Effects of supervised exercise program on metabolic function in overweight adolescents

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Original article

Background: **Inactivity is a primary factor related to childhood obesity, yet aerobic exercise has been shown to prevent weight gain and improve fitness in adolescents. Moreover, children become less active during their summer break from school. This study compared the effects of 4 and 8 weeks of supervised summer activity versus an unsupervised summer break on metabolic function and fitness in adolescents.**

Methods: **Twenty-two adolescents were divided into 4-week (*n*=6, weight 48.1±14.9 kg, body fat 27.4±8.4%) and 8-week exercise groups (*n*=6, weight 43.4±10.9 kg, body fat 28.5±12.8%), that performed supervised, play-based physical activity, versus an age-matched 8 week control group that maintained their typical summer break (*n*=10, weight 41.7±10.0 kg, body fat 23.7±8.0%). Anthropometrics, resting energy expenditure (REE), resting heart rate (RHR) and peak aerobic capacity (VO_{2peak}) were evaluated before and after the intervention (4 or 8 weeks).**

Results: **REE showed group differences in post-training conditions (the 4-week group *vs.* the control group, 1220±169 *vs.* 1067±144 kcal/die, and the 8-week group *vs.* the control group, 1202±151 *vs.* 1067±144 kcal/die, *P*=0.047), but RHR decreased (pre-program *vs.* post program: 97±22 *vs.* 80±8 beat/min, *P*=0.001) and VO_{2peak} significantly increased (pre-program *vs.* post program: 27.8±7.8 *vs.* 34.8±6.5 mL/kg/min, *P*=0.001) in the 8-week group compared to the control group.**

Conclusions: **Eight weeks of supervised play-based activity increased REE and VO_{2peak} in adolescents with concomitant decreases in RHR. These data suggest that this novel model of exercise prescription could be considered world-wide by clinicians to improve fitness base in adolescents and help to combat the growing epidemic of childhood obesity.**

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Key words: **cardiorespiratory fitness; functional physiology; overweight adolescents; supervised exercise**

Introduction

In the United States alone, childhood obesity has more than tripled over the past 30 years. The prevalence of obesity has increased in children and adolescents by 3.1% and 13.1% respectively from 1980 to 2008.[1] A sedentary lifestyle shows a positive correlation with adolescents becoming overweight and obese, which is partially attributable to increased screen time, for television, video games and recreational computer use.[2-5] Recently, it has been shown that adolescent screen time increases when children are away from school.[6] Decreasing the volume and duration of physical activity, especially since summer break may lead to less structured days in children who tend to be less active and increase body weight.[7,8]

It is well known that a sedentary lifestyle, combined with obesity is associated with chronic diseases such as diabetes, hypertension, and metabolic syndrome and these diseases originate at an earlier age than previously reported.[9-11] Therefore, adolescents with elevated body-mass index (BMI) and low cardiorespiratory fitness present a higher risk for developing hypertension, dyslipidemia, and diabetes,[12,13] which is associated with a clustering of cardiovascular risk factors.[14-16] Therefore, the adoption of a healthier lifestyle including moderate levels of physical activity is suggested to combat the associated risk related to excess weight in children and adolescents.[17]

Physical activity plays a major role in weight prevention by achieving optimal energy homeostasis and improving weight loss.[18] Previous studies with sedentary, obese children have shown positive results

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from a fitness program utilizing structured play-based aerobic or resistance skill-based activities.[19,20]

Adolescents have the potential to be less active during summer break, yet play-based activities show promising results to retain physical activity levels.[7,8,21] However, no studies have analyzed the effects of a short-term, supervised summer break intervention on resting energy expenditure and cardiorespiratory fitness in adolescent individuals without dietary intervention. Therefore, the purpose of this study was to compare the effects of 4 and 8 weeks of supervised, play-based physical activity versus an unsupervised 8-week summer break on metabolic function.[9] We hypothesized that play-based physical activity will increase peak oxygen consumption (VO_{2peak}) and resting energy expenditure (REE) even with concomitant decreases in heart rate (HR).

