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Follow up exercise studies in paediatric obesity: implications for long term effectiveness

M T Maziekas, L M LeMura, N M Stoddard, S Kaercher, T Martucci

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See end of article for authors' affiliations

Correspondence to: Professor LeMura, Le Moyne College, 1419 Salt Springs Rd., Syracuse, NY 13214–1399, USA; lemuralm@lemoyne.edu

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Objectives: To examine the effects of exercise training on paediatric obesity immediately after training and at a one year follow up and to provide recommendations for future research.
Methods: Studies that met the following criteria were included in a meta-analysis: (*a*) at least six subjects per group; (*b*) subject groups consisting of children in the 4–17 year age range; (*c*) pre-test and post-test values for body composition; (*d*) used exercise such as walking, jogging, cycle ergometry, high repetition resistance exercise, and combinations; (*e*) training programmes lasting eight weeks or more; (*f*) full length publications; (*g*) apparently healthy children.
Results: A total of 135 studies of exercise as a method of treatment of paediatric obesity were located. Eight, containing 236 subjects, met our criteria for inclusion. Across all designs and categories, fixed effects modelling yielded significant decreases in the dependent variable percentage body fat immediately (0 = 1.04 (0.35); 95% confidence interval (CI) 0.41 to 1.6) and one year after the exercise intervention (0 = 0.84 (0.51); 95% CI 0.22 to 0.94). Forward stepwise linear regression suggested that the percentage body fat measured at the end of exercise training, exercise duration, and programme length accounted for 53–86% of the variance for percentage body fat at one year.
Conclusions: These data indicate that exercise is efficacious for reducing percentage body fat in obese children and adolescents, and that exercise intervention may encourage long term maintenance of the observed gains.

Public health officials refer to paediatric obesity in descriptive terms such as "alarming" and "epidemic".[1] Prospective research has shown that obesity during childhood substantially increases the risk of orthopaedic, metabolic, respiratory, and psychosocial disorders.[2] These serious consequences have prompted researchers, clinicians, and healthcare professionals to study the impact of various treatment programmes in obese children.

Although there is agreement within the scientific community that exercise is an empirically validated method of treating obesity, numerous questions remain about the long term efficacy of exercise intervention programmes in children. A large number of studies on the role of physical activity in paediatric obesity were reviewed recently,[3] but only a few provided long term follow up data on the improvements derived. In the light of the impending direction in obesity research that involves molecular and behavioural genetics—that is, the next generation of treatments—it seems prudent to synthesise what we now know about the long term effectiveness of exercise as a treatment for paediatric obesity.

Meta-analysis is a quantitative approach popularised by Glass,[4] in which studies are converted into individual data points and then subjected to statistical analysis. This approach allows investigators to make comparisons on a common research problem that would be difficult or impossible to perform using conventional research paradigms. Thus the twofold purpose of this study was: to examine the effect of exercise programmes on changes in body composition of obese children and adolescents using the meta-analytic approach; to determine if the changes obtained for a one year follow up assessment were maintained or improved.

METHODS

Data sources

This study represents the second part of a two part quantitative review examining the factors that alter body fat percentage in obese children and adolescents after exercise training. In the first review, studies of changes in body composition immediately after exercise training were located after an extensive literature search. This analysis was published in 2002.[3] The search for literature was limited to human exercise training studies published between 1960 and 2001 in which body mass, fat free mass, and percentage body fat were measured in children aged 4–17. The studies were located by computer generated citation searches of the following databases: Current Contents, Medline, Dissertation Abstracts International, Psychological Abstracts, and Sport Discus. For the present (second) review, we used the literature obtained from the first search; however, additional hand searching and cross referencing were conducted to locate studies that included long term, follow up assessments as part of the original research design in studies published from 1960 to 2002.

Study selection

Studies were included if they met the following criteria: (*a*) at least six subjects per group; (*b*) subject groups consisting of children in the 4–17 year age range; (*c*) pre-test and post-test body measures for either body mass index (BMI; kg/m^2) or percentage body fat; (*d*) used exercise as a mode of training—for example, walking, jogging, cycle ergometry, high repetition resistance exercise, and combinations; (*e*) training programmes lasting eight weeks or more; (*f*) full length publications; (*g*) apparently "healthy" children and adolescents—that is, free from endocrine diseases and disorders; (*h*) provided at least one long term, follow up assessment.

