Original Article

Effects of a 12-week Exercise Training Programme on Aerobic Fitness, Body Composition, Blood Lipids and C-Reactive Protein in Adolescents with Obesity

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Abstract

Introduction: Developing effective exercise programmes for the paediatric population is a strategy for decreasing obesity and is expected to help in eventually limiting obesity-associated long-term health and societal impact. In this study, the effects of a 12-week twice weekly additional exercise training, which comprised a combination of circuit-based resistance training and aerobic exercises, in additional to typical physical education sessions, on aerobic fitness, body composition and serum C-reactive protein (CRP) and lipids were analysed in 13- to 14-year-old obese boys contrasted with a control group. Materials and Methods: Both the exercise group (EG, n = 12) and control group (CG, n = 12) participated in the typical 2 sessions of 40-minute physical education (PE) per week in schools, but only EG participated in additional 2 sessions per week of 45 to 60 minutes per session of exercise training, which comprised a combination of circuit-based resistance training and aerobic exercises maintained at 65% to 85% maximum heart rate (HRmax = 220 - age). Body composition was measured using dual energy X-ray absorptiometry (DEXA). Fasting serum CRP and blood lipids were analysed pre- and post-exercise programme. Aerobic fitness was measured by an objective laboratory submaximal exercise test, PWC_{170} (Predicted Work Capacity at HR 170 bpm). Results: Exercise training significantly improved lean muscle mass, body mass index, fitness, resting HR, systolic blood pressure and triglycerides in EG. Serum CRP concentrations were elevated at baseline in both groups, but training did not result in a change in CRP levels. In the CG, body weight increased significantly at the end of the 12-week period. Conclusion: This study supports the value of an additional exercise training programme, beyond the typical twice weekly physical education classes, to produce physiological benefits in the management of obesity in adolescents, including prevention of weight gain.

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Key words: Aerobic fitness, Body composition, C-reactive protein, Exercise training, Obese adolescents

Introduction

The prevalence of obesity in children and adolescents is increasing rapidly worldwide.[1] A rising rate of obesity in epidemic proportions also brings about economic consequences and substantial healthcare costs.[2] The early onset of obesity leads to an increased likelihood of obesity into adulthood and links to increased prevalence of obesity-related disorders such as coronary diseases, insulin resistance, diabetes mellitus, hypertension, sleep apnoea, arthritis, cancer, stroke and heart failure in later life.[3]

Strategies aimed at treating long-term established obesity in adults have not been effective. In view of the alarming rise in physical inactivity in children and adolescents worldwide, and even possible trends of decreasing physical fitness,[4] primary prevention should be emphasised as early as childhood to prevent the link between obesity in early life with obesity in later life.[5] It is therefore important to encourage sustainable physical activity habits in children, and further reinforcing these habits in adolescents, which will help establish desirable healthy lifestyle patterns that continue into adulthood.[6]

Studies in adults with obesity have demonstrated that low aerobic fitness is as important as body mass index (BMI) for predicting mortality,[7] and lifestyle interventions should

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target long-term improvement in aerobic fitness, as opposed to over-emphasis on change in fatness, as supported by recent paediatric studies.[6,7] However, not many studies have investigated the effect of exercise training on obesity in children and adolescents,[7] and most programmes for the paediatric populations were focused on long duration aerobic-based activities.[8,9] Children and adolescents with obesity may find these long duration aerobic-based activities lacking in variety, and therefore reluctant to continue exercising on a routine basis.[7,10] Furthermore, exercise programmes administered in these studies were usually not well described,[11] and information pertaining to the effect of exercise training on risk factors for cardiovascular disease such as blood pressure, blood lipids concentration and other indicators of cardiovascular risk in these groups is scant. Developing effective exercise programmes for the paediatric population is a strategy for decreasing obesity and is expected to help in eventually limiting obesity-associated long-term health and societal impact. Thus, it is the objective of this study to examine the effects of a 12-week twice weekly exercise training programme which combined various forms of aerobic activities, resistance training, sports and games, and stair-climbing exercises, on aerobic fitness, body composition, serum C-reactive protein (CRP) and lipid profile in 13- to 14-year-old obese boys compared with a control group.