Methods

Participants

Twenty-two adolescents (12 males and 10 females, mean age, 9.9±1.2 years) participated in the study. They were recruited in two weeks from the local community via flyers and only healthy, recreational active adolescents of 8 to 12 years old were chosen. Parents reported their child's health history and current activity status through a questionnaire prior to their enrollment in the study. Children did not meet any of the exclusion criteria including previous cardiovascular disease, renal disease, diabetes, or any use of medications and did not practice any structured or supervised sport activities out of school. Participants were randomly divided into three groups: two groups with a summer camp lasting 4 or 8 weeks (the 4-week group, n=6 or the 8-week group, n=6) respectively, or a control group (n=10) with neither activity supervision nor change of typical activity levels throughout the summer.

Study design

Participants reported to the Vascular Biology and Autonomic Studies Laboratory before and after the intervention (4 or 8 weeks). Both pre- and post-testing sessions included anthropometric, REE, and VO_{2peak} measurements. The pre-testing session was performed within 4 days of the exercise intervention for all enrolled participants. The post-testing session was performed within 48 hours of the group session termination. All measurements were repeated at the same time of day in a rested condition. Participants were tested early in the morning, twelve hours post-prandial and 24 hours from the last exercise effort. After baseline evaluation, the activity groups were enrolled in either 4 or 8 weeks (the 4-week and 8-week groups, respectively) of the play-based activity program (5 days per week, 6 hours a day). Participants were intermittently active for a total of 4 hours per day, performing supervised, play-based physical activity, in which both sport and recreational activities were supported by nutrition classes on healthy dietary habits where healthy snacks and lunches were provided. The 4-week group participated in the first 4 weeks of the total eight week program and the 8-week group continued the play-based activity for 8 weeks. Children were motivated by expert instructors who supervised each episode of physical activity in order to maintain participation in all of the exercise sessions. This program aimed to teach children new skills, to let them experiment with a wide variety of activities, and to increase strength (through swinging, hanging, climbing, carrying equipment, etc.), flexibility (with stretching and yoga) and cardiovascular fitness through moderate intensity activities (active recreation such as hiking, brisk walking, fun-runs and sports such as baseball, softball, dodgeball, soccer, etc.).[22] The main focus of the program was to have the adolescents learn lifetime sport and recreational activities while increasing the time spent in exercise, thereby reducing inactivity. The summer camp did not aim to reduce body weight in children, thus, hypo-caloric diets or changes in diet habits were not provided, only nutrition classes and healthy snacks and lunches were given during the program. The control group followed their usual summer break without any intervention from the study coordinators; however, they were asked to maintain their current level of physical activity for the duration of the study. Moreover, parents were asked not to change the dietary habits of children in order to mimic real-life scenarios during the study period. The study was approved by the Appalachian State University Institutional Review Board. All parents and participants gave written informed consent and assent before participation.

Experimental procedure

Height and weight were measured using a scale and a stadiometer to the nearest 0.01 kg and 0.1 cm, respectively. Stature was measured while children were standing in the erect position without shoes, with shoulders relaxed, arms hanging freely and their head aligned in the Frankfort plane. Weight was measured on a medical balance beam scale (Health-O-Meter) with participants wearing a t-shirt and shorts. Seated height velocity was recorded on the right side of the body while participants were seated in a hard chair and their backs were kept straight to control for upper and lower body growth changes over the study time.[23] Leg peak height velocity was detected measuring the leg length, between the floor and the knee (PHVl), and trunk peak height velocity measuring the trunk length, from the surface of chair to the apex of the head (PHVt). BMI values were calculated for each participant dividing the weight in kg by the height in meters squared (kg/m^2). The percentage of body fat (%BF) was measured by a "foot-to-foot" bioelectrical impedance analyzer (TBF-300A, Body Composition Analyzer) while children stood without shoes or socks.

Resting heart rate (RHR) and REE were assessed while participants laid quietly in the supine position in a dimly lit room where temperature was kept constant at 20°C throughout the measurements. RHR was recorded in real time by a polar device (Polar WearLink and transmitter) while REE was averaged at 30 second intervals by direct gas analysis (Parvo Medics TrueOne®). Participants rested on the table while an investigator explained the test procedure and during the following 20 minutes of the test. Data were recorded for 20 minutes and, during the last 10 minutes, the lowest averaged value in the final 3 minutes was used.

