Evaluating Anthropometric Indicators: Which is the Best Marker of Blood Pressure in 10 - 15 Years Old Children?
那些體型特徵是評估少年血壓的最佳指標？

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Abstract

The aim of this study was to determine which anthropometric indicator is the best marker of blood pressure in 10 -15 year old children. A one-time cross sectional experimental design was used for this study. A total of 605, 10 - 15 year old males and 640 females were recruited from 44 randomly selected schools in the North-West Province, which formed part of the THUSA BANA study during 2000 and 2001. Anthropometric measurements selected, were primarily those described in Norton and Olds (1996). Blood pressure was measured with the Finapres in a non-invasive way. Data analysis was performed using Statistica 2001 (Stat Soft., Inc) for Windows 98. A forward stepwise discriminant analysis was performed to determine which anthropometric indicator is the best marker of high systolic and diastolic blood pressure in 10 - 15 year old children. According to the results of the discriminant analysis, percentage body fat were the best marker of both high systolic and diastolic blood pressure followed by triceps skinfold and abdomen girth. Prediction models for high systolic and diastolic blood pressure were developed for males and females, using the results of the discriminant analysis. This prediction models had an overall accuracy of 89.25% of predicting high systolic blood pressure and a 90.91% overall accuracy of predicting high diastolic blood pressure.

Key words: Anthropometry, Blood pressure, Children

摘 要

本文旨在探討那些體型特徵是評估少年血壓的最佳指標，共有605男生和640女生年齡由10至15歲參與本研究，作者利用應用統計學方式，嘗試尋找出最理想的指標。

Introduction

Hypertension is currently the second most common form of cardiovascular disease in the USA (Berenson, Wattingney & Weber, 1996). High blood pressure, which can lead to hypertension and coronary atherosclerosis, already starts developing in childhood (Berenson, Wattigney & Weber, 1996).

Children and adolescents who are overweight and obese, have a two times higher risk of developing high blood pressure / hypertension than children and adolescents with a normal body weight (Rocchini, 1993). The relationship between high blood pressure and obesity is well documented and researchers report a direct increase in blood pressure with an increse in obesity (Lurbe, Alvarez, Liao, Tacons, Cooper, Cremades, Torro & Redon, 1998; Vinck, Vlietinck & Fagard, 1999; WHO, 1999). Excessive body fat is the main contributing factor towards an increase in predisposition for hypertension (WHO, 1999).

Currently anthropometric indicators like BMI (body mass index), WHR (waist-hip-ratio), percentage body fat and skinfolds are used to identify health risks like coronary artery disease and hypertension (Norton & Olds, 1996). Various studies have shown a relationship between systolic and diastolic blood pressure and BMI as well as WHR (Chu, Wang & Shieh, 2001; Vinck, Vlietinck & Fagard, 1999; Zwaier, Pakosa, Mueller & Widhalm, 1992).

It has been consistantly shown that body mass or relative weight is a potent predictor of blood pressure among adult populations (Daniels, Obarzek, Barton, Kimm & Similo, 1996; Chu, Wang & Shieh, 2001). Studies in childhod populations have also shown that body mass is a major determinant of blood pressure and appears too be more important than sex, age, ethnic group, dietary intake or physical activity.

Both systolic and diastolic blood pressure were also significantly correlated with height (Chu, Wang & Shieh, 1996; Daniels, Obarzek, Barton, Kimm & Similo, 1996), skinfolds thicknesses and percentage body fat (Sangi & Mueller, 1991; Zwaier, Pakosa, Mueller & Widhalm, 1992).

Early detection and effective treatment of high blood pressure is of utmost importance in preventative and curative medicine. Primary care in childhood and adolescence should aim at preventing or lessening the risk associated with hypertension and at identifying children who is at risk of developing high blood pressure (Gyarfas, 1985). Therefore the aim of this study was to determine which anthropometric indicator is the best marker of blood pressure in children. This information could help with the identification of children at risk of developing high blood pressure or hypertension. This method will especially be usefull during mass screenings.

