Relation of fitness and fatness with heart rate recovery after maximal exercise in Nigerian adolescents

Running title: Heart rate recovery in children

*Danladi I. Musa[1] , Abel L. Toriola[2], Makama A. Monyeki[3] and Craig A. Williams[4]

[1]*Department of Human Kinetics and Health Education, Kogi State University, Anyigba, Nigeria.*

[2]*Department of Sport and Rehabilitation and Dental Sciences, Tshwane University of Technology, Pretoria, Republic of South Africa*.

[3]*Physical Activity, Sport and Recreation Focus Area, North-West University, Potchefstroom 2520, South Africa.*

[4]*Children's Health and Exercise Research Centre, Sports and Health Sciences, University of Exeter, United Kingdom.*

*Corresponding author

Danladi I.Musa Ph.D.

Dept. Of Human Kinetics and Health Education, Kogi State University, Anyigba, Nigeria

E-mail: dimusaa@yahoo.com

Telephone: +2348033439322

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Tables 5

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Abstract

Purpose: Heart rate recovery is an independent risk factor for adverse cardiovascular events and overall mortality. While the prognostic value of delayed Heart rate recovery following cessation of exercise is well documented, relationship of aerobic fitness and fatness with heart rate recovery among youth is less clear. We hypothesized that a delayed fall in heart rate after a progressive aerobic cardiovascular endurance run (PACER) test might be due in part to the effects of fitness and overall adiposity.

Methods: A total of 454 adolescents (224 boys and 230 girls) ages 12 to 16 years were evaluated for fitness, body fatness, baseline heart rate and one minute recovery heart rate (HRR_1) after a PACER test. The participants were further divided into fit-fat groups to assess the influence of both fitness and fatness on HRR_1. Regression models assessing the associations of the independent variables with HRR_1were conducted.

Results: Fatness was the only independent predictor of HRR_1 in boys but not girls. Combined fitness and fatness in predicting HRR_1 was modest (R^2=3%). One minute HRR scores varied by fit-fat groups, the fit/Healthy Weight group demonstrated the most favorable HRR_1 recovery profiles while the unfit/overweight group showed the most adverse profiles.

Conclusions: Body fatness but not aerobic fitness was a better predictor of HRR_1 in boys but not girls. Youth with higher aerobic fitness and Healthy Weight had more favorable HRR_1 profiles than their unfit/Overweight peers.

Key words: Gender difference, autonomic cardiovascular control, cardiovascular risk factor, youth, health promotion

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Introduction

Involuntary physiological processes such as energy metabolism, hormonal regulation, blood pressure and heart rate recovery (HRR) are under the direct control of the autonomic nervous system (ANS). Heart rate recovery is therefore widely considered a standard non-invasive technique for assessing cardiovascular autonomic modulation and general ANS function.[1,2] Heart rate recovery represents the parasympathetic-mediated decline in heart rate (HR) immediately following exercise.[3] The delay in HRR after exercise is influenced by vagal reactivation and is considered a risk factor of overall mortality and adverse cardiovascular events[1,4] in the general population without prior evidence of cardiovascular disease (CVD). The associated risk of delayed HRR is also present in patients with chronic disease.[5,6]

The effects of aerobic fitness and adiposity on HRR have been documented in adults.[7,8] In the study on the effect of age and training status on HRR, Daar et al.[7] reported that participants with high aerobic fitness recovered faster than those with a lower level of fitness. In a three-month study of combined exercise and diet program in 125 obese adults, Nagashima et al.[8] reported a significantly faster HRR after the programme. According to these investigators, changes in HRR were significantly correlated with changes in body weight, BMI, % fat, waist circumference (WC) and resting HR among others.

