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Research Article
Physical Activity and Risk Factors of Cardio-metabolic Diseases in South African Children

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Abstract

Background and Objectives: Prevalence of overweight and obesity and its associated cardio-metabolic disease risk has become a major public health concern world-wide. This study examined the relationship between physical activity and risk factors of cardio-metabolic diseases among South African children. **Materials and Methods:** A total of 1361 (boys: n = 678; girls: n = 683) aged 9-13 years South African primary school children participated in the study. Body weight, body height, waist and hip circumferences and blood pressure were measured using standard protocol. Body mass index (BMI) and waist-to-hip ratio were calculated and used in the evaluation of health risks associated with cardio-metabolic diseases. A short version of the International Physical Activity Questionnaire was used to evaluate physical activity levels among the children. Data were coded and analyzed using SPSS software. **Results:** A total of 67.1 and 32.9% of boys and girls, participated in the study, respectively. A significant low physical activity level of participation was observed in the studied group. Derived physical activity categories as stratified by gender, indicated that 28.8, 56.7 and 14.5% of boys had low, moderate and vigorous mets, respectively. For girls, 26, 59 and 15% low, moderate and vigorous mets, was observed. **Conclusion:** The South African children had low levels of physical activity which were significantly associated with increased BMI, systolic and diastolic blood pressures.

Key words: Physical activity, obesity, cardio-metabolic disease risk, prevalence, regression

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

The exponential and persistent rise in the prevalence of overweight and obesity and their associated CMD risk factors in both developed and developing countries, has become a foundation of distress more than now it has ever been in the past[1]. Of particular concern, is the fact that physical inactivity (PI) and resultant obesity are considered predominant health problems which have contributed to rapid increase in global non-communicable disease (NCDs)[2]. A number of international studies have documented that PA habits in childhood could lead to elevated cholesterol levels and an increased risk of developing cardiovascular disease (CVD) in early adulthood[3,4]. In addition, childhood adiposity as measured by body mass index (BMI) is related to metabolic disorders during young adulthood such as obesity, overweight, hypertension and high triglyceride levels[2]. In children, high waist circumference (WC) and central fat distribution correlate positively with metabolic risk factors such as high systolic and diastolic blood pressure and elevated levels of cholesterol[5]. The combination of physical inactivity, high caloric intake and possible genetic predisposition are claimed to play a major role in the development of CMDs[6,1]. The inter relationships of unhealthy lifestyle, PI and the resultant CMD risk emphasise the need to plan an integrated comprehensive programmes to prevent such diseases in South Africa. Engagement in regular PA during childhood has been hypothesised to be associated with a healthier, longer life with a lower risk of heart disease, high blood pressure, diabetes, obesity and some cancers[7]. Apparently, this universal support for the promotion of PA seems to challenge how levels of participation should be defined and quantified. This perspective may be challenging due to the fact that children's and adolescents' PA vary with age, type of exercise and the settings[8-10].

Although considerable efforts have been made to encourage and sustain involvement in higher PA participation levels in children and adolescents, a marked decline in habitual PA has been identified[11,12]. Whilst scientific literature has shown that PA affects body composition favourably by promoting fat loss while maintaining or increasing lean tissue mass, it is still difficult to quantify the aggregate of PA needed to curb the development of CMD risks among children and adolescents. In spite of these convincing suppositions, very few recent studies have been reported concerning PA and risk factors of CMD among school children in Limpopo and Mpumalanga provinces of South Africa, uncertainty also exists as to whether the current development in PA and risk factors of CMD in children and adolescents in these provinces would be comparable to those obtained in other regions of the country. Therefore, this study was primarily designed to examine the relationships between PA and risk factors of CMDs among South African children. A secondary objective of the study was to determine the CMD risk factors with the highest PA prediction power among the children.

Unlike previous studies on South African children, the present investigation applies more robust and sophisticated data analysis techniques to evaluate the extent to which the CMD disease risk among South African children could be predicted from their data on PA participation. Such prediction analysis is important as it highlights the need for urgent preventative health promotion intervention to address the situation.

