoff sound is taken as systolic pressure. Some confusion still exists as to which should be taken as the diastolic signal - the point of muffing (phase IV) or the point of disappearance (phase V) of the Korotkoff sounds. The NIH[3] recommends K4 as the diastolic signal in children up to 12 years and K5 for children 13 years and older. Recently, the working groups of the NHBPEP[8] recommended K5, rather than K4, as the diastolic signal for children of all age groups, although this may not receive a wide support. When the points of muffing and of disappearance are more than 6 mm Hg apart, both values should be noted; for example, 110/75/50 mm Hg, where 110 mm Hg is systolic pressure (ie. the phase 1 of Korotkoff sound), 75 mm Hg is the point of muffing, and 50 mm Hg is the point of disappearance. When the points of muffing and of disappearance are less than 6 mm Hg apart, the physician should record phase V as the diastolic pressure. Although there is no single, reliable set of normative blood pressure values obtained by a large epidemiologic study, normative BP data derived from a recent study in San Antonio, Texas (USA)[43] may be used (Table 4). Single measurement commonly practiced may produce BP readings 2 to 4 mm Hg higher than the presented normative standard.

Recently, accuracy of indirect measurement by an oscillometric method (eg. Dinamap model 1846SX) has been demonstrated. The AHA's cuff width recommendation[7] is also appropriate for the Dinamap method. Normative blood pressure levels obtained by the Dinamap method for newborns is found in the text and those for infants and small children are presented in Table 2[28]. There have been questions raised about the reliability of another model such as Dinamap model 8100. This model requires further evaluation. Leg pressures are measured with the patient prone so that the stethoscope can placed on the popliteal artery. The same selection criterion applies for the leg pressure determination; ie. 40 to 50% of the leg's circumference. Even when a considerably wider cuff is selected for the thigh, the systolic pressure in the thigh is 10 to 20 mm Hg higher than that obtained in the arm by the auscultatory method. By the Dinamap method, the systolic pressure in the thigh or calf is about 5 to 10 mm Hg higher than that found in the arm[53]. Thus the systolic pressure in the thigh should be at least equal to that in the arm when using the appropriate cuffs. If the systolic pressure is lower, COA is likely. Thigh blood pressure determinations are mandatory in a child with hypertension in the arm. The presence of a femoral pulse does not rule out a coarctation.

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