The Influence of Cardiac and Vascular Responses on Baseline Cardiovascular Parameters in Black African Children

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Background: The prevalence of hypertension among Black adults in South Africa is high. Because cardiovascular reactivity can be used to predict hypertension in later life, we attempted to determine whether cardiac and vascular responses to a task in Black South African children influence their cardiovascular parameters.

Design: This study was embedded in the Transition and Health during Urbanization in South Africa in Children study, which studied the health status of children. During the study, cardiovascular reactivity was determined with a hand dynamometer in 670 Black African children. Systolic blood pressure, diastolic blood pressure, mean arterial pressure, heart rate, stroke volume, cardiac output, total peripheral resistance, and Windkessel compliance of the arterial system were obtained by means of the Finapres (finger arterial pressure) apparatus and the Fast Modelflow software program. Anthropometric measurements were performed according to standard methods. Cardiac and vascular responders were classified with a regression-based approach.

Results: Cardiac responders had higher stroke volume; a trend to higher cardiac output; lower diastolic blood pressure; and a tendency toward lower systolic blood pressure, heart rate, and total peripheral resistance. Vascular responders showed no significant changes in cardiovascular parameters when responders and nonresponders were compared.

Conclusions: Cardiac responders had higher stroke volume and a trend toward higher cardiac output, which may be an early indication of hypertension. (*Ethn Dis*. 2008;18:187–191)

Key Words: Blood Pressure Reactivity, Cardiovascular, Children

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Introduction

Increased cardiovascular reactivity is a risk factor for the development of cardiovascular diseases,[1] and it may be a critical mediator in the development of hypertension.[2] Cardiovascular reactivity to a task that elicits cardiovascular responses can therefore be used to predict hypertension in later life.[3,4]

By making use of a regression-based approach, subjects can be classified into cardiac and vascular responders according to their cardiac output (CO) and total peripheral resistance (TPR) reactivity to a task that elicits both myocardial and vascular responses.[4] A stressor like the hand dynamometer exercise evokes cardiovascular responses via myocardial influences (of presumably β-adrenergic origin) and also results in changes in vascular resistance (presumably α-adrenergic in origin).[5] A primary β-adrenergic pattern of activation of the sympathetic nervous system is typically characterized by increased CO, cardiac contractility, systolic blood pressure (SBP), and a relatively normal[1] or decreased TPR.[6]

Biobehavioral models suggest that a sympathetic overreaction, such as an elevated β-adrenergic activation pattern, in young persons over a long term leads to changes in the morphologic structure of blood vessels and to chronic elevated blood pressure.[1,6] This early hemodynamic profile undergoes transition with time as β-adrenergic receptors downregulate, resulting in a normal or low CO and high TPR, the characteristic profile of established hypertension in later life.[7,8] Sympathetic overreaction, which starts in childhood, is evident in 30% of patients with incipient hypertension.[9]

Cardiovascular reactivity to a task that elicits cardiovascular responses can therefore be used to predict hypertension in later life.[3,4]

Because the prevalence of hypertension in the Black adult population of South Africa is high,[10] risk factors must be identified in children to predict the possible development of hypertension. In this study, we attempted to determine whether cardiac and vascular responses to a handgrip exercise influence baseline cardiovascular parameters in Black South African children.

Methods

Study Design

This study was embedded in the THUSA BANA (Transition and Health during Urbanization in South Africa in children; *bana* means "children" in the Setswana language study which was designed to assess the relationship between the level of urbanization and the health status of children in North West Province of South Africa. Thirty schools that enrolled African children were randomly selected from a list of schools in the five regions of North West Province. These schools were visited during the weeks preceding data collection to obtain permission from the school principals and the children's parents. The study took place from 2000 through 2001.

Participants

African boys and girls from 10 to 15 years of age were randomly selected from class lists. These 670 children included 297 boys and 373 girls. The ethics committee of North-West University approved the study, and all the students' parents gave informed consent.

