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ORIGINAL ARTICLE

Case Control Study

Effects of resistance training on cardiovascular health in non-obese active adolescents

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Abstract

AIM: To determine the benefits of a 10-wk resistance training programme on cardiovascular health in non-obese and active adolescents.

METHODS: This is a pragmatic randomised controlled intervention. The study was carried out in a Hong Kong Government secondary school. Thirty-eight lean and active boys and girls were randomised to either the resistance training group or the control group. Students in the resistance training group received in-school 10-wk supervised resistance training twice per week, with each session lasting 70 min. Main outcome measures taken before and after training included brachial endothelial dependent flow-mediated dilation, body composition, fasting serum lipids, fasting glucose and insulin, high sensitive C-reactive protein, 24-h ambulatory blood pressure and aerobic fitness.

RESULTS: The only training related change was in endothelial dependent flow-mediated dilation which increased from 8.5% to 9.8%. A main effect of time and an interaction (P < 0.005) indicated that this improvement was a result of the 10-wk resistance training. Main effects for time (P < 0.05) in a number of anthropometric, metabolic and vascular variables were noted; however, there were no significant interactions indicating the change was more likely an outcome of normal growth and development as opposed to a training effect.

CONCLUSION: Ten weeks of resistance training in school appears to have some vascular benefit in active, lean children.

Key words: Strength training; Children; Cardiometabolic risk factors; Endothelial function; School-based training program; High sensitive C-reactive protein; 24-h ambulatory blood pressure; Aerobic fitness

Core tip: We have shown that a school-based resistance training programme is adhered to and provides vascular benefit in lean children, lending support to the role school-based physical activity can play in the primary prevention of heart disease.

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INTRODUCTION

The endothelium plays an integral role in maintaining vascular tone and reactivity and in preserving vascular health, but impaired endothelial function predisposes individuals to early atherosclerosis[1]. The cardio-protective property of physical activity is well established and resistance training, either on its own, or in combination with aerobic exercise, has proven to be particularly effective for both cardiovascular and endothelial function in adults with hypertension, chronic heart failure, or type II diabetes[2-5]. In children and adolescents, there is growing evidence that resistance training not only increases muscle strength, but also contributes to an increase in bone strength, a desirable change in body composition, and an improvement in motor skills and sports performance[6]. We have shown considerable improvements in endothelial function following combined aerobic-resistance training and dietary modification programmes in overweight and obese children and adolescents[7]. Resistance training is potentially appealing and easy to administer within a school settings, but there is little evidence of the benefit of such training on cardiovascular and endothelial function in healthy active adolescents.

This study was therefore designed to evaluate the effectiveness of a resistance training intervention on aspects of vascular and metabolic health in normal weight 11 to 13 years old.

MATERIALS AND METHODS

Study design and subjects

Flyers were delivered to students and their parents attending a Government Secondary school in Hong Kong. Those who showed interest in the study were invited to attend an information seminar and 38 students (25 boys and 13 girls) aged 11 to 13 years old volunteered to participate. The school was chosen because it introduced a novel compulsory physical education (PE) programme comprising of one 70 min skill-based PE session per week (5 school days), plus 3 h per week of sport (students can join one of the following sports: Table-tennis, volleyball, soccer, badminton, basketball, squash, fencing, track and field, cross-country, swimming, cycling, or wushu). Although we did not assess physical activity, we believe that all the students can be classified as active on the basis of their participation in the extra sport programme. The study began at the start of the school term and all participants had been involved in the new PE programme for three weeks prior to joining the study.

All participants were classified as normal weight on the basis of having a body mass ≥ 40th and ≤ 60th percentile expressed in relation to height using sex, age and race specific normative charts[8]. None had congenital or chronic diseases that restricted them from physical activity. The study received ethical approval from the Institutional Review Board for Human Ethics of The University of Hong Kong and Hong Kong Hospital Authority West Cluster. Written informed consent was obtained from all participants and their legal guardians.