Method

Study Design and Subjects

A cross-sectional experimental design was used for this study. The subjects of this study consisted of 605 males and 640 females between the ages of 10 and 15 years, from different ethnic backgrounds. The subjects formed part of the THUSA BANA Study (Transition and Health during Urbanization in South Africa; Bana: Children) conducted during 2000 and 2001, and were recruited from 44 schools in the North West Province of South-Africa. Schools were randomly selected from a list of all the schools in the province. Subjects between 10 and 15 years were also randomly selected from class lists, proportionate to each ethnic group in the South African population. Informed consent was obtained from the subjects and their parents, and the Ethics Committee of the Potchefstroom University, South Africa approved the study.

Data Collection

Anthropometric measurements were done by qualified anthropometrists, according to standard methods as described by Norton and Olds (1996). Stature, body mass, triceps, subscapular, supraspinale, iliac crest, thigh and calf skinfols, as well as upper arm, abdomen, hip and thigh girths was measured. Stature were measured by means of a stadiometer to the nearest 0.1 cm and body mass were measured with an electronic scale (Precision Health scale) to the nearest 0. 1 kg. Girths were measured with a flexible Lufkin steel tape to the nearest 0.1 cm, while skinfolds were taken with a Harpenden skinfold caliper with a constant jaw pressure of 10 g/mm^2 to the nearest 0.2 mm. Percentage body fat were calculated using the equations of Boileau, Lohmna and Slaughter (1985). The following formula was used to determine body mass index (BMI).

$$(BMI) = \frac{Body\ mass\ (kg)}{Stature\ (m^2)}$$

Blood pressure

For the purpose of this study blood pressure was measured by means of the Finapres ("finger arterial pressure"). The Finapres measures non-invasive continued blood pressure and is based on the method of Penaz (Wesseling, 1990).

Research has proven that the Finapres is an accurate method to determine blood pressure (Imholtz, Wieling, Van Montfrans & Wesseling, 1998). After a rest period of at least 10 minutes a resing blood pressure value were obtained. The blood pressure were seen as resting, if the systolic blood pressure did not vary by more than 10 mmHg in the last minute preceeding the measurement, otherwise the rest period were extended. The data were then saved onto a magnetic band by means of the Kyowa RTP-50A system from were the data were further analysed by means of the Fast Modelflo software program (Wesseling, 1990). The systolic, diastolic and mean blood pressure, aswell as the heartrate were obtained. The average of 10 cardiac cycles were used to determine the resting blood pressure.

Statistical analysis

Statistical analysis were performed using Statistica 1999 (StatSoft, Inc.) for Windows 98. Descriptive statistics of all the 10 - 15 year old males and females were calculated for the relevant variables for this study. A forward stepwise discriminant analysis was applied to determine which variables could best predict high blood pressure in children. The discriminatory power of the classification functions was established using the jack-knifed classification matrix. With the classification matrix children were classified back into the high blood pressure group and the percentage number of children classified back correctly into the high blood pressure group were also determined (see Table 3 and 5).

Results

For the purpose of this study, blood pressure was divided into three groups, namely low, normal and high normal according to the 30th and 70th percentile scale. The population of the THUSA BANA study is unique because no previous data regarding blood pressure of children exist for this population and therefore this classification is not based on health risk according to a specific blood pressure value, but rather is an indication of the distribution of blood pressure within the studied population. For the purpose of this article, only the prevalence of the high normal group (> 70th percentile) will be discussed. A systolic blood pressure (> 70th percentile) at the females was > 115.0 mmHg and at the males >109. 0 mmHg. A diastolic blood pressure (> 70th percentile) at the females was >72.3 mmHg and at the males > 69.7 mmHg. The prevalence of systolic and diastolic blood pressure > 70th percentile of the total male group were respectively 22.2% and 23.8%, while the prevalence of both systolic and diastolic blood pressure were 22.8% in the female group.

Descriptive and comparative statistics for the 10 - 15 years old males and females are provided in Table 1. The males had a higher mean stature and sitting height in comparison with the girls for both systolic and diastolic (70th percentile) blood pressure groups. Both the females high systolic and diastolic blood pressure groups however, had higher mean values for body mass, percentage body fat, BMI and for all seven skinfolds than the males (see Table 1). The females also had a higher mean gluteal hip girth than the males, while the arm (flexed), abdomen, thigh and calf girth mean values of both the males and females were very much similar.