Data Collection

Data collection took place during school hours (7:00 AM to 1:00 PM). Finapres (finger arterial pressure) was used to measure blood pressure.[11,12] Finapres is not recommended to assess absolute blood pressure levels, but it can track blood pressure responses and was preferable to invasive blood pressure measurement in our young sample.[13]

Each child's blood pressure was recorded continuously in a sitting position. After a 10-minute rest period, baseline blood pressure values were obtained. Blood pressure was considered to be at baseline when SBP did not change by >10 mm Hg during this period; otherwise the rest period was extended for another five minutes. The baseline blood pressure was then recorded for one minute. The hand dynamometer was used as a laboratory stressor[5] to challenge the cardiovascular system for one minute. Each participant pressed the hand dynamometer at 50% of his or her maximum (established before measurement), and data were computed with the Fast Modelflow software program. The Modelflow method digitally computes an aortic-flow waveform from a peripheral arterial pressure signal. It uses a nonlinear three-element model (Windkessel) of the aortic input impedance that consists of aortic characteristic impedance, arterial compliance, and peripheral vascular resistance.[14] In this way SBP, diastolic blood pressure (DBP), mean arterial pressure (MAP), pulse pressure (PP), heart rate, stroke volume, CO, TPR, and Windkessel compliance were obtained. Anthropometric measurements were performed according to standard methods.[15]

The hand dynamometer task elicits myocardial and vascular responses, and children were classified into cardiac and vascular responders with a regression-based approach.[4] The children's CO and TPR reactivity data were used to determine the y-intercept from the linear regression of the CO reactivity as a dependent variable and alternatively the TPR reactivity as dependent variable. An intercept value of .8 was used as the cutoff point for classification into CO and TPR responders and nonresponders. A change in reactivity <.8 was regarded as nonresponder, and a change in reactivity >.8 was regarded as a responder. After classification of the children into cardiac and vascular responders and nonresponders, baseline cardiovascular parameters were compared.

Table 1. Descriptive statistics of 670 children from North West Province, South Africa

	Boys (*n*=297)	Girls (*n*=373)
Parameter	Mean (95% CI) ± SD	Mean (95% CI) ± SD
Age (years)	12.5 (12.3–12.6)±1.7	12.4 (12.2–12.6)±1.8
BMI (kg/m^2)*	16.6 (16.3–16.9)±2.6	18.0 (17.7–18.4)±3.6
SBP (mm Hg)*	98.8 (97.0–100.0)±14.0	104.0 (103.0–106.0)±14.3
DBP (mm Hg)*	63.8 (63.0–65.0)±10.1	65.9 (65.0–67.0)±9.9
MAP (mm Hg)*	79.3 (78.0–81.0)±10.7	83.1 (82.0–84.0)±10.9
HR (beats/minute)*	79.2 (78.0–81.0)±11.8	85.6 (84.0–87.0)±11.8
SV (mL)	34.0 (33.0–36.0)±13.1	34.8 (33–36)±13.4
CO (L/min)*	2.6 (2.5–2.8)±1.0	2.9 (2.8–3.0)±1.1
TPR (mm Hg/mL)	2.2 (2.1–2.4)±1.2	2.1 (2.0–2.1)±.8
Cw (mL/mm Hg)	1.1 (1.0–1.1)±.4	1.0 (.98.0–1.1)±.4

CI = confidence interval, SD = standard deviation, BMI = body mass index, SBP = systolic blood pressure, DBP = diastolic blood pressure, MAP = mean arterial pressure, HR = heart rate, SV = stroke volume, CO = cardiac output, TPR = total peripheral resistance, Cw = Winkessel compliance.
* Significantly different at the $P<.05$ level.

Statistical Analysis

All processed data were statistically analyzed with STATISTICA, version 7 (Statsoft, Inc., Tulsa, Okla).[16] A *t* test for unequal group sizes was applied to obtain significant differences between groups (boys and girls). A covariance analysis was performed, and values were adjusted for body mass index to obtain significant differences between parameters for responders and nonresponders.

RESULTS

Table 1 shows the baseline measurements of the cardiovascular parameters for both boys and girls, describing the profile of the children used in the study. The average age was 12.5 years for the boys and 12.4 years for the girls.

Table 2 shows the cardiovascular parameters for both African boys and girls after the hand dynamometer task was applied.

From Figure 1 it is evident that the cardiac responders had significantly lower DBP and MAP than did nonresponders. In girls, cardiac responders had significantly lower baseline SBP than did nonresponders, and this difference trended toward significance in boys. Stroke volume was higher in all cardiac responders than in nonresponders, and heart rate trended to be lower in cardiac responders, but the difference did not reach significance in either boys or girls.

In Figure 2, Cw (compliance) was higher in cardiac responders, and CO had a tendency to be higher. In girls the TPR is significantly lower, while in boys the TPR tends to be lower in the cardiac responders.

No significant differences in cardiovascular parameters were seen between vascular responders and nonresponders (results not shown).