Materials and Methods

Subjects and Screening Measures

Twenty-four obese (BMI >/=25) male adolescents, aged 13 to 14 years, were recruited from a secondary school and randomly assigned into either one of 2 groups: Exercise Group (EG; n = 12; mean age 13.75 ± 1.06 years) and Control Group (CG; n = 12; mean age 14.25 ± 1.54 years). Exclusion criteria included musculo-skeletal disorders, hypertension, diabetes, or any other known medical conditions, use of anorexic medications or surgical procedures for weight loss, use of prescription medications, including nutritional supplement, and smoking. None of the participants recruited met the exclusion criteria. All participants underwent a medical screening conducted at a local hospital to determine their suitability for the study and obtained medical clearance to participate in this study. Institutional Ethics Committee approved this study, and informed consent was obtained from all participants and their parents. All participants also received verbal explanations of the exercise programme and the tests prior to commencement of this study.

Study Design

Both the EG and the CG participated in the typical 2 sessions of 40-minute physical education (PE) per session per week, except that the EG participated in additional 2 sessions per week of 45 to 60 minutes per session of exercise training for 12 weeks. Both groups were subjected to similar PE programmes aligned with the Ministry of Education (MOE) school curriculum and conducted by trained PE teachers. Subjects were specifically requested to avoid any activities that differed from their usual routines and not to modify their diet during the study period. This was monitored via daily diaries and dietary records throughout the period of this study. Subjects were instructed to report their change in diet if any. No major change in diet was reported throughout the study period.

Experimental Measurements

Definitions of obesity based on age- and gender-specific BMI were adopted.[12] All baseline measurements were done within the first 2 weeks prior to the commencement of the 12-week exercise training programme, while post-testing was performed within 2 weeks following the completion of the programme. Anthropometric and body composition measurements were obtained before exercise testing. Resting heart rate (HR) was measured using a HR monitor employing the telemetric method (Polar electro, Kempele, Finland) prior to taking anthropometric and body composition variables. The subjects were put through all the tests mentioned below over 2 separate sessions, not lasting more than an hour per session.

Anthropometric and Body Composition Measures

Body weight was measured using a platform beam balance (Seca 708, Germany) with an accuracy of 0.01 kg. Height was measured with a stadiometer (Harpenden, Great Britain) with an accuracy of 0.1 cm. BMI was determined according to the formula of body weight·height^{-2}. Whole-body fat percentage (%), fat mass and lean body mass were assessed by a dual-energy X-ray absorptiometry (DEXA) scan (QDR-4500 elite, Waltham, MA, USA). No special preparation was required except that participants wore lightweight clothing for these measures.

Exercise Testing

The exercise test involved 3 consecutive incremental 4-minute epochs of exercise on a bicycle ergometer (Monark) as described in studies previously using the PWC_{170} submaximal exercise test protocol.[13-15] Subjects were familiarised to the test once one week before the actual exercise testing prior to training. Subjects were instructed to cycle at 60 rpm and this was continuously monitored throughout the 12-minute duration of the exercise test by a trained exercise specialist. Identical exercise intensities for each 4-minute interval were used before and after training to allow us to assess changes in aerobic fitness by comparing HR responses at these matched workloads. HR was measured using a HR monitor employing the telemetric method (Polar electro, Kempele, Finland). HRs for the last 2 minutes of each 4-minute interval was recorded and averaged. Subjects were advised to abstain from exercise and food at least 3 hours before testing.

Blood Chemistry

Blood tests were performed by certified medical personnel at the hospital on a separate day, after an overnight fast in a post-absorptive state. Blood samples (5 mL), taken by a venepuncture, were then analysed for concentrations of total cholesterol and subfractions [high density lipoprotein (HDL) and low density lipoprotein (LDL)], triglycerides, CRP and fasting blood glucose. Plasma levels of CRP were measured by a highly sensitive enzyme linked immunosorbent assay (ELISA) technique as described previously.[15]

Exercise Training Programme

The training group exercised twice a week for 12 weeks. The sessions were conducted within the school compound. The standardised training sessions were led by an ACSM certified exercise specialist, who was briefed on the guidelines for the prescription of the training programme for this study. Each session lasted 45 to 62 minutes (mean duration of exercise sessions, 55 minutes).

