ORIGINAL ARTICLE

Effects of dietary intervention and strength training on blood lipid level in obese children

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Aims: To evaluate effects of a low energy diet, with or without strength training, on blood lipid profile in obese children.
Methods: Eighty two obese children were enrolled into a six week dietary programme, and were randomly allocated to a training group or a non-training group. The training group underwent regular exercise sessions with emphasis on strength training.
Results: Height increased significantly, with a non-significant reduction in body mass index. Fat free mass increased significantly in the training group. Serum total cholesterol was significantly reduced in both groups. The LDL:HDL ratio significantly decreased in the training group.
Conclusion: Results support the potentially beneficial effects of both diet and physical training. Further and longer term evaluation of such programmes is required.

Obesity has become the commonest paediatric nutritional problem in Hong Kong, affecting 10–13% of children aged 6–18.[1] Public health concern at the increasing prevalence of childhood obesity has led to the establishment in local hospitals and health centres of clinics aimed at dietary changes, exercise, and weight reduction in obese children.[2] Attendance and adherence to advice is often poor, however, and the potential benefit of such clinics has yet to be evaluated. We therefore took advantage of the summer vacation to mount and monitor the effects in obese children of a six week programme of dietary intervention, with or without additional exercise training. The physical training programme emphasised strength training, in contrast to previously reported regimes which have generally focused on aerobic, including weight bearing exercises, frustration with which could lead to poor adherence, particularly in obese children. Strength training may improve body composition by increasing lean mass and muscle strength, thereby facilitating exercise performance and aerobic energy expenditure.[3] We report the changes of body composition and serum lipid levels in children who participated in the six week intervention programme.

METHODS

Subjects

Invitations were sent via school teachers for obese 8–11 year old children in 13 local primary schools. A total of 170 children and their parents showed interest and underwent basic anthropometric measurements with an introductory explanation of the programme. All children whose weight was greater than 120% of the median weight for height were assessed medically.[4] Those with a history of diabetes, renal or cardiovascular disease, or steroid therapy, and those whose sexual maturity status was more advanced than stage 2 by Tanner's criteria were excluded. A total of 151 children (99 males and 52 females, ratio 2:1) were eligible; to maintain the same sex ratio a sample of 54 males and 28 females were randomly selected from a computer generated list of numbers. Further randomisation was done separately in boys and girls by asking the child to pick out a sealed opaque envelope with a note inside inviting the child either to the training or non-training group. The study protocol was approved by the ethics committee of the Chinese University. Informed consent forms were signed by the parents of all participating children.

Body composition

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 statiometer. Body composition was determined by dual energy *x* ray absorptiometry (Hologic QDR-4500, Waltham, MA, USA). The whole body scan time was 3–4 minutes using the fan beam model. All measurements were conducted in the morning, two hours postprandially.

Diet

All participating children were given the same dietary programme and interviewed by the dietitian blinded to the randomisation. The diet prescribed was a balanced low energy diet[5] providing 900–1200 kcal (3.8–5.0 MJ) daily, low in fat (20–25%), high in complex carbohydrate (50–60%), and sufficient in protein (25–30%) to support growth. The prescribed menu was varied to suit each child's age and eating habit. Bi-weekly follow up was scheduled throughout the study to allow the opportunity to discuss any difficulties in preparing or complying with the diet. The dietician taught the parents and the child how to record food consumption. Portions were measured in terms of familiar volume and size and by reference to an atlas of local food portions. At the beginning of the programme and before each follow up, a three day dietary record was made by each child with the help of their parents. These dietary data were transferred to a computer by a research assistant who did not participate in the family interview. Nutrient compositions were analysed with a PC program developed at the Chinese University of Hong Kong, based on Western and local food tables which included more than 500 food items.[6–8]

Exercise training programme

Physical fitness was assessed at the beginning and at the end of the six week programme. A "ten repetition maximum" (10-RM) was determined for biceps curl, shoulder press, bench press, triceps extension, quadriceps extension, straight

Abbreviations: 10-RM, 10 repetition maximum; LDL, low density lipoprotein; HDL, high desity lipoprotein; TC, total cholesterol

Table 1 Body characteristics before and after six week programme of dietary control, with or without exercise training

