Online version at http://www.minervamedica.it

Gazzetta Medica Italiana - Archivio per le Scienze Mediche 2020 January-February;179(1-2):1-6
DOI: 10.23736/S0393-3660.18.03955-4

ORIGINAL ARTICLE

Relationship between aerobic fitness and cardiometabolic disease risk in South African children

Violet K. MOSELAKGOMO [1] *, Abel L. TORIOLA [2], Sunday O. ONAGBIYE [3]

[1]Centre for Biokinetics, Recreation and Sports Science, University of Venda, Thohoyandou, South Africa; [2]Department of Sport, Rehabilitation and Dental Sciences, Tshwane University of Technology, Pretoria, South Africa; [3]School of Public Health, University of the Western Cape, Cape Town, South Africa

*Corresponding author: Violet K. Moselakgomo, Centre for Biokinetics, Recreation and Sports Science, University of Venda, Thohoyandou, South Africa. E-mail: violetmoselakgomo@yahoo.com

ABSTRACT

BACKGROUND: This study investigated the relationship between the aerobic capacity ($VO_{2\ peak}$) and cardiometabolic disease (CMD) risk in South African children and adolescents.

METHODS: A total of 1361 (boys: N.= 678; girls: N.=683) primary school children (Mean age: 10.9±1.28 years), whose parents gave signed informed consent, participated in the study. Anthropometric (height, weight, circumference of the hip and waist), physiological [systolic blood pressure (SBP); diastolic blood pressure (DBP)], and cardiorespiratory fitness (CRF) [(20-meters Multistage Shuttle Run (MSR)] measurements were taken using standardised protocols. To examine the relationship between aerobic fitness and CMD risk factors, bivariate correlation analysis was undertaken.

RESULTS: Boys had significantly higher VO_{2peak} (25.8±6.79) compared to girls (21.9±6.95) ($P<0.05$). There were low negative correlations between VO_{2peak} and BMI (r=-0.054, P=0.04), WHR (r=-0.110, $P<0.001$) and WHtR (r=-0.055, P=0.041), while DBP (r=0.097, $P<0.001$) yielded low positive association. Multiple linear regression analyses also showed that BMI (β=-0.165, P=0.000), SBP (β=-0.066, P=0.03), DBP (β=0.132, P=0.000), WHR (β=-0.182, P=0.000), and WHtR (β=-0.118, P=0.012) significantly predicted VO_{2peak}.

CONCLUSIONS: Cardiometabolic disease risks could be a significant predictor of aerobic fitness among South African children.

(*Cite this article as:* Moselakgomo VK, Toriola AL, Onagbiye SO. Relationship between aerobic fitness and cardiometabolic disease risk in South African children. Gazz Med Ital - Arch Sci Med 2020;179:1-6. DOI: 10.23736/S0393-3660.18.03955-4)

KEY WORDS: Oxygen consumption; Child; South Africa.

Globally, there is consensus that cardiometabolic disease (CMD) has its roots in childhood and adolescence.[1] Cardiometabolic disease could also be a risk for heart disease throughout the lifespan.[2] It has been suggested that a large number of children display one or more CMD risk indicators which could continue into later life.[3] Central obesity has been known to be one of the main causes of CMD risk.[2] In South Africa, childhood obesity continues to rise, and currently stands at thirteen percent which is more than twice the worldwide average of five percent.[4] This is coupled with low levels of aerobic fitness emanating from physical inactivity, thereby causing an increase in the risk of emerging vascular disease and metabolic disorders.[3] Furthermore, the reduced levels of aerobic capacity among the youth have suggested that many children could be at risk of having CMD.[3]

Aerobic fitness has been recognised as a valu-

able indicator of fitness and health status of which its low level is associated with increase mortality rate.[5-7] In addition to obesity, hyperglycemia, hypertension, insulin resistance, dyslipoproteinemia are other factors, which could increase CMD risk.[2] In spite of this evidence, studies on the relationship between the aerobic capacity and CMD risk in South African children and adolescents have hardly been reported in the literature. Given the fact that many South African children do not have ample opportunity to participate in Physical Education activities[8] as it is poorly taught in schools, it is assumed that they could have low levels of aerobic fitness. Therefore, this study examined the relationship between aerobic capacity and CMD risk in a cohort of South African children and adolescents.