A variety of indoor and outdoor activities were incorporated in our exercise training programme. This exercise programme comprised a combination of circuit-based aerobic exercises, strength conditioning and/or resistance training, and game activities such as soccer, handball, stair-climbing exercises and other active recreational activities involving continuous work bouts maintained on average at 65% to 85% of maximum HR (HRmax; calculated as 220-age). However, the training programme started with a training intensity of 50% to 60% HRmax in the first 2 weeks of the programme to ensure that participants developed a sense of success and positive self esteem early in the programme.[16] The intensity and duration of the exercise programme were gradually and progressively increased, as individually tolerated, to induce a training effect throughout the 12-week period. Each of these sessions commenced and concluded with a 7- to 10-minute warm up/cool down and stretching.

During the training sessions, HR was measured continuously with a HR monitor (Polar electro, Kempele, Finland) and the subjects were instructed on the use of the Polar watches during the exercise sessions. Heart rates were checked and recorded every 10 to 15 minutes in each session, with a minimum of 3 records taken in the beginning, in the middle and at the end of the training session. The participants were taught to increase the intensity of exercise by increasing the speed of movement if their heart rates fell below the prescribed HR training zone. Similarly, the participants were instructed to maintain and adjust their movement speeds when the target HR training zone was reached.

Indoor Activities

Indoor activities were conducted in the school's weight training gymnasium. It comprised of 20 to 35 minutes of circuit-based combination of light resistance training with 4 to 7 resistance stations, using body-weight and eventually progressed to using medicine balls (varied weights from 2 to 5 kg), alternated with 3 to 5 aerobic stations (cycle ergometry and/or treadmill walking). The number of resistance exercise circuits gradually increased from 1 to 3 sets, 8 to 25 repetitions, and then by increasing resistance or load. The exercise period for the resistance stations gradually increased from 1 to 3 minutes, while the exercise period for each aerobic station lasted from 5 to 10 minutes depending. Likewise, the cycling load for the aerobic stations was also gradually increased to accommodate for individual improvement made. Resistance exercises using only participant's own body weight include variations of sit-ups, push-ups, chin-ups, squats and so on, while resistance exercises with medicine balls include simple press-up activities, variations of passing and tossing the medicine ball to partners, using legs to manipulate medicine ball movements along the ground, and so on. Rest between sets was about 1 to 3 minutes for resistance stations depending on exercise period and/or level of the individual's aerobic fitness. The active recovery (aerobic exercises) between resistance stations was designed to maintain exercise HR within the training zone to facilitate changes in cardiorespiratory fitness and maximise energy expenditure.[17] Hence, passive rest recovery (standing or walking at a slow pace) was not included in this segment of the exercise programme.

Outdoor Activities (not necessarily administered in the order stated before)

1) Sports and games such as soccer, handball, basketball and other recreational activities involving continuous play for 10 to 15 minutes. Two teams, comprised of different members each session, were formed and these games would last between 7 to 10 minutes played over 2 sets of 2 to 4 minutes with a 1- to 2-minute rest between sets with modified rules to suit the average skill level of the participants, achieve successful and enjoyable outcomes, maintain self-confidence,[18] and ensure aerobic benefits. Brief passive rest recovery (<10 seconds) was incorporated intermittently to allow the instructor to provide specific instructions or tactical tips on how their play could be improved.
2) 2 to 4 sets of small-group relay or tag games which involved substantial intermittent running or striding

for another 3 to 5 minutes. Rest period of 30 seconds to 1 minute between sets was allowed depending on exercise period.

3) 5 to 15 minutes of stair-climbing ascending and descending exercises using available 4-storey stairs within the school compound or 11-storey stairs at a nearby HDB flat just outside the school compound. Participants were given the individual options to climb at their own comfortable pace as long as they adhered to the prescribed exercise HR. They were also given the option to rest for 30 seconds to 1 minute for every 4- to 6-storeys of stairs they continuously managed to climb.

Data Analysis

Data were presented as mean ± SD. Changes within and between the EG and the CG pre- and post-training for anthropometric, body composition, blood chemistry, hemodynamic and aerobic fitness variables were analysed using a 2-way ANOVA with repeated measures. To compare the effect of exercise training in the EG with the CG in controlling pre-training height, weight and BMI as covariates, ANCOVA was also used to examine for significant differences in selected variables between these 2 groups. Significance was set at P <0.05. Data were analysed using the Statistical Package for the Social Sciences (SPSS, version 12.0, Chicago. IL, USA) software.