	Training		Change (after − before)	Non-training		Change (after − before)
	Before	After		Before	After	
Number	41 (27/14)			41 (27/14)		
Height (cm)	145.9 (6.6)	147.4 (6.9)*	1.4 (0.9)	143.3 (6.5)	145.1 (6.9)*	1.8 (1.2)
Weight (kg)	54.6 (9.1)	55.2 (9.5)	0.6 (1.5)	51.0 (8.7)	50.9 (8.2)	−0.1 (2.2)
BMI (kg/m²)	25.5 (3.1)	25.3 (3.1)	−0.2 (1.5)	24.6 (2.9)	24.1 (2.7)	−0.5 (0.9)
Fat mass (kg)	21.2 (5.3)	21.2 (5.6)	−0.03 (1.1)	19.3 (4.1)	19.3 (4.1)	0.01 (0.9)
Fat free mass (kg)	34.2 (5.1)	35.0 (5.1)*	0.8 (1.1)	32.4 (5.1)	32.6 (4.7)	0.3 (1.2)**
Fat/total mass (%)	37.9 (4.1)	37.3 (4.2)*	−0.7 (1.5)	37.2 (3.3)	36.9 (3.3)	−0.2 (1.4)

Results expressed as mean (SD).
BMI, body mass index.
*p<0.05 compared to before; **p<0.05 for comparison between changes in the two groups.

leg raise, hand grip, and squat with sand bags on the shoulders. The 10-RM is defined as the maximum amount of resistance that can be actively overcome for 10 repetitions. Training intensity at 75% and 100% of the individually predetermined 10-RM was prescribed by the physiotherapist for each child. The exercise training programme was in circuit style with a preset sequence of more than 20 workout stations, nine of which included the strength training of all large muscles and were visited at each session. Aerobic exercise, including treadmill and aerobic dance, was incorporated in the programme to stimulate the children's interest. Each training session lasted 75 minutes, including 10 minutes of warm up, 20 minutes of strength training, 10 minutes of aerobic exercise, 10 minutes of agility training, and 5 minutes of cool down, with short rests between stations. Aerobic exercise intensity was maintained at 60–70% predicted maximum heart rate (monitored by pulse oximetry) for 10 minutes.

Serum lipid profile

Fasting serum total cholesterol (TC) and triglyceride were assayed enzymatically using the Boehringer Mannheim Hitachi 911 analyser. High desity lipoprotein (HDL) cholesterol was measured after phosphotungstate magnesium precipitation. Low density lipoprotein (LDL) cholesterol was calculated by the Friedewald formula.[9] The hospital laboratory performing the lipid analyses is internationally accredited, with intra-assay imprecision of cholesterol measurement <3% and accuracy standardised by the Center for Disease Control National Heart, Lung, and Blood Institute programme. Serum apolipoproteins A-I (apo A-I) and B (apo B), and Lp(a) lipoprotein were assayed by rate nephelometry (Array analyser, Beckman Instruments, Brea, CA, USA).

Statistics

All data are presented as mean (SD). Between group differences were analysed by Student's *t* test, and changes from the start to the end of the six week programme were compared by repeated measures ANOVA. Sex was entered into the model to increase the precision of between group comparison.

RESULTS

The non-training groups had a slightly lower body weight and lean body mass at the start of the study, but the difference was not significant (table 1). Median attendance at the training class was 83% (interquartile range: 77% to 100%). All training sessions were attended by 75% or more children (range: 75% to 97.7%) Height increased significantly in both groups during the six weeks of the programme, and body mass index declined, though not to the point of statistical significance. In the training group, fat free mass increased (+2.3%) significantly more than in the non-training group (0.9%) after the programme.

Serum total cholesterol was significantly reduced in both groups after the interventions. Significant decreases of HDL cholesterol in the non-training group and of LDL cholesterol in the training group were detected. However, comparisons between changes in the two groups were not significant. The LDL:HDL ratio decreased significantly in the training group compared to the non-training group. The levels of apolipoprotein A1 and B remained unchanged (table 2).