The transition during adolescence is a critical period during which physiological and behavioural changes (i.e. smoking, binge alcohol abuse, excessive use of social media) amongst others occurs,[9,10,11] which if not well managed may consequently lead to pediatric non-communicable diseases of life style. Pediatric obesity and low physical fitness are known to be increasing globally and these situations put youth at an increased risk of non-communicable diseases of life style. Both pediatric obesity and low fitness are known to track from childhood to adulthood.[12] For example, it has been documented that overweight adolescents have a 70% likelihood of remaining overweight or obese as adults.[13] A study by Singh et al.[14] revealed that age, gender, baseline HR and BMI accounted for 30% of the variance in heart rate recovery (HRR). In another study by Laguna, Anzar, Lara, Lucia and Ruiz[15] waist circumference and sum of skinfolds among others were found to be associated with HRR in boys. Early interventions to reverse this negative health trend are warranted among this group in order to guarantee optimal health prospects during adulthood.

The prognostic implications of HRR during or after exercise is well documented in the adult population[3,16] but the prognostic value of delayed HRR following cessation of exercise has not been well characterized in youth. Furthermore, the association of aerobic fitness and BMI with the rate of decline in HR during recovery from exercise in adolescents remains to be fully explored. We therefore hypothesized that higher aerobic fitness and desirable weight status may be closely associated with faster HRR_1 immediately after the progressive aerobic cardiovascular endurance run (PACER) in adolescent boys and girls from Benue State of Nigeria.

Methods

Participants

Female and male adolescent participants aged between 12 – 16 years were recruited from the Benue State of Nigeria. The volunteer participants were selected from the three senatorial districts of the State: Benue North, Benue Central and Benue South. Multistage and systematic sampling techniques were used to select 470 black African adolescents. In the first stage, 12 schools (4 from each senatorial district) were randomly selected from 450 secondary schools within the study area. In the second stage, participants were selected in a systematic manner from the school registers. In each selected class, every fifth child starting from the second on the class list was selected to participate in the study. At the time of the data collection, all participants were apparently healthy and had not participated in any organized exercise program for at least six months prior to the study. Participants whose medical records indicated health problems such as chest pain, fatigue, history of heart disease that could contraindicate their participation were excluded from the study. The purpose and procedure of the tests were fully explained to participants after obtaining permission from the heads of schools.

The research study was approved by the ethics review board of Benue State University, and written parental consent and assent of children were obtained before participation. All procedures were in accordance with those presented in the Helsinki declaration. Due to absenteeism and incomplete data only 454 (224 boys and 230 girls) out of a total of 470 participants who completed all the measurements were included in the statistical analysis. This yielded a participation rate of 96.5%.

Anthropometric measurements

Participants' physical characteristics were measured according to standard procedures.[17] Body mass and stature were measured indoors in each school with the aid of an electronic weighing scale (Seca digital floor scale, sec-880, Seca, Birmingham, UK) and a wall-mounted Stadiometer (model sec-206; Seca, Birmingham, UK). Both body mass and stature were measured with participants in minimal clothing to the nearest 0.1 kg and 0.1 cm respectively. Participants' BMI ($kg.m^{-2}$) were determined and used to estimate body fatness.

Participants were categorized into two groups based on their BMI values according to the FITNESSGRAM revised data.[18] Details of the procedure for classification into healthy weight (HW) and overweight (OW) have been described elsewhere.[19]

Aerobic fitness measurement

Aerobic fitness was assessed with the PACER protocol. The PACER is a multistage aerobic capacity test adapted from the 20-M shuttle run test (20-MST) that progresses in intensity. The PACER is a widely used test of aerobic fitness in children and adolescents and it is considered valid and reliable.[20] Participants ran back and forth between two lines 20 m apart. The running speed starts at 8.5 $km.h^{-1}$ and increases by 0.5 $km.h^{-1}$ each minute. Participants ran in groups of 10, with research assistants counting the number of laps covered during the test. A 20-m distance constituted a lap. The test was terminated when a participant could no longer follow the set pace on two successful shuttles or withdrew voluntarily. The number of laps completed by each participant was used to estimate his/her aerobic fitness.[21] Details of the administrative procedure of this test and procedure for classification of participants into healthy fitness or fit and unfit based on FITNESSGRAM revised data.[18]

