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Is Physical Fitness Associated with Health in Overweight and Obese Youth? A Systematic Review

Melinda Millard-Stafford¹, Jeffrey S. Becasen², Michael W. Beets³, Allison J. Nihiser⁴, Sarah M. Lee⁴, and Janet E. Fulton⁵

¹School of Applied Physiology, Georgia Institute of Technology, Atlanta GA

²Division of Adolescent and School Health, Centers for Disease Control and Prevention

³Arnold School of Public Health, University of South Carolina, Columbia SC

⁴Division of Population Health, Centers for Disease Control and Prevention

⁵Division of Nutrition, Physical Activity and Obesity, Centers for Disease Control and Prevention

Abstract

A systematic review of literature was conducted to examine the association between changes in health-related fitness (e.g. aerobic capacity and muscular strength /endurance) and chronic disease risk factors in overweight and/or obese youth. Studies published from 2000–2010 were included if the physical activity intervention was a randomized controlled trial and reported changes in fitness and health outcomes by direction and significance ($p < 0.05$) of the effect. Aerobic capacity improved in 91% and muscular fitness improved in 82% of measures reported. Nearly all studies (32 of 33) reported improvement in at least one fitness test. Changes in outcomes related to adiposity, cardiovascular, musculoskeletal, metabolic, and mental/emotional health improved in 60%, 32%, 53%, 41%, and 33% of comparisons studied, respectively. In conclusion, overweight and obese youth can improve physical fitness across a variety of test measures. When fitness improves, beneficial health effects are observed in some, but not all chronic disease risk factors.

Keywords

Aerobic capacity; muscular strength; muscular endurance; children; adolescents; adiposity; cardiovascular; obesity

INTRODUCTION

In the United States, one in three school-aged youth are considered either overweight or obese (Ogden, Carroll, Kit, & Flegal, 2012). Being overweight or obese during childhood or adolescence increases the risk for negative health consequences. Overweight or obese youth are more likely than their normal-weight counterparts to become obese adults (Whitaker,

Correspondence to: Mindy Millard-Stafford, School of Applied Physiology, Georgia Institute of Technology, 555 14th St., Atlanta GA 30332 Mm6@mail.gatech.edu.

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Wright, Pepe, Seidel, & Dietz, 1997) and may be more likely to develop the risk factors for chronic disease such as coronary heart disease, stroke, and Type II diabetes (Daniels et al., 2005; Must & Strauss, 1999).

Obese youth, compared to those of normal weight, tend to be less physically active and are, therefore, less likely to obtain the health benefits of physical activity (Physical Activity Guidelines for Americans, 2008; Strong et al., 2005). Physically active youth are more likely to remain active as they mature into adults (Powell & Dysinger, 1987). Participation in regular physical activity during childhood and adolescence reduces adiposity, improves bone health, and improves risk factors for some chronic diseases (LeMura & Maziekas, 2002; Physical Activity Guidelines for Americans, 2008). School-aged youth are, therefore, recommended to obtain specific amounts of aerobic and musculoskeletal-strengthening physical activities as part of US public health guidelines (Physical Activity Guidelines for Americans, 2008) and national health objectives (Healthy People 2020, 2010).

Physical fitness is an outcome of physical activity (Caspersen, Powell, & Christenson, 1985) and functional measures (e.g., aerobic capacity, muscular strength, and muscular endurance) can be assessed in school-aged youth through standardized test batteries (Morrow, Zhu, Franks, Meredith, & Spain, 2009). In adults, the importance of physical fitness to health is well established: (Sui et al., 2007) men and women with higher levels of aerobic capacity have lower risks for mortality and chronic diseases. Few summary reports have examined the association between changes in physical fitness and health outcomes in youth, particularly for those who are overweight or obese. This bears importance because greater aerobic fitness in adolescence is associated with reduced adiposity in adulthood (Eisenmann, Wickel, Welk, & Blair, 2005).

Whether improvements in physical fitness influence health in overweight or obese youth remains unclear. A recent review (Kim & Lee, 2009) of randomized and non-randomized controlled trials of children and adolescents indicated aerobic activity was moderately effective in reducing age-related increases in visceral adiposity, although the 11 studies were not exclusively based on obese youth. In addition, the evidence related to resistance training and abdominal obesity was considered limited due to relatively few studies (Kim & Lee, 2009), thus, warranting further investigation.

Therefore, the objective of our review was to systematically examine and summarize: (1) a decade of peer-reviewed literature describing the association between selected components of physical fitness (i.e., aerobic capacity, muscular strength and muscular endurance) on health in school-aged youth who are overweight and obese; and (2) whether improvements in fitness are associated with beneficial changes in measures of chronic disease including adiposity, cardiovascular or metabolic health risk factors.