The diets reported in the three day diet records, both before and at the end of the programme, were similar in the two groups (table 3) and the changes observed supported adherence to the prescribed diets. Energy, fat, carbohydrate,

Table 2 Serum lipids and apolipoproteins before and after six week programme of dietary control, with or without exercise training

	Training		Change (after − before)	Non-training		Change (after − before)
	Before	After		Before	After	
Number	41 (27/14)			41 (27/14)		
TC (mmol/l)	4.8 (0.7)	4.5 (0.8)*	−0.3 (0.5)	4.8 (0.9)	4.5 (0.8)*	−0.3 (0.5)
TG (mmol/l)	1.2 (0.5)	1.5 (0.7)	0.3 (0.6)	1.2 (0.5)	1.2 (0.6)	0.1 (0.5)
HDL-C (mmon/l)	1.3 (0.3)	1.2 (0.3)	−0.1 (0.2)	1.3 (0.3)	1.2 (0.2)*	−0.1 (0.2)
LDL-C (mmon/l)	2.9 (0.8)	2.6 (0.8)*	−0.4 (0.5)	2.9 (0.8)	2.7 (0.7)	−0.2 (0.5)
TC:HDL	3.9 (1.1)	3.8 (0.9)	−0.1 (0.4)	3.8 (0.9)	3.9 (1.0)	0.1 (0.4)
TG:HDL	1.0 (0.5)	1.3 (0.8)*	0.3 (0.6)	0.9 (0.6)	1.1 (0.7)	0.2 (0.4)
LDL:HDL	2.4 (0.9)	2.2 (0.8)*	−0.2 (0.4)	2.3 (0.8)	2.4 (0.8)	0.4 (0.4)**
Apo A1 (mg/dl)	130.6 (19.4)	128.2 (20.3)	−2.4 (12.6)	131.4 (19.8)	126.4 (17.4)	−4.9 (14.2)
Apo B (mg/dl)	81.6 (20.1)	80.5 (19.7)	−1.1 (10.1)	78.4 (19.2)	80.2 (19.5)	1.9 (10.2)

Results expressed as mean (SD).
TC, total cholesterol; LDL-C, low density lipoprotein cholesterol; HDL-C, high density lipoprotein cholesterol, TG, triglyceride; Apo A1, apolipoprotein A1; ApoB, apolipoprotein B.
*p<0.05 compared with before; **p<0.05 for comparison between changes in the two groups.

Table 3 Daily intake of energy and macronutrients before and after the intervention

	Training		Change (after − before)	Non-training		Change (after − before)
	Before	After		Before	After	
Energy (kcal)	15 56 (511)	127 3 (431)	–28 3	1561 (600)	1272 (393)	–288
CHO (g)	215 (75.7)	190 (57.3)	–25	215 (81.8)	194 (54.7)	–22
% energy	55.9 (8.4)	60.9 (8.7)*	5	55.6 (7.5)	61.8 (7.1)*	6.2
Protein (g)	75.9 (31.7)	65.4 (29.9)	–10.5	76.9 (33.2)	61.7 (24.5)	–15.2
% energy	19.3 (4.4)	20.2 (4.5)	0.9	19.6 (2.7)	19.1 (3.8)	–0.5
Fat (g)	43.3 (18.0)	28.1 (16.4)*	–15.2	43.7 (21.7)	27.9 (12.9)*	–15.8
% energy	24.6 (6.4)	19.1 (6.9)*	–5.5	24.9 (6.1)	19.2 (5.1)*	–5.7
SFA (g)	13.2 (5.9)	8.9 (5.6)*	–4.3	13.8 (7.0)	8.8 (4.6)*	–5
MUFA (g)	15.1 (6.6)	10.4 (6.9)	–4.7	16.1 (8.1)	10.2 (4.9)*	–5.9
PUFA (g)	5.8 (2.6)	4.1 (2.5)	–1.7	5.8 (3.4)	3.9 (1.6)*	–1.9
P:S	0.5 (0.2)	0.5 (0.2)	0	0.4 (0.1)	0.5 (0.3)	0.1
M:S	1.2 (0.2)	1.2 (0.2)	0	1.2 (0.1)	1.2 (0.2)	0
Cholesterol	240 (136)	217 (130)	–24	262 (132)	206 (119)	–5.6

Results expressed as mean (SD).
CHO, carbohydrate; SFA, saturated fatty acid; MUFA, monounsaturated fatty acid; PUFA, polyunsaturated fatty acid; P:S, ratio of polyunsaturated to saturated fatty acids; M:S, ratio of monounsaturated to saturated fatty acids.
*$p<0.05$ compared with before (Student's paired *t* test), after Bonferroni adjustment. All comparisons of the changes were non-significant.

and protein intake were all significantly lower at the end of the six week programme; the relative contribution to energy intake of fat was lower, of carbohydrate was higher, and of protein was unchanged.

No training related injuries were reported during the programme.