Results

Training Programme

Attendance was taken for the EG throughout the 12 weeks. Two participants missed 2 sessions out of a total 24 sessions, while only 1 participant missed 3 sessions, but not subsequently. Reasons for missing these sessions, self-reported by the participants, were due to either other school commitments or illness. All other participants met the criterion of 2 times per week. All participants were able to exercise at HR equal to or above the prescribed training HR.

General and Anthropometric Characteristics

The general and anthropometric characteristics of the 24 adolescents who agreed to participate in the 12-week exercise training programme are shown in Table 1. All subjects in both the EG and the CG were classified as obese.[12]

There was no significant difference in height, weight and BMI between the EG and the CG during pre-training testing. There was a significant BMI reduction (P <0.05) in the EG after the training programme. No significant change in BMI was observed in the CG between pre- and post-testing, despite the observed significant weight increase in the CG (P <0.05). Controlling pre-training height, weight and BMI as covariates, further ANCOVA analysis highlighted significant lower weight (F = 9.98, P <0.01) and BMI (F = 4.85, P <0.05) in the EG during post-training testing between the EG and the CG.

A significant increase in lean body mass was observed in the EG (P <0.05), but not in the CG, after training. There was no significant difference in fat mass and whole body fat percentage in each group between pre- and post-testing. However, ANCOVA analysis controlling pre-training weight, height and BMI as covariates showed that the EG

Table 1. General and Anthropometric Characteristics of the EG and the CG at Baseline and at the End of Training

	EG		CG	
	Pre	Post	Pre	Post
Age (y)	13.8 ± 1.1	–	14.3 ± 1.5	–
Height (cm)	164.9 ± 7.2	165.7 ± 7.1	165.6 ± 8.8	166.9 ± 8.3
Weight (kg)	83.1 ± 8.1	80.7 ± 8.1	87.6 ± 9.2	88.9 ± 7.4^+
BMI	30.6 ± 2.1	29.4 ± 2.8*	31.8 ± 4.4	31.7 ± 4.4+
DEXA results				
Fat (%)	35.6 ± 7.2	34.8 ± 7.0	37.8 ± 4.1	36.3 ± 3.8+
Fat mass (kg)	29.3 ± 5.4	29.2 ± 5.8	31.6 ± 7.6	30.8 ± 7.6
Lean body mass (kg)	51.3 ± 7.4	52.9 ± 6.9*	50.1 ± 11.4	51.7 ± 11.7

BMI: body mass index; CG: control group; EG: exercise group; DEXA: dual-energy X-ray absorptiometry
Data were presented as the mean value ± standard deviation.
*P <0.05, Pre-EG vs Post-EG;
^P <0.05, Pre-CG vs Post-CG;
+P <0.05, Post-EG vs Post-CG (ANCOVA)

Table 2. Blood Chemistry and Hemodynamic Data of the EG and the CG at Baseline and at the End of Training

	EG		CG	
	Pre	Post	Pre	Post
Systolic blood pressure (mm Hg)	119.6 ± 10.8	113.8 ± 7.1*	115.0 ± 8.0	117.0 ± 6.2
Diastolic blood pressure (mm Hg)	73.8 ± 8.8	71.7 ± 7.5	71.3 ± 6.8	70.8 ± 6.7
Fasting blood glucose (mmol/L)	4.7 ± 0.3	4.7 ± 0.4	4.5 ± 0.2	4.8 ± 0.8
Total cholesterol (mmol/L)	4.5 ± 0.8	4.7 ± 1.0	4.6 ± 0.9	4.5 ± 0.7
HDL cholesterol (mmol/L)	1.3 ± 0.2	1.3 ± 0.3	1.2 ± 0.1	1.2 ± 0.2
LDL cholesterol (mmol/L)	2.7 ± 0.8	2.7 ± 0.9	2.9 ± 0.7	2.8 ± 0.7
Triglycerides (mmol/L)	1.1 ± 0.7	1.0 ± 0.5	1.0 ± 0.5	1.0 ± 0.4
C-reactive protein (mg/L)	3.1 ± 1.4	4.1 ± 5.0	3.4 ± 2.4	4.3 ± 3.5

CG: control group; EG: exercise group
Data were presented as the mean value ± standard deviation
*P <0.05, Pre-EG vs Post-EG

had a significant lower fat percentage than the CG during post-testing (F = 2.21, P <0.05).

