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Effect of school-based physical activity interventions on body mass index in children: a meta-analysis

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Abstract

Background: The prevalence of childhood obesity is increasing at an alarming rate. Many local governments have enacted policies to increase physical activity in schools as a way to combat childhood obesity. We conducted a systematic review and meta-analysis to determine the effect of school-based physical activity interventions on body mass index (BMI) in children.

Methods: We searched MEDLINE, EMBASE, CINAHL and the Cochrane Central Register of Controlled Trials up to September 2008. We also hand-searched relevant journals and article reference lists. We included randomized controlled trials and controlled clinical trials that had objective data for BMI from before and after the intervention, that involved school-based physical activity interventions and that lasted for a minimum of 6 months.

Results: Of 398 potentially relevant articles that we identified, 18 studies involving 18 141 children met the inclusion criteria. The participants were primarily elementary school children. The study duration ranged from 6 months to 3 years. In 15 of these 18 studies, there was some type of co-intervention. Meta-analysis showed that BMI did not improve with physical activity interventions (weighted mean difference –0.05 kg/m^2, 95% confidence interval –0.19 to 0.10). We found no consistent changes in other measures of body composition.

Interpretation: School-based physical activity interventions did not improve BMI, although they had other beneficial health effects. Current population-based policies that mandate increased physical activity in schools are unlikely to have a significant effect on the increasing prevalence of childhood obesity.

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Childhood obesity is a major public health problem, given its increasing prevalence and adverse health consequences.[1] In the United States, the prevalence of obesity among children, defined as body mass index (BMI) greater than or equal to the 95th centile, has more than tripled since 1970.[2,3] The proportion of children 6 to 11 years old exceeding the 95th centile increased from 4.0% in 1971–1974 to 18.8% in 2003–2004, and the proportion of obese adolescents (12 to 19 years of age) increased from 4.6% in 1966–1970 to 17.4% in 2003–2004.[2,3] Similar trends have been observed in Canada,[4] the United Kingdom[5] and Europe.[6] In addition to the growing numbers of obese children, the proportions of children with BMI greater than the 10th, 50th, 85th and 90th centiles continue to increase, which indicates an increase in weight for height across the entire population.[2,7] These trends are likely to result in significant increases in the rates of coronary artery disease, hypertension, diabetes mellitus and other obesity-related diseases in young and middle-aged adults.[8–10] This in turn may result in the first-ever decline in life expectancy in the developed world.[11]

Reversing the trend of increasing weight for height in children has proven difficult. It is widely accepted that increasing energy expenditure and reducing energy intake form the theoretical basis for management. Therefore, interventions aiming to increase physical activity and improve diet are the foundation of efforts to prevent and treat childhood obesity. Such lifestyle interventions have been supported by recent systematic reviews,[12,13] as well as by the Canadian Paediatric Society,[14] the Royal College of Paediatrics and Child Health,[15] and the American Academy of Pediatrics.[16] However, these interventions are fraught with poor adherence.[17] Thus, school-based interventions are theoretically appealing because adherence with interventions can be improved. Consequently, many local governments have enacted or are considering policies that mandate increased physical activity in schools,[18–22] although the effect of such interventions on body composition has not been assessed.

The objective of this study was to determine whether school-based physical activity interventions improve children's body composition, as measured by BMI.

Methods

Literature search

In collaboration with a professional librarian, we created individualized search strategies for 4 electronic databases: MEDLINE (January 1966 to September 2008), Cochrane CENTRAL Register of Controlled Trials (up to September 2008), EMBASE (January 1980 to September 2008) and CINAHL (January 1982 to September 2008). We searched the data-

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bases for randomized controlled trials and nonrandomized clinical trials with an appropriate control group in which there was a school-based exercise or physical activity intervention. We did not apply a language restriction. We used the following MeSH terms: "obesity" or "overweight" and "schools" and "child" or "adolescent" and "exercise." A sample of the MEDLINE search strategy appears in Appendix 1 (available online at www.cmaj.ca/cgi/content/full/180/7/719/DC2). We also hand-searched the electronic versions of *Pediatrics*, the *Journal of Pediatrics* and the *Archives of Pediatric and Adolescent Medicine* from January 2003 through September 2008. We searched the reference lists of included articles and relevant reviews for additional eligible studies.