Table 1. Descriptive Statistics of Anthropometric Variables of the 10 - 15 Years Old Boys and Girls with a Systolic and Diastolic Blood Pressure > 70th Percentile.

Variables	BOYS (N=96)				GIRLS (N=134)			
	Systolic BP (>70th percentile)		Diastolic BP (>70th percentile)		Systolic BP (>70th percentile)		Diastolic BP (>70th percentile)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Stature (cm)	152.4	14.7	151.9	13.3	149.3	12.1	149.7	12.3
Body mass (kg)	42.4	13.4	41.5	11.8	43.1	12.3	42.9	12.7
Body mass index (BMI)	17.9	3.6	17.7	3.4	19.0	3.8	18.8	3.7
Sitting height (cm)	114.4	7.8	114.1	6.9	113.9	6.5	113.8	6.6
Percentage body fat (%)	16.3	7.2	14.8	6.6	23.2	6.7	23.4	6.7
SKINFOLDS (mm)								
Triceps	11.1	6.1	10.0	5.8	14.8	6.9	14.7	6.5
Subscapular	9.0	6.0	8.4	6.0	13.4	9.1	12.9	7.9
Supraspinale	8.3	8.1	7.6	6.3	10.7	6.5	11.0	6.8
Abdominal	10.8	8.2	10.5	8.1	14.9	8.1	15.3	8.2
Frontal thigh	16.8	9.3	15.3	8.5	25.5	11.6	25.7	11.5
Medial calf	12.2	9.5	11.1	7.3	17.8	9.7	17.6	9.3
Iliac crest	9.6	7.2	9.3	7.5	14.2	9.1	14.1	8.8
GIRTHS (cm)								
Arm (flexed)	23.7	3.8	23.4	3.8	23.5	3.6	23.3	3.5
Abdomen	63.5	8.8	62.7	8.4	62.9	8.3	62.4	7.9
Gluteal hip	77.3	10.8	75.9	11.2	82.5	12.4	82.3	12.6
Thigh	43.5	6.4	43.1	6.9	45.2	7.2	44.9	7.2
Calf	29.4	4.4	29.3	4.0	29.5	4.0	29.5	4.2

A forward stepwise discriminant analysis was used to determine which of the 17 variables in Table 1 were the best predictors of high systolic and diastolic blood pressure in 10 -15 year old children.

Table 2. Discriminant Analysis for the 10 -15 years Old Males and Females with a Systolic Blood Pressure > 70th percentile: THUSA BANA Study (n=173).

Forward Selection Summary				
Step	Variable entered	F [a]	P [b]	WL [c]
1	% Body fat	41.73	0.00000	0.60
2	Abdomen girth	18.65	0.00003	0.54
3	Triceps skinfold	19.52	0.00002	0.52
4	Gluteal hip girth	12.20	0.00060	0.54
5	Medial calf skinfold	18.44	0.00003	0.50
6	Arm girth (flexed)	6.98	0.00900	0.50
7	Sitting height	5.13	0.02470	0.49
8	Body mass	1.98	0.16078	0.49
9	Calf girth	2.52	0.24108	0.49
10	Abdominal skinfold	2.62	0.19106	0.49
11	Thigh girth	1.29	0.11843	0.49
12	Iliac crest skinfold	1.02	0.19150	0.49

[a]F (12,173) = 15.372 [b]p<0.000 [c]WL=Wilks' lamda

A subset of 12 variables which discriminated maximally between the high systolic male and female groups were determined by the discriminant analysis. The subset were percentage body fat, abdomen girth, triceps skinfold, gluteal hip girth, medial calf skinfold, arm girth (flexed), sitting height, body mass, calf girth, abdominal skinfold, thigh girth and iliac crest skinfold (see Table 2). According to the statistics in Table 2, percentage body fat (F=43.73, p<0.00), triceps skinfold (F=19.52, p<0.00), abdomen girth (F=18.65, p<0.00) and medial calf skinfold (F=18.44, p<0.00) were the variables that best discriminated between the male and female high systolic blood pressure groups.