DISCUSSION

We found increased stroke volume and CO, reduced vascular resistance,

Table 2. Hemodynamic parameters after hand dynamometer task in 670 children from North West Province, South Africa

Parameter	Boys	Girls
	Mean (95% CI) ± SD	Mean (95% CI) ± SD
SBP (mm Hg)	125.0 (123.0–126.0)±16.3	128.0 (126.0–129.0)±15.4
DBP (mm Hg)	86.0 (84.0–87.0)±12.2	86.0 (85.0–87.0)±11.2
MAP (mm Hg)	103.0 (102.0–105.0)±13.2	105.0 (104.0–107.0)±12.4
HR (beats/minute)	101.0 (99.0–103.0)±14.9	106.0 (105.0–108.0)±14.2
SV (mL)	34.0 (32.0–35.0)±14.1	34.3 (33.0–36.0)±13.2
CO (L/min)	3.3 (3.1–3.5)±1.4	3.5 (3.4–3.7)±1.4
TPR (mm Hg/mL)	2.4 (2.2–2.5)±1.2	2.3 (2.1–2.4)±1.1
Cw (mL/mm Hg)	.9 (.9–1.0)±0.3	.9 (.9–1.0)±.3

CI = confidence interval, SD = standard deviation, SBP = systolic blood pressure, DBP = diastolic blood pressure, MAP = mean arterial pressure, HR = heart rate, SV = stroke volume, CO = cardiac output, TPR = total peripheral resistance, Cw = Winkessel compliance.

and consequently a decrease in DBP in South African children who were cardiac responders. These results likely indicate a sympathetic stimulatory effect, and other researchers have found that SBP may increase as a result of increased cardiac output[17] or stroke volume. In our study, CO tended to be higher, stroke volume increased significantly, but SBP did not increase. Mathews et al[18] evaluated the stability of hemodynamic responses to tasks in a multiethnic sample of 8- to 10-year-old children and 15- to 17-year-old adolescents. Their results showed that hemodynamic responses, although they change with aging, can be measured reliably during childhood and adolescense.[18]

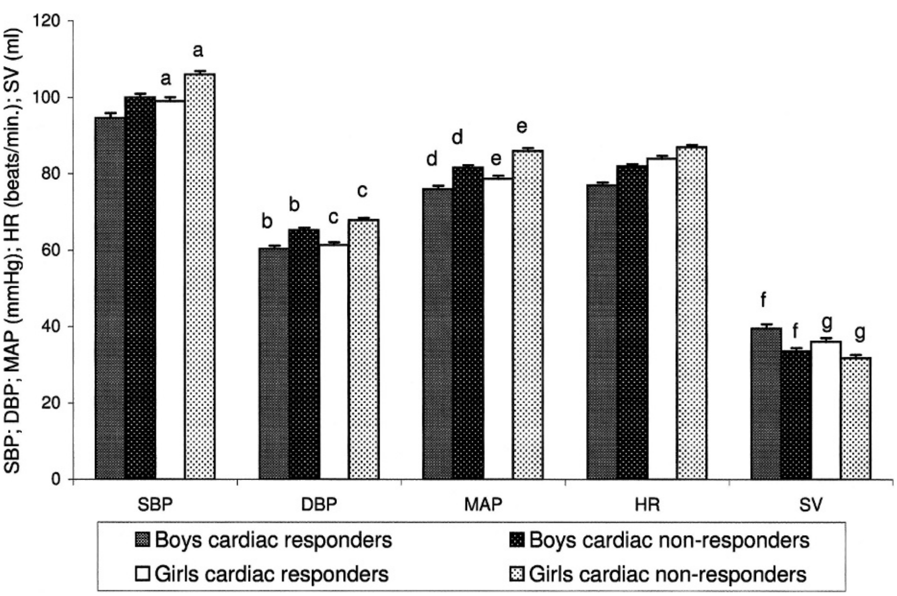

Fig 1. Baseline cardiovascular parameters of cardiac responders and non-responders namely systolic, diastolic and mean arterial pressure (SBP, DBP and MAP), pulse pressure (PP), heart rate (HR) and stroke volume (SV). A regression based approach to cardiovascular changes after the hand dynamometer task was used to classify the African children into cardiac responders and non-responders. Error bars indicate standard error of mean. Bars with same superscript letter differ significantly (*P*≤.05)