Methods

Literature Review

A systematic review of the literature was conducted to identify the relationship between physical fitness and health in youth (ages 5–18 years). A search of the literature was

performed from September to December 2010 by the Centers for Disease Control and Prevention Public Health Library and Information Center (Atlanta, GA). Studies published between January 1, 2000 and December 20, 2010 were identified through a search of electronic databases (CINAHL, Sport Discus, PubMed, Medline, Embase, PsycInfo, ISI: Web of Science, Web of Knowledge). The grey literature (including dissertations and theses) were not included in the search. Since other pertinent reviews (Goran, 2001; Kim & Lee, 2009; LeMura & Maziekas, 2002; Sothorn, 2001; Watts, Jones, Davis, & Green, 2005) were performed on studies published prior to 2000, the decade of published studies from 2000–2010 was delimited in the search strategy.

Five independent searches were conducted for each of the following components that frequently comprise fitness test batteries: 1) aerobic capacity/cardio-respiratory endurance, 2) muscular strength (ability to exert maximal force), 3) muscular endurance (ability to sustain repeated contractions against resistance for a period of time), 4) body composition, and 5) flexibility combined with key words reflecting a broad spectrum of health indicators, similar to those utilized in the 2008 Physical Activity Guidelines for Americans (“Physical Activity Guidelines for Americans,” 2008). For example, these key words (Appendix 1) included an array of health terms related to obesity (e.g., adiposity, BMI, visceral fat, waist circumference, body fat), cardiovascular (e.g., blood pressure, blood lipids, inflammatory markers), musculoskeletal (e.g., bone mineral density, fat-free mass), metabolic (e.g., insulin resistance, fasting insulin, blood glucose), mental (e.g., depression, stress, anxiety), immune function (e.g., cortisol, lymphocytes), pulmonary function (e.g., vital capacity), growth/maturation (e.g., peak height velocity, testosterone), injury (e.g., low back, pain scores).

Study inclusion and exclusion criteria

After reviewing for redundancy, 20,016 publications were screened based on the title and review of the abstract (Figure 1). Abstracts meeting the following criteria were identified for retrieval of the full article: 1) published in English; 2) presented original research data; 3) conducted on humans and, specifically, healthy children, youth, or adolescents (i.e., without congenital disease or physical disability) with results reported separately from adults; and 4) measured at least one component of physical fitness and a health outcome measure. Review articles, meta-analyses, and unpublished studies were excluded during this screening process. Abstracts that focused exclusively on physical activity without a measure of physical fitness were excluded. The abstract screening process resulted in 1,545 full articles retrieved.

Selection and Coding of Studies

A team of eight trained reviewers read and coded the 1,545 articles to be considered for eligibility for final inclusion in the database. Only articles using a randomized controlled trial to evaluate an exercise or physical activity intervention treatment for overweight or obese youth were included. Studies were also included if the intervention combined a calorie-restrictive diet and/or life style education program along with physical activity or exercise. The criteria used for defining overweight and obesity were verified in the articles. In the majority of studies, overweight was presented and defined by a BMI at or above the 85th and below the 95th percentile for age, and obese was defined by a BMI at or above the

95th percentile for age. In studies where the sample was described as overweight or obese but did not specify BMI age percentile, the Cole's international age-related cut-off, 85th percentile for triceps skinfold thickness, or the baseline % body fat were verified to be indicative of overweight/obesity.

An assessment of quality or risk bias (low, high or unclear risk) for each individual study was not systematically performed. Criteria often assessed in quality scales (i.e., allocation concealment, blinded outcome assessments and care providers) were either difficult to evaluate or not reported. Blinding of participants and supervising personnel is not typically possible in physical activity intervention trials, thus creating an inherent potential for bias, particularly when health outcome measures are subjective (e.g., ratings for self-efficacy). In most studies, baseline characteristics of the control and intervention groups were similar after randomization suggesting low risk of selection bias.

The article coding process was similar to methodology used in other systematic reviews within the field of physical activity and public health (Stone, McKenzie, Welk, & Booth, 1998); (Welk, Corbin, & Dale, 2000). Relevant information was extracted from the articles into a central data repository (i.e. Microsoft Access database) including the sample size and participant characteristics; description of the exercise/physical activity intervention; fitness test description; fitness test values obtained (including p value for change in fitness); and health risk factor outcome measures (and p value for change in health outcome). Each individual study could contribute multiple health outcomes (e.g. blood glucose, body fat, triglycerides) depending on the number of measures reported. To examine the effect of the intervention on health outcomes, reviewers assigned a rating of either beneficial, adverse, or no effect. The rating was based on: 1) an interaction effect over time for the intervention group relative to the control group, 2) a group difference based on Analysis of Covariance, or 3) a change score comparison across groups with an alpha level of <0.05. In three studies (Ben Ounis 2010; Ben Ounis 2010; Chang et al. 2008), none of these comparisons were reported; therefore, a significant time effect for the intervention group (with no change reported for control) was also used to provide a rating for the intervention effect.