Blood Chemistry and Hemodynamic Variables

The results of the blood chemistry and haemodynamic variables during pre- and post-training programme are shown in Table 2. All blood lipids variables fell within the clinically specified normal ranges, except for CRP concentrations that were slightly elevated above the healthy normal range. During post-testing, the EG had a significant drop in systolic blood pressure (P <0.05). In the CG, there was no significant difference in systolic blood pressure and diastolic blood pressure during pre- and post-testing.

A comparison between pre- and post-testing in both groups revealed no significant difference in fasting blood glucose, triglycerides, total cholesterol, HDL-cholesterol and LDL-cholesterol. There was no change in CRP levels pre- and post-training in both groups.

Effect of Exercise Training on Aerobic Fitness

The changes observed after the 12-week training period for aerobic performance are shown in Table 3.

The pre- and post-training cycle ergometer exercise tests were well tolerated by all participants. Post-training resting HR was significantly lower (P <0.05) than pre-training values for the EG. The resting HR of the EG was significantly lower (P <0.05) than the CG during post-testing. There were significant reductions in the submaximal exercise heart rates at matched workloads (stages 2 and 3) of the exercise protocol at post-training in the EG (P <0.05) when compared to pre-training indicating a significant improvement in cardiorespiratory fitness. There were no significant differences in exercise heart rates at matched workloads of the exercise protocol between pre- and post-testing for the CG. Only exercise HR values of stage 3 of the exercise protocol of the EG were significantly lower (P <0.05) than the CG during post-testing.

Table 3. Effect of Exercise Training on Aerobic Fitness

	EG		CG	
	Pre	Post	Pre	Post
Resting HR (bpm)	78 ± 2.4	71 ± 2.5*	76 ± 3.4	76 ± 3.9+
Exercise HR (bpm)				
Stage 1	119 ± 11.5	108 ± 6.6	109 ± 7.9	112 ± 8.2
Stage 2	134 ± 9.3	123 ± 7.4*	128 ± 6.8	128 ± 5.7
Stage 3	152 ± 12.8	139 ± 11.9*	148 ± 9.0	149 ± 8.5+

CG: control group; EG: exercise group; HR: heart rate
Data were presented as the mean value ± standard deviation.
*P <0.05, Pre EG vs Post EG;
+P <0.05, Post EG vs Post CG

Discussion

This study investigated the effect of a varied exercise training programme on aerobic fitness, body composition, serum CRP and lipid profiles in an EG contrasted with a CG with similar general and anthropometric characteristics recruited at baseline over a 12-week period. In this study, we did not focus on a training programme that targeted mainly on continuous aerobic-based exercises, such as jogging or cycling over 30 minutes, as we felt that these may not be the exercises of choice for obese adolescents to continue over long periods of time.[11,18] While it is desirable, and perhaps essential, to use some forms of structured exercise training as a medium to increase physical activity levels towards the management of obesity, we felt it was necessary to incorporate a variety of physical activities that can appeal to obese adolescents. This will allow them to develop their own preferences and choices for the types of physical activities over the long haul, which can help reduce the incidence of sedentary behaviours in their lifestyles in adulthood.[11,18] As such, we also incorporated short-duration sports and games activities, as well as conditioning exercises into the planning of the training programme to keep the programme varied, interesting and fun, yet able to provide adequate aerobic benefits. The participation rate of this exercise programme was high. We recommend that future studies look into activity perceptions and motivational issues of children and adolescents surrounding adherence to the various types of exercise intervention programmes.

Our exercise programme required participants to attend up to 1-hour per session of exercise training that comprised of a combination of resistance and aerobic-based activities in both indoor and outdoor settings twice a week. Our training programme effectively improved the aerobic fitness of adolescents with obesity. Results from the EG showed a marked improvement in aerobic performance, as reflected by the lower submaximal exercise HR responses at matched workloads during exercise testing after training, as well as a significant decrease in resting HR and systolic blood pressure which also confirmed overall improvement in aerobic fitness after 12 weeks of adhering to this training programme. While the apparent beneficial effect of exercise training is noted, training benefits are not likely to persist after the cessation of training, even shortly within 4 to 6 weeks of cessation.[19] There is still a need for sustained regular physical activity even after obese children and adolescents have completed any well-structured modular exercise training programme that saw beneficial results.

