The physiological and psychological effects of resistance training on Chinese obese adolescents

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Abstract
The present study was to evaluate the effects of a moderately hypocaloric diet, with resistance training on obese adolescents' body composition, muscle strength, bone mineral density, blood lipids, glucose, and insulin levels. A total of 36 obese adolescents aged 10-17 were recruited. Fasting blood samples were collected for lipids, glucose and insulin levels. Body composition was measured by DEXA. Participants were assigned into intervention and control group randomly. Both groups had dietary intervention (hypocaloric balanced diet). Intervention group had resistance training, three times per week for six weeks. The resistance exercises were tailored to individual participants according to their baseline fitness level. The resistance was set at a level (70 to 85% of 1RM) that permitted at least 5 lifts with full range of motion. After six weeks, it was found that resistance trained participants demonstrated a decrease of resting heart rate, systolic blood pressure, total triglycerides and insulin level. Likewise, an increase of bone mineral content and high-density lipoprotein cholesterol was observed in the intervention group, while percentage fat mass was maintained. However, all of the changes did not reach statistical significance except the bone mineral content. With regards to the psychological effects of resistance training in depression and anxiety, there was no statistical difference within each group and between the two groups. To summarize, there was a trend of improvement in body composition, blood lipids, and insulin levels in the intervention group. Increased training period is recommended to bring on more significant changes in physiological and psychological constructs.

Keywords: Adolescent obesity, Resistance training, Physiological effect, Depression, Anxiety

Introduction
Resistance training is a common component of fitness training programmes. The American Academy of Pediatrics (AAP 2001) recently revised its views on resistance exercise in children and made recommendations of the use in children's fitness. Data on the effects of resistance training in children however were limited and further evidence of its physiological and psychological effects is needed. Obese children and adolescents are seldom encouraged to participate in resistance exercise because of ill-founded concern that it may not have positive effects for their weight management (Sung et al. 2002). Research on childhood obesity and resistance training is complicated by the natural rate of growth of children (Gregory et al. 1997). Only in very recent years evidence began to appear that resistance training is an effective and safe method of conditioning, provided that certain guidelines are followed (Faigenbaum et al. 1996; Falk & Tenenbaum 1996; AAP 2001). Resistance training can enhance strength and muscle hypertrophy in adolescents (Kraemer et al. 1989; Webb 1990). Favorable effects on bone and lean mass (Heinonen et al. 2000; Morris et al. 1997) and psychosocial parameters like anxiety and depression (Focht 2002; Mazzeo et al. 1998; O’Nan et al. 2000) were reported in children and adults. Resistance training could also help obese adolescents adhere to their weight reduction program (Sothern et al. 2000).

In Hong Kong, limitations of space in school and at home militate against aerobic exercise training to
obese adolescents. Resistance exercise regimes could offer a practical alternative since simple and small piece of equipment like dumbbell and sandbag would be convenient and effective in doing exercise. But there have been application concerns about their use in obesity management and it is not currently promoted for obese population. The resistance exercise has however been shown to be effective and safe in obese treatment, reducing also the severity of other cardiovascular factors (Sung et al. 2002). Resistance training could therefore be particularly appropriate for obese people in Hong Kong. As anxiety and depression are important concerns among obese people (Berg 1997), the psychological benefit of resistance training to obese adolescents also requires further examination in this area.

Stronger scientific evidence of the benefit of resistance training in obese management would help towards its provision and promotion, bringing important long-term health benefits to the obese people of Hong Kong. The present study was to evaluate the effects of a moderately hypocaloric diet, with resistance training on obese adolescents' body composition, muscle strength, bone mineral density, blood lipids, glucose, and insulin levels.

Both groups received identical nutrition education and behavior modification treatment. Goals were set at each week and checked for compliance during follow up. The prescription of diet was based on United States Department of Agriculture Food Guide Pyramid, with recommendations of 55-60 % carbohydrates, 15-20 % protein, and 25-30 % fat. Individual energy requirements was approximated according to their baseline dietary intakes and physical activity level, and adjusted to promote weight loss at approximately 0.5 kg/week. Parents were given instructions on preparing low fat meals and monitoring children's food intake. A snack exchange list and guidelines were provided to instruct children how to choose the snacks, and a contract of moderately hypocaloric diet (1500-1800 kcal diet with no more than 30 % of calories from fat) was made between participants and the dietitian.