Data Extraction and Synthesis

The data extraction system was designed to categorize and organize data extracted from studies by fitness component (aerobic capacity/cardiorespiratory endurance or muscular strength/muscular endurance), fitness test (e.g., distance run or walk test, maximal oxygen uptake on treadmill/bike, curl-up or sit-up, standing broad jump, one repetition maximum for upper or lower body), health risk factor categories (adiposity, cardiovascular, musculoskeletal, metabolic, and mental/emotional), and specific measures within health risk factor categories (e.g., body mass index, % body fatness, total serum cholesterol, bone mineral density, fasting blood glucose, insulin sensitivity).

For the purpose of this qualitative review, data were classified by the frequency that fitness improved among overweight and obese youth for tests of aerobic capacity and muscular strength/muscular endurance. Coded data were stratified by studies that demonstrated a significant change ($p < 0.05$) in at least one measure of fitness and cross tabulated by health outcomes. If a study demonstrated a significant improvement in fitness and a beneficial

change in a health measure, this was coded as a positive effect (+). If a study demonstrated a significant improvement in fitness but an adverse change in a health measure, this was coded as an adverse or negative effect (-). If a study demonstrated a significant improvement in fitness and showed no change in a health outcome, this was coded as no effect (Ø). Two reviewers independently hand tallied and verified counts to summarize the significant changes in fitness and health. Discrepancies were resolved through discussion and consensus. To determine the percent of beneficial changes in health, the frequency of positive effects was calculated relative to the total number of each specific health outcome. Some studies reported a greater number of health outcomes and thus contributed more to the overall findings than those with fewer health outcomes although no single study contributed more than one count for any specific health outcome.

Since the studies focused on overweight and obese children, the median absolute change score in measures of adiposity (BMI, % body fatness as derived from a variety of methods, waist circumference, fat mass) was reported. Body mass, or weight (kg), was not extracted as a health outcome using the Ø, + or - effect designation. This decision was based on the potential for multiple intervening factors that limit the interpretation of short-term body mass change in youth. An example of intervening factors includes resistance training interventions that increase fat-free mass and thereby increase body mass. In addition, youth changes in body mass (and height) are expected over time since this population is being studied during periods of potentially rapid growth and maturation.

Results

Summary of Studies

A total of 78 experimental studies on overweight/obese youth published from 2000–2010 were identified and evaluated. Of these, 33 studies met the inclusion criteria of an exercise or physical activity intervention for overweight and/or obese participants randomized into intervention and control groups. These studies formed the basis of our analyses and are presented in Table 1. One study (Gutin, et al., 2000) was part of a comprehensive investigation that resulted in a series of publications from the same intervention study. The health outcome data from two related papers (Ferguson et al., 1999); (Owens et al., 1999), therefore, were extracted and merged as if from a single source (i.e., fitness data tabulated as one entry) for the purpose of the summary analysis.

An additional eight studies (Adam, Westenhofer, Rudolphi, & Kraaibeek, 2009; Eliakim et al., 2002; Gately, Barth, Radley, & Cooke, 2005; Gately et al., 2005; Ildiko et al., 2007; Naylor et al., 2008; Stella et al., 2005; Vajda et al., 2007) were also considered for the review but were excluded, because they were deemed “quasi-experimental” since it was not clear that intervention and control group assignments were randomized. Two other studies (Watts et al., 2004; Watts et al., 2004b) used a randomized cross-over study design (with participants serving as their own control in “trained” and “untrained” phases), but it was unclear if there was a potential carry-over effect due to an insufficient wash-out period to minimize residual effects on fitness or health for the group that “trained” first then became “untrained” later. Therefore, these studies were not included in our analysis.

Demographics of the studies are presented in Table 1. The total sample size across all studies (n=33) ranged from 18 to 120 (median sample size = 41). Thirty studies included boys and girls, one exclusively on boys and two exclusively on girls. The median age of participants across all studies was 10.9 y ranging from 8.9 to 16.9 y. A variety of exercise and physical activity interventions were implemented including aerobic activity, resistance training, games/sports, martial arts, or combination of activities. Regarding the physical activity interventions described across all studies: the median (minimum-maximum) length was 12 weeks (6 to 36 weeks), weekly dose was 120 min per week (80 to 420 min per week) with two studies reporting 1250 kcal per week. Intensity was not always specified in the physical activity intervention program but those described were between moderate and vigorous.

Seventeen studies implemented an intervention consisting only of an exercise/physical activity treatment. The control group in these studies had no supervised activity programs except for one study which used “placebo” activity (Tai Chi) for the control group compared to a Kung Fu intervention (Tsang, et al., 2009). Sixteen studies coupled physical activity along with another component in the intervention. Diet restriction was reported in four studies, an educational component (lifestyle related to nutrition, physical activity or behavior change) was reported in six studies, and both dietary and lifestyle educational components were reported in six studies. These studies were not excluded because the control group in 12 studies (out of 16) also received the corresponding diet or lifestyle component (differing only by physical activity). However, one set of studies from the same research team (Nemet, et al., 2005; Nemet, et al., 2008; Nemet, et al., 2006) designed the control group to be counseled in diet and exercise while the intervention group met with a dietitian and performed exercise. There was also one study (Ben Ounis, Elloumi, Zouhal, et al., 2010) which used a true “control” group with no programmatic intervention other than instructions to maintain normal diet and activity patterns compared to an intervention group that combined a modest reduction in caloric intake (500 kcal/d) along with structured exercise (360 min/wk). The aforementioned studies with interventions that were not strictly exercise or physical activity treatment were still included, because the studies reported changes in fitness measures along with health outcomes.