MATERIALS AND METHODS

Participants: A total 1361, of 678 boys and 683 girls aged 9-13 years were randomly selected from eight primary schools in each of Limpopo (LP) (n = 708) and Mpumalanga (MP) (n = 653) provinces, located in the northern and north-eastern parts of South Africa, respectively. Class registers were used to draw targeted samples of children depending on the pupil's population density at each school. Information regarding the children's socio-demographic characteristics (PA and CMD risk) which included age, gender, ethnicity and residence, were obtained from the school register. However, children who were reportedly ill and whose ages were beyond the lower and upper limits of the categories set for the study were excluded. The study was conducted from May to September 2013.

Measures: The participants' anthropometric measurements, which included body weight, body height, waist and hip circumferences, were measured using the International Society for the Advancement of Kinanthropometry (ISAK) protocol[13]. Based on these variables, BMI (weight/height^2) was derived and used to classify the children according to weight categories as follows: underweight (0<18), normal (18.5<25), overweight (25<30) or obese (>30) for age and gender. Waist-to-hip ratio (WHR) was calculated by dividing waist circumference (WC) (cm) by hip circumference (HC) (cm) and used to measure abdominal visceral adipose tissue (VAT) among children. BMI and WHR both were used in the evaluation of health risks associated with CMDs.

Blood pressure measurement: Blood pressure (BP) was measured using electronic BP 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) were applied for the BP measurements to determine potential health risk factors and the relationship between PA and BP among children[14]. BP values between 90th and 95th percentiles in childhood are labelled as "high normal" or "pre-hypertensive," and are an indication for lifestyle modification. Based on these guidelines, the readings at the first and third BP monitors were taken as SBP and DBP, respectively.

Physical activity measurement: A short version of the IPAQ, which is a valid and reliable tool was used to evaluate PA level among the children[15,16]. The self-report questionnaire included items on habitual PA, frequency and duration of sports participation including indoor ball games such as soccer, basketball, volleyball and other outdoor activities like running/jogging, track-and-field sports, dancing and free play among the school children. The school children completed the IPAQ in the classroom under the supervision and guidance of trained research assistants. The children were defined as physically active (those who participate in sports and/or vigorous activities), moderately active (those who participate in hard physical and moderate activities) and low active (those who participate in activities like walking and sitting) according to their participation in the mentioned activities at least seven times per week for a minimum of 10 min at a time. Using the IPAQ only those sessions which lasted 10 min or more were analysed. All types of PA related to occupation, transportation, household chores and leisure time were also included. IPAQ also covers information about time spent sitting, which was used as an indicator of PI. Based on the children's IPAQ scores, their PA levels were categorised as follows: Low = the METs scores of less than 500; Moderate = METs scores of between 500-1499 and Vigorous = METs>1500.

Procedures: A cross-sectional design was used to collect data on anthropometric, blood pressure (BP) and PA variables as determinants of health risks in the targeted samples of primary school children. Eight trained research assistants who were post-graduate students at the Department of Nursing and School of Education, University of the Limpopo, South Africa participated in the data collection. A specialized training workshop was conducted for the research assistants to enable them to competently undertake the measurements. At the workshop each assistant was trained to perform a specific task and measurement procedure at a designated work station, e.g. body weight measurement. Each work station had a team leader who coordinated prescribed data collection procedures. Before data collection commenced, the participants filled the demographic section of the data form and reported their habitual PA under the supervision of the principal investigators.

Statistical analysis: Data were analysed using descriptive statistics, such as means, standard deviations and frequencies. Independent t-test was used to examine significant differences between two ordinal variables to assess disparity between the categorical variables. Data on the children's CMD risk factors based on categorised PA levels of low, moderate and vigorous, were computed using one-way analysis of variance (ANOVA). Spearman's correlation coefficient was calculated to determine the relationship between PA and risk factors of CMDs among the school children. Univariate regression analysis was performed in order to identify significant predictors of PA categories. Multiple linear (backward) regression model wasused to determine the relative influence of the variables. Only the most predicting variable in the best possible models were reported for each PA categories. All data analyses were performed using the Statistical Package for the Social Sciences (SPSS) (version 23.0 of 2015 for Windows; SPSS Inc., Chicago, IL)[17]. For all statistical analyses the level of significance was set at $p \leq 0.05$.