Study selection

Two authors (K.C.H. and J.E.R.) independently assessed the abstracts of potentially eligible studies. Controlled trials of a school-based exercise or physical activity intervention, in which the intervention took place during regular class time, were eligible for inclusion. The control group could not have received the intervention and must have continued with the existing physical education curriculum, with no change in duration or intensity. The participants had to have been of school age (5–18 years), and objective height and weight data demonstrating any change in BMI over the study period had to have been measured in both the intervention and control groups. The minimum study duration was 6 months. If there was doubt about study eligibility on the basis of information in the abstract, the reviewers examined the full text of the article. Discrepancies regarding study eligibility between the 2 reviewers were resolved by consensus. For studies that met the inclusion criteria but for which BMI data were incomplete, we contacted the authors and requested complete data for analysis. If we did not receive a response to the initial request, we sent a second request. We included studies without complete BMI data in the review but excluded them from the meta-analysis.

Data extraction and validity assessment

Two authors (K.C.H. and J.E.R.) independently extracted 4 categories of data from each included study: study design (randomized or nonrandomized study design and duration of study), population (grade level, ethnic origin, sex distribution, socio-economic status and numbers of children in the intervention and control groups) intervention (type and frequency of physical activity intervention and, in the case of mixed programs, data characterizing the type of co-intervention) and outcome (mean BMI and standard deviation in the intervention and control groups at baseline and follow-up and measures of physical activity). Where available, we also extracted data on other anthropometric measures of body composition, such as percent body fat, waist circumference, waist-to-hip ratio, triceps skin-fold thickness and subscapular skin-fold thickness.

We evaluated study quality using an assessment form designed specifically for this review based on the Jadad criteria[23] and the Cochrane Effective Practice and Organisation of Care Review Group criteria.[24] We based our quality assessment on the description of baseline characteristics, the method of randomization (for randomized controlled trials only), a priori power calculation, blinding of the outcome assessment, the description of the attrition rate and the description of the statistical analysis. Assigning a score to each study on the basis of individual scales does not provide a valid or comprehensive assessment of study quality.[25] Therefore, we reported how each study rated on each criterion, as recommended in the most recent update of the Cochrane handbook.[25]

The 2 authors resolved discrepancies in data extraction and quality assessment by repeated review of the studies and discussion to reach consensus. If 2 or more articles presented data on the identical patient population, the BMI data were included only once in the meta-analysis.

Data synthesis and analysis

The primary outcome measure was mean change in BMI, calculated as mean BMI after intervention minus mean BMI before intervention. We selected BMI as the primary outcome measure because it has been shown to be a good measure of adiposity, it is superior to the *z* score for BMI, and it is commonly measured and reported in studies assessing the effect of interventions for childhood obesity.[26–29] For each study, we calculated the effect size as the difference in the mean change in BMI, as mean change in BMI in the intervention group minus mean change in BMI in the control group. For studies that reported the mean change in BMI with standard deviation, we used these values for the meta-analysis. For studies that reported BMI data before and after the intervention, we calculated the variance in the mean change in BMI, assuming a correlation coefficient of 0.9. We based this estimate on 2 studies in which standard deviation data were available for the mean pre-intervention BMI, mean post-intervention BMI and mean change in BMI.[30,31] We obtained a summary estimate for the difference in mean change in BMI, along with the 95% confidence interval (CI), using a weighted inverse variance approach and a random-effects model.

We used the I^2 statistic to assess the heterogeneity of summary estimates,[32,33] where we considered a value greater than 50% as evidence of significant heterogeneity. We assessed the presence of publication bias using a funnel plot. We performed multiple 1-way sensitivity analyses to assess the robustness of the results. We performed a jackknife analysis, removing each study individually to assess its impact on the summary estimate. We also calculated the following summary estimates: studies that had co-interventions compared with studies that did not have co-interventions; studies that were longer than 1 year in duration compared with those up to 1 year in duration; studies with both boys and girls compared with those with only girls or only boys; and randomized controlled trials compared with controlled clinical trials. We also varied the correlation coefficient from 0.5 to 0.95 as part of the sensitivity analysis. For cluster controlled trials with measurements at the individual level but randomization at the school level, we examined the studies to ensure that cluster-adjusted analyses had been performed. For trials in which it was unclear how this issue had been handled in the original study, we carried out appropriate cluster adjustments.

