

Original Article

Modification of Cardiometabolic Disease Risk Factors in Overweight Children: An Exploratory Study of Different Exercise Doses

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Abstract

The purpose of this study was to assess the effects of two different exercise doses on cardiometabolic risk factors in overweight children. Participants were randomly assigned to either moderate-intensity high-frequency exercise or vigorous-intensity low-frequency exercise for a total duration of 6 weeks. The moderate-intensity high-frequency group (n = 5) participated in 30 sessions, which were set at 40% – 60% of heart rate reserve. The vigorous-intensity low-frequency group (n = 7) participated in 18 sessions, which were set at 60% – 80% heart rate reserve. The results showed that fasting glucose level (- 6.79%, $p < 0.13$) responded better to moderate-intensity high-frequency exercise whereas vigorous-intensity low-frequency exercise induced greater improvements in systolic blood pressure (- 5.98%, $p < 0.23$) with a mean change of -6.4 mmHg. This study showed that two different exercise doses improved selected cardiometabolic variables in overweight children. Hence, this study provides exercise recommendations for achieving specific cardiometabolic health benefits in overweight children.

Key words: Cardiometabolic disease risk factors, obesity, overweight children

Introduction

The percentage of overweight primary school children in South Africa increased from 1.2% in 1994 to 13% in 2004 (Armstrong et al., 2011). Although morbidity from obesity-related disorders (e.g. cancer, congestive heart failure, pulmonary embolism, chronic renal failure, and depression) generally manifests during adult years, the pathological processes begin during pediatric years (Guillaume et al., 1997; Shalitin et al., 2009; Gutin & Owens, 2011). The NAHSIT-ESC (Nutrition and Health Survey in Taiwan Elementary School Children) survey reported that obese children have higher blood pressure, triglyceride levels, low-density lipoprotein cholesterol, uric acid, and serum glutamic pyruvic transaminase levels when compared with normal weight children (Chu, 2005; Chu & Pan, 2007). The prevalence of children leading sedentary lifestyles has increased over the years, and a variety of environmental factors have contributed to this problem. Two key environmental factors that have fueled the obesity epidemic are diets rich in fat and processed carbohydrates as well as physical inactivity (Shalitin et al., 2009). Regular physical activity (PA) lowers the prevalence of cardiometabolic disease risk factors (Sattelmair et al., 2011). The progression and associated complications of the disease is best modified during early years (Barbeau et al., 2007). A range of substantial health benefits is associated with accumulating 150 minutes of moderate-intensity or 75 minutes of vigorous-intensity PA per week (ACSM, 2010). Classification of the required amount of PA is possible when considering the metabolic equivalent of activities, though restrictions exist when assigning energy costs in children (Spadano et al., 2003; Warburton, Nicol, & Bredin, 2006; Bushman, 2012). Several studies question the effectiveness of the recommended PA guidelines for children in preventing cardiovascular disease risks (Andersen et al., 2006; Gutin & Owens, 2011). An observational study suggests that 90 minutes of moderate-intensity PA per day is necessary to prevent insulin resistance in children (Andersen et al., 2006). In contrast, meta-analysis revealed that vigorous-intensity PA is more effective in modulating biomarkers and is associated with greater improvements in fitness and fat percentages in youth compared with moderate-intensity PA (Gutin & Owens, 2011).

The global obesity epidemic will likely result in the prevalence of cardiometabolic disease risk factors manifesting at younger and younger ages, yet little evidence is available on the particular exercise prescription for reducing cardiometabolic disease risk factors in children. Therefore, the current study sought to investigate the effect of 2 different exercise doses on cardiometabolic disease risk factors in overweight children.

Materials & Methods

Participants A convenience sample of twelve (nine male, three female) 11-13-year-old children were recruited from the Zululand area in South Africa. Nine participants were Caucasian, and 3 were African. Participants were

screened prior to the inclusion in the study to ensure that the requirements of being classified as overweight were met (Heber, 2002). Participants taking chronic medications that are known to affect heart rate/pulmonary function were excluded. The study was approved by the Ethics Committee of the Faculty of Science & Agriculture at the University of Zululand, South Africa. Signed informed assent and consent forms were obtained from the participants and parents or guardians of the participants.

Instruments and Measurements

Data collection took place over three consecutive days. Post-measurements were taken within a week after the participants completed the exercise programs.