The 12 variables determined by the dicriminant analysis were used to create prediction models to classify the children into the high systolic blood pressure groups according to their anthropometric characteristics. The Statistica 2001 (StatSoft, Inc.) package for Windows 98 was used to calculate a model for each gender. The models are as follows:

Male: High systolic blood pressure group = - 448.655 + 2.057 (% body fat) + 3.710 (abdomen girth) + 0.626 (triceps skinfold) - 0.989 (gluteal hip girth) + 0.731 (medial calf skinfold) - 3.558 (arm girth (flexed)) + 7.762 (sitting height) - 5.240 (body mass) + 1.181 (calf girth) - 0.986 (abdominal skinfold) + 1.861 (thigh girth) + 0.042 (iliac crest skinfold)

Female: High systolic blood pressure group = - 455. 897 + 2.584 (% body fat) + 3.433 (abdomen girth) + 0. 228 (triceps skinfold) - 0.805 (gluteal hip girth) + 0.918 (medial calf skinfold) - 3.980 (arm girth (flexed)) + 7.912 (sitting height) - 5.321 (body mass) + 1.001 (calf girth) - 1.092 (abdominal skinfold) + 1.970 (thigh girth) + 0.111 (iliac crest skinfold)

Table 3. The Percentage of 10 -15 Years Old Males and Females that were Classified back into the High Systolic Blood Pressure Groups (> 70th percentile).

Classified back into high systolic blood presure groups			
Group	Percent correct (%)	Male	Female
Male	83.58	56	11
Female	92.44	9	110
TOTAL	89.25	65	121

By means of the prediction model 83.5% of the males and 92.44% of the females (see Table 3), were re-classified into their correct high systolic blood pressure groups.

Table 4. Discriminant Analysis for the 10 -15 Years Old Males and Females with a Diastolic Blood Pressure > 70th percentile: THUSA BANA Study (n=198).

Forward Selection Summary				
Step	Variable entered	F^a	P^b	WL^c
1	% Body fat	81.43	0.00000	0.58
2	Abdomen girth	17.08	0.00005	0.45
3	Triceps skinfold	28.23	0.00000	0.47
4	Medial calf skinfold	9.16	0.00279	0.43
5	Gluteal hip girth	6.43	0.01202	0.43
6	Arm girth (flexed)	8.06	0.00500	0.43
7	Sitting height	8.32	0.00436	0.43
8	Abdominal skinfold	3.24	0.07347	0.42
9	Calf girth	3.23	0.07385	0.42
10	Frontal thigh skinfold	1.11	0.29422	0.41

[a]F (10,198) = 28.053 [b]p<0.000 [c]WL = Wilks' lamda

A subset of 10 variables which discriminated maximally between the high diastolic blood pressure male and female groups were determined by the discriminant analysis. The subset were percentage body fat, abdomen girth, arm girth (flexed), sitting height, abdominal skinfold, calf girth and frontal thigh skinfold (see Table 4).

According to the statistics in Table 4, the anthropometric variables that best discriminated between the male and female high diastolic blood pressure groups were percentage body fat (F=81.43, p<0.00000), triceps skinfold (F=28.23, p<0.00000), abdomen girth (F=17.08, p<0.00005) and medial calf skinfold (F=9.16, p<0.00279).

The 10 variables determined by the dicriminant analysis were used to create prediction models to classify the children into the high diastolic blood pressure groups according to their anthropometric characteristics. The Statistica 2001 (StatSoft, Inc.) package for Windows 98 was used to calculate a model for each gender. The models are as follows:

Male: High diastolic blood pressure group: = - 241.534 + 1.710 (% body fat) + 2.379 (abdomen girth) + 0.007 (triceps skinfold) - 0.042 (medial calf skinfold) - 1.023 (gluteal hip girth) - 5.942 (arm girth (flexed)) + 5.056 (sitting height) - 1.251(abdominal skinfold) - 1.630 (calf girth) + 0.460 (thigh girth)

Female: High diastolic blood pressure group: = - 247. 564 + 2.475 (% body fat) + 2.126 (abdomen girth) - 0.503 (triceps skinfold) + 0.122 (medial calf skinfold) - 0.915 (gluteal hip girth) - 6.372 (arm girth (flexed)) + 5.224 (sitting height) - 1.356(abdominal skinfold) - 1.824 (calf girth) + 0.507 (thigh girth)

Table 5. The percentage of 10 -15 year old males and females that were classified back into the high diastolic blood pressure groups (> 70th percentile).

