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ORIGINAL ARTICLE

Heart Rate Recovery after Maximal Exercise and the Risk of Cardiometabolic Disease in Nigerian Adolescents

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ABSTRACT

Objective: This study assessed the association of one minute heart rate recovery (HRR_1) following progressive aerobic cardiovascular endurance run (PACER) with CVD risk factors in 12 to 16 year Nigerian adolescents.

Study Design: A cross-sectional school-based study comprising 454 school children.

Place and Duration of Study: The study was conducted in three senatorial districts of Benue State, north central Nigeria between April and July 2013.

Material and Methods: Participants were evaluated for physical characteristics, cardiorespiratory fitness, waist circumference, blood pressure, and HRR_1 after PACER test. They were divided into abnormal versus normal HRR_1 groups. **Results:** Prevalence of abnormal HRR_1 was 23.8% among participants, with boys displaying higher risk (12.3%). A greater proportion of participants were at risk of elevated SBP and DBP, majority from the abnormal HRR_1 group. Fitness (β =.277; p<0.0005) and SBP (β =-269; p=0.007) independently predicted HRR_1.

Conclusion: Among Nigerian adolescents, HRR_1 is associated with cardiometabolic disease (CMD) risks, suggesting a link between CMD and autonomic nervous function at early age. One minute heart rate recovery may be useful for identifying children at risk of CMD risk factors.

Key Words: *Autonomic nervous system, Cardiovascular disease risk factors, Health promotion, Youth*

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INTRODUCTION

Cardiovascular disease (CVD) is a major cause of mortality and disability in adults, independent of traditional risk factors in both western societies and the developing world.[1,2] It is generally recognized that CVD is partly a pediatric problem, even though the clinical symptoms of the disease manifests much later in life. Because the incidence of morbidity and mortality related to the CVD is rather low in the pediatric population, studies investigating the relationship between other health indices and cardiovascular function in children and adolescents are therefore mostly limited to CVD risk factors as dependent measures.[3,4]

Attenuated first minute heart rate recovery (HRR_1) after cessation of exercise has been recently described as a CVD risk factor, and a likelihood of increased risk of death and leading cause of mortality in adults independent of the traditional risk factors.[1,2] Heart rate recovery(HRR) (speed at which heart rate decreases after cessation of moderate to severe exercise) is influenced by vagal reactivation.[5] It has been observed that slower HRR after termination of exercise is linked to metabolic syndrome (MS) and risk of CVD in young adults and the elderly.[6-8] In addition, HRR is an independent predictor of adverse cardiovascular outcomes affecting the cardiometabolic health of both children and adults.[3,9] Previous studies have documented that derangement in the autonomic nervous system (ANS) such as parasympathetic withdrawal is associated with poor aerobic fitness, elevated heart rate (HR), blood pressure (BP), abdominal obesity, and insulin resistance among other abnormalities like the MS.[6,7] In a study involving 1276 boys and girls (mean age:11.5 years), Simhaee et al.[3] reported that the least fit (as measured by HRR) children had higher body mass index (BMI), low density lipoprotein cholesterol (LDL-C), and low high density lipoprotein cholesterol (HDL-C) when compared to their most fit peers. They concluded that among middle school children, HRR may prove useful in identification of children at increased risk for CVD risk factors.

Research in adults has indicated that lower HRR after exercise is associated with increased CVD risk,[1,10] but the relationship of HRR_1 after cessation of exercise with CVD risk has not been fully explored in the pediatric population. Moreover, several previous studies evaluating the association of HRR with cardiometabolic disease (CMD) risks were mostly laboratory based.[11,12] which required expensive equipment, technical personnel and difficulty to extend the findings to the wider population because of small sample sizes. There is paucity of population-based data on this problem. This study therefore examined the relationship between HRR_1 after the progressive aerobic cardiovascular endurance run (PACER) test and the cardiorespiratory fitness (CRF), abdominal adiposity and BP in Nigerian adolescents. We hypothesized that slower HRR_1 in adolescents would be associated with unfavorable CVD risk factors.

MATERIAL AND METHODS

Study design, setting and participants: This was a cross-sectional descriptive study conducted among 462 school children aged 12 to 16 years in three selected senatorial districts in Benue State, Nigeria. Benue state, with its capital in Makurdi, is located in the middle belt region of Nigeria. The predominant tribes are the Tiv, Idoma, Igede and Etulo. We applied a multistage and systematic sampling procedure to select adolescents from 24 schools in the State. Details of the sampling procedures have been previously described.[13] This study was conducted between April and July 2013.

The ethics review board of Benue State University approved the study protocol. Informed consent was obtained from parents and assent was sought from minors prior to data collection. The study was conducted according to the ethical guidelines of the Helsinki declaration.