The incidence of increased blood pressure among these children was 11% (boys) and 19% (girls).[19] The cardiac responders had signs of a hyperkinetic circulatory state[7] as seen by the higher stroke volume and slightly higher CO, and this factor may be a mediator in the development of hypertension and cardiovascular disease (CVD).[2] The development of early hypertension in younger people can be mediated by increases in either CO or TPR, while hypertension in older people is characterized by an increase in TPR,[20] as has been found in African adults.[21] An initial state of myocardial activation (high cardiac output) may progress to a state of increased peripheral resistance.[7,8]

Sympathetic overreaction may therefore be a precursor for future cardiovascular health events. If cardiovascular hyperactivity persists over time, it may lead to hypertension,[20] and evaluation should be made at an early age. The prevalence of CVD among Blacks is high in South Africa,[10] and if children at risk can be identified early, CVD could be prevented.

An increase in CO and a decrease in TPR is typical of the early development of volume-loading hypertension.[22] The slightly higher CO and lower TPR seen in these children may be an early indicator of volume-loading hypertension and may help to explain the development of hypertension in later life.

To conclude, it was found that the cardiac responders showed a significantly higher SV and tendency of a higher CO, indicating a hyperkinetic circula-

The prevalence of CVD among Blacks is high in South Africa,[10] and if children at risk can be identified early, CVD could be prevented.

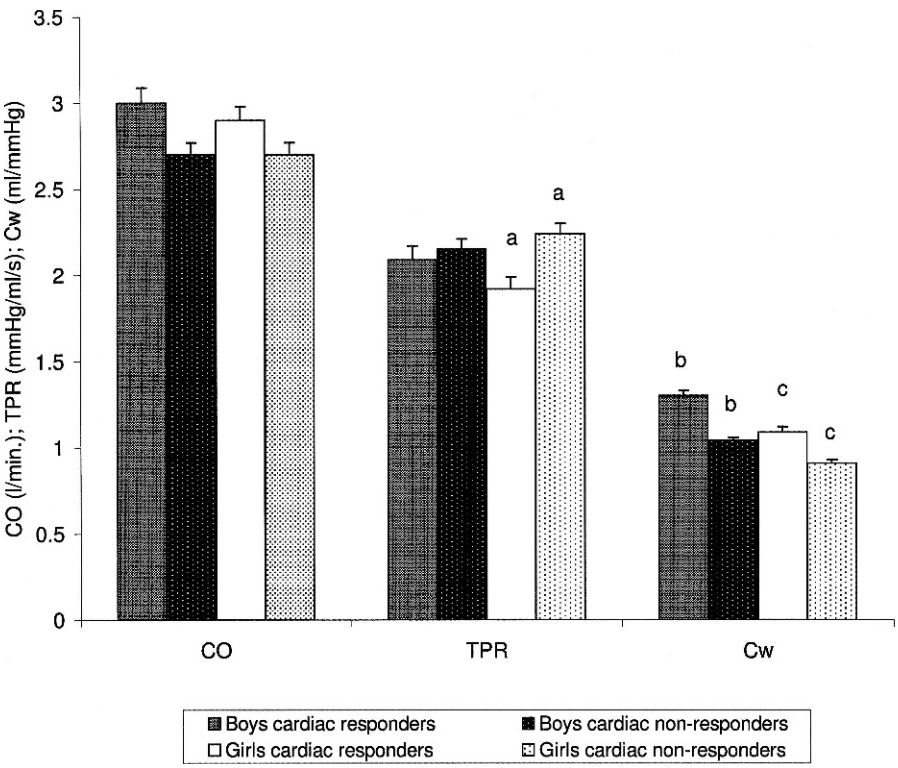

Fig 2. Baseline cardiovascular parameters of cardiac responders and non-responders, namely cardiac output (CO), total peripheral resistance (TPR) and compliance (Cw). A regression based approach to cardiovascular changes after the hand dynamometer task was used to classify the children into cardiac responders and non-responders. Error bars indicate standard error of mean. Bars with same superscript letter differ significantly (*P*≤.05)

tory state which influenced the baseline cardiovascular parameters and this may be an early indication of the development of hypertension.

ACKNOWLEDGMENTS

We thank the THUSA BANA research team and Professor H.S. Steyn of the Statistical Consultation Service of North-West University, Potchefstroom Campus. We also thank those who have funded the study: The South Africa Sugar Association, the Medical Research Council of South Africa, North-West University, Hypertension Society of South Africa, and Department of Trade and Industry through the Technology for Human Resources and Industry Programme.

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