Procedures

Prior to the start of the training programme, our research team went to the school in the early morning to take fasting blood samples and assess body composition, pubertal stage, resting blood pressure and heart rate for all participants. Within one week participants attended the hospital laboratory twice for cardiorespiratory fitness testing and endothelial function of the brachial artery. During this baseline assessment period, the children were also fitted with an ambulatory 24-h blood pressure monitor at school early in a morning before their lessons started. The monitor was returned 24 h later to the school. This sequence of testing was repeated within 1-wk of completion of the 10-wk intervention, with the exception of pubertal rating. All baseline and post-training outcomes were assessed by individuals blinded to the grouping of the students.

After the baseline assessments, the 38 students were randomised to either the control group or resistance training group using gender specific sealed opaque envelopes. Students in the resistance training group (7 girls and 12 boys) received supervised resistance training twice per week for 10 wk, while students in the control group (6 girls and 13 boys) did not receive any resistance training. Both groups of students were asked to maintain their PE classes and their normal out-of-school lifestyle.

Intervention

The resistance training group joined twice weekly sessions in small groups (9 to 10 students per group), supervised by a professional trainer with two assistants. Each training session started with 10 min of warm-up and stretching exercises, followed by 40 min of resistance training (exercise order: Elbow extension, elbow flexion, trunk extension, trunk flexion, shoulder press, knee extension, knee flexion, push ups, squats, incline dip, hip abduction, and hip adduction), and ended with 5 min of stretching exercises to cool down. The training was carried out in circuit style and the participants were asked to complete three sets of 12 repetitions for each exercise in total. One set of a single exercise lasted for about 30 s and there was no rest between repetitions. The rest period between each set of single exercise items was about 16 s (therefore one set of all 13 exercises took about 9.7 min to finish). After that, the class moved on to the second and the third set of 13 exercises. Exercise order within each set of all exercises followed the principle of alternating upper-body exercises with lower-body exercises, or alternating pushing exercises with pulling exercises. This arrangement minimized the length of the rest periods required between exercises and maximizes the rest between body areas[9].

Training intensity was set at 12-RM (repetitions maximum), which implies the maximum amount of weight one can lift in 12 repetitions for most of the exercises (not including push-ups, incline dip, trunk extension, trunk flexion, and sit-ups). Twelve-RM was assessed at the first training session. This moderate intensity training programme is in keeping with published recommendations for safe resistance training in youth[10,11]. Equipment for the resistance training included dumbbells, sandbags, and exercise rubber tubing of varying resistances and fitness balls. After 4 wk the training load was increased by increasing the sets to four, whilst resistance remained constant.

Measurements

Anthropometric measures: Body mass was measured using electronic scales (Seca Delta Model 707, Hamburg, Germany) with subjects barefoot and dressed in light t-shirts and shorts. Body height was measured barefoot using a Harpenden stadiometer. Body fat was determined using foot-to-foot bio-electrical impedance (TBF-401, Tanita Co, Tokyo, Japan). The bio-electrical impedance measurement was arranged to be taken at the same day of fasting blood sampling at school to make sure that the measurement was taken in a fasting state and early in the morning. Participants emptied their bladder before the measurement.

Pubertal staging: Pubertal staging was assessed at baseline by a physician or nurse of our research team in school according to Tanner's indices for pubic hair, genitalia and breast development[12]. The highest rating for pubic hair, genitalia or breast development was recorded as the pubertal stage. Of the 38 participants, 2 were prepubertal (1 girl and 1 boy), 11 were stage 2 (1 girl, 10 boys), 19 were stage 3 (5 girls, 14 boys) and 6 were stage 4 (6 girls, no boys).

Endothelial function: Participants were studied fasting and at rest, between 900 and 1100 h. Brachial artery diameter was measured by high-resolution B-mode ultrasound (ATL 5000 system, L10-5 transducer, Bothell, Washington, United States) at rest, during reactive hyperaemia, again after 15 min rest, and after sublingual nitroglycerin spray (400 μg), as previously described[13,14]. Hyperaemia was induced by release of an occluding cuff, inflated to supra-arterial pressure for 5 min on the forearm distal to the site of measurement. Brachial artery diameter was measured continuously from 30 s before to > 2 min after cuff release. Flow-mediated vasodilatation (FMD) and nitroglycerin-mediated dilation (NMD) were recorded as the peak responses relative to the preceding rest measurements occurring within 90 s after cuff release and at 3 to 4 min after nitroglycerin administration. All scans were recorded on optic disc for subsequent off-line analysis, blinded as to which treatment group the subjects had been assigned. The scanning time took approximately 30 min for each student. We utilised a protocol established in our laboratory, which has been found to have good accuracy, reproducibility, and low interobserver error[15,16].