Physical Characteristics Measurements: Anthropometric measurements followed a standard procedure.[14] Body mass was measured in light clothing without shoes and socks using a calibrated digital electronic weighing scale (Sec-880, Seca, Birmingham, UK) to the nearest 0.1 kilogramme. Stature was measured with a calibrated vertical stadiometer (model sec-206; Seca, Birmingham, UK) to the nearest 0.1 centimetre. To estimate body fatness, body mass index ($kg.m^{-2}$) was calculated by dividing the body mass in kilogramme by the stature in meter-square (m^2). We measured waist circumference (WC) with a Lufkin non-extensible flexible anthropometric tape (W606PM, Rosscraft, Canada,) to the nearest 0.1 centimetre, and used to estimate abdominal fat.[15] Details of the measurement procedure have been previously described.[13]

Cardiorespiratory Fitness Testing: The progressive aerobic cardiovascular endurance run (PACER) was used to measure CRF. It is a multistage aerobic capacity test adapted from the 20-meter shuttle run test, with progression in the intensity of the race between two lines drawn 20 meters apart. Participants were instructed to run until exhaustion while they were given verbal encouragement throughout the test. Participants ran in line with the audio signals from the PACER compact disc (CD). Participants who failed to complete two successive shuttles were withdrawn from the test. We estimated CRF by the recorded laps completed by participants. Details of the administrative procedure of this test and procedure for classification of participants into healthy fitness zone (HFZ) or high fitness and unfit or low fitness based on FITNESSGRAM revised data[16] have been described elsewhere.[13]

Blood Pressure Measurement: Blood pressure was measured on the right arm, using a digital BP monitor (HEM-705 CP; Omron, Tokyo, Japan). Participants were made to sit comfortably with legs uncrossed and feet resting on a firm surface. Measurements were taken after the participants have rested quietly for at least 10 minutes. Systolic (SBP), diastolic pressure (DBP) and pulse rate were consecutively measured twice for each participant and their mean recorded. Specific details of the BP protocol have been described.[13]

Heart Rate Measurement: Heart rate (HR) was measured while participants were seated after 10 minutes of rest. Finger Pulse Oximeter (Baseline 12-1926 Fingertip pulse Oximeter, Fabrication Enterprises Inc. NY, USA) was used to measure baseline HR. As soon as participants completed the PACER test, they were requested to sit down on a bench and immediate post-exercise HR was recorded. One minute HR recovery was determined using the same protocol as with the baseline pulse rate in one minute immediately after test termination. HRR_1 was calculated as the decrease of HR during one minute of recovery. An abnormal value for HRR_1 was defined as a 25th percentile value of participants' HRR_1[11]. Throughout the duration of data collection, the same members of the research team administered the tests in the same order to ensure consistency.

Statistical Analysis: Frequencies and percentage distributions were used to indicate prevalence of CMD risk abnormalities in participants. Data were also presented as means and standard deviations. Independent samples t-test was used to compare the physical characteristics and CMD risk abnormalities between abnormal and normal HRR_1 categories. The Pearson's Product Moment correlation statistic was used to assess the relationships among HRR_1 and the cardiometabolic risk factors. We applied multiple regression analysis to determine the association of HRR_1 with the independent variables. The IBM-SPSS software (Windows Version 20: SPSS Inc, Chicago, IL) was used to analyse the data. The level of significance was set at 0.05 or less.

RESULTS

Physical and Physiological Characteristics: Of the 462 participants recruited, 8 had incomplete information; therefore, 454 participants (98.3%) were included in the analysis. Table 1 presents physical and physiological characteristics of the participants across HRR_1 status. In general, 23.8% of participants displayed abnormal HRR, with the prevalence higher in males (12.3% vs. 11.5%). Participants with normal HRR_1 demonstrated significantly ($p<0.05$) faster HRR_1, slower HR_{rest}, better fitness and lower DBP than their counterparts with abnormal HRR_1.

TABLE 1: Physical characteristics and cardio metabolic disease risk factors in Children by HRR_1 Status (n = 454)

Variable	$HRR_1<P_{25}$ (n=108)	$HRR_1>P_{25}$ (n =346)	t-value	*P*
Sex (M/F)	56/52	168/178		
Age (y)	10.3 ± 0.8	10.2 ± 0.8	0.33	0.74
Stature (cm)	136.8 ± 8.5	139.2 ± 9.7	1.54	0.13
Body mass (kg)	33.9 ± 7.0	34.5 ± 7.9	0.50	0.62
BMI ($kg.m^{-2}$)	18.0 ± 2.4	17.8 ± 3.4	0.36	0.72
WC (cm)	63.0 ± 8.7	61.9 ± 8.3	0.81	0.42
PACER (lap)	31.4 ± 18.0	38.5 ± 19.8	2.23	0.027
SBP (mmHg)	110 ± 17.5	108.1 ± 16.3	0.68	0.50
DBP (mmHg)	73.8 ± 14.5	70.2 ± 15.4	1.46	0.15
HRR_1 ($b.m^{-1}$)	10.2 ± 4.8	42.4 ± 18.7	11.92	0.0005
HR_{pre}($b.m^{-1}$)	101.3 ± 14.9	84.0 ± 12.6	8.06	0.0005