Ethical considerations: The Ethics Sub-committee of the Faculty of Health Sciences, North-West University, South Africa (Ethics no: NWU-00088-12-S1) and other relevant provincial regulatory organisations granted ethics approval for the research to be carried out. Before data collection, permission to conduct the study was granted by Provincial Heads of Education Departments and District Managers for the Department of Basic Education in the Limpopo and Mpumalanga Provinces. An information leaflet and informed consent forms were administered to the head teachers, pupils and their parents or guardians who gave permission for the study to be conducted.

RESULTS

This study examined the relationship between PA and risk factors of CMD in South African primary school children aged 9-13 years. Physical characteristics of the children according to gender were are presented in Table 1. The results showed that the girls (11.0±1.29) were significantly older than the boys (10.8±1.26). In terms of the weight categories, boys (35.2±9.66 kg) were significantly heavier

Table 1: Physical characteristics of the participants (Mean±SD) (n =1361)

Variables	Boys (n = 683)	Girls (n = 678)	Total (n = 1361)	p-value
Age (year)	10.80±1.26	11.00±1.29	10.90±1.28	0.006
Height (cm)	140.00±9.94	139.00±9.16	139.50±9.57	0.051
Weight (kg)	35.20±9.66	33.50±8.68	34.40±9.22	0.001
BMI (kg m^{-2})	17.70±3.43	17.10±3.24	17.40±3.35	0.004
Waist circ. (cm)	60.00±28.3	58.70±5.89	59.30±20.4	0.237
Hip circ. (cm)	74.30±9.93	70.50±7.53	72.40±9.01	0.000
WHR	0.81±0.39	0.83±0.04	0.82±0.28	0.136
Systolic (mmHg)	113.60±13.5	110.10±13.1	111.90±13.4	0.000
Diastolic (mmHg)	78.20±12.6	76.70±13.3	77.50±13.0	0.035
Low PA (Mets)	26.70±127.4	41.20±197.7	33.90±166.3	0.107
Moderate PA (Mets)	410.60±388.0	415.10±374.2	412.80±381.1	0.830
Vigorous PA (Mets)	411.20±372.3	409.60±352.0	410.40±362.2	0.934
Total PA (Mets)	848.60±575.8	865.90±560.0	857.20±567.8	0.573

*p<0.05

Table 2: CMD risk factors of the participants based on categorised PA of low, moderate and high levels

	Low PA (mets) (n = 373)		Mod. PA (mets) (n = 787)		Vig. PA (mets) (n = 201)		T. PA (Mets) (n = 1361)		
Variables	Mean	SD	Mean	SD	Mean	SD	Mean	SD	p-value
Age (year)	11.60	1.21	10.70	1.26	10.70	0.97	10.90	1.28	0.000
Stature (cm)	143.20	10.60	138.00	9.01	138.80	7.58	139.50	9.57	0.000
Weight (kg)	36.90	8.92	33.50	9.53	33.10	7.48	34.40	9.22	0.000
BMI (kg m^{-2})	17.80	3.39	17.30	3.49	17.00	2.53	17.40	3.35	0.007
Waist circ. (cm)	63.10	37.30	58.20	6.92	57.00	6.02	59.30	20.40	0.000
Hip circ. (cm)	75.40	8.87	71.40	9.11	70.80	7.52	72.40	9.01	0.000
WHR	0.84	0.53	0.81	0.05	0.80	0.52	0.82	0.28	0.254
Systolic (mmHg)	113.50	10.40	111.40	13.80	110.80	16.50	111.90	13.40	0.022
Diastolic (mmHg)	80.30	12.60	76.90	12.80	74.30	13.50	77.50	13.00	0.000

*p<0.05, BMI: Body mass index, WHR: Waist-to-hip ratio, SBP: Systolic blood pressure, DBP: Diastolic blood pressure, SD: Standard deviation

than girls (33.5±8.68 kg). However, BM4 I results revealed a significantly higher mean value in boys (17.7±3.43 kg m^{-2}) than girls' (17.1±3.24 kg m^{-2}). With regards to SBP and DBP, a high significant difference was observed in boys (113.6±13.5 and 78.2±12.6 mmHg) compared with girls (110.1±13.1 and 76.7±13.3 mmHg). No significant differences were observed in PA categories among the boys and girls.