Heart Rate Measurement

Baseline heart rate was measured while the participants occupied a sitting position after 10 min of rest. Baseline pulse rates were recorded using a Finger Pulse Oximeter (Baseline 12-1926 Fingertip Pulse Oximeter, Fabrication Enterprises Inc., USA). Thereafter participants underwent the PACER test. Once the participants completed the PACER test, immediate post exercise HR was recorded, then, they were told to sit down on a bench. One minute heart rate recovery was determined the same way as during pretest in one minute immediately after test termination. The HRR_1 was defined as HR value immediately after cessation of exercise minus HR at one minute of recovery (HRR_1= HR attained immediately post test – 1 min HR). An abnormal value for HRR was defined as a 25^{th} percentile value of participants' HRR_1.[14] Throughout the duration of the project, all tests were performed in the same order by the same members of the testing team to ensure consistency.

Statistical analysis

All values of measured and derived variables were expressed as mean and standard deviation (±SD). Comparisons of means between boys and girls were conducted using the Independent samples t-test. Comparisons of fitness and fatness groups were also performed using the independent samples t-test. For hypothesis testing, the effect size was calculated as the difference in group means/pooled SD; the criteria used to characterize a small, moderate, and large effect size were 0.20, 0.50, and 0.80 respectively. Using the categorical variables for both fitness and fatness, participants were categorized into four groups: "fit and unfat"; "fit and fat"; "unfit and unfat"; and "unfit and fat". Differences across fit/fat groups were assessed by One-way ANOVA and Scheffe comparison method. Zero-order correlation coefficients were used to assess the relationship among Fitness, BMI and HRR_1. Standard regression models were used to determine the relationship between HRR_1, fitness and BMI. Statistical analyses were performed using SPSS software (Windows Version 18; SPSS Inc, Chicago, IL) at an alpha level of 0.05 or less.

Results

Physical and physiological characteristics

Participants' physical and physiological characteristics are presented in Table 1 stratified according to CRF and weight status. On the average, HW youth were significantly ($p<0.0001$) lighter (43.8 ± 8.6 vs 55.8 ± 11.7), significantly ($p<0.0001$) taller (152.6±10.1 vs 137.4± 13.2), displayed a significantly ($p<0.0001$) lower BMI (18.7±2.7 vs 29.6±4.5) and significantly ($p<0.008$) faster HRR_1 (47.6±18.6 vs 34.6±21.9). There were no significant differences in age

(13.6±1.3 vs 14.0± 1.3; p=0.184), baseline HR (86.5±15.3 vs 87.0±17.7; p=.891) and CRF (38.8±18.2 vs 37.8±18.5; p=0.816) between HW and OW youth. When HW and OW youth were further stratified according to CRF levels, children in high fitness category tended to display faster HRR_1 but other variables were similar (Table 1).

Insert Table 1 here

Clinical characteristics of participants

The 25th percentile values of participants' HRR_1 by age and sex are presented in Table 2. As shown in the table, 22.3% of the boys had HRR_1 values below the 25th percentile while 19.6% of girls had their HRR_1 values below the 25th percentile.

Insert Table 2 here

Influence of weight status and fitness on HRR_1

Results regarding the influence of weight status and fitness on HRR_1 are presented in Table 3. The table displays Independent samples t-test results for boys and girls. For both genders, participants did not differ in both the baseline HR and HRR_1 on the fitness test but there was a significant difference (p=0.004; effect size = 0.077) in the weight status of male participant's HRR_1.

Insert Table 3 here

Predictors of recovery HRR_1 by univariate analysis

To determine whether fitness and BMI were independently associated with HRR_1, Standard multiple regression analyses were conducted (Table 4). The results of boys showed that in combination, both fitness and weight status explained only 3% of the variance in HRR_1. Only BMI contributed significantly (p = 0.034) in predicting the dependent variable accounting for 2.2% of the variance in $HRR_{1.}$ Fitness did not significantly (p = 0.173) contribute in predicting the criterion. In girls, both independent variables did not make any statistically significant (p > 0.005) contribution in predicting the criterion.