Summary of Fitness Measures

The frequency that fitness improved in overweight/obese youth across specific test measures is presented in Table 2. Three studies measured both aerobic fitness and muscular strength/endurance, five studies measured only muscular strength and/or muscular endurance, and 25 studies measured only aerobic fitness. Out of the 33 studies, there was only one study (Daley, et al., 2006) for which any measure of fitness failed to improve (aerobic fitness assessed by a graded Balke treadmill walking test).

A total of 35 tests (both laboratory and field-based) of aerobic fitness were reported across 28 studies (i.e., multiple measures of aerobic fitness were reported in six studies). A total of 91% of these tests indicated improved aerobic fitness in the overweight/obese intervention group (Table 2). In only three cases did a test of aerobic fitness not significantly improve in obese youth (a laboratory-based VO₂max using either a bicycle ergometer or treadmill test

and a field-based walking test). In one case of non-significant change in VO₂max, values were expressed in absolute terms (ml/min) but were improved when expressed relative to body mass (ml/kg/min)(Prado, et al., 2009).

Overall, there were fewer studies which assessed either muscular strength or muscular endurance. A total of 17 muscular fitness tests were reported across eight studies measuring abdominal muscular endurance, upper and lower body strength and muscular endurance in overweight or obese youth. A total of 82% of these test results indicated improved muscular strength or muscular endurance following an exercise intervention. However, for several tests (curl-up/sit-up, push-up, handgrip dynamometry and weighted ball throw) only one test result was reported across all studies.

Summary of Changes in Health Outcomes When Fitness Significantly Improved

Measures of selected health outcomes were extracted from all included studies. However, only those health measures which were associated with a significant improvement in fitness ($p < 0.05$) were tallied and presented in Table 3. Health outcome measures were sub-categorized by improvements relative to aerobic fitness, muscular strength/muscular endurance, or if both aerobic and muscular strength/endurance improved. There were relatively few measures reported for mental/emotional ($n = 3$) and musculoskeletal health ($n = 15$) as compared to adiposity ($n = 73$), and risk factors for cardiovascular ($n = 85$) and metabolic diseases ($n = 61$). For the one study (Daley, et al., 2006) which observed no fitness improvements (i.e., aerobic fitness), there were also no beneficial changes in BMI or depression, although there was a significant positive interaction effect for self-efficacy/self-esteem in the intervention group. Therefore, since fitness did not improve in this study (1 study out of 33), these health outcome data were not included in Table 3.

A total of 237 measures of chronic disease risk factors were extracted (fourth data column, Table 3). Overall, a total of 105 (44%) of health measures improved *when* at least one significant change in fitness (aerobic, muscular strength and/or muscular endurance) was reported. Specifically, health outcomes within each risk factor category for adiposity, cardiovascular, musculoskeletal, metabolic, and mental/emotional health were improved in 60%, 32%, 53%, 41%, and 33% of the measures, respectively. Improvements in adiposity were reported as high as 71%–75% for waist circumference ($n = 7$) and visceral fat ($n = 4$) and lower for others such as BMI (58%, $n = 26$). Improvements in cardiovascular risk factors varied from 47% of cases for blood triglyceride ($n = 15$) to 17% for LDL-cholesterol ($n = 12$). Improvements in metabolic health varied from 0%–67% for adiponectin and insulin sensitivity, respectively, but with very few cases in each. Musculoskeletal health was improved overall in 53% of cases for measures of bone mineral content, bone density and fat free mass combined ($n = 15$). Overall, only a single negative health outcome was reported (i.e., loss of fat free body mass) out of 237 total measures when a measure of fitness improved.

When aerobic fitness improved (first data column, Table 3), adiposity improved in 36 out of 53 measures (68%), compared to cardiovascular risk factors (25 of 70 cases or 36%) and metabolic health (20 out of 44 measures or 45%). Regarding specific health outcomes within adiposity, improvements in visceral fat, % body fat, and waist circumference ranged from

74–100% compared to 58% for BMI. Regarding measures of cardiovascular risk, C-reactive protein improved in 14% of measures compared to serum triglyceride (50% of measures). Metabolic health improvements varied from 36% for fasting glucose to 60% of measures for fasting insulin. Although some health measures (e.g., adiponectin, bone mineral density, insulin sensitivity) had scores of either 0 or 100% reporting improvement, the number of studies reporting on these measures was extremely limited. To summarize, a total of 177 health outcome measures were reported when aerobic fitness improved and, of these, 49% reflected beneficial changes in health for overweight/obese youth.