Participants' CMD risk factors based on categorised PA levels of low, moderate and vigorous mets were derived as presented in Table 2. The CMD risk factors of the participants based on PA categories using one-way ANOVA revealed that there was a significant difference in age (p = 0.000), height (p = 0.000), weight (p = 0.000), BMI (p = 0.007), WC (p = 0.000), HC (p = 0.000), SBP (p = 0.022) and DBP (p = 0.000). However, no significance difference was found with regards to WHR (p = 0.254). The results showed that children with low PA were at higher risks of developing CMD in view of their significantly higher mean values of body weight (36.9 kg), BMI (17.8 kg m^{-2}), waist (63.1 cm) and hip (75.4 cm) circumferences, SBP (113.5 mmHg) and DBP (80.3 mmHg) in comparison to those with moderate and vigorous PA levels (p<0.001). WHR did not significantly discriminate any of the PA categories.

Correlation matrix showing the relationship between PA categories and CMD risk factorsareprovided in Table 3. Bivariate correlation analysis showed that there was statistically a significant correlation between age and MPA (r = -0.198, p<0.001), age also inversely correlated with TPA (r = -0.138, p<0.001). However, participants' body weight, stature and BMI (r = -0.152, p<0.001); (r = -0.131, p<0.001) and (r = -0.117, p<0.001), showed a significant negative correlation with MPA and stature also correlated positively with VPA (r = 0.102, p<0.001). Further analysis also indicated a significantly negative correlation between SBP, DBP and TPA (r = -0.119, p<0.001) and (r = -0.173, p<0.001), respectively. DBP was found to be inversely correlated with LPA (r = -0.193, p<0.001). A significantly negative correlation was observed between the waist and hip circumferences and MPA (r = -0.162, p<0.001) and (r = -0.181, p<0.001). Waist and hip circumferences were also noted to be inversely correlated with TPA (r = -0.116, p<0.001) and (r = -0.105, p<0.001) (Table 3).

Presented in Table 4 is the multiple linear regression analysis to examine the best variables from the model for CMD risk factorsthat predicts PA categories. Multiple linear regression analyses revealed that age (β = -0.058, p = 0.036),

Table 3: Correlation matrix showing the relationship between PA categories and CMD risk factors

Variables	Age	Weight	Stature	BMI	Waist	Hip	WHR	SBP	DBP	LPA	MPA	VPA	TPA
Age (years)	1.000	0.570**	0.644**	0.304**	0.440**	0.467**	-0.148**	0.115**	-0.025	-0.033	-0.198	0.082	-0.138**
Weight (kg)	0.570**	1.000	0.822**	0.813**	0.817**	0.906**	-0.293	0.245	0.091**	0.039	-0.152	0.062	-0.068*
Stature (cm)	0.644**	0.822**	1.000	0.378**	0.592**	0.687**	-0.266**	0.174**	0.038	0.001	-0.131**	0.102**	-0.069*
BMI (kg m^{-2})	0.304**	0.813**	0.378**	1.000	0.752**	0.799**	-0.223**	0.248**	0.112**	0.067*	-0.117**	0.004	-0.039
Waist circ. (cm)	0.440**	0.817**	0.592**	0.752	1.000	0.793**	0.103**	0.234**	0.096**	-0.022	-0.162**	0.060*	-0.116**
Hip circ. (cm)	0.467**	0.906**	0.687**	0.799**	0.793**	1.000	-0.462	0.277**	0.098**	0.023	-0.181**	0.051	-0.105**
WHR	-0.148**	-0.293**	-0.266**	-0.223	0.103**	-0.462**	1.000	-0.120**	-0.027	-0.060	0.052	-0.003	0.004
SBP (mmHg)	0.115**	0.245**	0.174**	0.248**	0.234**	0.277**	-0.120**	1.000	0.381**	-0.077	-0.089**	0.032	-0.119**
DBP (mmHg)	-0.025	0.091**	0.038	0.112**	0.096**	0.098**	-0.027	0.381**	1.000	-0.193**	-0.036	-0.011	-0.173**
LPA (low METs)	-0.33	0.039	0.001	0.067*	-0.022	0.023	-0.060*	-0.077**	-0.193**	1.000	0.043	0.001	0.678**
MPA (mod. METs)	-0.198**	-0.152**	-0.131**	-0.117**	-0.162**	-0.181**	0.052	-0.089	-0.036	0.043	1.000	0.009	0.708**
VPA (high METs)	0.082**	0.062*	0.102**	0.004	0.060*	0.051	-0.003	0.032	-0.011	0.001	0.009	1.000	0.157**
TPA (total METs)	-0.138**	-0.068*	-0.069*	-0.039	-0.116**	-0.105**	0.004	-0.119**	-0.173**	0.678**	0.708**	0.157**	1.000