We collected data on other measures of body composition, if such data were available, but we did not perform meta-analyses because of insufficient reporting. Instead, we summarized these data descriptively.

Results

Literature search

Using the search protocol, we identified 398 potentially relevant articles. Twenty-three of these studies met the inclusion criteria, but data were incomplete in 11 of them. We contacted the lead authors of these studies twice by email, and 8 of 11 of them provided additional data to allow meta-analysis.[30,34–40] Overall, 18 unique studies (from 23 articles) were available for inclusion in the analysis, and 15 of these studies were amenable to meta-analysis (Appendix 2, available online at www.cmaj.ca/cgi/content/full/180/7/719/DC2).

Study characteristics

The characteristics of the 18 studies[30,31,34-49] are summarized in Appendix 3 (available online at www.cmaj.ca/cgi/content/full /180/7/719/DC2. Thirteen of the studies were randomized controlled trials (n = 13 519), and 5 were controlled clinical trials (n = 4622). Twelve of the 13 randomized controlled trials were cluster trials, with randomization at the school level. In the 13th study, participants were randomized at the individual level.[41] The type, duration and frequency of the physical activity intervention varied among the studies. Nine studies focused on increasing moderate to vigorous physical activity, 5 studies focused on increasing the time devoted to general physical activity, 2 studies implemented a new weight-bearing exercise, 1 study focused on activities using large muscle groups and 1 study introduced a physical education program personalized for each student (Appendix 3). Fifteen studies had some measure of physical activity. Of these, 5 studies used an objective measure: accelerometers in 2 studies[45,49] and the System for Observing Fitness Instruction Time (SOFIT)[50] in 3 studies.[31,46,48] Thirteen studies used questionnaires to assess levels of physical activity: 6 assessed total 24-hour physical activity,[35,38,40,43–45] 5 assessed physical activity outside of school only,[31,34,37,42,46] and 2 assessed physical activity both inside and outside of school.[36,39] In 4 studies, adherence to the physical activity program was measured through teachers' logs of activities.[43–45,49] No study objectively measured adherence to the physical activity program at the individual level.

Three studies consisted of only exercise interventions, and 15 studies had a co-intervention (Appendix 3). All co-interventions included a component of classroom nutrition or health education or family involvement. Twelve of the 15 studies with a co-intervention also promoted physical education through a modified classroom curriculum. The study duration ranged from 6 months to 3 years (median 18.5 months). Twelve studies were conducted in the United States, 3 in Canada and 1 in each of Australia, Chile and Sweden.

Participant characteristics

The analysis included a total of 18 141 children. The majority of the children were in grades 3–6 (range: grades 1–12). Of the 13 studies that reported the participants' ethnicity, 7 involved primarily white populations.[30,31,34,40,46,47,49] Six studies included only girls,[35–38,43,49] and 1 study included only boys.[44] In terms of baseline body composition, 16 studies sampled the general school population, 1 study gave preference to children with BMI at or above the 75th centile and decreased physical activity[37] and 1 study included only obese children.[41]

Methodologic quality

Overall, the included studies had relatively good quality of reporting (Appendix 4, available online at www.cmaj.ca/cgi/ content/full/180/7/719/DC2). Irrespective of randomization, the randomized controlled trials generally had a higher standard of reporting than the controlled clinical trials. Of the 13 randomized controlled trials, 4 studies clearly had the highest level of methodologic quality.[31,43–45] Thirteen of the 18 studies reported the attrition rate. Only in the study by Kain and associates[42] was there a significantly different attrition rate between the 2 groups: 9% in the intervention group and 21% in the control group.

Change in body mass index

The meta-analysis was conducted with 15 of the 18 studies. The following analyses, including the sensitivity analyses, refer to this subset of 15 studies.[30,31,34–46]

Primary outcome

The change in BMI was not significantly different between children who received a school-based physical activity intervention and those in the control group (weighted mean difference –0.05 kg/m^2; 95% CI –0.19 to 0.10) (Figure 1). This indicates that body composition did not improve with physical activity. The result was statistically heterogeneous (I^2 = 54%). The funnel plot showed no evidence of publication bias.