When muscular strength and/or muscular endurance improved (third data column, Table 3), beneficial changes in adiposity occurred in 5 out of 15 measures (33%), compared to cardiovascular risk factors (1 of 11 or 9%) and metabolic health (2 of 14 or 14%). Fat mass was reduced in only one of five studies (20%) compared to two of four for %body fatness (50%). Many of the individual risk factors within cardiovascular and metabolic health had five or fewer measures reported. Of these, neither fasting blood glucose nor insulin yielded a beneficial change occurring > 20% of the time. Out of a total of 48 health outcome measures, 23% of these improved when muscular strength and/or muscular endurance improved in the overweight/obese youth. However, when both aerobic and muscular fitness improved (second data column of Table 3), positive health effects increased to 58%, although this was based on a total of only 12 measures tabulated across all health outcome categories.

Median absolute change scores for measures of adiposity in the intervention and control groups were tabulated. Since the control groups in several studies had dietary restriction without exercise, mean reductions in some adiposity measures were observed for both intervention and control. The median absolute change reported for BMI (n=25) was -0.7 (kg/m^2) within the intervention groups and -0.1 (kg/m^2) within control groups. The median absolute change in % body fatness (n= 23) was a gain (+0.4) for control compared to a reduction (-1.6%) in intervention groups. The same pattern was observed in median waist circumference (+0.9 cm for control, -5.1 cm for intervention groups, n=6). The median change score in total fat mass (-0.1 and -3.0 kg; n=15) and visceral fat (-11.0 and -42.0 cm^3 ; n=5) reflected a loss of fat for both control and intervention groups, respectively. The greatest magnitude of difference in BMI and % body fat (-3.9 kg/m^2 and -4.5%) in a single study occurred with a diet plus exercise intervention compared to a control group with no dietary component (gain of $+0.4$ kg/m^2 and $+0.7\%$ respectively) (Ben Ounis, Elloumi, Zouhal, et al., 2010).

DISCUSSION

Our review indicates that overweight and obese youth can improve aerobic capacity or muscular strength/muscular endurance with interventions consisting of a variety of physical activity programs. Furthermore, improved aerobic and muscular fitness was observed across many different fitness tests conducted both in the field and the laboratory. When beneficial changes in fitness are achieved in overweight and obese youth, reductions in many, but not all, chronic disease risk factors are observed following the intervention. These findings suggest that programs and policies designed to reduce the immediate and potential long-term

health effects of chronic disease risk factors in overweight and obese youth should include a focus on improving and maintaining physical fitness through physical activity (Physical Activity Guidelines for Americans, 2008).

Exercise interventions for overweight and/or obese youth frequently involve aerobic activity (e.g., cycling, walking), resistance training (weights), or some combination. Our review suggests that any of these can result in an array of health benefits. An improvement in aerobic capacity was associated with improvements in adiposity measures such as waist circumference and cardiovascular and metabolic measures such as triglycerides and insulin sensitivity. Not surprisingly, the interventions showed beneficial changes in musculoskeletal health (i.e., bone mineral, fat free mass) in response to improved muscular strength and/or muscular endurance. Improvements in aerobic capacity, relative to improvements in muscular strength/endurance, tended to show beneficial changes in more examined health outcomes.

The effectiveness of exercise interventions in obese youth has been summarized previously (Sothorn, 2001; Watts, et al., 2005) and evaluated based on short-term outcomes related to adiposity (e.g., body mass, BMI, and body fatness) (Kim & Lee, 2009; LeMura & Maziekas, 2002). None, to our knowledge, have simultaneously examined whether health was concomitantly improved with aerobic and muscular fitness as a result of the intervention. Whether changes in adiposity should be the *primary* dependent variable to evaluate efficacy of an intervention is in question since measures of adiposity in youth have limitations. The fact that youth are being assessed during potentially rapid stages of growth and development can complicate the utility of longitudinal measures involving height and weight. Body mass measures (i.e., weight) alone in youth also do not reflect changes in body composition. Therefore, we elected not to use body mass as a health outcome measure in this review.

Our findings suggest that when aerobic capacity improves, more than two-thirds of comparisons measuring adiposity resulted in beneficial changes. However, some adiposity measures were more likely to improve than others. This is congruent with other publications (Bedogni et al., 2003; Demerath et al., 2006; Watts, et al., 2005) including a meta-analysis (McGovern et al., 2008) which reported a moderate effect size (d) of *physical activity* on adiposity reduction in childhood obesity when measured via percentage body fatness and fat free mass ($d = -0.52$) compared to a non-significant effect on BMI ($d = -0.02$). In the present review, when aerobic fitness improved, waist circumference improved in all 4 comparisons (100%) while BMI improved in 11 of 19 (58%) of comparisons. Change in waist circumference appears to be a potentially useful clinical measure (Bassali, Waller, Gower, Allison, & Davis, 2010) for overweight or obese youth.