Insert Table 4 here

To further assess the influence of fitness and weight status in combination on the dependent variable, participants were categorized into four fit/fat groups and the results are presented as follows: The proportion of adolescents within these categories were 61.7%, 33.9%, 2.9% and 1.5% for fit/HW, unfit/HW, fit/OW and unfit/OW respectively. Significant ($F_{2,450}$= 4.222, p=0.006; effect size = 0.021) group difference was noted following the PACER. The only difference was between the fit/HW (51.9±15.4) and unfit/OW (33.0±21.3).

Insert Table 5 here

Discussion

The result of the present study shows that a modest proportion of adolescents (20.9%) demonstrated HRR_1 values below the 25th percentile of the sample which is considered low, with the situation being worse in boys. Since it has been established that delayed HRR is a risk factor of cardiovascular disease and mortality[1], this result shows that the risk of adverse cardiovascular events may be evident even during adolescence. Slow heart rate implies impaired activity of the parasympathetic component of the ANS and is recognized as a marker of cardiovascular health because of its association with health states.[3,22] This result therefore has important implications on adolescent cardiovascular health. It is important to initiate preventive strategies at this early stage for better health prospects later in life.

This study clearly demonstrates that adolescents with high BMI show a prolonged HRR in boys but not girls. This result shows that there is a link between body fatness and impaired vagal activity, a finding which is supported by studies in adults[8,16,22] and youths.[14,23,] In this study, BMI used as a surrogate measure of fatness was the only predictor of HRR in both the combined group and in boys. But in girls, both independent variables (i.e. BMI and PACER) were not significantly associated with HRR. However, findings from the study of Castneret al.[24] are at variance with our results. Using 45 preadolescent American children, these investigators studied the effects of adiposity and Prader-Willi Syndrome on post-exercise HRR and found no significant effect of adiposity on HRR between normal weight and obese children. A possible reason for this inconsistency in the two studies may be due to the high fitness level among participants (normal weight versus obese children) in the study by Castner et al.[24]. The high fitness level could have dampened the effect of adiposity on HRR.

Our results show that the adverse effect of body fatness on HRR is more clearly observed in boys than girls. This finding is consistent with that of Laguna et al.[15] who among others reported that HRR was associated with obesity traits mainly in healthy adolescent boys. Although, fitness did not demonstrate any significant association with the dependent variable, there was a tendency towards this direction (Tables 3 and 4). This study provides further evidence in support of a physically active lifestyle that promotes cardiovascular health by increasing fitness and reducing fatness.

Our results also indicated that only fatness contributed modestly (3%) in explaining the variance in the one-minute recovery HRR after severe exercise in boys. This finding is not surprising as it has been earlier reported[22] that pre-exercise variables such as age, gender and baseline heart rates are strong predictors of one-minute HRR which were not considered in the present study. These variables are likely to have contributed to the large unexplained variance. Although there is hardly any data to relate HRR in children to clinical outcomes, the fact that higher BMI attenuated HRR[1] among the subjects of this study is a reminder that childhood obesity which is now recognized as a public health problem may have important implications for cardiovascular health of the present study participants.[14]

This study extends the fit/fat debate to HRR. To the best of our knowledge, the interaction of fitness and fatness on HRR has not been fully explored in African youth. The study examined fit-fat group variations in HRR among the participants. Significant fit-fat group differences were found only between fit/HW versus unfit/OW. Results of the present study demonstrate that HR varied by clinical cut-off points for fitness and fatness category. Specifically, high levels of fitness resulted in faster HR values especially within fatness categories. These findings are in support of previous studies in youth.[19,25] In a study involving 3240 Nigerian children and adolescents, Musa and Williams[19] reported that the unfit and fat group had significantly higher resting blood pressure values, especially systolic blood pressure in adolescents. Our results show that participants with low fat and high fitness have better HRR profiles than their peers in high fat and unfit group. This beneficial effect of fitness on high fat level has positive implication for adolescent health and has been documented in previous studies in youth[19,25] and adults.[26]

However, the findings of this study should be interpreted cautiously in the light of a number of limitations. Firstly, the findings are constrained by the fact that a cross-sectional design was used which precludes the confirmation of cause-and-effect relationship among the variables studied. The non-inclusion of sexual maturation is another limitation as this variable is known to influence fitness test score in youth.[25] The use of BMI though valuable for international comparisons, has limitations in assessing body fat percent, visceral adiposity and central obesity, particularly among non-European populations.[27] Thus, the use of BMI as a measure of adiposity in the present study may not seem appropriate like laboratory measures such DEXA or hydrostatic weighing. Nevertheless, a major strength of this study was the use of health-related cut-points for estimating fitness and fatness. This approach showed that youth with high fitness and low fat have faster recovery HR values than their less fit and overweight peers.