Testing of muscular strength for children

Based upon the concept of training and testing specificity, the criteria of Sale's (1991) strength testing adopted in the present study. Sale contended that the more specific and similar of the training and testing movements, the greater the accuracy of the evaluation of program effectiveness was. As a result, the major muscle groups of the leg, chest and arm were tested under the same type of contraction, joint angle, speed of contraction and movement pattern. Since the training focused on the isotonic muscular strength and using stacked weight in a fitness room, the same testing equipment, movements and techniques were taught to the participants in the pre-test of muscular strength. Although the use of stacked weight to evaluate muscular strength was not a true laboratory protocol, the use of stacked weight in repetition maximum (RM) was still a valid test in consideration of the specificity principle of training and testing (Gaul 1996). Multiple repetition sub-maximum (5 RM, 6 RM and 10 RM) was considered the least risk of injury for children provided proper instruction and supervision was offered (Blimkie & Macauley 2000; Watkins & Docherty 1986). Since the greater the number of repetitions in the test, the more it would become a muscular endurance test rather than strength (Blimkie & Macauley 2000). Based on these studies, 5 RM, using stacked weight, of major muscle groups was administered to the obese participants in order to reduce the risk of injury and enhance the specificity of the testing.

After stretching and warm up exercises, children were asked to do 3-7 warm up sub-maximal repetitions for each station. A one minute rest was given after the trial lift. A 5 RM lift was performed and the weight was increased conservatively. If the lift was successful, participant should rest and attempt next weight increment. Follow this procedure until the

Method

Participants

Thirty-seven children aged 10-17 (12 girls, 24 boys) were recruited in the present study. They were patients of a pediatric obesity clinic of a hospital. Participants and their parents were given consent letters, which explained to them about the aims and procedures, before the start of the study. They were also reminded that their participation in the study was voluntary and they could withdraw at any time of the study without any prejudice. No participants and their parents refused to take part. They were assigned into intervention and control group randomly. Intervention group (7 girls, 14 boys) was trained in a fitness room and attended a nutrition counseling constantly and the control group (5 girls, 11 boys) only attended the nutrition sessions only.

Diet program

Current dietary intake was assessed at week 0 and 8 using a 3 days food record. Participants were asked to record everything they consumed for 2 consecutive weekdays plus 1 weekend day. The time of the day, the type, and quantity of food using standard household measures were recorded. The food record was checked and verified by a trained dietitian assisted by the parent. A computerized nutrient database was used to calculate the daily intake.
participant failed to complete the lift with full range of motion. Once the target load was identified, participant should rest 3-4 minutes and attempted again to verify the true repetition maximum identified. Finally, the instructors recorded the 5 RM value for the station (Blimkie & Macauley 2000).

Furthermore, all participants were accompanied by individual fitness instructors during the fitness pre-test and post-test in order to ensure for valid results in 5 RM test. According to the literature, leg press, bench press and bicep arm curl were recommended to test the major muscle groups like knee and hip extensor, pectoral major and biceps brachii muscles for children aged 8 or above (ACSM 2001; Blimkie & Macauley 2000; Gaul 1996).

Testing procedures of body composition and blood profiles

Body weight was measured using an electronic body weight scale (Seca Delta Model 707) with subjects dressed in light T-shirt and shorts. Height was measured using a Harpenden stadiometer. Bone mineral content, body lean mass and fat mass were determined by dual-energy X-ray absorptiometry (DEXA). The DEXA instrument was a Hologic QDR-4500 (Waltham, MA, USA). The whole body scan time was 3 to 4 minutes using the fan beam model. Waist circumference was taken as the mean of two readings of the minimum circumference between the umbilicus and xiphoid process. Hip circumference was measured as the mean of two measurements of the maximum circumference around the buttocks and the symphysis pubis. Blood pressure was measured in the right arm after at least 5 minutes of sitting with a standard mercury sphygmomanometer using cuffs of appropriate sizes. The blood pressure at the Karotkoff sound V was taken as the diastolic blood pressure.

Fasting serum lipids were assayed enzymatically by using the Boehringer Mannheim Hitachi 911 analyzer. High density lipoprotein cholesterol was measured after precipitation with phosphotungstic acid-magnesium. Low density lipoprotein cholesterol was calculated by means of the Friedewald formula. The hospital laboratory performing the lipid analyses was currently accredited with intra-assay imprecision of cholesterol measurement <3% and the accuracy standardized by the Center for Disease Control National Heart, Lung and Blood institute program. Plasma glucose (was measured by a glucose oxidase method (Diagnostic Chemicals reagents kit, Diagnostic Chemicals Ltd., Prince Edward Island, Canada). The intra-assay coefficient of variation (CV) of glucose was 2% at 6.6 mmol.l⁻¹. Insulin assay was performed using radioimmunoassay (Pharmacia Sweden). The lowest limit of detection was <2µU·ml⁻¹. The inter-assay CV was 5%.