Despite the beneficial association observed between improved fitness and the reduction of many chronic disease risk factors, our results indicated this was not consistent across risk factor categories or among fitness components. Our finding that health outcomes are not uniformly improved despite improvements in fitness is consistent with a recent review of prospective clinical trials of adults. In that review, adults who improved aerobic fitness (Bouchard et al., 2012) varied in their response related to cardiovascular and metabolic risk factors. In fact, up to 10% of individual adults in that report had “negative” or adverse

changes even though aerobic fitness had improved over the time period. Thus, the variability in mean responses across studies of obese and overweight youth is not surprising.

In our review, when aerobic fitness improved in overweight and obese youth, adiposity/obesity improved in 68% of the reported outcomes compared to 36% and 45% of the reported cardiovascular risk and metabolic health outcomes, respectively. When strength/muscular endurance improved in overweight and obese youth, adiposity/obesity improved in 33% of the reported outcomes compared to 9% and 14% of the reported cardiovascular risk and metabolic health outcomes, respectively. Improvements in aerobic fitness may have a greater impact on adiposity/obesity than improved muscular fitness. However, since fat-free mass increases with resistance training, loss of fat may be masked if BMI is the measure selected to assess adiposity. Thus, whether one form of exercise training or a combination (aerobic and resistance training) yields superior benefits remains difficult to accurately determine.

Certain health outcomes may be more resistant to change in obese youth. Ferguson et al. (Ferguson, et al., 1999) suggested that, as in the case for adults, hypertriglyceridemia may be more sensitive to change in obese youth as compared to other blood lipids. Moreover, although Watts et al. (2004) found improved strength in obese youth (who served as their own control in a cross-over study), no changes occurred in blood lipids, fasting blood glucose, mean arterial pressure, BMI, or skinfold thicknesses; although trunk fat was reduced and vascular dysfunction normalized. Recent evidence also indicates that although the relationship between adult obesity and cardiovascular disease (CVD) is established, the view that the same relationship exists between adult CVD and childhood obesity has been recently challenged (Lloyd, Langley-Evans, & McMullen, 2010).

The ability to draw definitive conclusions about the fitness attribute that infers the greatest health benefits remains difficult. We acknowledge the following limitations in our review. First, our approach only captured “statistically significant” changes, which does not reflect a true effect size (standardized mean differences) for either the fitness or health outcomes. The number of studies reporting a given chronic disease risk factor was also low for many outcomes. The total number of studies that assessed muscular fitness or a combination of aerobic and muscular fitness was substantially lower than those assessing aerobic fitness despite the fact that both are considered important in the 2008 Federal guidelines. This review also did not consider the potential efficacy of the activity dose (which varied greatly across studies); notably, only three studies provided the recommended physical activity (60 min per day) (Physical Activity Guidelines for Americans, 2008) which could explain the inconsistency in health outcomes. Changes in fitness that occurred in conjunction with or independent of body mass loss were also not distinguished. Attrition bias related to participant drop-out or incomplete health outcome data was also not systematically assessed or used as a basis for study exclusion. Finally, publication bias in a narrative review can exist, since studies with non-significant or negative findings may be less likely to be published, thus creating the potential for selective reporting of positive findings.

While the relationship between fitness and health in youth has been acknowledged (Institute of Medicine Washington, 2012), the relationship for obese youth is not as well-defined. Our

review demonstrates similar to another report (Saavedra, Escalante, & Garcia-Hermoso, 2011) that, with appropriate physical activity programming, aerobic fitness can be improved in obese youth. Additionally, improvements in fitness in this population may lead to improved health, although few randomized clinical trials have been conducted. Therefore, our study supports population-level efforts to improve health-related fitness in all youth through activities such as physical education and community-based physical activity/sports programs. Incorporating fitness assessments into physical education allows all youth to understand their current level of fitness and set goals for improvement.

Finally, this review identifies areas where future research is warranted to further understand the association between fitness and health among overweight and obese youth. Whether a sedentary lifestyle during the child's growth and developmental years results in impaired cardio-respiratory or muscular fitness or the ability to adapt favorably to physical activity later in life is still unclear (Teran-Garcia, Rankinen, & Bouchard, 2008). The present review emphasizes the importance of and likely success for overweight and obese youth to improve their physical fitness, and that some, but not all, health benefits may be concomitant.

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Appendix

Example of Keywords Used in Search Strategy

(fitness center* OR strength training OR resistance training OR weight lift* OR weight lifting OR gymnastic* OR calisthenic* OR tree climbing OR rope climbing OR rock climbing OR climb* OR stair* OR strength OR aerobic capacity OR cardiorespiratory fitness OR cardio respiratory fitness OR cardiovascular health OR exercise tolerance OR endurance capacity OR maximum oxygen uptake OR oxygen consumption OR endurance training OR aerobic exercise OR muscular endurance OR endurance OR muscle* endurance OR sit up OR situp OR sit-up OR chin up OR chin-up OR curl up OR curl-up OR bicep curl OR pull up OR pull-up OR fitnessgram* OR fitnessgram* OR exercise test*) AND (cardiovascular disease* OR cardiovascular system OR cerebrovascular disorder* OR cardiac function* OR respiratory tract disease* OR chronic obstructive disease* OR obstructive lung disease* OR respiratory function test* OR lung function* OR mental health OR anxiety OR depression OR cognition OR memory OR dementia OR psychological stress OR anger OR self concept OR attention deficit disorder OR hyperactivity OR functional