Sensitivity analysis

When only randomized controlled trials were included (12 studies, n = 8381), the difference in change in BMI remained nonsignificant (weighted mean difference 0.01 kg/m^2, 95% CI –0.14 to 0.14), but, notably, there was no longer significant statistical heterogeneity (I^2 = 19%) (Figure 2). The presence of a co-intervention did not affect the summary estimate. Specifically, the change in BMI for those who received a co-intervention in addition to the physical activity intervention was not significantly different from that of control children (weighted mean difference –0.08 kg/m^2, 95% CI –0.22 to 0.07). Similarly, the duration of the study did not affect the results significantly. For studies that lasted up to 1 year, the weighted mean difference was –0.09 kg/m^2 (95% CI –0.29 to 0.12). This was not significantly different from the weighted mean difference for studies that lasted longer than 1 year (weighted mean difference 0.00 kg/m^2, 95% CI –0.21 to 0.21). We also compared the highest-quality studies with the lower-quality studies to determine whether study quality influenced the results. The weighted mean difference for high-quality studies was –0.08 kg/m^2 (95% CI –0.35 to 0.19), which indicates that variance in study quality had no effect on the results. We assessed sex-related data to determine whether there was a different response for boys and girls. The single study involving only boys did not show a significant change in BMI. The weighted mean difference for studies involving only girls was –0.02 kg/m^2 (95% CI –0.30 to 0.27). The weighted mean difference for studies involving both boys and girls was –0.07 kg/m^2 (95% –0.25 to 0.10). Sex did not influence the results of the meta-analysis, although there was only 1 study that involved only boys.

The jackknife analysis did not change the results significantly. Interestingly, removal of the study by Spiegel and Foulk[39] (1 of the 5 controlled clinical trials) eliminated the statistical heterogeneity (I^2 = 24%), although the summary estimate of change in BMI was unchanged (weighted mean difference –0.01 kg/m^2, 95% CI –0.12 to 0.11). No other single study had a significant effect on the summary estimate or the statistical heterogeneity.

We obtained our summary estimate using an estimated correlation coefficient of 0.9 in studies that reported pre-intervention and post-intervention BMI data (n = 9). Varying the correlation coefficient from 0.5 (weighted mean difference –0.04 kg/m^2, 95% CI –0.22 to 0.13) to 0.95 (weighted mean difference –0.05 kg/m^2, 95% CI –0.18 to 0.09) did not change the summary estimate significantly.

Ten of 15 studies clearly described appropriate cluster-adjusted analyses[31,34–38,40,42,45] or did not require cluster adjustment.[41] In the 5 studies where the analysis was less clearly described, we performed appropriate cluster adjustments.[30,39,43,44,46] The weighted mean difference using these additional cluster adjustments was –0.05 kg/m^2 (95% CI –0.18 to 0.08).

Three studies reported BMI data that were not amenable to meta-analysis (Table 1). In 2 of these 3 studies, there was no significant change in BMI with the intervention.[48,49] The third study reported that BMI increased more in girls with the physical activity intervention, but there was no significant change in boys.[47]

Change in other measures of body composition

Ten studies presented at least one other measure of body composition in addition to BMI. Outcome measures reported included percent body fat, waist circumference, waist-to-hip ratio, triceps skin-fold thickness, subscapular skin-fold thickness, total lean mass, total fat mass and skin-fold sum. Only 3 of the 18 reported comparisons demonstrated significant improvement with physical activity intervention,[41,42,44] 1 demonstrated deterioration with physical activity intervention,[46] and 14 did not show any significant change (Table 1). None of the 3 outcomes with improvements in body composition were associated with improved BMI.[41,42,44]

Source	No. of children	Weighted mean difference in BMI, kg/m² (95% CI)
Pate et al.[38]	1 539	0.05 (–0.20 to 0.30)
Spiegel et al.[39]	1 013	–0.36 (–0.48 to –0.24)
Chavarro et al.[35]	508	–0.30 (–0.65 to 0.05)
Linden et al.[36]	99	0.54 (0.02 to 1.06)
Burke et al.[34]	471	0.13 (–0.08 to 0.34)
Lohman et al.[45]	1 367	–0.30 (–0.57 to –0.03)
Carrel et al.[41]	50	1.00 (–1.20 to 3.20)
MacKelvie et al.[44]	64	0.30 (–0.39 to 0.99)
MacKelvie et al.[43]	75	–0.30 (–0.83 to 0.23)
Luepker et al.[31]	3 959	0.07 (–0.06 to 0.20)
Neumark-Sztainer et al.[37]	179	0.03 (–0.86 to 0.92)
Hopper et al.[30]	169	0.34 (–0.03 to 0.71)
Kain et al.[42]	3 086	0.00 (–0.12 to 0.12)
Stock et al.[40]	316	–0.33 (–0.63 to –0.02)
Donnelly et al.[46]	108	–0.20 (–0.85 to 0.45)
Summary estimate	13 003	–0.05 (–0.19 to 0.10)