Abnormalities of cardiometabolic disease risk: The frequencies and percentage distribution of participants in different HRR_1 categories considered to be at risk of CMD are presented in fig 1. As expected, there were higher proportions of adolescents in the abnormal HRR_1 with elevated SBP and DBP compared with their peers with normal HRR_1. The participants from both groups had similar proportions of those with elevated abdominal adiposity and low fitness.

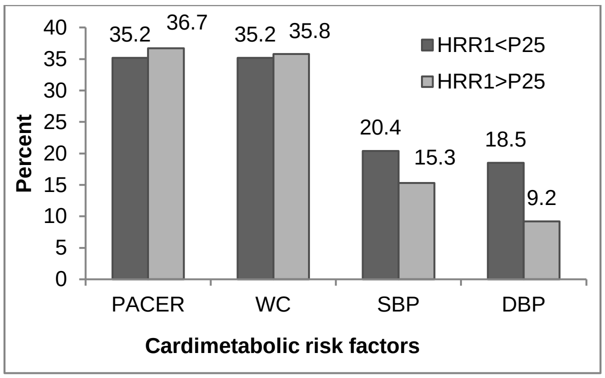

Fig 1: Proportion of adolescents with CMD risk abnormalities

The frequencies and percentage distribution of participants by chronological age are presented in table 2. Higher proportion of participants with abnormal HR condition demonstrated elevated SBP and DBP compared to their peers with normal HR recovery. However, the patterns in elevated abdominal adiposity and low fitness were not consistent across age levels. For instance, in abdominal adiposity, adolescents aged 13 and 14 years displayed results in which higher proportions of participants with normal one minute recovery HR had poorer profile than their peers with abnormal HRR_1. Similarly, adolescents aged 15 years demonstrated low fitness results in which those with abnormal conditions had lower proportion than their peers with normal condition. Overall, the differences are not substantial (table 2).

TABLE 2: Proportion of cardiometabolic disease risk abnormalities by chronological age and HRR_1Status (n = 454)

Age	N	PACER		WC		SBP		DBP	
		$<P_{25}$	$>P_{25}$	$<P_{25}$	$>P_{25}$	$<P_{25}$	$>P_{25}$	$<P_{25}$	$>P_{25}$
12	106	5 (20.0)	16 (19.8)	8 (32.0)	27 (33.3)	2 (8.0)	8 (9.9)	3 (12.0)	6 (7.4)
13	112	14 (42.5)	31 (39.2)	12 (36.4)	36 (45.6)	5 (15.2)	11 (13.9)	4 (12.1)	10 (12.7)
14	113	12 (36.4)	27 (33.8)	13 (39.4)	34 (42.5)	9 (27.3)	10 (12.5)	7 (21.2)	3 (3.8)
15	84	5 (38.5)	29 (40.8)	4 (30.8)	20 (28.2)	5 (38.5)	13 (18.3)	5 (38.5)	8 (11.3)
16	39	3 (75.0)	24 (68.6)	1 (25.0)	7 (20.0)	1 (25.0)	11 (31.4)	1 (25.0)	5 (14.3)

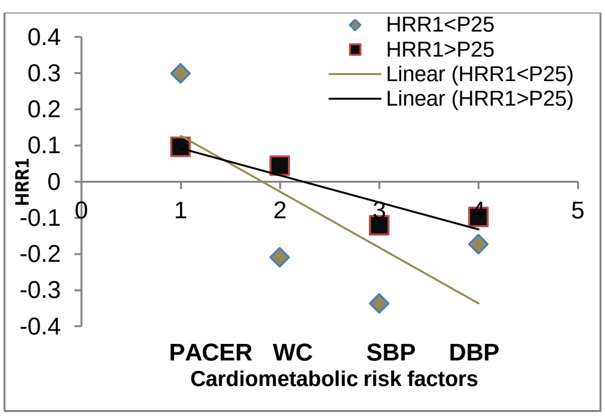

Fig 2: Correlation between HRR_1 and cardiometabolic risk factors

Univariate Relationship: The zero-order correlation coefficients between HRR_1 and cardio-metabolic risks (fig 2) shows the relationships were generally stronger among participants with abnormal HRR_1 than those with normal HRR_1. The SBP had the strongest relationship with the dependent variable.