**Correlation is significant at the 0.01 level (2-tailed), *Correlation is significant at the 0.05 level (2-tailed), PA: Physical activity, BMI: Body mass index, WHR: Waist-to-hip ratio, SBP: Systolic blood pressure, DBP: Diastolic blood pressure, VPA: Vigorous physical activity, MPA: Moderate physical activity, LPA: Low physical activity, TPA: Total physical activity

Table 4: Multiple linear regression analysis examining the best variables from the model for CMD risk factors predicting of PA category levels

PA categories	R^2	Independent variables	Standardised beta	p-value	F-ratio
Low PA	0.045	Age	-0.058	0.036	15.978**
		BMI	0.089	0.002	
		Systolic BP	0.051	0.091	
		Diastolic BP	-0.219	0.000	
Moderate PA	0.037	Age	-0.195	0.000	53.653**
Vigorous PA	0.003	Diastolic BP	-0.062	0.022	5.283*
Total PA	0.048	Age	-0.141	0.000	30.206**
		Diastolic BP	-0.155	0.000	

**p<0.01, F-ratio, PA: Physical activity, BP: Blood pressure

body mass index (β = 0.089, p = 0.002), systolic blood pressure β = 0.051, p = 0.091) and diastolic blood pressure (β = -0.219, p = 0.000) significantly predicted low physical activity among the children, whilst age (β = -0.195, p = 0.000) and diastolic blood pressure (β = -0.062, p = 0.022) significantly predicted moderate and vigorous physical activity, age (β = -0.141, p = 0.000) and diastolic blood pressure (β = -0.155, p = 0.000) also substantially predicted total physical activity.

With regards to univariate analysis age, BMI, SBP, DBP, WHR and gender (β = -0.059; p = 0.034, β = 0.088; p = 0.002, β = 0.051; p = 0.098, β = -0.217; p = 0.000, β = -0.042; p = 0.119, β = 0.005; p = 0.856) significantly predicted LPA. In the backward regression analysis, 3 possible models were generated. The results showed that the 3rd model with age, BMI, SBP and DBP was the best of all possible models, since it had the highest value of adjusted R^2 which represents the amount of variance (4.5%) accounted for in the LPA predicted model. Also, univariate analysis revealed that age, BMI, SBP, DBP, WHR and gender (β = -0.192; p = 0.000, β = -0.020; p = 0.487, β = -0.009; p = 0.775, β = -0.020; p = 0.511, β = -0.038; p = 0.155, β = 0.018; p = 0.509) significantly predict MPA. In the backward regression analysis, 4 possible models were generated. The results showed that the 4th model with age variable was the best of all possible models, since it had the highest value of adjusted R^2 which represents the 3.7% of the variance in the MPA predicted model. The univariate analysis also revealed that age, BMI, SBP, DBP, WHR and gender (β = 0.030; p = 0.296, β = -0.016; p = 0.573, β = 0.013; p = 0.673, β = -0.062; p = 0.040, β = -0.005; p = 0.862, β = 0.039; p = 0.161) non-significantly predicted higher PA.

In the backward regression analysis, 4 possible models were generated. The results showed that the 4th model with DBP was the best of all possible models, since it had the highest value of adjusted R^2 which represents 0.3% the amount of variance in the VPA predicted model. Further analysis indicated that age, BMI, SBP, DBP, WHR and gender (β = -0.158; p = 0.000, β = 0.038; p = 0.177, β = 0.030; p = 0.322, β = -0.170; p = 0.000, β = -0.053; p = 0.045, β = 0.026; p = 0.327), significantly predict TPA. In the backward regression of 3 possible models that were generated, the results showed that the 3rd model with age and DBP was the best of all possible models, since it had the highest value of adjusted R^2 which represents 4.1% of the amount of variance in the TPA predicted model (Table 4).