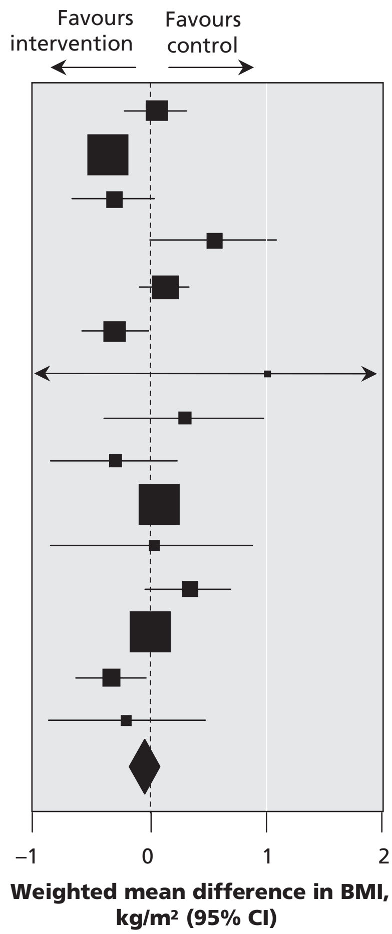

Figure 1: Weighted mean difference in change in body mass index (BMI) between the intervention group (school-based physical activity) and the control group. The size of each data marker indicates the weight assigned to the individual study. These weights are proportional to the inverse of the variance for each study. Larger studies tend to have less variance (because of sample size) and therefore receive more weight. Note: CI = confidence interval.

Interpretation

Our meta-analysis indicated that school-based physical activity interventions did not improve BMI. Therefore, such interventions are unlikely to have a significant effect on the increasing prevalence of childhood obesity. Our inferences appeared consistent among the many secondary analyses that we performed. Variation in the duration, intensity and structure of school-based physical activity interventions had minimal effects on short-term or long-term BMI change. The consistency of the BMI results among the studies included in the meta-analysis was striking (r = 0.97). This finding is important for policy-makers who continue to promote school-based physical activity as a central component of the strategy to reduce childhood obesity.[19–22,51]

Whereas other authors have suggested that physical activity interventions may be ineffective in improving body composition in children,[12] our study provides quantitative evidence for this conclusion. Although the physical activity interventions in the studies we analyzed were not successful in improving BMI, the underlying reasons for failure were unclear. It is possible that the "dose" of physical activity achieved in these studies was insufficient to improve BMI, either because of the quantity of physical activity in the intervention or the adherence of individual children to the intervention. Only 5 of the 18 studies had objective measures of physical activity. In the 3 studies in which physical activity was compared with the SOFIT instrument, there was more physical activity in the intervention group than the control group. However, both Lohman and associates[45] and Webber and colleagues[49] used accelerometers and found no difference in physical activity between the intervention and control groups. Notably, all of these objective measures were used for only a short segment of the study protocol. None of the studies measured adherence to the intervention at the individual level, and only 4 studies measured adherence at the school level. A second possibility is that there may have been a small effect in a subset of children, but the effect was attenuated in the assessment of the entire population. For example, it is plausible that children with higher baseline BMI would benefit more from such interventions. Conversely, children with higher BMI may have lower levels of adherence. As a consequence, they would benefit less from such interventions. A third possibility is that physical activity may have relatively little influence on body composition compared with dietary intake.

The association between reduced physical activity and obesity has been well established.[52,53] However, there is no conclusive evidence that reduced physical activity is a causal component in the pathway leading to childhood obesity. Rather, there is evidence to suggest that the observed association may be a downstream effect of obesity.[54,55] Specifically, a prospective study demonstrated that increased BMI predicts a decline in physical activity,[54] and another recent study demonstrated that improvements in body composition may be attained through dietary change rather than physical activity.[55] A better understanding of the causal pathway leading to childhood obesity may facilitate the development of new interventions that will improve body composition.