Cardiorespiratory fitness: Was assessed from a peak oxygen uptake (peak VO_2) treadmill running test. The speed and gradient of the treadmill was increased gradually until volitional exhaustion. Gas samples were analyzed using the Medgraphics CPX/D™ metabolic cart (Medical Graphics Corporation, St. Paul, MN, United States). Heart rate was monitored continuously during the exercise test from heart rate telemetry (Polar Eletro Oy, Finland). Peak VO_2 was determined when two of the following three conditions were reached: (1) a respiratory exchange ratio > 1.0; (2) heart rate > 85% of age predicted maximum or levelled off; and (3) the student showed visible signs of exhaustion and refused to carry on despite strong verbal encouragement.

Laboratory investigations: A phlebotomist went to the school in the early morning and fasting (12 h) venous blood samples (4 mL) were drawn from all participants. Total cholesterol (TC) and triglyceride were assayed enzymatically using DP Modular Analytics, Roche Diagnostics Corp, Indianapolis, IN, United States. HDL cholesterol (HDL-C) was measured by cholesterol esterase/cholesterol oxidase coupling Trinder's reaction with pre-treatment steps using PEG modified enzyme and dextran sulphate. LDL cholesterol (LDL-C) was calculated using the Friedewald equation. Plasma glucose was measured by hexokinase method (DP Modular Analytics). Serum insulin and high sensitivity C-reactive protein (hsCRP) were determined by chemiluminescence immunoassay using the IMMULITE 1000 Analyzer (Siemens Healthcare Diagnostics, Deerfield, IL, United States).

Blood pressure: Resting blood pressure was assessed in the laboratory from the right arm after at least 5 min of supine rest, using a standard mercury sphygmomanometer with cuffs of appropriate sizes. Korotkoff sound V was taken as the diastolic blood pressure. Heart rate was recorded by electrocardiogram. Ambulatory blood pressure (ABP) was monitored using an oscillometric monitor (SpaceLabs 90217, SpaceLabs Medical, Redmond, Washington, United States), which has been validated for use in children[17]. Systolic, diastolic and mean arterial BP were measured hourly during sleep and every 30 min when awake. The exact cut-off time dividing wake and sleep BP was defined individually according to a self-reported sleep habit diary. An appropriate sized cuff was placed on the non-dominant arm. Recordings were included in the analyses if they possessed a minimum of 14 successful readings during active wakefulness and at least 7 successful readings during sleep[17]. Individual mean systolic, diastolic and mean arterial BP were calculated for wake and sleep periods.

Statistical analysis

Histograms were produced for all variables to exclude any skew, in the presence of which the data were transformed before comparing group differences. Among all variables, fasting insulin was log transformed. Analysis of variance was used to compare baseline characteristics between the two groups. Group differences in the distribution of pubertal stage were examined using χ^2. Group (resistance training group, control group) by time (baseline, post-training) analyses of variance (ANOVA) with repeated measures were used to examine differences in the outcome measures. Analysis of covariance (ANCOVA), taking baseline scores as the covariate, was used to further deconstruct differences on fasting TC and HDL-C. A P value of 0.05 was set a priori.

RESULTS

Descriptive characteristics and markers of cardiovascular health at baseline and after the 10 wk intervention period are presented in Table 1. The distribution of pubertal ratings between the two groups was similar (resistance training group: Tanner 1 = 0, Tanner 2 = 5, Tanner 3 = 10, Tanner 4 = 4; Control group: Tanner 1 = 2, Tanner 2 = 6, Tanner 3 = 9, Tanner 4 = 2, χ^2 = 2.46; P = 0.483). There were no baseline differences between the two groups for any of the anthropometric variables. The mean attendance rate of the resistance training sessions was 83% and the students only missed sessions because of minor illness. All subjects in the resistance training group completed at least 80% of the 20 exercise sessions and were therefore all included in the final analyses. They were also able to finish all prescribed sets of exercises in each training session and there were no resistance training-related injuries.