Data extraction

The studies in this review were coded according to the following characteristics: (*a*) exercise programme characteristics (length, frequency, intensity, duration, mode, and compliance defined as the number of exercise sessions attended); (*b*) study characteristics (author(s), year, study design, comparison groups—for example, exercise plus diet versus exercise plus behaviour intervention—and number of subjects); (*c*) subject characteristics (age, weight, sex, health status, and race; (*d*) primary outcomes (changes in one or more measures of body composition) immediately after exercise intervention and during a follow up assessment. To avoid interobserver bias, the authors of this study independently extracted all data. The authors then met and reviewed each item for accuracy and consistency. Disagreements were resolved by consensus.

Statistical analysis
The primary outcome (dependent variable) in this study was effect size changes in body composition at the end of the exercise intervention and during a follow up assessment period. Analyses of the dependent variable(s) partitioned by subgroup were performed when the data for each coded characteristic were available. The subgroups were analysed according to: (*a*) intensity (the percentage of maximal oxygen uptake and heart rate maximum at which exercise training was prescribed); (*b*) exercise duration (the amount of time spent during each exercise session); (*c*) length of training (the number of weeks or months that the training protocols lasted); (*d*) frequency (the number of exercise sessions per week); (*e*) mode (the type of activity used to train the subjects); (*f*) the method of assessing body composition; (*g*) subject characteristics; (*h*) research design (randomised control trials, controlled trials, no control group); (*i*) the type of intervention programme (exercise versus diet, or exercise versus behaviour modification).

ES computation and analysis
The research findings from each study were transformed into a common metric known as an effect size (ES) which was submitted to further statistical analysis. The purpose of the ES analysis was to allow us to draw conclusions about the efficacy of exercise on obese children and adolescents immediately after an exercise intervention and one year later. In this study, the only dependent variable to emerge for analysis was body fat percentage. The mean (SD) value for body fat percentage for the subjects in this analysis was 35.4 (5.2). The authors provided various definitions of obesity including: (*a*) >120% of mean body weight for height; (*b*) >85% of triceps skinfold; (*c*) >90% BMI. We also coded for changes in BMI, body mass, and fat free mass; however, there were too few data available on these dependent variables to perform meaningful statistical analyses.

For those studies that included a control group (nonexercise, dietary, or behavioural intervention) the standard ES formula was applied. When a research design did not include a control group, the changes in body fat percentage after training were used to determine the ES values for each study—that is, the value obtained after training minus that obtained before training. Thus positive ES values for the dependent variable indicated improvements after the training period. The differences in measures obtained before and after training for the primary outcomes were then divided by a pooled variance designed to provide a more precise estimate of the population variance.[5]

We calculated the variance for each ES and corrected for small sample bias by bootstrap resampling to generate 95% confidence intervals (CI) around the mean ES.[6] The estimate generated from this approach is based on the sample itself, rather than from a theoretical distribution. This nonparametric method of estimating the reliability of the original sample estimate is calculated by randomly drawing from the available sample, with replacement.[5] We used this method because it is not restricted by large sample assumptions. Thus, if the CI included zero (0.00), we concluded that there was no effect of exercise on obesity in children and adolescents after the treatment period. To obtain a measure of the variability of the data, we examined the heterogeneity of the ES values by identifying the outliers beyond the 10th and 90th centiles. We examined carefully each study represented by an outlier further. If a methodological flaw existed to explain the variability, the study was precluded from additional analysis. In addition, because there is a propensity for studies to be published that generate statistically significant results, we also addressed the issue of publication bias—that is, the tendency for authors to submit, and journal editors to publish, studies that yield statistically significant results. We examined publication bias with the Kendal J rank[7] correlation test (r_J). This consisted of correlating observed outcomes—that is, changes in the ES values of percentage body fat sample size.

We used a random effects model to pool the ES data on changes in body composition if heterogeneity was present. ES values were then averaged across studies to determine treatment effects, and were further stratified according to coded characteristics of interest. Stepwise regression was used to find which combination of independent variables were most closely related to changes in percentage body fat at the one year follow up assessment period. Independent variables were considered to be significant predictors if $p \leqslant 0.05$. All ES values were calculated with Meta Stat (version 1.3).[8] Mixed effects analysis, resampling, and randomisation analyses were performed with Meta Win (version 1.0).[9]

RESULTS
Subject characteristics
We coded for age, sex, ethnicity, and health status. As the subjects' ages were often reported as a range of years, an analysis of older and younger children was not possible. Because many investigators combined boys and girls in their studies, we could not analyse effects of sex. No data on ethnicity were provided. All of the subjects were free from endocrine diseases or other comorbidities as determined from a doctor's evaluation.