Study characteristic	No. of children	Weighted mean difference in BMI, kg/m² (95% CI)
Randomized controlled trials	8 381	0.01 (–0.14 to 0.14)
Study duration ≤ 1 yr	6 654	–0.09 (–0.29 to 0.12)
Study duration > 1 yr	6 349	0.00 (–0.21 to 0.21)
High-quality studies	5 465	–0.08 (–0.35 to 0.19)
Studies with a co-intervention	12 765	–0.08 (–0.22 to 0.07)
Boys and girls	10 539	–0.07 (–0.25 to 0.10)
Girls only	2 400	–0.02 (–0.30 to 0.27)

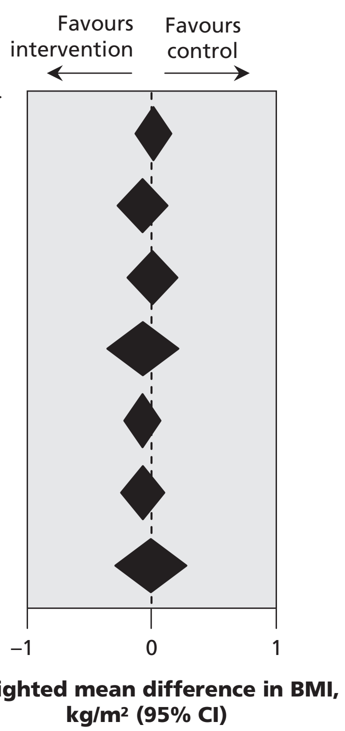

Figure 2: Sensitivity analysis for weighted mean difference in change in body mass index (BMI) between the intervention group (school-based physical activity) and the control group. Note: CI = confidence interval.

Limitations

Our meta-analysis showed that school-based physical activity interventions did not improve BMI, but there are limitations to BMI as a measure of body composition. BMI reflects both fat and fat-free components of body weight.[56] Populations may vary with respect to relative amounts of lean muscle mass and body fat. Furthermore, the distribution of body fat may vary among individuals or populations, which can have important prognostic significance. It is possible that school-based physical activity could increase lean muscle mass and decrease fat mass with no overall change in BMI.

Other measures of body composition have been suggested, such as waist circumference, skin-fold thickness and percent body fat, and all of these warrant investigation.[57–59] However, BMI is the most consistently reported measure of body composition,[56] which makes it amenable to meta-analysis. It is our view that BMI is an important outcome measure, as the links between elevated BMI and adverse health outcomes have been clearly established. In adults, an elevated BMI is associated with increased rates of diabetes mellitus, heart disease, cancer and death.[60–62] Similarly, elevated BMI in children is associated with increased blood pressure, hyperlipidemia and type 2 diabetes, as well as development of coronary artery disease and increased all-cause mortality later in life.[1,63–66] Children with elevated BMI are at high risk of having elevated BMI as adults.[67] Future studies should continue to focus

Table 1: Effect of school-based physical activity on measures of body composition

Measure of body composition	No. of children	Outcome in intervention group relative to control	Difference in mean change* (95% CI)	*p* value†
% body fat				
Lohman et al.[45]	1367	No difference	0.2% (–0.84% to 1.31%)	0.66
Carrel et al.[41]	50	Decreased	–2.0%	0.04
Donnelly et al.[46]	108	Increased	+1.3%	Not reported
Triceps skin-fold				
Lohman et al.[45]	1367	No difference	0.1 mm (–0.67 to 0.83)	0.84
Luepker et al.[31]	3959	No difference	+0.1 mm	0.70
Kain et al.[42]	3086	Boys: no difference	+0.3 mm	0.14
		Girls: no difference	–0.3 mm	0.35
Subscapular skin-fold				
Lohman et al.[45]	1367	No difference	–0.1 mm (–0.85 to 0.70)	0.85
Luepker et al.[31]	3959	No difference	+0.1 mm	0.64
Total lean mass				
MacKelvie et al.[43]	75	No difference	–0.3 kg	> 0.01
MacKelvie et al.[44]	64	Increased	1.267 kg	< 0.05
Total fat mass				
MacKelvie et al.[43]	75	No difference	–0.7 kg	> 0.01
MacKelvie et al.[44]	64	No difference	–0.367 kg	> 0.05
Waist circumference				
Kain et al.[42]	3086	Girls: no difference	–0.3 cm	0.18
		Boys: decreased	–1.8 cm	< 0.001
Skin-fold sum				
Hopper et al.[30]	169	No difference	–0.18 mm	> 0.05
Sallis et al.[47]	740	Boys and girls: no difference	Not reported	> 0.05
Waist-to-hip ratio				
Coleman et al.[48]	896	No difference	Not reported	Not reported
Body mass index‡				
Sallis et al.[47]	740	Boys: no difference	Not reported	> 0.05
		Girls: increased	Not reported	< 0.01
Webber et al.[49]	3502	No difference	0	Not reported
Coleman et al.[48]	896	No difference	Not reported	Not reported