DISCUSSION

The purpose of this study was to examine the relationships between PA and the risk factors of CMD diseases among South African children and to investigate the CMD risk factors with the highest PA prediction power among the children. Obesity has a profound influence on both children and adolescents' quality of life and donates to an expansive variety of adverse health effects. The combination of inactivity, excessive energy intake and a possible genetic predisposition plays an increasing role in this development. However, systematic evaluation of the independent contributions of CMD risk factors to PA categories (low, moderate and vigorous) in youth in under-studied populations such as South African children and adolescents, is limited and needs further investigation.

The results of the present study showed that large numbers of boys and girls were physically inactive, with the girls having a higher PA level than boys on average. This finding seems surprising and unique in the sense that boys are usually reported to engage more in PA than girls[18,19]. The low levels of participation in PA reported for many South African children could be attributed to several reasons. One of the main reasons was the low priority given to physical education (PE) in public schools[20]. Many of the schools are also without the necessary sport facilities and play grounds that could accommodate large number of pupil at the same time, living many of the children inactive[20]. Addressing the low prevalence of PA levels among children and youth is therefore highly important in the quest to prevent chronic disease risks factors.

The derived PA categories (low, moderate and vigorous/high Mets) of the participants according to gender revealed that both boys and girls were involved in low to moderate levels of PA. McCrindle *et al.*[21] stated that lower PA levels were significantly associated with worse observed overall health. This denotes that high PA is associated with a high metabolic equivalent which yields better quality of life.

Present study showed a significant relationship between the children's age, moderate and total PA. Age has been reported to be related to PA and that, as one ages, PA also declines[22]. This study was also found a significant relationship between BMI and moderate PA. This finding is consistent with those of Hemmingsson and Ekelund[23] who reported a significant association between BMI and six PA categories. The PA categories listed were sedentary, light, moderate, vigorous, activity counts and steps per day (Table 3), although it was suggested that the association between BMI and PA categories could be different based on the status of obesity. Furthermore, the association between PA and CMD risks may be mediated through the effect of excess adiposity[24].

Findings from the multiple regression (univariate) analysis revealed that age, BMI, SBP, DBP, WHR and gender significantly predicted LPA, MPA, TPA, but could only insignificantly forecast VPA or higher PA. However, the use of backward regression analyses to examine the best variables from the model for CMD risk factors that could predict each PA category indicated that age, BMI, SBP and DBP significantly predicted low PA category. The finding thus suggested that a unit increase in low PA could reduce one's life span. Furthermore, a unit increase in low PA could result to an increase in BMI and SBP, while DBP declines. Age was seen to be the main variable that significantly predicted moderate PA. Consequently, a unit increase in MPA could significantly promote reduction in the future adverse effects of ageing. Furthermore, a unit increase in higher or VPA could result in a unit reduction of DBP in youths. The findings of this study therefore suggested that South African youths with low levels of PA and increased sedentary habits are vulnerable to risk of developing CMD.

This study is one of the few that examined the relationship between PA and the risk factors of CMD among school children. However, its findings cannot be generalised to the entire South African population as data were collected only in specific schools.

CONCLUSION

The results of this study demonstrated clear relationships between PA and non-communicable disease risk among South African children. The children had low levels of physical activity which were significantly associated with increased BMI, systolic and diastolic blood pressures.

SIGNIFICANCE STATEMENT

This study is significant as it has shown that low physical fitness and inadequate PA levels among children and adolescents are associated with the development of CMDs later in life. Thus, understanding the relationship between the amounts of PA needed to restrain the development of CMD risks could possibly reverse the growing trends among children and youth. These findings showed a clear relationship between PA and CMD risks in South African children. The results will be supportive to coaches, physical education teachers, sport scientists and clinical experts to periodically evaluate PA levels in South African children in order to alleviate increasing concerns over health crises and improve the quality of life.

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