Even though we did not use individualised maximal HR that can be obtained during a maximal progressive exercise test for each participant to prescribe individual target training heart rates to optimise training effects, our guideline prescription for exercise HR for indoor and outdoor activities over the 12-week period was either equivalent to or already higher than what most studies previously prescribed.[20] To account for individual differences and rate of improvement of fitness in our study, both intensity and duration of training were gradually and progressively increased, as individually tolerated. This also helped to ensure that all subjects in the EG received adequate physiological overload benefits, but, most importantly, at the same time, prevented them from experiencing under-stimulation or being overly exerted. Overall, our programme is considered as an effective one that can bring about improvement in aerobic performance.

While most studies have evaluated the effect of exercise training in obese children and adolescents on various aspects of functional capacities, body composition, haemodynamic and metabolic variables, the exercise training programmes implemented in these studies were not well described. The lack of comprehensive assessment of body composition in these studies also did not allow consistent documentation of changes in body composition, and the effect of exercise on changes in fat and lean body mass could not be accurately distinguished by merely using gross measures of body composition.[7,11] For this reason, we used DEXA to detect relative changes in body composition in the whole body in both the EG and the CG in this study, and found a significant increase in lean body mass in the EG, as well as significant decreases in gross measure of BMI, following exercise training.

Controlling pre-training height, weight and BMI as covariates, further ANCOVA analysis also revealed that the EG had a lower body fat percentage when compared to the CG post-training. These results are not surprising. Eventhough energy expenditure is not explicitly measured in this study, the additional 2 sessions of exercise training per week beyond the typical school PE lessons were closely monitored and continually adjusted and increased in intensity to produce adequate training effects, and thus would have been sufficient to increase energy expenditure of the obese participants in the EG throughout the 12-week period. Elements of resistance training incorporated in our training programme would certainly have anabolic effects on muscle protein metabolism, resulting in an increase in lean body mass.[7,14] Relative to fat mass, lean body mass has a high basal metabolic rate[7] and increase in lean body mass will increase total energy expenditure even at rest.[21]

Interestingly, we found a significant gain in body weight in the CG following the 12-week period. Decrease in lean body mass can result in subsequent reduction in metabolic rate, which then becomes a major risk factor for weight gain.[10] Bearing in mind that the CG was not recruited from normal-weight adolescents but adolescents who are classified as obese, this could mean that the twice weekly PE lessons may not even be sufficient to create negative energy balance to just maintain body composition in the obese population. A recent study that developed a modular aerobic training programme that also incorporated many varied activities to instill continued interest and motivation in their young obese participants reported a decrease in fat free mass (also lean body mass) over a 12-week period.[10] Although, in our opinion, their varied aerobic-based programme was a well-structured programme, it still did not incorporate resistance exercises or strength conditioning activities that could have effect positive changes in lean body mass. While we acknowledged that the decrease in body fat could be due partly to possible changes in dietary intake, it is unlikely in our study as the subjects in both the CG and the EG were specifically instructed not to modify their daily dietary intake and to report accordingly any changes. In view of this limitation in our study, we do recommend that future studies look into stratifying the independent effect of exercise versus dietary modification that could be conducted with several intervention groups; exercise only, exercise plus diet, and diet only, as recommended in the literature.[10] Nevertheless, we support exercise training programmes that incorporate elements of resistance training and strength conditioning to induce an increase in, or maintenance of, lean body mass as a method to increase daily energy expenditure, thereby influencing fat loss over the long term to optimise weight management.

Many studies that examined the efficacy of exercise training in obesity have documented little effect on blood lipid and vascular inflammatory profiles.[13,14,19,22] Apart from obtaining blood lipid profiles pre- and post-training, our study is likely the first to document the effect of exercise training on concentrations of CRP in obese adolescents. Recent evidence indicates that arterial inflammation may have an important role in the initiation and progression of atherosclerosis.[23] CRP, an acute phase reactant, is a sensitive marker of inflammation. It has been proposed that elevated levels of CRP are associated with an increased risk of coronary heart disease in healthy adults[23] and can predict increased risk of future coronary events.[24] Concentrations of CRP have been shown to be positively correlated with the measures of obesity and insulin resistance in adults.[25] Our study showed that the obese subjects in both the EG and the CG had elevated CRP concentrations at baseline and at the end of training, above the clinically recommended normal range. This is important as an elevated CRP level with a cut-off point of just 3 mg/L has already been shown to be associated with an increased risk of occlusive arterial diseases, especially acute coronary syndromes,[24] and our subjects are only in their teens.