Cardiorespiratory fitness was measured as VO_{2peak} assessed by direct gas analysis (Parvo Medics TrueOne®) during a modified Balke protocol treadmill test. Briefly, participants walked or ran at a constant speed ranging from 5 to 9 km/h which varied by age and physical capacity. Once a comfortable speed was reached, they started the incremental test and the intensity was regulated by increasing the grade of the treadmill by 2% every 2 minutes. The test, that lasted from 8 to 12 minutes, and ended when volitional exhaustion was reached or three of the four criteria were obtained, i.e., a RER higher than 1.15, a value on the adolescent omniscale equal or greater than 8 overall, a plateau of VO_2 in spite of a load increase, or a HR at a value close to the theoretical HRmax.[24]

Treatment of the data

A 3×2 (group by time) analysis of variance (ANOVA) with repeated measures was performed on all dependent variables to detect the differences between the three conditions and if significance was found, a Bonferroni post hoc test was conducted to determine where the significance lied between the group comparisons. The data were reported as means±SD and the significance was set at $P \leq 0.05$. Analyses were made using SPSS statistical software version 18 (IBM® SPSS®, Charlotte, NC). Power for this study was determined A priori (G*Power, Version 3.1.3; Franz Faul, Uni Kiel, Germany) from the means and standard deviations of REE from a prior study.[25] It was determined that 18 participants (6 per group; 3 groups) were needed to achieve a significant 3%-5% difference with moderate (0.4-0.5) effect size based on REE.

Results

The descriptive characteristics of each group are presented in Table 1 and metabolic parameters in Table 2. There were no significant differences between the control, 4-week and 8-week groups in all parameters at baseline. The height of participants was not significantly different between the groups during the study period and no significant differences were found in peak height velocity following the intervention (Table 1). The results showed no significant changes in body weight and body composition in all the three groups after the 4 and 8-week period (P=0.1, eta^2=0.056). However, BF% decreased by 7.3% and 6.7% in the 4-week and 8-week groups, respectively, whereas the control group did not change after the study period (Table 1). REE reported a significant increase of post-treatment group difference (P=0.047, eta^2=0.440) in both 4-week and 8-week groups (of 33 and 48 kcal, respectively), but no changes were found in the control group (Table 2). A reduction in RHR was seen in all the groups; however a significant reduction in RHR was shown only in the 8-week group

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Table 1. Descriptive characteristics in pre and post conditions in 4-week (4 wk) and 8-week activity groups (8 wk), and in the control group (C)

Variables	Pre			Post		
	C (10)	4 wk (6)	8 wk (6)	C (10)	4 wk (6)	8 wk (6)
Height (cm)	145.3±11.0	145.7±11.7	139.2±11.2	146.0±11.6	146.4±11.5	140.2±11.1
Weight (kg)	41.7±10.0	48.1±14.9	43.4±10.9	42.3±9.9	47.7±14.7	43.7±11.8
PHVt (cm)	72.1±7.8	76.7±8.4	76.0±8.1	72.5±8.4	77.0±8.2	76.4±9.5
PHVl (cm)	38.4±5.6	39.1±6.2	39.4±6.6	38.6±5.9	39.2±7.7	39.5±7.2
BMI (kg/m^2)	19.5±3.4	22.5±3.4	22.2±4.0	19.6±3.7	22.3±3.4	22.0±3.9
%BF (%)	23.7±8.0	27.4±8.4	28.5±12.8	23.6±7.1	25.4±6.7	26.6±7.0

Values are mean±SD. PHVt: trunk peak height velocity; PHVl: leg peak height velocity; BMI: body mass index; %BF: body fat percentage.

Table 2. Metabolic and fitness parameters in pre and post conditions in 4-week (4 wk) and 8-week activity groups (8 wk), and in control group (C)

Variables	Pre			Post		
	C (10)	4 wk (6)	8 wk (6)	C (10)	4 wk (6)	8 wk (6)
REE (kcal/die)	1072±127	1187±150	1154±140	1067±144	1220±169*	1202±151*
RHR (beat/min)	104±16	98±6	97±22	99±18	91±10	80±8†
VO_{2peak} (mL/kg/min)	30.2±5.6	31.1±4.1	27.8±7.8	30.8±5.6	33.8±1.0	34.8±6.5†

Values are mean±SD. REE: resting energy expenditure; RHR: resting heart rate; VO_{2peak}: peak oxygen consumption. *: $P \leq 0.05$, compared to control; †: $P \leq 0.001$, compared to pre-conditions.