This study has shown that fatness but not fitness is independently associated with recovery HR in Nigerian adolescents. The relationship between fatness and HRR is stronger in boys than girls. The association of fitness and fatness with HRR_1 is modest. The combination of low fitness and OW resulted in the most unfavorable HRR profile, and generally being physically fit with HW provides better HRR profiles among adolescents with a healthier future potential.

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Table 1: Participants' descriptive characteristics (n=454)

	Healthy Weight (n=433)		Overweight (n=21)	
	Unfit	Fit	Unfit	Fit
Gender (boys/girls)	89/96	122/158	6/2	7/6
Age (y)	14.0±1.3	13.4±1.2	14..0±1.3	14.0±1.4
Stature (cm)	152.8±10.9	152.5±9.7	137.7±19.4	137.2±13.2
Weight (kg)	44.3±8.6	43.5±8.5	56.6±16.7	55.3±8.2
BMI (kg.m2)	18.9±2.9	18.5±2.6	29.7±5.2	29.6±4.3
HR_{rest}(freq)	87.5±15.5	85.9±15.1	92.9±16.7	83.3±18.0
HRR_1 (freq)	33.0±21.3	37.4±22.9	47.3±19.7	48.0±18.0

Table 2: Frequency and percentage distribution of One minute HRR 25th percentile by Age and Sex

	Boys			Girls		
Age	N	25th	Freq*	N	25th	Freq*
12	51	36	11	55	26	12
13	54	35	11	58	21	10
14	60	30	14	53	16	9
15	36	25	9	48	12	10
16	23	14	5	16	9	4
Total	224		50 (22.3)	230		45 (19.6)

*Figures in parentheses are percentages

Table 3: Influence of fitness and BMI on one minute heart rate recovery

Variable	Period	Group	N	Mean	SD	df	t-value	Sig.
Boys(n=224)								
PACER	HR_{rest}	Fit	129	84.9	14.5	222	1.571	0.116
		Unfit	95	81.7	15.5			
	HRR_1	Fit	129	42.2	23.3	222	1.152	0.250
		Unfit	95	38.8	20.8			
BMI	HR_{rest}	Fit	211	78.6	14.3	222	1.149	0.270
		Unfit	13	83.3	15.2			
	HRR_1	Fit	211	57.2	15.2	222	2.918	0.004
		Unfit	13	39.2	21.8			
Girls (n=230)								
PACER	HR_{rest}	Fit	164	92.0	16.2	228	1.347	0.179
		Unfit	66	89.0	14.2			
	HRR_1	Fit	164	31.9	20.6	228	0.798	0.426
		Unfit	66	29.5	21.0			
BMI	HR_{rest}	Fit	222	89.5	14.5	228	2.074	0.039
		Unfit	08	100.5	14.8			
	HRR_1	Fit	222	32.0	12.0	228	0.416	0.687
		Unfit	08	30.1	21.2			

Table 4: Predictors of change in HRR_1 after PACER

Gender	Predictors	R^2	R^2 *change*	*B*	*F-ratio*	*P*
Boys	Fitness	0.008	0.008	0.095	1.871	0.173
	BMI	0.030	0.022	0.148	3.430	0.034
Girls	Fitness	0.003	0.003	0.054	0.721	0.397
	BMI	0.004	0.001	-0.035	0.499	0.608

Table 5: Differences in HRR_1 according to fit/fat groups (n=454)

Group	N	Mean	SD
fit/HW	280	51.9	22.0
Unfit/HW	154	47.3	19.7
Fit/OW	13	37.4	22.7
Unfit/OW	07	33.0	21.3