Target Heart Rate

Target heart rate was measured continuously using a polar heart rate monitor during the exercise programs. This ensured the set target heart rate ranges for the respective exercise groups. More specifically, the target heart rate ranges were calculated using the Karvonen method with heart rate reserve (HRR), accounting for individual resting heart rate. Resting heart rate was measured in a private classroom after sitting quietly for 5 minutes. The target heart rate range of the moderate-intensity high-frequency (MIHF) group was calculated at 40% – 60% of HRR, and that of the vigorous-intensity low-frequency (VILF) group was set at an intensity range of 60% – 80%. Alarms were set on polar watches to denote deviancy of intensity.

Resting Blood Pressure

Blood pressure was assessed manually using a Nantong Honsun (Co. Ltd, China) sphygmomanometer and stethoscope. Measurements were recorded in millimeters of mercury (mmHg). Blood pressure was assessed in a seated position after participants rested quietly for 5 minutes.

Fasting Glucose & Total Cholesterol

Fasting blood glucose and total cholesterol levels were measured using an Accu-chek[®] Performa (Roche Diagnostics, Germany) system early in the morning after fasting for >10 hours (ACSM, 2010). Samples were obtained via finger prick.

Anthropometric Measurements

Stature and body mass of the participants were measured using a stadiometer and a digital metric scale to the nearest 0.1 cm and 0.1 kg respectively. BMI percentile was calculated for the participant inclusion criteria. A measuring tape was used to obtain waist and hip circumferences to the nearest 0.1 cm (ACSM, 2010). Participants were bare footed and dressed in PE attire (lightweight shorts and collar shirts).

Cardiorespiratory fitness

Participants completed the 20-meter shuttle run test to obtain indirect VO_{2max} values (Leger et al., 1988). Participants were encouraged and guided through the test up to the point where they could not complete the specific level of the test. The latter was recorded on individual data sheets immediately after the level failure. The formula for estimating VO_2 peak was calculated as $VO_2 \text{ peak} = 31.025 + 3.238 \text{ Speed (km/h)} - 3.248 \text{ Age (years)} + 0.1536 \text{ Speed} \times \text{Age}$ (Leger et al., 1988).

Exercise Program Protocols

The moderate-intensity high-frequency (MIHF) exercise was set at 40% - 60% of HRR and consisted of 30 sessions (5 days/wk). The vigorous-intensity low-frequency (VILF) exercise entailed 18 sessions (3 days/wk) set at 60% - 80% of HRR. Both 6-week exercise protocols were a combination of cardiorespiratory and body weight resistance activities that lasted 40 minutes in total. Each session was divided into warm-up, cool-down and work-out periods. All sessions were conducted on the sports field at the school after school hours. Sessions were moved to the school hall in the event of bad weather. Each participant was fitted with a polar heart rate monitor before the start of the exercise session. Table 1 outlines the specific activities that were included within the exercise protocols (McKenzie et al., 2000). Exercise activities and volumes (work: rest, repetitions and duration) that are shown in the table are estimated and were adjusted according to target heart rates and motivation/interest of participants.

Table 1. Overview of 6-Week Activities.

WEEK	MIHF GROUP (40% - 60% HRR)	VILF GROUP (60% - 80% HRR)
1	Climbing steps (5×2 ; 30 s rest) Gallop 10m (5×1 ; 15 s rest) Hula hoop ($1 \text{ min} \times 3$; 30 s rest) Lunges ($5 \text{ with each leg} \times 2$; 30 s rest) Crunches (20×3 ; 30 s rest) Leg lifts ($20 \text{ with each leg} \times 2$; 30 s rest) One hundreds ($100 \text{ counts} \times 2$; 30 s rest) Ladies push-ups (8×2 ; 30 s rest) Pelvic lifts (20×2 ; 15 s rest) Skipping rope ($20 \text{ s} \times 3$; 30 s rest)	Jumping jacks ($15 \text{ jumps} \times 5$; 15 s rest) Hop on one leg between rugby goal posts ($\text{One leg there, other leg back} \times 3$; 15 s rest) Sprint 10m (5×1 ; 10 s rest) Jump 10m (5×1 ; 10 s rest) Squats (10×4 ; 15 s rest) Crunches (20×3 ; 30 s rest) Cross over crunch (10×2 ; 30 s rest) One hundreds ($100 \text{ counts} \times 2$; 30 s rest) Leg lifts on a side (20×2 ; 30 s rest) Ladies push-ups (8×2 ; 30 s rest) Plank ($30 \text{ s} \times 2$; 30 s rest) Skipping rope ($30 \text{ s} \times 5$; 30 s rest)
2	BOOTCAMP WEEK ($15 \text{ reps} \times 3 \text{ sets}$) Rest 2 min between sets Squats	BOOTCAMP WEEK ($20 \text{ reps} \times 4 \text{ sets}$) Rest 1 min between sets Squats