Classified back into high diastolic blood presure groups			
Group	Percent correct (%)	Male	Female
Male	88.64	78	10
Female	92.56	9	112
TOTAL	90.91	87	122

By means of the prediction models 88.64% of the males and 92.56% of the females (see Table 5), were re-classified into their correct high diastolic blood pressure groups.

Discussion

Epidemiologic studies have consistently shown an association between obesity and blood pressure elevation in children (Sangi & Mueller, 1991; Colditz, 1999 & Daniels, 2001). Various anthropometric indicators are used to identify obesity and health risks like hypertension (Norton and Olds, 1996). A number of 12 anthropometric variables, which best predict high systolic blood pressure and 10 variables that best predict high diastolic blood pressure among both 10 - 15 year old males and females were identified by means of a discriminant analysis. According to the results of this study percentage body fat were the best marker of both high systolic and diastolic blood pressure in 10 -15 year old males and females. It is also known that both systolic and diastolic blood pressure increase with an increase in percentage body fat (Zwaier, Pakosa. Mueller & Wilhalm, 1992).

The second best indicator of both high systolic and diastolic blood pressure in 10 - 15 year old children were triceps skinfold. This is in accordance with existing literature that found an increased risk of hypertension with an increasing triseps skinfold (Cassano, Segal, Vkonas & Weis, 1990; Zwaier, Pakosa. Mueller & Wilhalm, 1992;) Abdomen girth were the third best marker of both systolic and diastolic blood pressure in 10 -15 year old males and females. According to Vinck, Vlietinck and Fagard (1999) abdomen girth (waist circumference) is a probable indication of trunkal body fat distrubution. Cassano, Segal, Vokonas and Weis, (1990) and Lurbe, Alvarez, Liao, Tacons, Cooper, Cremades, Torro and Redon (1998) report that measures of central or upper body fat like abdomen girth, have been positively related to high levels of both systolic and diastolic blood pressure in adults.

It is interesting to note that the same variables namely percentage body fat, triceps skinfold, abdomen girth, medial calf skinfold, gluteal hip girth, arm girth (flexed), sitting height, abdominal skinfold, calf girth and frontal thigh skinfold, were identified as anthropometric markers of high systolic and diastolic blood pressure. Body mass however, was only identified as a marker of high systolic blood pressure and not of high diastolic blood pressure. This is opposing to existing resaerch that found that body mass is a potent predictor of both systolic and diastolic blood pressure (Chen, Rennie & Reeder, 1995). Iliac crest skinfold was also only an indicator of high systolic blood pressure and not of high diastolic blood pressure.

It is interesting that staure (height) was not identified as an marker of high systolic or diastolic blood pressure. According to the iterature, stature (height) has an influence on blood pressure through it's effect on body size (Daniels, Obarzek, Barton, Kimm & Similo, 1996). Sitting height was however identified in this as an marker of both high sysytolic and diastolic blood pressure.

Prediction models for high systolic and diastolic blood pressure were developed, using the results of the discriminant analyses. According to the prediction models (see Tables 3 and 5) 88.64% of males and 92.56% of the females were correctly classified into the high diastolic blood pressure groups, while 83.58% of the males and 92.44% of the females were correctly classified into the high systolic blood pressure groups. The prediction models thus had an overall accuracy of 89.25% of predicting high systolic blood pressure and a 90.91% overall accuracy of predicting high diastolic blood pressure.

Conclusion

Based on the results of this study, it is concluded that percentage body fat seems to be the best marker of high blood pressure in 10 - 15 year old children, followed by triceps skinfold and abdomen girth. This information will be usefull with the identification of children at risk of developing high blood pressure or hypertension, especially during mass healthscreenings

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