Materials and methods

Research design and sample

Cross-sectional and descriptive design was used to assess anthropometric characteristics, aerobic fitness and CMD risk in targeted samples of school children in the Limpopo and Mpumalanga provinces of South Africa. Specifically, a total of 1361 (boys: N.=678 and girls: N.=683) aged 9-12 years who were randomly selected from eight schools in each of the Limpopo (LP) (N.=708) and Mpumalanga (MP) (N.=653) provinces participated in the study. The children's ages were verified from class registers at each school.

Ethical considerations

The study was approved by the Ethics Subcommittee of the Faculty of Health Sciences, North-West University, South Africa (Ethics approval number - NWU-00088-12-S1), and other relevant provincial regulatory bodies. Preceding the data collection, approval to conduct the study was also granted by Provincial Heads of Department of Education and District Managers for the Department of Basic Education in Limpopo and Mpumalanga Provinces. In addition, informed consent forms were distributed to head teachers, children and their parents or guardians who also endorsed the research.

Anthropometric measurement

Height, body weight, and body circumferences (waist and hip) were measured according to the protocol of the International Society for the Advancement of Kinanthropmetry (ISAK).[9] Height was measured to the nearest 0.1 cm in bare feet with participants standing upright against a mounted stadiometer. A portable digital weighing (Tanita HD 309, Creative Products, MI, USA) scale calibrated after 20 successive measurements to the nearest 0.1 kg was used to assess body mass with participants lightly dressed. Body composition indices including body mass index (BMI) [weight (in kg) divided by height squared (in centimeters], waist-to-height ratio (WHtR) (waist circumference divided by height, both measured in the same units), and waist-to-hip ratio (WHR) (calculated by dividing the waist girth by hip circumference) were subsequently computed from height and weight, waist and height, and waist-to-hip ratio, respectively.

Blood pressure

Blood pressure (BP) was measured using electronic blood pressure monitor with cuff designed for children (Omron HEM-705 CP devices, Tokyo, Japan). The standardised guidelines of the National Heart, Lung, and Blood Institute/the National High Blood Pressure Education Programme (NHLBI/NHBPEP)[10] were applied for the BP measurements to determine potential health risk factors and examine the relationship between PA and BP among children. BP values between 90th and 95th percentiles in childhood are labelled as "high normal" or "prehypertensive," and are an indication for lifestyle modification. Based on these guidelines, the readings at the first and third BP monitors were taken as systolic blood pressure (SBP) and diastolic blood pressure (DBP), respectively.

Aerobic capacity

Aerobic capacity was determined indirectly by using 20-meters Multistage Shuttle Run (MSR). The 20m MSR test was administered in accordance with the procedures of the study by Paradisis *et al.*[11], except for the temperature, which ranged

from between 24-27° C. Based on the children's MSR data, their aerobic capacity scores were determined.

Statistical analysis

The participants' data were analysed using descriptive statistics, *i.e.* means and standard deviations. Bivariate association between the aerobic fitness and CMD variables were determined with Pearson's product correlation coefficient separately for boys and girls, whose data were subsequently combined for further analysis. Multiple linear regression modelling was used to determine the relative influence of CMD risk factors (age, body weight, height, gender, blood pressure, BMI, WHtR and WHR) in predicting aerobic capacity among the children. All statistical analyses were conducted with the Statistical Package for the Social Sciences (SPSS), version 21.0. A probability level of 0.05 or less ($P \leq 0.05$) was taken to indicate significance.

Results

The descriptive characteristics of the participants are presented in Table I. The correlation matrix showing the relationship between aerobic fitness and CMD risks are presented in Table II. Girls (11.1±1.29) were significantly older than boys (10.8±1.27), while the boys (35.3±9.66) were significantly heavier than the girls (33.6±8.68).

Girls had significantly higher WHR (0.83±0.04) and WHtR (0.42±0.03) than boys, while the boys possessed significantly higher hip circumference, BMI, body weight, SBP, DBP, and PVO_{2max} ($P<0.05$) than girls.