(P=0.001, eta^2=0.518) (Table 2). Peak aerobic capacity increased in the 8-week group (P=0.001, eta^2=0.868) following the intervention (Table 2).

Discussion

The most significant results of the present study indicated that 8 weeks of play-based physical activity increased REE and VO_{2peak} in adolescents with concomitant decreases in RHR. To our knowledge, this is the first study examining the effects of short-term, supervised play-based physical activity on metabolic function and fitness levels in adolescents without diet intervention.

Similar to our research, two earlier studies have shown the effects of a short-term, summer-camp exercise program consisting of six 1-hour sessions and five 90-minute sessions per day of structured, play and skill-based activities on body composition and aerobic fitness in overweight and obese adolescents obtaining significant reductions in %BF after 6 weeks,[19] and BMI after 8 weeks,[26] respectively. Our study reported no significant changes in body composition, but body fat reductions of 7.3% and 6.7% in the active groups without changes in body weight. This finding suggested that discontinuous play-based activity alone could reduce body fat, while maintaining body mass. The differences between our study and the aforementioned studies could be explained by the fact that a dietary intervention and obese children were used in the prior studies. Trying to mimic real-life scenarios, our study asked that all children keep the same dietary habits prior to their enrollment, and as a small education component of the camp, our participants only received healthy snacks and lunches during camp days and were lectured on healthy dietary habits. Similarly, Matvienko and colleagues[27] reported no changes in anthropometrics but sustainable improvements in motor skill and fitness levels in normal weight kindergarten and first grade children after 4 weeks of a nonstructured, active-play exercise intervention placing an emphasis on motor skill development and nutrition/health lessons and healthy snacks.

It is well known that REE is greater in individuals that have higher ratios of fat free mass, which is more metabolically active tissue than fat depots,[28] and energy expenditure fluctuates as body composition changes.[29] This highlights the important role of physical activity in energy expenditure and weight management since physical activity is more likely to increase lean body mass.[30] Our study reported a significant increase in REE after just 4 and 8 weeks of moderately intense, play-based activity when compared with the control group. In addition, the increased REE in the activity group, was supported by a decrease in %BF, yet no changes in the control group. In addition, the 8-week group realized a cardiovascular training effect after the play-based activity intervention with a significant increase in VO_{2peak} and a concomitant decrease in RHR, suggesting that maintaining adolescent active through games and fun activities is a model that shows favorable cardiovascular results within 8 weeks. Moreover, by increasing physical activity and developing lifetime sport skill sets, adolescents may be more likely to maintain their increased activity levels throughout their lifetime which may attenuate their development of risk factors associated with sedentary behavior. In support of our findings, DeStefano and colleagues[30] reported that 12 weeks of supervised aerobic and resistance training, performed 2 days per week, for 30 minutes each session, decreased fat mass and increased fat free mass percentage in children without changes in body mass consequently increasing REE and, more importantly, increased the hours of daily physical activity performed during free time.

We acknowledge limitations to the interpretation of this study. The small treatment group sizes warrant caution when interpreting the results. Despite the small sample, no group differences were observed at baseline and our hypothesis was supported by significant eta^2 sizes that were presented with our data. Moreover, it is important to stress that all participants were recreational active before the start of the study. However, the post-treatment data clearly showed divergent results between the populations for REE. Another limitation was the lack of direct measurements of physical activity intensity in the active groups and the daily energy expenditure data on the control group. In our study with the pre-post design, monitoring activity levels is difficult and we intended to motivate the participants to adopt an active lifestyle through moderate intensity, play-based physical activities. Moreover, prior studies show that wearable pedometers or actigraphs will artificially increase the adolescents activity level in the short-term which would have confounded our results by enhancing their REE.

These data demonstrate that supervised play-based activity yields positive benefits that may lead to the attenuation of metabolic, cardiovascular and skeletal muscle risk factors as ages. Therefore, the adoption of an active lifestyle with supervised physical activity during the school break may aid in improving metabolic and cardiorespiratory functions increasing resting energy expenditure and fitness levels with a dose-effect response, which in turn may help to prevent adolescent obesity leading to future decrements in adult risk factors. This novel model of exercise prescription for children can be employed world-wide by future clinicians to prescribe physical activity that will further help to combat the growing epidemic of childhood obesity.

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