Body height, body mass, body mass index and fat-free mass all increased significantly over the 10-wk period in both groups. No significant interactions confirmed none of the anthropometric changes over time were a result of the training programme.

Baseline differences between the resistance training group and control group were apparent for both TC and HDL-C, and ANCOVA was therefore utilised to compare values after 10 wk with pre-training levels as the covariate. No time or between group differences were found after removing the effect of baseline values for either TC or HDL-C (P > 0.05). LDL-C and insulin level decreased significantly in both groups over time.

Peak VO_2 expressed absolutely showed an increase in both groups over the 10-wk period, but when adjusted for body size, this increase was no longer apparent.

Thirty-two of the 38 participants agreed to be scanned for endothelial function before and after the intervention. Mean values for flow-mediated dilation and NMD at baseline and post 10 wk of training are provided by group in Table 2. Individual values for FMD at baseline and post 10 wk of training are presented graphically in Figure 1. A main effect of time [$F(1,30) = 13.47$; $P < 0.001$; $\eta^2 = 0.310$] and a significant interaction [$F(1,30) = 9.37$; $P < 0.005$; $\eta^2 = 0.238$] were apparent for FMD. Follow-up analyses indicated a greater increase in FMD in the resistance training group compared to the control group. Although there was a

Table 1 Descriptive characteristics at baseline and following the intervention by group

	Resistance training group (*n* = 19)		Control group (*n* = 19)		Time effect (*P* value)	Group effect (*P* value)	Interaction (*P* value)
	Baseline	After	Baseline	After			
Age, yr	12.3 ± 0.42	12.5 ± 0.42	12.1 ± 0.30	12.3 ± 0.30	< 0.001	0.100	1.000
Height, cm	151.4 ± 5.8	153.4 ± 5.5	151.0 ± 8.6	152.7 ± 8.8	< 0.001	0.800	0.300
Mass, kg	42.8 ± 6.7	44.3 ± 7.3	40.5 ± 7.1	41.9 ± 7.3	< 0.001	0.300	0.800
Body mass index, kg/m^2	18.6 ± 2.4	18.8 ± 2.5	17.7 ± 2.3	17.9 ± 2.1	0.048	0.200	0.700
Body fat, %	19.0 ± 6.1	19.0 ± 6.1	16.3 ± 3.7	16.3 ± 3.7	1.000	0.100	0.900
Fat free mass, %	34.9 ± 4.5	36.1 ± 4.9	33.9 ± 5.9	35.0 ± 6.1	< 0.001	0.900	0.600
SBP, mmHg	110 ± 9	107 ± 11	108 ± 11	107 ± 9	0.131	0.780	0.461
DBP, mmHg	68 ± 6	67 ± 8	67 ± 8	67 ± 7	0.652	0.751	0.557
TC, mmol/L	3.9 ± 0.6	3.7 ± 0.6	4.4 ± 0.5	4.2 ± 0.7	0.025	0.025	0.814
HDL-C, mmol/L	1.5 ± 0.2	1.5 ± 0.3	1.7 ± 0.4	1.8 ± 0.5	0.220	0.047	0.278
LDL-C, mmol/L	2.0 ± 0.6	1.8 ± 0.5	2.3 ± 0.5	2.0 ± 0.5	< 0.001	0.199	0.850
TG, mmol/L	1.0 ± 0.4	1.0 ± 0.4	0.9 ± 0.4	1.0 ± 0.4	0.554	0.756	0.848
Glucose, mmol/L	5.1 ± 0.3	5.0 ± 0.3	4.9 ± 0.3	4.9 ± 0.3	0.269	0.094	0.315
log insulin, pmol/L	4.4 ± 0.5	4.1 ± 0.3	4.0 ± 0.5	3.9 ± 0.5	0.027	0.099	0.169
hsCRP, mg/L	0.31 ± 0.45	0.25 ± 0.35	0.19 ± 0.18	0.65 ± 2.3	0.486	0.638	0.344
Peak VO_2, mL/min	1741 ± 322	1870 ± 446	1776 ± 466	1963 ± 540	0.003	0.700	0.500
Peak VO_2, mL/kg per minute	40.5 ± 7.1	41.8 ± 8.0	43.1 ± 8.8	45.6 ± 7.9	0.081	0.300	0.600