Study selection
A total of 135 studies of exercise as a method of treatment of paediatric obesity were located. Eight met our criteria for inclusion.[10–17] These eight studies generated 16 ES values based on a total of 307 subjects ranging from 4 to 17 years of age. Reasons for the rejection of studies in this analysis included a lack of, or an inability to, obtain data on changes in percentage body fat as the result of training, the use of the same subject pool in more than one study, cross sectional rather than longitudinal designs, acute response study designs, and the absence of follow up measurements. Epstein *et al* published two studies in which six month[11] and 5 year[10] follow up data were reported. However, every study included in the analysis provided follow up assessments at one year intervals; therefore we compared the treatment effects obtained immediately after the exercise programme with those obtained one year later. The time to code each study ranged from 1.0 to 1.5 hours (0 = 1.2 (0.25) hours). An examination of the outliers beyond the 10th and 90th centiles revealed one outlier. This outlier remained in the analysis because there were no methodological reasons to exclude it. In addition, no publication bias was found for ES changes in percentage body fat ($p = 0.09$). The average length of training ranged from 8 to 16 weeks (0 = 12.75 (5.9)), exercise duration per session from 20 to 60 minutes (0 = 38 (17.5)), and frequency from one to seven days (0 = 3.9 (1.5)). The rate of compliance, defined as the percentage of exercise sessions completed, was 90–100%. The one year follow up compliance data ranged from 36% to 100%. Table 1 details the coding characteristics of studies and their associated ES values.

Main effects
Across all designs, intervention strategies, and categories, the ES changes for percentage body fat immediately and one year after an exercise programme were: 0 = 1.04 (0.35) (95% CI

Table 1 Coded characteristics of the studies

Study	No	Age (years)	Exercise prescription	Mode	Research design	Treatment groups	Body composition	IPT ES	F/U ES
Epstein *et al*[10]	28	8–12	F- NI I- NI D- NI L- NI	Aerobics	RCT	Diet + BM + Ex No Ex	NI	1.34	0.20
Epstein *et al*[11]	17	Mean=4.0	F- 1 day/week I- NI D- NI L- 10 weeks	Walking	NC	NA	NI	0.90	0.97
Epstein *et al*[12]	19	8–12	F- 3 days/week I- 60–75%* D- 60 min L- 8 weeks	Walking	RCT	Diet only Diet + Ex	NI	0.08	0.14
Reybrouck *et al*[13]	3	5.1–12.11	F- 7 days/week I- 250 kcal/ses D- varied L- 4 months	Aerobics	CT	Diet only Diet + Ex	NI	0.92	0.60
Sothern *et al*[14]	15	7–12	F- NI I- 55–65%* D- 30–45 min L- 10 weeks	Aerobics + strength + flexibility	CT	C = walking only	Skinfold triceps & subscapular HC	1.40	1.49
Sothern *et al*[15]	19	7–17	F- NI I- 55–65%* D- NI L- 10–20 weeks	Aerobics + strength + flexibility	NC	NA	Skinfold triceps & subscapular HC	1.35	1.34
Sothern *et al*[16]	87 39m 48f	7–17	F- NI I- varied D- 30–45 min L- 10–20 weeks	Aerobics + strength + flexibility	NC	NA	Skinfold triceps & subscapular HC	0.82	0.73
Sothern *et al*[17]	48	7–17	F- 1–6days/week I- 45–55%† D- 30–45 min L- 10–30 weeks	Aerobics	NC	NA	Skinfold triceps & subscapular HC	1.30	1.27

*Intensity based on maximal oxygen uptake .
†Intensity based on heart rate.
m, Males; f, females; NI, not included; F, frequency; I, intensity; D, duration; L, length; d/wk^{-1}, days a week; RCT, randomised controlled design; CT, controlled design; NC, no control; Ex, exercise; NA, not applicable; HC, Harpenden skinfold calipers; BM, behavioural modification; IPT, immediately after exercise; F/U, follow up; ES, effect size.

0.41 to 1.6) and 0 = 0.84 (0.51) (95% CI 0.22 to 0.94) respectively. According to Cohen's categories for classification of ES values (<0.41 = small; 0.41 to 0.70 = moderate; >0.70 = large),[18] the degree to which exercise treatment programmes in paediatric obesity produced favourable changes in percentage body fat was "large." These data indicate that, after completing an exercise programme, obese children decreased their percentage body fat by about one standard deviation (0 = 1.04) compared with untrained controls or baseline values in uncontrolled trials. Similarly, after a one year follow up, the same children appeared to have maintained (0 = 0.84) the lower percentage body fat.