Psychological measures

Psychological well-being was measured by the Hospital Anxiety and Depression Inventory (Zigmond & Snaith 1983). Two dimensions of psychological distress were measured, namely, anxiety and depression. The Hospital Anxiety and Depression Inventory (HADS) is a 14-item self-report instrument for assessing psychological symptoms of individuals with actual or potential physical problems. It deliberately excluded physical ramifications of psychological disturbances such as headache. There are two subscales of seven items each, one for measuring anxiety and the other for measuring depression. Respondents were asked to rate the items on a four-point scale. The validated Chinese version (Leung et al. 1992) was used. Participants were assessed prior to intervention (in Week 0) and after intervention (in Week 6).

Resistance training program

The training program covered six weeks from July to August 2002. All participants were trained in a fitness room, Hong Kong Baptist University. This resistance training session were conducted three times a week on alternate days (Monday, Wednesday & Friday). During the recruitment process, the safety concern and potential benefits of the training were explained. Realistic outcome was introduced to the participants in order to avoid wrong expectation of the training and dropout. Professional fitness instructors taught and demonstrated correct postures and techniques to the participants.

In addition to warm up and cool down exercise, 10 resistance training stations with machines were performed by the participants in the 1-hour intervention. Three-set circuit training format was employed and 3 instructors provided individual help to the twenty-one participants. Three to five minutes of rest between sets of training was set as resting period. Resistance exercises were tailored prior to individual participants according to their fitness test results prior to the training. The resistance was set at a level that permitted at least 5 lifts with full range of motion and good form. Five repetition maximum (5-RM) was established in each movement by asking a subject to lift a load through a full range of motion. This information was served as the prescription basis for different exercise stations. Quantitatively, the resistance training level was set at 70 to 85% of 1RM depending on individual performance and progression. All training intensity (set, weight and repetitions) and stations were adjusted and modified according to the real situation of the training progression. The stations included chest press, lat pull down, shoulder press, leg press, leg extension, leg curl, heel raise, biceps curl, triceps extension, and adjusted push-up.
Statistical analysis

Baseline differences between groups of all outcome variables were compared by using One-Way ANOVA with a commercially available statistical package (SPSS for Windows, version 10.0, Chicago, IL). Histograms were also produced to look for any skewness for all variables. If baseline differences and skewness distribution of that variable existed, transformation was made before comparisons.

All parameters were compared between groups using a 2 x 2 repeated measures ANOVA to detect changes with time within the treatment condition (at the beginning, and after the six-week programme) and among groups (control vs exercise). The effects of the additional exercise training would be indicated by the Time-by-Group interaction.

Results

After six weeks, both groups of children had their height increase significantly, with their body mass index and waist-to-hip ratio maintained. There was a trend of decrease in resting heart rate and systolic blood pressure in the exercise group after the strength training program, though the changes did not reach statistically significant. Bone mineral content increased significantly in both groups ($P < 0.05$). Percentage fat mass in the exercise group was maintained, while in control group showed an increase by 0.6% (Table 1). The changes of total cholesterol and low-density lipoprotein level in both groups were similar after six weeks. Exercise group experienced 8.3% increase in high-density lipoprotein and 7.1% decrease in total triglycerides level. The median of changes in insulin level (post-pre) was 11.5 pmol.L$^{-1}$ (ranged from -32.9 to 7.0 pmol.L$^{-1}$) in the intervention group, and 8.5 pmol.L$^{-1}$ (ranged from -48.2 to 18.1 pmol.L$^{-1}$) in the control group (Table 2) although no significant difference was found within group and between groups.

Both groups showed an increase in leg and chest muscle strength. However, the increase was significantly greater for the intervention group than for their counterparts for both leg muscle strength (mean increase =89.4 lbs for intervention group and