Data are presented as mean ± SD. *P* values were obtained from repeated measures ANOVA. SBP: Systolic blood pressure; DBP: Diastole blood pressure; TC: Total cholesterol; HDL-C: High-density lipoprotein cholesterol; LDL-C: Low-density lipoprotein cholesterol; TG: Triglyceride; hsCRP: High sensitive C-reactive protein; VO_2: Oxygen consumption.

Table 2 Endothelial function of the brachial artery at baseline and following the intervention by group

	Resistance training group (*n* = 17)		Control group (*n* = 15)		Time effect (*P* value)	Group effect (*P* value)	Interaction (*P* value)
	Baseline	After	Baseline	After			
FMD, %	8.5 ± 1.0	9.8 ± 1.3	8.8 ± 1.2	8.9 ± 0.9	0.001	0.451	0.005
NMD, %	21.7 ± 2.8	20.7 ± 1.8	22.5 ± 2.9	21.5 ± 2.7	0.011	0.336	0.985

Data are presented as mean ± SD. *P* values were obtained from repeated measures ANOVA. FMD: Flow-mediated dilation; NMD: Nitroglycerin-mediated dilation.

main effect of time for NMD, there was no interaction, with both groups showing a change in NMD over time (Table 2).

Mean ABP values awake and asleep are presented in Table 3. No main effects were found for either waking or sleeping diastolic ABP, nor interactions. There was no significant difference between the two groups for mean ambulatory systolic blood pressure during sleep or awake (Table 3). Sleeping systolic ABP did show a decline in both groups over the 10-wk period.

DISCUSSION

The key finding from this study was that 10 wk of resistance training resulted in enhanced endothelial function in lean, active youngsters. Improvements from baseline to 10 wk were noted in both groups for a number of anthropometric, metabolic and non-endothelial dependent vascular measures, but these were most likely simply a reflection of normal growth and development.

Accumulating evidence from the adult literature indicates that acute exercise promotes the number and activity of endothelial progenitor cells, increases blood flow and shear stress on the endothelium, which in turn causes an increase in the activity of endothelial nitric oxide synthase and vascular production of nitro-oxide[18]. Resistance exercise elevates blood flow for short periods of time under much higher pressure than sustained periods of moderate exercise and this may produce a more intensive stress stimulus for endothelial cells. In well-trained adult athletes, repetitive intensive exercise exposure has been shown to result in arterial remodelling, with and without change in dilatory capacity[19,20]. Other mechanisms such as hormonal and inflammatory effects, as well as peripheral resistance have been related to exercise-induced improvements in endothelial integrity[21]. The increase in FMD noted in the present study was apparent in the absence of any training-related change in blood pressure or markers of inflammation, and supports the proposition that resistance training most likely increases laminar shear stress, thus has a direct influence on endothelial function.

To the best of our knowledge, this is the first study to show that endothelial function can be enhanced in lean, active children following resistance training. Previous exercise interventions have focused upon normalising vascular dysfunction in groups of overweight and obese children. The relative increase in FMD from baseline

Table 3 Twenty-four hours ambulatory blood pressure at baseline and following the intervention by group

	Resistance training group (*n* = 19)		Control group (*n* = 19)		Time effect (*P* value)	Group effect (*P* value)	Interaction (*P* value)
	Baseline	After	Baseline	After			
Awake							
SBP, mmHg	113 ± 8	111 ± 7	110 ± 9	109 ± 8	0.100	0.200	0.700
DBP, mmHg	71 ± 5	70 ± 5	68 ± 4	67 ± 5	0.400	0.093	0.900
Mean BP, mmHg	85 ± 5	84 ± 5	82 ± 4	82 ± 5	0.400	0.100	0.800
Mean HR, beat/min	87 ± 9	86 ± 7	87 ± 9	83 ± 8	0.100	0.600	0.200
Asleep							
SBP, mmHg	103 ± 11	98 ± 8	101 ± 11	98 ± 9	0.041	0.800	0.600
DBP, mmHg	55 ± 7	54 ± 7	54 ± 6	54 ± 6	0.600	1.000	0.500
Mean BP, mmHg	73 ± 8	71 ± 7	73 ± 6	72 ± 6	0.200	1.000	0.600
Mean HR, beat/min	68 ± 6	70 ± 6	66 ± 8	68 ± 8	0.087	0.500	0.900