	Fast feet Twist bend knee sit up Burpies Arm lifts High knees Side bends In and out hops Floor swimming Kick buttock Walking lunges Scissor jumps	Fast feet Twist bend knee sit up Burpies Arm lifts High knees Side bends In and out hops Floor swimming Kick buttock Walking lunges Scissor jumps
3	Jumping Jacks (15 × 3; 30 s rest) 1-Leg jumps on a spot (15 × 1; 15 s rest) Hula hopscotch (5 min; 30 s rest) Squats (8 × 2; 30 s rest) Heal taps (20 × 2; 30 s rest) Side plank (20 s × 2; 30 s rest) Zigzag running (2 min; 30 s rest) Bridge hold (30 s × 4; 30 s rest) Tricep dips on chair (8 × 2; 30 s rest) Crunches 45° arms (20 × 2; 30 s rest)	Jumping Jacks (15 × 5; 15 s rest) 1-Leg jumps on a spot (15 × 2; 10 s rest) Hula hopscotch (2 min × 3; 10 s rest) Squats (8 × 2; 15 s rest) Heal taps (20 × 3; 10 s rest) Side plank (20 s × 2; 10 s rest) Zigzag running (2 min × 3; 10 s rest) Bridge hold (30 s × 4; 10 s rest) Tricep dips on chair (8 × 2; 15 s rest) Crunches 45° arms (20 × 2; 15 s rest)
4	Agility T-run (4 sets; 45 s rest) 10m Ladder run for (5 min) 10m Hula hoop hurdles (5 min) Builders and bulldozers (7 min) Freeze and go (4 sets) Climbing stairs (3 min; 1 min rest)	Agility T-run (6 sets; 30 s rest) 10m Ladder run for (7 min) 10m Hula hoop hurdles (7 min) Builders and bulldozers (10 min) Freeze and go (6 sets) Climbing stairs (5 min; 1 min rest)
5	Toss bean bag in air and catch it (3 min) Crust & Crumbles (7 min) Frog jumps, Grandpa walk, Crab sidewalks (7 min) Quiz (Star jumps, Burpies) (7 min) High knees Kick bum Jog Grapevine Fast feet sideways Sprint Run backwards	Toss bean bag in air and catch it (5 min) Crust & Crumbles (10 min) Frog jumps, Grandpa walk, Crab sidewalks (8 min) Quiz (Star jumps, Burpies) (10 min) High knees Kick bum Jog Grapevine Fast feet sideways Sprint Run backwards
6	Circuit training (10 min) Resistance bands-leg lifts, ball-lift from ground to sky SLOWLY, weights-bicep curls, mat-crunches Moving around the track 7 m × 7 m (5 min) Jogging Aerobic bowling Star jumps, scissor jump (8 min) Jump back and forth over rope (10 jumps each) Ocean wave, snake in the grass Four lines (5 min) 1, 2, 3, 4	Circuit training (10 min) Resistance bands-leg lifts, ball-lift from ground to sky FAST, weights-bicep curls, mat-crunches Moving around the track 10 m × 10 m (5 min) Sprinting Aerobic bowling Star jumps, burpies (8 min) Jump back and forth over rope (20 jumps each) Ocean wave, snake in the grass Four lines (10 min) 1, 2, 3, 4

Data Analysis

Descriptive data are expressed as means, standard deviations (SD) and percentage change. Pearson Correlation Coefficients were used to assess associations between variables. The Mann-Whitney U test was utilized to compare measurements between the two exercise groups and the Wilcoxon signed-rank test was calculated to determine pre and post-intervention measures within each group. Significance was set at $p < 0.05$ using GraphPad Prism® (GraphPad Software. Inc., CA, USA).

Results

Five ($n = 5$) participants completed 30 sessions of MIHF, and seven ($n = 7$) participants completed 18 sessions of VILF. The main findings of this study showed that two different exercise doses elicited specific cardiometabolic benefits in overweight children. Fasting glucose level (- 6.79%, $p < 0.13$) responded better to MIHF, whereas VILF provided greater improvements in systolic blood pressure (- 5.98%, $p < 0.23$). Mean values and percentage change are presented in table 2.