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Changes of physiological measures of obese children after exercise intervention</th>
<th>Data are mean ±SD.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>Intervention</td>
<td>Time effect</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>156.8 ±11.7</td>
<td>157.7 ±11.5</td>
</tr>
<tr>
<td>Weight (Kg)</td>
<td>72.3 ±21.5</td>
<td>73.0 ±22.6</td>
</tr>
<tr>
<td>BMI</td>
<td>29.0 ±5.1</td>
<td>28.9 ±5.4</td>
</tr>
<tr>
<td>Systolic Blood Pressure (mmHg)</td>
<td>115.2 ±6.8</td>
<td>114.8 ±11.6</td>
</tr>
<tr>
<td>Diastolic Blood Pressure (mmHg)</td>
<td>71 ±8.9</td>
<td>69.6 ±6.9</td>
</tr>
<tr>
<td>HR (beats.min$^{-1}$)*</td>
<td>82.5 ±11.1</td>
<td>84.3 ±12.2</td>
</tr>
<tr>
<td>Waist (cm)</td>
<td>91.4 ±12.5</td>
<td>93.0 ±14.8</td>
</tr>
<tr>
<td>Hip (cm)</td>
<td>103.2 ±13.0</td>
<td>104.3 ±14.0</td>
</tr>
<tr>
<td>Waist-to-hip ratio</td>
<td>0.9 ±0.1</td>
<td>0.9 ±0.1</td>
</tr>
<tr>
<td>Bone Mineral Content (g)</td>
<td>1711 ±502</td>
<td>1732 ±493</td>
</tr>
<tr>
<td>Lean mass (kg)</td>
<td>46.7 ±14.4</td>
<td>46.8 ±14.8</td>
</tr>
<tr>
<td>Fat mass (kg)</td>
<td>27.4 ±11.1</td>
<td>28.0 ±10.9</td>
</tr>
<tr>
<td>%Fat</td>
<td>35.8 ±5.6</td>
<td>36.4 ±5.6</td>
</tr>
</tbody>
</table>

*Baseline difference exists

| Table 2 | Changes of cholesterol, glucose and insulin levels. TC total cholesterol, HDL-C high-density lipoprotein cholesterol, LDL-C low-density lipoprotein cholesterol, TG triglycerides, lg_Insulin log-transformed insulin. Data are mean ±SD. |
|---------|---------------------------------|------------------|
| Control | Exercise | Time effect | Group effect | Interaction |
| TC (mmol.L$^{-1}$) | 4.5 ±0.8 | 4.4 ±0.8 | 4.6 ±0.8 | 4.5 ±0.9 | 0.49 | 0.59 | 0.67 |
| HDL-C (mmol.L$^{-1}$) | 1.1 ±0.3 | 1.1 ±0.3 | 1.2 ±0.2 | 1.3 ±0.3 | 0.46 | 0.23 | 0.39 |
| TG (mmol.L$^{-1}$) | 1.4 ±0.6 | 1.5 ±0.7 | 1.4 ±0.7 | 1.3 ±0.7 | 0.99 | 0.90 | 0.42 |
| LDL-C (mmol.L$^{-1}$) | 2.7 ±0.9 | 2.6 ±0.8 | 2.8 ±0.7 | 2.7 ±0.7 | 0.20 | 0.82 | 0.69 |
| Plasma Glucose (mmol.L$^{-1}$) | 4.9 ±0.4 | 5.0 ±0.4 | 4.6 ±0.3 | 4.8 ±0.4 | 0.01 | 0.11 | 0.18 |
| lg_Insulin (pmol.L$^{-1}$) | 5.1 ±0.7 | 5.1 ±0.5 | 4.9 ±0.3 | 4.8 ±0.4 | 0.13 | 0.14 | 0.16 |
34.0 lbs for control group, $t = 4.31, P < 0.001$) and chest muscle strength (mean increase = 33.9 lbs for intervention group and 14.7 lbs for control group, $t = 4.31, P < 0.001$). There was no statistical difference in change in biceps muscle strength between the two groups. For both groups, BMI decreased (mean decrease = 0.10 for intervention group and 0.03 for control group) while their height increased significantly. However, the between-group BMI difference was not statistically significant. Results from MANOVA showed that the intervention group had a significantly greater improvement in overall fitness compared to the control group (Wilk's $\lambda = 0.50, F(2,29) = 9.88, P < 0.001$).

The changes in psychological well-being were also examined. Repeated Measures ANOVA was conducted to test if there were significant differences between the intervention group and the control group on change in anxiety and depression scores. No significant difference was found between the two groups on change in anxiety (Wilk's $\lambda = 0.964, F(1,30) = 1.13, P = 0.295$) and change in depression (Wilk's $\lambda = 0.942, F(1,29) = 1.79, P = 0.192$). For the intervention group, there was a reduction in anxiety from 6.87 in the pre-intervention assessment to 5.33 in the post-intervention assessment but the change was not statistically significant ($t = 1.53, P = 0.147$), and an increase in depression from 4.73 to 6.27 although the change was also not statistically significant ($t = -1.72, P = 0.108$). There were also no significant changes in anxiety and depression for the control group (pre-intervention anxiety = 4.94, post-intervention anxiety = 4.59, $t = -0.64, P = 0.534$; pre-intervention depression = 5.56, post-intervention depression = 5.38, $t = 0.20, P = 0.840$). The scores of both groups indicated that obese children at this age had low anxiety and depression level with or without intervention.