health OR pain OR obesity OR overweight OR adiposity OR body weight OR body mass index OR abdominal fat OR adipose tissue OR glucose metabolism disorder* OR body composition OR body fat OR osteoporosis OR physiologic calcification OR muscular atrophy OR fat-free mass OR arthritis OR bone OR bones OR bone mineral density OR bone density OR injury risk OR cardiovascular risk OR injury) AND (child OR children OR youth OR adolescent* OR teenager* OR pediatric* OR juvenile)

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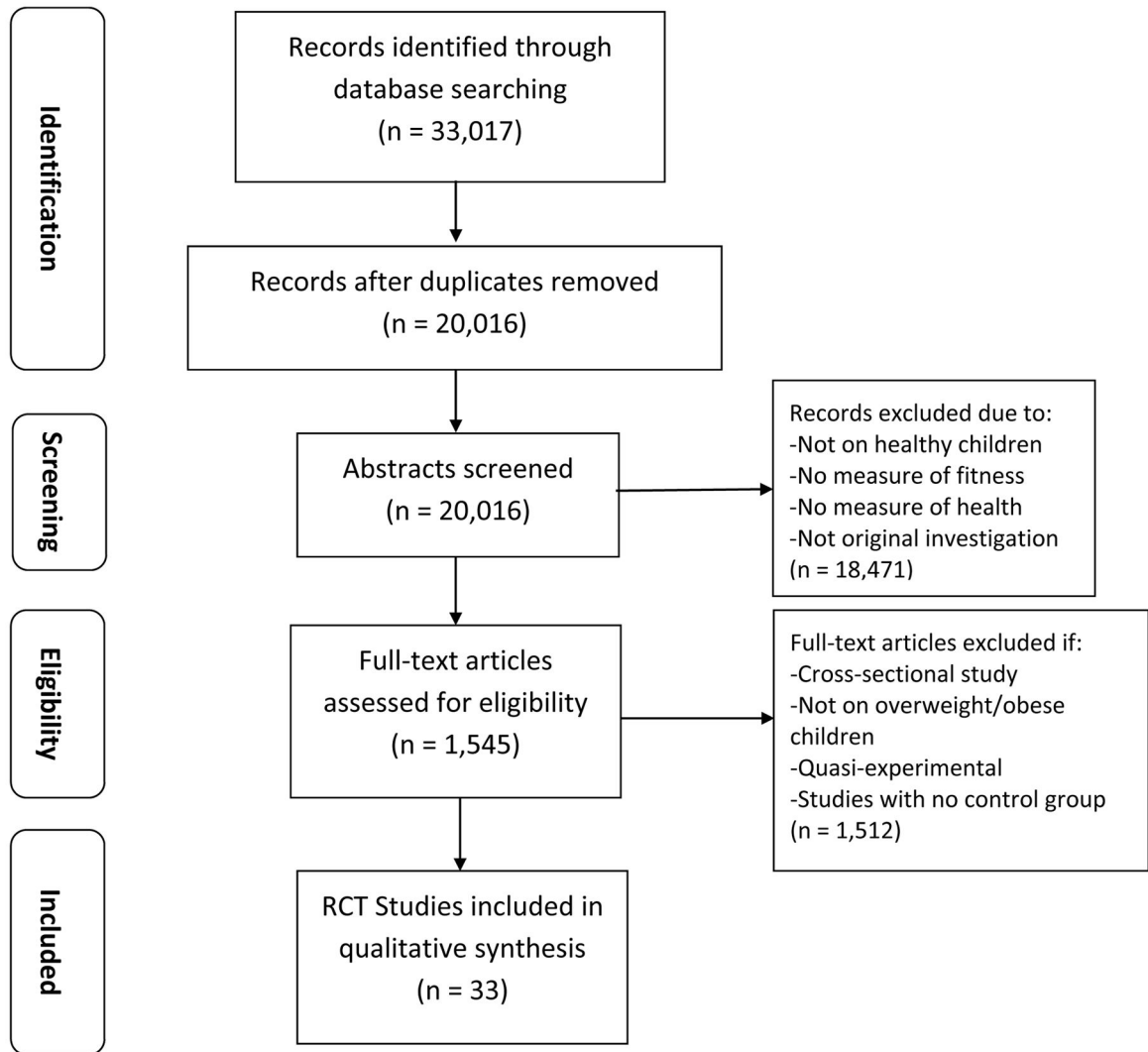


Figure 1. Process for systematic review of the literature resulting in 33 randomized controlled trials (RCT) of overweight/obese youth which reported changes in both physical fitness and a health outcome.

Table 1
Description of the randomized controlled trials with physical activity/exercise interventions included in the review (n=33).