Table 2. Pre-post changes in CMD risk factors in participants.

Variables	MIHF Group (n = 5)				VILF Group (n = 7)			
	Pre test Mean $\pm$ SD	Post test Mean $\pm$ SD	% Change	p	Pre test Mean $\pm$ SD	Post test Mean $\pm$ SD	% Change	p
BM (kg)	76.1 $\pm$ 12.93	75.6 $\pm$ 13.85	-0.66%	0.44	76.11 $\pm$ 19.01	77.31 $\pm$ 20.43	1.58%	0.23
BMI (kg/m ²)	31.05 $\pm$ 5.05	30.85 $\pm$ 5.37	-0.64%	0.44	29.9 $\pm$ 4.97	30.34 $\pm$ 5.48	1.47%	0.22
WC (cm)	91.60 $\pm$ 10.01	84.2 $\pm$ 10.03	-8.08%	0.06	91.14 $\pm$ 9.62	86.14 $\pm$ 12.85	-5.49%	0.03*
HC (cm)	107 $\pm$ 7.97	103.4 $\pm$ 7.64	-3.36%	0.13	105.9 $\pm$ 12.5	101.4 $\pm$ 12.53	-4.25%	0.09
SBP (mmHg)	110.60 $\pm$ 8.53	108 $\pm$ 9.27	-2.35%	0.63	107.1 $\pm$ 10.82	100.7 $\pm$ 10.56	-5.98%	0.23
DBP (mmHg)	72 $\pm$ 10.30	68.8 $\pm$ 10.35	-4.44%	0.63	68 $\pm$ 7.30	61.71 $\pm$ 10.8	-9.25%	0.23
FBG (mmol/L)	4.42 $\pm$ 0.28	4.12 $\pm$ 0.30	-6.79%	0.13	4.67 $\pm$ 0.67	4.36 $\pm$ 0.44	-6.64%	0.06
TC (mmol/L)	4.25 $\pm$ 0.41	4.52 $\pm$ 0.69	6.35%	0.31	4.42 $\pm$ 0.60	4.59 $\pm$ 0.59	3.85%	0.47
VO _{2max} (ml/kg/min)	39.17 $\pm$ 2.58	40.68 $\pm$ 3.48	3.71%	0.25	41.16 $\pm$ 3.65	41.89 $\pm$ 3.95	1.74%	0.62

BM: body mass; BMI: body mass index; WC: waist circumference; HC: hip circumference SBP: systolic blood pressure; DBP: diastolic blood pressure; FBC: fasting blood glucose; TC: total cholesterol; VO_{2max}: maximal volume of oxygen. *significant reduction set at $p < 0.05$.

Discussion

The purpose of this study was to determine if two different exercise doses would impact differently on cardiometabolic disease risk factors in overweight children.

Pearson correlations shown in table 3 show that participants with high body mass and body mass index presented lower fitness levels, higher-waist circumference, -blood pressure, -total cholesterol and -fasting blood glucose. CRF is known to increase mortality in adults, though there is a lack of research in children. CRF is a variable that can be easily modified with physical activity interventions.

Table 3. Pearson Coefficient Correlation between Body Mass (kg) and Body Mass Index (kg/m²) at baseline for n = 12 participants.

	VO _{2max} (ml/kg/min)	SBP (mmHg)	DBP (mmHg)	FBG (mmol/L)	TC (mmol)	WC (cm)
BM (kg)	-0.24	0.2	0.36	0.13	0.72	0.94
BMI (kg/m²)	-0.48	0.34	0.23	-0.08	0.5	0.86

BM: body mass; BMI: body mass index; WC: waist circumference; DBP: diastolic blood pressure; SBP: systolic blood pressure; TC: total cholesterol; FBC: fasting blood glucose; VO_{2max}: maximal volume of oxygen.

Waist circumference and cardiorespiratory fitness were improved by -8.08% and 3.78%, respectively, in the MIHF group. These improvements were associated with marginal reduction in body mass (-0.5 kg). Interestingly, the VILF group showed a slight increase in body mass (1.2 kg), yet still showed improvements of -5.49% and 1.76% for the same variables. Research has indicated that girls (>37 ml/kg/min) and boys (>42.1 ml/kg/min) with higher cardiorespiratory fitness levels were 3.09 and 2.42 times, respectively, more likely to have a lower metabolic disease risk profile (Ruiz et al., 2007).