There were significant relationships between aerobic fitness and BMI (r=-0.054; P=0.04), WHR (r=-0.110; P<0.001), WHtR (r=-0.055; P=0.04), and DBP (r=-0.097; P<0.001). Similarly, insignificant inverse relationship was found between aerobic fitness and SBP (r=-0.007 (P>0.05) among the children.

TABLE I.—*Physical characteristics of the participants (mean±SD) (N.=1361).*

Variables	Boys (N.=683)	Girls (N.=678)	Total (N.=1361)	P value
Age (yr.)	10.8±1.27	11.1±1.29	10.9±1.28	0.006*
Height (cm)	140.1±9.94	139.1±9.16	139.6±9.58	0.051*
Weight (kg)	35.3±9.66	33.6±8.68	34.4±9.22	0.001*
BMI (kg/m²)	17.7±3.43	17.2±3.25	17.4±3.35	0.004*
Waist (cm)	58.6±7.57	58.7±5.89	58.7±6.79	0.65
Hip (cm)	74.3±9.93	70.6±7.54	72.5±9.01	0.000*
WHR	0.79±0.04	0.83±0.04	0.81±0.05	0.000*
WHtR	0.41±0.04	0.42±0.03	0.42±0.04	0.032*
SBP (mmHg)	113.6±13.5	110.2±13.2	111.9±13.5	0.000*
DBP (mmHg)	78.3±12.7	76.7±13.4	77.5±13.0	0.035*
PVO_{2max} (ml/kg/min)	25.9±6.79	21.9±6.95	23.9±7.14	0.000*

* Significant $P \leq 0.05$; PVO_{2peak}: predicted peak maximum oxygen consumption; BMI: Body Mass Index; Yrs.: years; kg: kilogram; cm: centimeter; kg/m²: kilogram per meter square; ml/kg/min: millilitre per kilogram per minutes; n: number; WHtR: waist-to-height ratio; SPB: systolic blood pressure; DBP: diastolic blood pressure; mmHg: millimetres of mercury.

TABLE II.—*Correlation matrix showing the relationship between the aerobic fitness and cardiometabolic disease risks in children (N.=1361).*

Variables	BMI (kg/m²)	WHR	WHtR	SBP (mmHg)	DBP (mmHg)	$PVO_{2\,peak}$ (ml/kg/min)
BMI (kg/m²)	1.00					
WHR	0.155**	1.00				
WHtR	0.676**	0.355**	1.00			
SBP (mmHg)	0.241**	-0.109**	0.368**	1.00		
DBP (mmHg)	0.140**	0.025	0.111**	0.440**	1.00	
PVO_{2peak} (ml/kg/min)	-0.054	-0.110	-0.055*	-0.007	-0.097**	1.00

**Correlation is significant at the 0.01 level (2-tailed); * Correlation is significant at the 0.05 level (2-tailed); $PVO_{2\,peak}$; predicted peak maximum oxygen consumption; BMI; body mass index, kg/m²; kilogram per meter square, ml/kg/min; millilitre per kilogram per minutes, mmHg; millimetres of mercury

TABLE III.—*Multiple linear regression analysis to predict aerobic fitness and CMD risks variables in children.*

Variables	Coefficient (β)	P value
BMI (kg/m^2)	-0.352	<0.001
WHR	-24.080	<0.001
WHtR	21.035	0.012
SBP (mmHg)	-0.035	0.030
DBP (mmHg)	0.072	<0.001

R square =0.036; adjusted R square =0.032; P≤0.05.