Data are presented as mean ± SD. *P* values were obtained from repeated measures ANOVA. SBP: Systolic blood pressure; DBP: Diastole blood pressure; HR: Heart rate.

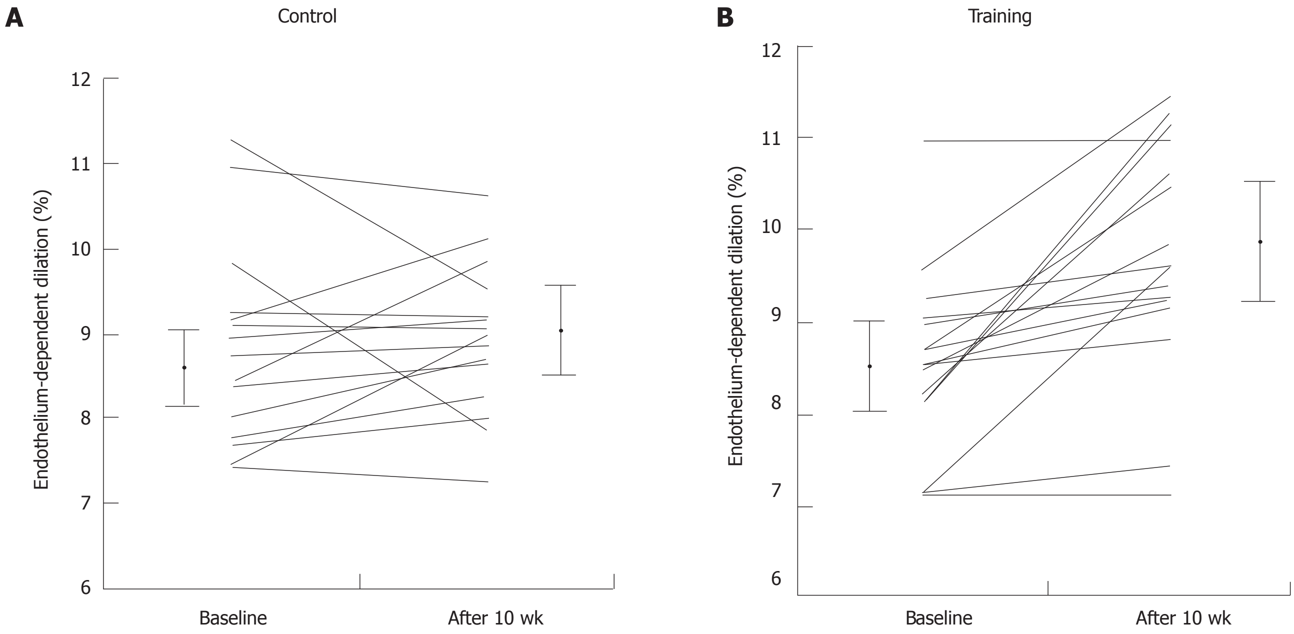

Figure 1 Individual values for flow-mediated dilation at baseline and after 10 wk of intervention in the control (A) and training group (B).

of 15% noted in our group of normal weight Chinese youngsters is marginally less than the improvement in FMD reported for overweight Chinese youngsters, where a relative increase in FMD from baseline of 18% was reported after a 6-wk diet and resistance training intervention[7].

The changes in anthropometric, metabolic and vascular variables in both groups over the 10-wk period could be in part due to active participation in the additional three hours of sport activities per week; however, these were not accompanied by an increase in aerobic fitness and are more likely a reflection of normal growth and development.