Predictors of HRR_1: Multivariate linear regression model was computed using pre-exercise CMD risk factors: PACER, WC, SBP and DBP as independent variables predicting HRR_1. Results showed that in participants with abnormal HRR_1, only SBP (β =-0.269, p=0.007) and PACER (β = 0.277; p = 0.019) independently predicted HRR_1. The model explained 19.5% of the variance in HRR_1 ($F_{4,107} = 4.93$; $p<0.0005$). In participants with normal HRR_1, the model only explained 4.3% of the variation in the dependent variable ($F_{4,345} = 3.022$; $p = 0.011$) with only SBP (β = -0.136; p = 0.026), making a unique contribution to the model.

DISCUSSION

In the present study, we documented prevalence of abnormal HRR_1 of 23.8% among participants. This rate looks high, and is comparable to approximately 22% observed in a cohort of 480 American adolescents from high socioeconomic background[17]. In this study, participants with normal one-minute recovery HR displayed more favorable HR_{rest}, HRR_1 and DBP than their peers with abnormal data. These findings are consistent with those of previous studies.[11,18] Singh and colleagues[11] documented the association of baseline HR among other variables with first minute HRR among children. In addition, Castner et al.[18] study reported HR decrease is not only associated with an elevated adiposity but low CRF, resting HR and other autonomic dysfunction. Our findings also support results of studies in obese children.[6,12,19]

To a large extent, decreasing levels of post-exercise HR were associated with unfavorable CMD risks in the participants (table 2 and fig 1). For instance, 20.4% of participants with abnormal HRR had elevated SBP compared to 15.3% of their peers with normal HRR. The same trend was noted for the DBP. Comparable trends were also observed with the age levels (table 2) except for some inconsistencies with low fitness and abdominal adiposity. Our findings are consistent with those of studies in other populations of children and adolescents.[3,20] Our findings are also supported by data from studies in adults[7,21] which reported slower HRR to be associated with elevated BP among other CVD risk factors.

Our findings indicate that SBP and fitness were the only predictors of HRR_1 in participants. Our results are supported by data from the Chilean children[19] in which one minute HRR was associated with low fitness among other findings. This is important particularly with regard to low fitness and suggests that lifestyles that lead to better physical endurance may result in faster HRR_1 early in life. The fact that the association of HRR_1 with the CMD risks, especially SBP and fitness are stronger in adolescents with abnormal HRR suggests that this group should be the target for programs aimed at reducing blood pressure and increasing fitness among this population.

The findings of this present study demonstrate that abdominal adiposity was not a good predictor of one-minute HRR. The finding is supported by those of Hanifah et al.[22] study comprising 1071 healthy Malaysian adolescents aged 13 years which found WC predicted only two-minute HRR but not one-minute post-exercise HR in boys. In contrast, Yu et al.[9] reported WC to be a predictor of HRR_1 in boys. The inconsistencies in the findings of these studies could be attributed to the different measurement techniques and methodological approaches that exist among studies. Another probable explanation could be linked to the normal WC values observed among our sample. There was no significant (p>0.05) difference in abdominal fat between participants with abnormal and normal one-minute HR recovery.

Our findings are in support of previous studies in children and young adults which have found slower HRR to be associated with MS and its components.[6,7,9] The findings of our study suggest that to minimize metabolic risks in this population, intervention should target reduction in blood pressure and increase aerobic fitness among youth particularly those with abnormal one-minute HRR.

The results of this current study clearly showed that correlations between HRR_1 and CMD risks were generally weak but higher in youth with abnormal recovery HR, particularly those in low fitness and elevated BP categories. These results are instructive, and emphasize the need to identify this group of youth for the purpose of early prevention of CMD risks through appropriate strategies such as increasing fitness and reducing blood pressure.

One obvious limitation of the study was its cross-sectional design, which precludes determination of causality. Besides, we could not assess sexual maturity, a variable known to have an influence on fitness in adolescents. Not with standing these limitations, the present study provides useful information for future comparative studies concerning heart rate recovery after maximal exercise and the risk of cardiometabolic disease in Nigerian adolescents. We believe such information would be relevant in designing interventions to address the cardiometabolic health of adolescents, at least in this setting.

CONCLUSION

This study has shown there is association between delayed one-minute HRR and CMD risks in Nigerian children. The relationship between HRR_1 and the metabolic risks is stronger in participants with abnormal than those with normal recovery HR. Low fitness and high BP are the major determinants of one-minute recovery particularly in children with abnormal HRR_1. Measurement of one-minute HRR is recommended as part of the cardiovascular risk assessment of adolescents.

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Conflict of Interest: The authors have no conflict of interest.

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