The results of the multiple linear regression analysis are provided in Table III. It was revealed that every kilogram per meter square (kg/m_2) change in BMI is associated with a higher significant decrease in VO_2 peak by -0.352 ml/kg/min (P≤0.01). Similarly, every unit increase in WHR is associated with a higher significant decrease in VO_2 peak by -24.080 ml/kg/min (P≤0.01). Furthermore, every unit increase in WHtR is associated with a significant increase in VO_2 peak by 21.035 ml/kg/min (P≤0.05). The results also showed that every unit increase in SBP is associated with a significant decrease in VO_2 peak by -0.035 ml/kg/min (P≤0.05), while every unit increase in millimetres of mercury of DBP is associated with higher significant increase in VO_2 peak by 0.072 ml/kg/min (P≤0.01). The following generalised equation was utilised to predict VO_2 peak from BMI, WHR, WHtR, SBP and DBP: VO_2 peak = 21.035 (WHtR) + 0.072 (DBP) -24.080 (WHR) -0.352 (BMI) -0.035 (SBP). The variables in combination significantly predicted VO_2 peak, $F_{(5, 1355)} = 493.614$, P<0.0001, R^2=0.036 at P≤0.05. Therefore, BMI, WHR, WHtR, SBP and DBP were significant predictors of VO_2 peak.

Discussion

This study examined the relationship between the aerobic capacity and CMD risks in South African children. It has been reported that a potential information on cardiorespiratory fitness as predictors of cardiometabolic syndrome occurrence is scarce.[12] Few studies, if any, have examined the relationship between the incidence of cardiorespiratory fitness and CMD risks in South African children. However, low aerobic capacity has been understood to be a major risk for cardiometabolic syndrome, which has its origin in childhood and usually progresses into adulthood if not controlled. On the other hand, the higher the cardiorespiratory fitness, the lower the incidence of CMD.

The results of this study showed that boys had significantly higher VO_{2peak} compared to their girl counterparts. A similar finding was reported by Lintu *et al.*[13] who examined the cardiorespiratory fitness, respiratory function and hemodynamic responses to maximal cycle ergometer exercise test in boys and girls aged 9–11 years, and found that boys had superior cardiorespiratory fitness (CFR) scores than girls. Minatto *et al.*[14] who studied the health-related physical fitness in Brazilian adolescents aged 10-17 years also found CRF to be better in boys than girls. Several other studies have also found CRF to be higher in boys compared to girls.[6, 15-17] The low levels of aerobic capacity in girls could be attributed to low levels of their involvement in physical activity.[16]

In this study, a significant inverse relationship was observed between CRF and BMI. This corroborates the findings of previous studies, which also indicated a significant relationship between CRF and BMI in school-going children and adolescents.[6, 17-19] Studies have also shown that the higher the BMI values, the lower the CRF status.[6, 17, 19] That is, individuals whose BMI falls within 18.5 to 24.9 seem to have a good CRF level compared to other weight categories.[6] Abdominal obesity, commonly known as waist-to- hip ratio, has been regarded as a risk factor for long-lasting illnesses.[20] Our findings revealed a significant inverse correlation between CRF and WHR in children. These findings contradict those of Freitas Junior *et al.*[21] and Sarpong[22] which indicated a positive correlation between the CRF and WHR.

Waist-to-height ratio is regarded as one of the major anthropometric indices that could be used to screen children for CMD risk.[23] Other studies have also shown that waist-to-hip ratio was significantly associated with the cardiorespiratory fitness indices.[5] Based on Misra *et al.*, it is assumed that the higher value of BMI, WHR, SBP and DBP could be accountable for the reduction in CRF level in South African children, more especially those with excessive body fatness. However, it has been reported that improved fit-

ness levels could enhance better SBP and DBP which could postpone the onset of rising blood pressure.[24] Findings for BMI support those of Onagbiye et al.[6] in which BMI was found to be a good predictor of CRF among school-going adolescents aged 12 to 20 -year old. The findings in the present study also showed a significant inverse relationship between the WHtR and CRF. This finding corroborates that of Cooper[25] who found WHtR ratio to be correlated with cardiorespiratory fitness in children. The current study also revealed a significant inverse correlation between CRF and DBP, although, a small insignificant relationship between CRF and SBP was observed. These findings are contrary to the report of Klasson-Heggebø *et al.*[26] that indicated a significant relationship between cardiorespiratory fitness and SBP in 9- and 15- year-old European youths.

Results from multiple linear regression analysis revealed that independent variables (BMI, WHR, WHtR, SBP and DBP) significantly predicted VO_2 peak in the studied population. Furthermore, in our study, WHtR was found to be a good predictor of CRF in children. Consequently, an increase in WHR was associated with an increase in CFR.[24] In general, results of the present study showed that CMD risk factors could have undesirable influence on aerobic capacity in children and adolescents.