DISCUSSION

The increased prevalence of obesity in children is of concern, particularly in relation to the risk of cardiovascular disease. The importance of introducing measures in early life to control weight and to prevent adverse clinical consequences is becoming recognised.

The present study was of short duration, from expediency in order to minimise interruption of school learning during term time and encourage participation. It nevertheless provided promising evidence in these growing children of an improvement in lean (fat free) body mass in the group also undergoing exercise training, and of changes consistent with a reduction in body mass index. Although the reduction in body mass index was modest and did not reach statistical significance, parents and children were not disappointed because they had been warned not to expect the rapid weight loss seen with adult programmes. The aim, in these growing children, was to prevent them getting more obese and developing related complications by a change in eating habits.

Total cholesterol level was reduced by 6%, while HDL and LDL cholesterol were also slightly reduced in the non-training group and training group respectively. The LDL:HDL cholesterol ratio was significantly decreased in the training group, but slightly increased in the non-training group, indicating that the strength training programme may have a beneficial effect on the lipid composition.

A standard low energy balanced diet was chosen because of its long term safety and beneficial impact on lipid profile.[10 11] It appeared to be well tolerated, as confirmed by monitoring of dietary intake, menus for which were individually tailored and encouragement provided by continuing supervision. The small increase in triglycerides (significant in the study as a whole) was unexpected; it may be related to the quite large relative increase in carbohydrate intake,[12] derived mainly from rice. Reductions in triglyceride level have been reported in obese adults on high protein, fat reduced diets, but not in those on high carbohydrate, fat reduced diets.[13] Reduced triglyceride level without change in HDL cholesterol has also been observed in children slightly older than in our study,[14] following regimes of dietary control with exercise training; the differences may be ascribed to their more rigorous dietary restriction, with much less carbohydrate (to the point of ketosis) but more protein.

The exercise regime, which proved acceptable, was, unlike in most previous studies, designed to include strength training to improve muscle development, and also to be varied so as to retain the children's interest. An increase in lean mass will increase oxygen consumption. Exercise training may also facilitate motor function and enhance exercise safety. It was, as anticipated, associated with a significant improvement of body composition with an increase in lean body mass and decrease in percentage body fat.[15] We did not find any further improvement in serum lipid profile with exercise, as has been reported in normal children following a six month programme of balanced diet, with or without exercise training.[16]

In conclusion, our findings provide support for the potentially beneficial effects in obese children of both diet and exercise. There is a need for further and longer term evaluation of such regimes.

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ARCHIVIST

Personal magnetism

The adult fashion for body piercing seems to have had a strange spin-off in children. Over a period of 51 days (13 April to 3 June 2000) 24 children aged 5–15 years attended Sheffield Children's Hospital because of problems related to the body application of small magnets (S McCormick and colleagues Emergency Medicine Journal 2002;**19**:51–3).

These magnets are neodymium magnets, made from a mixture of iron, boron, and neodymium, and they are said to be five to ten times stronger than ordinary magnets. They measure 7 mm × 4 mm × 1 mm. The children applied paired magnets across body parts (nose 11, penis 3, ear 1) or swallowed them (9). One child, a girl of 9 years, had swallowed several magnets during attempts to imitate tongue piercing and presented initially with diarrhoea and vomiting diagnosed as gastroenteritis. Two days later she came back with abdominal pain and bile stained vomiting. *x* ray showed opacities in the lower abdomen and at laparotomy there was a "mass of magnets" in the peritoneal cavity and she had one perforation of the caecum and five of the small bowel. She spent one week in the intensive care unit and another week on the ward before going home. She had swallowed the magnets separately over a period of time and they had therefore been able to pass into the bowel separately and attract each other across bowel loops. In the other eight children who had swallowed magnets they stuck together as a single mass in the stomach and the children came to no harm.

The magnets were so strong that it was very difficult to slide or pull them apart and attempts to do so caused pain. Of the 11 children with magnets in the nose two needed general anaesthesia for their removal and most had to be referred to the ear, nose, and throat department because the magnets could not be removed in the emergency department. Several children had necrosis of nasal mucosa. One of the three boys who had got a fold of penile skin caught between the magnets needed sedation with midazolam before they could be removed.

Children were selling these magnets for a penny each in the schoolyard but where they got them from is not known. Most of the children came from a fairly restricted area within the city and local press publicity markedly reduced the number of cases.