Subgroup analysis

Stepwise linear regression was used to find which combination of independent variables best accounted for changes in percentage body fat one year after an exercise programme. Table 2 includes the results of this analysis for all of the children combined. The major predictors of change in body fat were: (*a*) percentage body fat at the conclusion of the exercise programme; (*b*) exercise duration; (*c*) exercise mode (aerobic versus aerobic plus resistance exercise); (*d*) length of exercise programme. These variables accounted for 53–86% of the variance associated with changes in percentage body fat.

Table 2 Results of forward stepwise regression analysis to determine the best factors to predict changes in body fat percentage one year after participation in an exercise training programme

Major predictors	*R*	R^2	SEM	p Value
Body fat percentage after training	0.93	0.86	0.30	<0.03
Training mode (aerobic *v* aerobic + resistance)	0.75	0.55	0.25	<0.04
Training duration (minutes)	0.76	0.57	0.01	<0.04
Training length (weeks)	0.73	0.53	0.31	<0.05

DISCUSSION

This quantitative review included studies that measured changes in percentage body fat in children at the end of an exercise programme and at a one year follow up. To have confidence in the results of a meta-analysis, two conditions must be met. Firstly, the data must not be biased by the absence of unpublished studies in which changes do not achieve statistical significance. Secondly, the results of studies meeting the minimum criteria for analysis must be included. We addressed the former issue by searching vigorously for unpublished and published studies, and the latter issue by retrieving and including all relevant studies. Only one relevant unpublished doctoral dissertation was located; however, it was ultimately published. Nevertheless, the study did not include any follow up data and was therefore precluded from the analyses.[19]

As few studies included a follow up assessment after the initial intervention, eight studies met our inclusion criteria. This underscores the necessity to design prospective studies of paediatric obesity that include follow up measurements. These data will allow researchers to determine the presence and magnitude of long term changes in body composition in obese children and adolescents after a programme of exercise. The results generated by this research synthesis suggest that exercise successfully reduces percentage body fat at the conclusion of the intervention, and that favourable reductions can be maintained for an extended period after exercise training.

In the light of the limitations inherent in the meta-analytic approach,[5] we would like to address potential sources of bias in this study to evaluate the results in their proper context. A potential limitation of these analyses relates to the number of studies that met our criteria for inclusion. We had difficulty locating research studies designed to identify the optimal exercise programme characteristics to maximise weight loss in obese children that included one or more post-exercise measurement periods. This underscores the need to design controlled prospective studies with multiple measurement periods after the formal training sessions end. The small number of studies in this review precluded analyses that may have revealed between group differences—for example, the impact of various levels of exercise intensity on a wide range of dependent variables of interest. Furthermore, although this study is based on data generated initially by 307 subjects, the ES values calculated on the follow up data were based on 236. It is possible that the children who did not return for follow up assessments actually gained weight over baseline values. Many investigators neglected to include pertinent pre-test and post-test data for characteristics such as body weight, fat free mass, and BMI, and data on ethnicity or descriptions of matching procedures were unavailable. Finally, even if a multitude of studies met our inclusion criteria, the most significant limitation relates to the inability to control for numerous confounding variables during the one year follow up period—that is, dietary changes, illness, medication, etc. Perhaps the most important limitation relates to the failure to control for growth and development changes during the intervention period. For example, Sothern *et al*[16] studied 48 female and 37 male subjects. In comparison with the other studies by Sothern and coworkers,[14 15 17] the ES was considerably lower (0.82 *v* 1.30, 1.33, and 1.40). If the other studies by Sothern *et al* involved mainly boys, a differential gain in fat free mass could explain the lower ES, and point to the possibility that growth explains the largest portion of the changes in body fat percentage. This idea is complicated further by the idea that obese children and adolescents may have dense bones because of the greater resistance placed on them; thus the benefits of physical activity to fat free mass are derived from muscle and the loss of body fat. An alternative explanation may be that the subjects are so sedentary that body fat percentage is underestimated on the basis of assumptions of bone density.

One additional limitation may be that only three authors are represented among the eight studies in this review. This may present as much bias as any other factor. For example, three of the four papers by Sothern and coworkers used similar exercise modes, the same age range with no control groups, and skinfolds to estimate body fat percentage.[15–17] Finally, it is important to note that only two studies were randomised controlled designs[10 12], two were controlled designs,[13 14] and four were not controlled at all.[11 15–17] Although exercise was a component in three of the studies, it was combined with one or more treatments such a diet and behaviour modification.[10 12 13] None of the investigators who published the results of controlled trials used exercise training as an isolated treatment group.