Limitations of the study

The results of this study should be treated with caution as the sample used might not exactly represent the entire population of South African children. The sample used in this study were from a low socio-economic background, which limits the generalizability of the findings. Furthermore, BMI as a major limitation of this study, might not represent the real body fat percentage of the children. However, the strength of the study lies in the fact that the results could create an awareness to increase the level of CRF in in order to lower CMD risk among South African youths.

Conclusions

Cardiometabolic disease risks could be a significant predictor of aerobic fitness among South African children. The decreased levels of CRF among South African children should necessitate intervention targeted at increasing aerobic fitness status and improve healthy lifestyle among the children.

References

1. Gobbi RM, Davies IG, Fairclough SJ, *et al.* Clustered cardiometabolic risk, cardiorespiratory fitness and physical activity in 10-11 year old children. The CHANGE! Project Baseline. Archives of Exercise in Health and Disease 2012;3:207–13.

2. Health Dialogue. *Cardiometabolic Risk Faqs*. AmeriHealth HMO, Inc.; 2009 [Internet]. Available from: https://www.amerihealth.com/pdfs/providers/resources/connections/cardiometabolic_ah.pdf. [cited 2018, May 11].

3. Houston EL, Baker JS, Buchan DS, Stratton G, Fairclough SJ, Foweather L, *et al.* Cardiorespiratory fitness predicts clustered cardiometabolic risk in 10-11.9-year-olds. Eur J Pediatr 2013;172:913–8.

4. ealth24. *Shocking findings for SA in global obesity study*.; 2017 [Internet]. Available from:http://www.health24.com/Diet-and-nutrition/News/nejm-obesity-study-shocking-results-20170612 [cited 2018, May 11].

5. Misra SK, Dutta K, Dua P, *et al.* Associations of Obesity Indices with Cardiorespiratory Fitness in Bengali School Going Boys in India. Int J Life Sci Scienti Res 2017;3:856–62.

6. Onagbiye SO, Mwila M, Marie YM, *et al.* Relationship between Cardiorespiratory Fitness and Anthropometric Variables among School-going Adolescents in Nigeria. T-Anth 2017;29:65–72.

7. Bailey DP, Savory LA, Denton SJ, Kerr CJ. The association between cardiorespiratory fitness and cardiometabolic risk in children is mediated by abdominal adiposity: the HAPPY study. J Phys Act Health 2015;12:1148–52.

8. Reddy SP, Panday S, Swart D, *et al. Umthenthe Uhlaba Usamila – The South African Youth Risk Behaviour Survey 2002*. Cape Town: South African Medical Research Council; 2003.

9. Marfell-Jones MJ, Stewart AD, de Ridder JH. *International standards for anthropometric assessment*. Lower Hutt, New Zealand: International Society for the Advancement of Kinanthropometry; 2012.

10. Chobanian AV, Bakris GL, Black HR, Cushman WC, Green LA, Izzo JL Jr, *et al.*; National Heart, Lung, and Blood Institute Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure; National High Blood Pressure Education Program Coordinating Committee. The seventh report of the joint national committee on prevention, detection, evaluation, and treatment of high blood pressure: the JNC 7 report. JAMA 2003;289:2560–72.

11. Paradisis GP, Zacharogiannis E, Mandila D, Smirtiotou A, Argeitaki P, Cooke CB. Multi-stage 20-m shuttle run fitness test, maximal oxygen uptake and velocity at maximal oxygen uptake. J Hum Kinet 2014;41:81–7.

12. LaMonte MJ, Barlow CE, Jurca R, Kampert JB, Church TS, Blair SN. Cardiorespiratory fitness is inversely associated with the incidence of metabolic syndrome: a prospective study of men and women. Circulation 2005;112:505–12.

13. Lintu N, Viitasalo A, Tompuri T, Veijalainen A, Hakulinen M, Laitinen T, *et al.* Cardiorespiratory fitness, respira-

tory function and hemodynamic responses to maximal cycle ergometer exercise test in girls and boys aged 9-11 years: the PANIC Study. Eur J Appl Physiol 2015;115:235–43.