Note: CI = confidence interval.
*Intervention minus control.
†As reported in original articles.
‡Data not amenable to meta-analysis.

on improving BMI, given the recent dramatic increases in BMI across the entire population of children and the clear links between elevated BMI and adverse health outcomes.[68]

We are concerned that these results may have a negative impact on the promotion of physical activity in schools. From a public health perspective, school-based physical activity is important, because of the significant health benefits that have been demonstrated. These include reducing blood pressure,[69] increasing lean muscle mass,[43] increasing bone mineral density,[36,43,44] increasing aerobic capacity[41,52] and improving flexibility.[52] It is therefore important to promote school-based physical activity for its demonstrated health benefits, even though there is currently no evidence that it is an effective method to reverse the trend of increasing BMI in children. The results of this meta-analysis may help to clarify the goals of government policies.

We included both randomized controlled trials and controlled clinical trials in our study because we recognized the inherent difficulties in engaging schools in randomized controlled trials. The summary estimate and confidence interval that we obtained from our meta-analysis of the randomized controlled trials, which represent the gold standard for meta-analysis,[70] were remarkably similar to those obtained from all studies. Importantly, there was no significant statistical heterogeneity among the randomized controlled trials.

Our analysis may be limited by variation among the studies. The most significant source of variation among studies was the range of physical activity interventions implemented. Each of the 18 physical activity interventions included in the analysis was completed as a component of a research protocol and may have received more intensive support than would be possible in the typical school environment. Given that these studies were not efficacious, it is unlikely that such interventions would be effective if widely implemented through changes in policy.

The 2 main limitations observed in the primary studies were lack of assessment of adherence to study protocols, both at the school level and at the individual level, and lack of objective assessment of the "dose" of physical activity achieved with such interventions. Future studies should address these issues. We believe that a well-conducted cluster randomized controlled trial should be of sufficient duration to allow observation of clinically important changes in body composition and should be designed with enough students to detect small but meaningful changes in BMI. Based upon our results and those of previous studies it appears that if there is a positive effect of school-based physical activity on BMI, the effect size is likely small. Therefore, having a study that is appropriately powered is critical.[12] Finally, in addition to collecting appropriate anthropometric data, future studies should also assess the impact of such interventions on the metabolic profile of children.

Conclusion

Physical activity should be included and promoted within schools, as it is an important component of a healthy lifestyle and improves many aspects of health.[15,71,72] However, our meta-analysis has shown that school-based physical activity interventions do not improve body composition. Further studies that improve on previous methodologic weakness are required before widespread promotion of school-based physical activity as a central component of the solution for childhood obesity. Should such policies be implemented before further study, they should be part of a research protocol. Multiple interventions that target different aspects in the causal pathway may be more successful in improving children's body composition. Interventions that aim to improve diet have shown promise in improving BMI.[73-76] Effective interventions should be pursued, and the school setting is an important setting in which to initiate change.

This article has been peer reviewed.

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Contributors: Kevin Harris participated in the study concept and design, the acquisition, analysis and interpretation of data, and the drafting and critical revision of the manuscript. Jennifer Retallack participated in the acquisition, analysis and interpretation of data and in drafting and critical revision of the manuscript. Kevin Harris and Jennifer Retallack had full access to all of the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis. Lisa Kuramoto participated in the analysis and interpretation of the data, the statistical analysis of the study and critical revision of the manuscript. Michael Schulzer participated in the analysis and interpretation of the data, the statistical analysis of the study and critical revision of the manuscript. Each of the authors saw and approved the final version of the manuscript.

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