Currently there are no data on whether an increased FMD during childhood (either obese or non-obese) will translate into decreased risk of future cardiovascular risk, and only longitudinal studies will provide an answer to this question. However, various reports from the American Heart Association have reaffirmed the importance of primary cardiovascular disease prevention[22-24]. All children, not just those at risk, are thought to benefit from cardiovascular health promotion. Children and adolescents spend 7 to 8 h a day on average in school and it is therefore an ideal site for establishing appropriate behavioural patterns, particularly physical activity habits[25]. In Hong Kong the community places a strong emphasis on a student's academic performance and pays less attention to a student's physical activity. Physical activity levels in Hong Kong youngsters have been found to be low in comparison with other countries[26] with most of a child's active behaviour occurring in school, and nominal amounts of physical activity apparent in the home[27]. We have shown that a school-based resistance training programme is adhered to and provides vascular benefit in lean children, lending support to the role school-based physical activity can play in the primary prevention of heart disease.

This study is not without limitations. We have not included strength measures in the current study. Muscular strength is likely to be improved after receiving resistance training in children and adolescents population[11,28], however, a primary consideration was compliance of participants to attend all investigations before and after the program (especially participants in the control group), and we felt assessment of strength measures would be too burdensome for participants. Participants in the resistance training group progressed to 4 sets of exercises at 12RM in most of the exercises by the end of the program and we accepted this as a reflection of their improvement in muscular strength. We did not directly assess physical activity, rather used school PE as a surrogate marker. PE in the majority of Hong Kong Government schools consists of 70 min every 10 d, of largely skill-based activity. The participants in this study received 250 min of PE every 7 d. We can probably assume that this population was engaged in more physical activity per week than many youngsters in Hong Kong; however, it would be beneficial to have a direct measure of physical activity habits in future studies.

With respect to the practical application of this study, the training programme in this study is designed in a circuit-style that is practical for schools. Schools and policy makers may consider the inclusion of resistance training as a part of a varied physical activity programme for promoting cardiovascular health in youth.

In conclusion, this study has shown that 10 wk of a school-based resistance training programme is effective in improving endothelial function in active, lean children. These findings stress even more the importance of schools offering plentiful and varied physical activity opportunities for the cardiovascular health of young people, in particular resistance exercise.

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COMMENTS

Background

The endothelium plays an integral role in maintaining vascular tone and reactivity and in preserving vascular health, but impaired endothelial function predisposes individuals to early atherosclerosis. The authors have previously reported that impairment of endothelium function in overweight and obese children can be improved following combined aerobic-resistance training and dietary modification programmes. Resistance training is easy to administer within a school settings, but there is little evidence of the benefit of resistance training on cardiovascular and endothelial function in healthy active adolescents.

Research frontiers

Primary prevention of cardiovascular disease through modification of lifestyle behaviors, such as exercise during childhood and adolescence is paramount because of the growing evidence that the origins of cardiovascular disease begin in childhood. Much of the research attention focusing on the role exercise plays in endothelial health has been on the obese child. Cross-sectional evidence has shown that the lean child is also at risk of vascular dysfunction because of insufficient physical activity and excessive sedentary behavior. This confirms the importance of strategies to encourage active lifestyles in children and adolescents, but requires better understanding of the role exercise plays in vascular health in lean children and adolescents.

Innovations and breakthroughs

Exercise and vascular function is a recent issue in healthy weight children and adolescents. This study addresses exercise induced alterations in endothelial function in healthy lean adolescents and provides novel insight into the benefits of resistance exercise training in this younger population.

Applications

The exercise training programme used in this study is designed in a circuit-style that is practical for schools. Schools and policy makers may consider the inclusion of resistance training as a part of a varied physical activity programme for promoting cardiovascular health in youth.

Terminology

Endothelium dependent flow-mediated dilation: A technique used to increase blood flow and therefore shear stress, stimulating the endothelium to release nitric oxide and induce vasodilation. Endothelial independent flow-mediated dilation: The use of an exogenous nitric oxide donor, such as nitroglycerin to induce vasodilation independent of the endothelium, reflecting vascular smooth muscle function.

Peer-review

The manuscript is well written. The study is well designed with detailed methodology to assess the change in body composition and cardiovascular function.

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