14. Minatto G, Petroski EL, Silva DA. Health-related physical fitness in Brazilian adolescents from a small town of German colonization. Rev Andal Med Deporte 2016;9:67–74.

15. Silva DA, Tremblay M, Pelegrini A, Dos Santos Silva RJ, Cabral de Oliveira AC, Petroski EL. Association between aerobic fitness and high blood pressure in adolescents in Brazil: evidence for criterion-referenced cut-points. Pediatr Exerc Sci 2016;28:312–20.

16. Gonçalves EC, Silva DA. [Factors associated with low levels of aerobic fitness among adolescents]. Rev Paul Pediatr 2016;34:141–7. Portuguese.

17. De Araujo SS, Miguel-dos-Santos R, Silva RJ, *et al.* Association between body mass index and cardiorespiratory fitness as predictor of health status in schoolchildren. Rev Andal Med Deporte 2015;8:73–8.

18. Victo ER, Ferrari GL, Silva JP Junior, Araújo TL, Matsudo VK. Lifestyle Indicators and Cardiorespiratory Fitness in Adolescents. Rev Paul Pediatr 2017;35:61–8. English, Portuguese.

19. Hsieh PL, Chen ML, Huang CM, Chen WC, Li CH, Chang LC. Physical activity, body mass index, and cardiorespiratory fitness among school children in Taiwan: a cross-sectional study. Int J Environ Res Public Health 2014;11:7275–85.

20. Hu G, Tuomilehto J, Silventoinen K, Barengo N, Jousilahti P. Joint effects of physical activity, body mass index, waist circumference and waist-to-hip ratio with the risk of cardiovascular disease among middle-aged Finnish men and women. Eur Heart J 2004;25:2212–9.

21. Freitas Júnior IF, Rosa CS, Codogno JS, Bueno DR, Buonani C, Conterato I, *et al.* [Cardiorespiratory fitness and body fat distribution in women with 50 years or more]. Rev Esc Enferm USP 2010;44:395–400. Portuguese.

22. Sarpong EO. Waist-to-hip ratio measures as predictors of cardiorespiratory fitness among females human kinetics students in university of Ilorin. Int J Phys Educ Sports Health 2016;3:65–9.

23. Toriola AL, Ajayi-Vincent OB, Oyeniyi PO. Diagnostic comparison of three anthropometric indices to predict blood pressure in Nigerian Children: A multinomial regression analysis. In: R. Cruz de Oliveira, N.R. Cruz de Oliveira, D.M. Noronha, R.R. Uvinha, editors. BRICS "Sports Mega Events and Health Promotion: Policies and Legacies in Exercise and Sports Science" 2017; pp. 1-110. Santos Brazil: BRICSCESS.

24. Liu J, Sui X, Lavie CJ, Zhou H, Park YM, Cai B, *et al.* Effects of cardiorespiratory fitness on blood pressure trajectory with aging in a cohort of healthy men. J Am Coll Cardiol 2014;64:1245–53.

25. Cooper RJ. Waist to height ratio in relation to time to run 550 m in primary school children in the Waikato region (Doctoral dissertation, Auckland University of Technology); 2013 [Internet]. Available from: https://niphmhr.aut.ac.nz/__data/assets/pdf_file/0013/7600/Rebecca-Copper-Masters-Thesis.pdf [cited 2018, May 11].

26. Klasson-Heggebø L, Andersen LB, Wennlöf AH, Sardinha LB, Harro M, Froberg K, *et al.* Graded associations between cardiorespiratory fitness, fatness, and blood pressure in children and adolescents. Br J Sports Med 2006;40:25–9, discussion 25–9.

Conflicts of interest.—The authors certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

Funding.—The authors wish to acknowledge National Research Foundation (NRF), South Africa for partly funding the study (NRF Grant No. SFP: 190129411856).

Acknowledgements.—Appreciation is extended to the parents and their children who participated in the study.

History.—Manuscript accepted: October 2, 2018. - Manuscript received: July 23, 2018.