Recent studies have shown that circuit-based resistance exercise training can produce improvement in vascular endothelial function within 8 to 12 weeks, even in the absence of changes in blood lipid profiles, blood pressure or glycaemic control.[13,14,26] This is consistent with the findings in our study that saw no change in blood lipid and CRP levels pre- and post-training over the 12-week period. Eventhough the relationship between the endothelial function and the CRP levels are not well understood in obese children and adolescents, measuring endothelial dysfunction and/or CRP are still particularly relevant given recent evidence that these can predict cardiovascular mortality and morbidity, and that these may be more sensitive than the traditional blood lipids as markers to detect early manifestation of atherosclerotic disease. Nevertheless, these collective findings confirm that continuous exercise training or regular physical activities are valuable and can maintain and/or produce vascular benefits, with or without early changes in blood lipid, haemodynamic or anthropometric variables.

In a recent study, it was shown that there is a significant inverse correlation between CRP level and aerobic fitness measured by objective laboratory exercise testing in obese adolescents but not in the normal-weight counterparts.[15] This raised the question on whether improvement in aerobic fitness may be a useful intervention in lowering CRP levels for the obese individuals, therefore ameliorating the inflammatory status, with or without substantial weight loss.[15] It is now proposed that regular physical activity may be associated with lower CRP levels in adults.[27] In a recent randomised trial, obese women assigned to a 2-year weight-loss programme that emphasised dietary modification and moderate physical activity experienced favourable changes in CRP levels.[28] However, it is worthwhile to note that this study, as with most studies, have not specifically stratified the independent effect of exercise versus dietary modification, thus making it difficult to accurately interpret the efficacy of such programmes. Another study found a reduction in the plasma concentration of CRP following 9 months of endurance training (n = 12) with no change in the CG (n = 10).[29] Again, these collective findings demonstrated the possibility of improving the status of CRP with long-term lifestyle intervention.[30] However in our study, we did not detect positive changes in CRP concentrations following 12 weeks of exercise training programme, which could be considered as a short-term programme.[31] Sustained or regular exercise may cause the down-regulation of the release of 2 cytokines, tumour necrosis factor-alpha (TNF-α) and interleukin-6 (IL-6), major regulators of CRP production, which then affect the production of CRP by the liver.[32] Therefore, this study recommends that future short-term and long-term exercise intervention studies could confirm this by measuring cytokine levels in conjunction with more sensitive markers of cardiovascular risk other than the traditional blood lipid profile.

Study Limitations

There are important limitations of the current study. There was a possibility that improvement in the exercise HR in the EG during the submaximal cycle PWC_{170} test could be due to enhancement of the subjects' cycle economy, as subjects were required to cycle for up to 10 minutes during each session of the exercise programme throughout the 12-week period, eventhough it was beyond the scope of this study to examine this aspect. Our study have relatively small sample sizes for both the EG and the CG. To the best of our knowledge, as this is the first study to examine CRP as an indication of changes in inflammatory markers following a 12-week exercise training programme in obese adolescents, we used the basis of previously done studies to detect the magnitude of observed changes in outcome measures of vascular endothelial function, insulin sensitivity and aerobic fitness with similar sample sizes.[13,14,33] Hence, due to the small sample size and the lack of a pre-study power analysis to determine adequate effect size for this study, we suggest that our subgroup analyses and results must be interpreted with caution.

Conclusion

Our study describes in detail an exercise training programme that adopted varied indoor and outdoor activities comprising of a combination of aerobic and resistance-based exercises, as well as inclusion of sports and games activities, all of which are easily reproducible in a typical school environment. Our results in the EG contrasted with the CG confirmed that this twice-weekly exercise training programme provided improvement in aerobic fitness within a 12-week period. However, it is felt that a 12-week additional twice weekly exercise training may not be sufficient to result in improvement on the parameters related to adiposity and risk factors for cardiovascular and metabolic diseases, suggesting the need of higher intensity and/or a combination with dietary intervention to achieve desirable health effects. Eventhough both groups also participated in twice weekly PE lessons throughout the period of the training programme, we propose that additional exercise training or regular physical activities of appropriate intensities that, firstly, incorporate elements of resistance or strength conditioning activities and, secondly, can produce physiological overload benefits, may be necessary for obese paediatric populations to achieve greater energy expenditure essential to prevent further weight gain, if not to achieve substantial weight loss.

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