The present study could only implement 6 weeks due to the summer vacation for the school children so they could come to the University fitness room. It is speculated that even the frequency has been increased to 3 times per week to supplement the short period of duration for the intervention, it is believed that the shorter duration with higher training frequency could not compensate the short period of training. Extended duration of the intervention program would be a critical factor which let the positive changes emerge to a significance level.

Age is another factor that should be considered in this study. In Sung et al. study (2002), their participants were younger children from primary schools. Therefore, the puberty level might have an important impact on the body composition during the intervention. As Magill (1988) and Malina (1988, 2004) suggested that biological maturity status of individual adolescents could lead to big difference between early and late maturation in obese boys and girls at this age. It is believed that once the adolescents are in the puberty stage, the physiological changes due to resistance training could be very different. As a result, earlier intervention like Sung et al. (2002) is recommended for achieving better effect in weight management.

With regards to the anxiety and depression changes, the participants' psychological well-being was not significantly changed by the resistance training program. There was a slight reduction in anxiety and a slight increase in depression scores in the intervention group but the changes were not statistically different. The difference between the intervention group and the control group was likewise not statistically different. One possible reason might be the small sample size which resulted in a low power in detecting any possible difference brought about by the resistance training programme. Another reason might be the short duration of the intervention programme. Should a longer intervention be implemented, the intervention effect on could be further discovered. Finally, the pre-intervention anxiety and depression scores of the intervention group participants were not elevated to start with. The mean anxiety score of the intervention group participants was 6.87. This was lower than the Hong Kong mean of 7.32 (Leung et al. 1992). Similar finding was demonstrated in Hale's study (2002) that anxiety level had no changes after resistance training in low baseline anxiety group but on the contrary, significant changes was found in high baseline group. This offered a possible conclusion that resistance training might only have impact on high anxiety baseline participants. In the present study, all adolescents had low scores in anxiety level before the intervention. Thus, no significant change is conceivable.

Discussion

Results of the study demonstrated different degrees of improvements of percentage body fat, high-density lipoprotein, triglycerides level, insulin level, resting heart rate and systolic blood pressure, muscular strength in the exercise group of obese children after the six-week resistance training program. Although all these changes, besides muscular strength, did not reach the significance level in statistics, a positive trend of healthy body indicators has been emerged. Based on the previous experience in resistance training on the younger obese children (Sung et al. 2002), the duration of the resistance exercise intervention might be the determining factor. The resistance program of Sung and her colleagues (2002) lasted for 9 months and showed significant changes in body composition, insulin level and cholesterol of younger children.
The depression score of the intervention group participants was 4.73. Again, this was lower than the mean of 4.92 in the validation study in Hong Kong. In other words, the participants were not particularly anxious and depressed to start with. Hence, it is difficult for the intervention programme to further improve their psychological well-being in any significant degree. With regards to the slightly increase of depression scores, intensive training could elevate depression (Paluska & Schwenk 2000). Contrast with the obese participants' physical inactive lifestyle, the intervention really made a huge difference to them and it might create a slight increase of depression to them.

Contrast with previous summer in which most of the obese participants had gained weight over 9.09 kg as measured by an electronic body weight scale (Seca Delta Model 707) and a Harpenden stadiometer, the participants in this summer only gained 0.4 kg in average. Likewise, their height has increased and their BMI and waist-hip ratio were slightly decreased. In addition to the significant muscular strength gain after the resistance training, their body weight management could be considered a successful start through this summer intervention since rapid weight loss is not recommended according to pediatricians (Sung et al. 2002). The present finding also demonstrated that resistance training is safe and effective for obese adolescents under supervision. Results indicated that both their upper and lower body muscular strength was improved and this will definitely decrease their injury rate in physical activity and sport participation. In turn, their motivation and confidence in participating in sport and exercise may be enhanced.

To conclude, the resistance training program should be extended to a longer training period to achieve significant changes in obese adolescents' body composition and blood cholesterol. With regards to the anxiety and depression of obese adolescents, more time should be allowed for these psychological changes to occur and follow up studies are needed. Based upon the present findings, the obese participants demonstrated low anxiety and depression.

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References