Despite these potential limitations, it seems prudent to synthesise what we do know about the potential long term benefits of exercise on paediatric obesity. The results of this meta-analysis allow us to proffer plausible explanations for the primary outcome in percentage body fat immediately after and one year after training. Firstly, the data indicate that exercise programmes using a longer duration (minutes) and training length (weeks) and a combination of exercise modes (aerobic exercise plus resistance training) emerged as major predictors of percentage body fat at the one year follow up assessment. The longer duration of exercise and the likely lower exercise intensity is consistent with the reliance on β oxidation rather than glycolysis as the primary energy system. Secondly, the data also suggested that the reduction in percentage body fat immediately after participation in the exercise programme was a predictor of the follow up measure of percentage body fat. For children who significantly reduced body fat after training, we postulate that the intervention may have served as the catalyst to continue exercise well after the end of the formal programme. The greatest treatment effects were observed in studies using the longest programme length and exercise session duration, and in studies that used combination training. Perhaps the reinforcement associated with obtaining positive results after exercise encouraged a sustained effort in some positive behaviours such as continued exercise and a healthy diet, and/or a reduction of some negative behaviours—for example, excessive sedentary activities, poor diet.

Finally, the greatest treatment effects observed at the end of the exercise study and one year later were derived from three studies[14 16] using a resistance training component. It is reasonable to speculate that, whereas both aerobic and combination training reduce percentage body fat in children, high repetition resistance exercise may simultaneously increase fat free mass. Unfortunately, we could not calculate ES values for fat free mass because the necessary data were unavailable. However, beyond the physiological and metabolic implications of "combination training," it is possible that the children enjoyed the variations in training and continued to exercise using one or more modes of training learned during the exercise study.

To determine the long term efficacy of exercise as a palliative treatment for paediatric obesity will require additional study. Data collection involving a multitude of research perspectives, such as metabolic, molecular, psychological, sociocultural, may be necessary to identify factors that will encourage exercise adherence. Some of the questions that require additional research include: (*a*) What is the nature of the relation between aerobic fitness and percentage body fat in obese children and, alternatively, does an increased percentage body fat preclude the attainment of aerobic fitness? (*b*) Should behaviour modification programmes be used synergistically with exercise programmes? If so, which type(s)? Only one study[10] in this review used a behaviour modification component; additional research is needed on the effectiveness of "alternative" intervention strategies. For example, would behavioural strategies that included the family to support exercise (at home and in the clinical setting) increase exercise adherence? How can an "at home" exercise programme be designed and monitored to determine if long term exercise adherence is improved when compared with conventional "clinical setting" designs? In addition, should classes on variations in energy and nutrient intake be included as a standard intervention strategy? (*c*) How can participation in spontaneous activity over sedentary activities be encouraged and reinforced? (*d*) What is the most effective exercise prescription to facilitate positive changes in body composition and cardiorespiratory fitness? (*e*) What are the factors that either support or discourage an active lifestyle in ethnic or minority groups? (*f*) It is well established that sex significantly influences fat deposition and removal, and girls are socialised differently from boys with reference to participation in physical activity.[20] Consequently, which intervention(s) will encourage and reinforce activity in girls from late childhood through adolescence? (*g*) The investigators used skinfold calipers to estimate body composition. Are there more appropriate methods to measure body composition for long term exercise studies?

Another practical question relates to the design of effective research paradigms to answer the questions above. We looked to the studies included in this review to provide some insight on different experimental designs. Controlled studies generally yield smaller treatment effects,[5] therefore we expected the randomised controlled trials (n = 2) and controlled trials (n = 2) to generate lower mean ES values than those with no controls (n = 4) during both assessment periods. However, the small number of cases in each subgroup leaves the important question about the impact of research designs unanswered. It seems reasonable to approach these research questions with carefully selected controls for the purpose of generalisability, particularly when follow up assessments are an integral part of the research design.

This analysis suggests that exercise is an effective way to promote favourable changes in body composition in obese children. The results also indicate that few follow up data are available to confirm the maintenance or improvement of favourable body composition alterations after an exercise intervention. Of the eight studies that included an assessment of percentage body fat one year after an exercise programme, only one did not report successful outcomes compared with baseline values.[12] It was also shown that the major predictors of the results obtained at the one year follow up were the amount of body fat lost after the initial exercise programme and the mode, duration, and length of the exercise used in the studies. Finally, the number and type of factors that affect the long term success of an exercise intervention strategy to treat paediatric obesity will require further investigation.

Authors' affiliations

M T Maziekas, L M LeMura, N M Stoddard, S Kaercher, T Martucci, Bloomsburg University, PA Bloomsburg, PA 17815, USA

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