Maximal volume of oxygen, an indirect measurement of cardiorespiratory fitness, showed an inverse correlation with body mass ($r = -0.27$) and body mass index ($r = -0.48$). A cross sectional study has established significant inverse associations with cardiorespiratory fitness and the clustering of metabolic risk factors in children (Machado-Rodrigues et al., 2014). Several studies have investigated the independent values of cardiorespiratory fitness, body mass index and waist circumferences for predicting cardiometabolic risk in children (Buchan et al., 2015; Burgos et al., 2015). The body mass index and waist circumference changes were most evident due to the clustering of cardiometabolic risk with body mass index, which is described as the main predictor in Brazilian children (Burgos et al., 2015). This is consistent with strong to very strong associations found with body mass in the current study for total cholesterol ($r = 0.72$) and waist circumference ($r = 0.94$). Weaker associations were reported with SBP ($r = 0.2$), DBP ($r = 0.36$) and FBG ($r = 0.13$). SBP ($r = 0.34$) showed stronger association with body mass index.

While most variables showed a trend towards improvement, the increases in total cholesterol and body mass were observed in the groups. Similar increases in triglycerides in overweight/obese children were found after an 8-week exercise program (Patel et al., 2015). The latter study concluded that the growth-related increased lipid mobilization during puberty was a critical contributing factor for this finding. It appears that serum cholesterol levels are more likely to change with a combination of diet and exercise interventions in obese children (Christiansen et al., 2010). A 6-week combined intervention program improved total cholesterol with a mean reduction of -0.8 mmol/L in obese girls and -0.88 mmol/L in obese boys (Luo et al., 2013).

Both exercise groups demonstrated modest improvements of blood pressure. This change seems to be a more pronounced in the VILF group. The mean systolic blood pressure change for participants in this group was -6.4 mmHg. In the same group, mean diastolic blood pressure was reduced from 68 mmHg to 61.71 mmHg. A systematic analysis of nineteen studies that evaluated the effect of childhood obesity prevention programs (physical activity, diet and their combinations) observed an average reduction of -1.64 mmHg in SBP and -1.44 mmHg in DBP (Cai et al., 2014). The MIHF group achieved similar reductions of -2.6 mmHg in SBP and -3.2 mmHg in DBP. Clinical studies suggest that even a small reduction in blood pressure has beneficial effects on reducing cardiovascular disease morbidity and mortality (Kelley & Kelley, 2000). A decrease in systolic blood pressure by 5 mmHg, reduces deaths from stroke by 14% (Whelton, He, & Appel, 2002).

Research suggests that large amounts of exercise are not required for improving metabolic profiles when lower volumes can achieve similar reductions and are more convenient for overweight children (Chen, Roberts & Barnard, 2006). The modest changes observed in cardiometabolic risk factors in this study are supported by meta-analyses that investigated the effects of exercise in children (Cai et al., 2014; Shaibi et al., 2015). In the current study, it was interesting to note that cardiorespiratory fitness induced improvements in SBP, DBP, WC and FBG without significant weight loss. Research acknowledges cardioprotective benefits of exercise interventions but points out that slight modifications in traditional risk factors alone cannot explain this benefit (Green et al., 2011). Subclinical changes induced by exercise provide further explanation for reduced disease risk with marginal clinical improvements. The focus on clinical markers as the primary inclusion criteria for exercise intervention studies can underestimate subclinical events of atherosclerosis that occurs in children (Barlow, 2007; Shaibi et al., 2015). More attention should be given to screening and monitoring subclinical markers during exercise interventions.

The absence of monitoring average target heart rates and energy expenditure per session are major limitations that will be useful to address in future studies. Furthermore, the small sample size, indirect measurement of cardiorespiratory fitness and the lack of dietary control limit the validity of assumptions that are made in this study. Lastly, it is difficult to say which exercise variable (frequency and intensity) induced the most benefits.

Conclusion

Despite the limitations, this study suggests that MIHF and VILF exercise protocols may impart favorable changes on selected cardiometabolic disease risk factors. The lack of statistical significance underlies percentage changes that taken together may confer clinical benefits for children. This needs to be confirmed using larger sample sizes and a non-exercising control group. The latter may see us advocate for programs that include a combination of exercise doses to produce the most meaningful outcomes.

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