Author (year)	Sample Characteristics				Physical Activity/Exercise Intervention					
	Total N	M	F	Age [Range]	Treatment	Duration (min/wk)	Length (wk)	Intensity	Diet	LSE
Randomized Control Trials										
Barbeau P, Litaker M, Woods K et al. (2002)	74	23	51	14.5 [12–16]	Aerobic	1250 kcal/wk	32	Moderate, Vigorous	N	Y
Ben Ounis O, Elloumi M, Makni E et al. (2010)	32	15	17	13.3 [12–14]	Aerobic	360	8	Moderate	N	N
Ben Ounis O, Elloumi M, Zouhal H et al. (2010)	28	14	14	13.2 [NR]	Aerobic	360	8	Moderate	Y	N
Carrel A, Clark R, Peterson S et al. (2005)	50	26	24	12 [NR]	Aerobic	112	36	NR	N	N
Chang C, Liu W, Zhao X et al. (2008)	49	36	13	12.4 [NR]	Combined:Aerobic+Strength	420	24	Moderate	N	Y
Daley A, Copeland R, Wright N et al. (2006)	81	36	45	13.1 [11–16]	Aerobic	90	8	Moderate	N	N
Davis C, Tomporowski P, Boyle C et al. (2007)	94	38	56	9.2 [7–11]	Aerobic	100, 200	15	Moderate, Vigorous	N	Y
Davis J, Kelly L, Lane C et al. (2009)	54	28	26	15.5 [14–18]	Resistance training	120	16	NR	Y	N
Davis J, Tung A, Chak S et al. (2009)	41	0	41	15.2 [NR]	Combined:Aerobic+Strength	120	16	Moderate	Y	Y
Elloumi M, Makni E, Ounis O et al. (2007)	20	NR	NR	13.2 [NR]	Aerobic	90	8	NR	Y	N
Farpour-Lambert N, Aggoun Y, Marchand L et al. (2009)	44	16	28	8.9 [6–11]	Combined:Aerobic+Strength	180	12	Moderate, Vigorous	N	N
Gutin B, Barbeau P, Litaker M et al. (2000)	79	26	53	9.5 [7–11]	Aerobic	200	16	Vigorous	N	N
Gutin B, Barbeau P, Owens S et al. (2002)	57	NR	NR	NR [13–16]	Aerobic	1250 kcal/wk	32	Moderate	N	Y
Huang S, Weng K, Hsieh K et al. (2007)	120	65	55	10.6 [10–13]	Aerobic	120	12	NR	N	N
Kang H, Gutin B, Barbeau P et al. (2002)	59	NR	NR	NR [13–16]	Aerobic	150	32	Moderate, Vigorous	N	Y
Kaufman C, Kelly A, Kaiser D et al. (2007)	20	NR	NR	10.9 [8–14]	Aerobic	120	8	Moderate, Vigorous	N	N
Kelly A, Steinberger J, Olson T et al. (2007)	19	8	11	10.8 [NR]	Aerobic	120	8	Moderate	N	N

Author (year)	Sample Characteristics					Physical Activity/Exercise Intervention				
	Total N	M	F	Age [Range]	Treatment	Duration (min/wk)	Length (wk)	Intensity	Diet	LSE
Kelly A, Wetzsteon R, Kaiser D et al (2004)	20	NR	NR	10.9 [NR]	Aerobic	120	8	Moderate, Vigorous	N	N
Lau P, Yu C, Lee A et al. (2004)	37	24	12	NR [10–17]	Resistance training	NR	6	Moderate, Vigorous	Y	Y
Lee K, Shin Y, Lee K et al (2010)	18	0	18	16.9 [NR]	Aerobic	160	12	Moderate	N	N
Murphy E, Carson L, Neal W et al. (2009)	35	18	17	10.2 [7–12]	Games, Sports, Other	150	12	NR	N	N
Nemet D, Barkan S, Epstein Y et al. (2005)	46	26	20	11 [6–16]	Games, Sports, Other	120	12	NR	Y	Y
Nemet D, Barzilay-Teeni N, Aliakim A et al.(2008)	22	8	14	NR [8–11]	Games, Sports, Other	120	NR	NR	Y	Y
Nemet D, Berger-Shemesh E, Wolach et al. (2006)	24	9	15	9.9 [6–16]	Combined:Run+Sports	120	12	NR	Y	Y
Prado D, Silva A, Trombetta I et al. (2009)	38	NR	NR	10.1 [NR]	Aerobic	180	16	NR	Y	Y
Ribeiro M, Silva A, Santos N et al. (2005)	39	NR	NR	10 [8–12]	Aerobic	180	16	Moderate	N	N
Sacher P, Kolotourou M, Chadwick P et al. (2010)	116	53	103	NR [8–12]	Games, Sports, Other	120	9	NR	N	Y
Shaibi G, Cruz M, Ball G et al. (2006)	22	22	0	15 [NR]	Resistance training	120	16	NR	N	N
Tan S, Yang C, Wang J et al. (2010)	60	34	26	9.5 [NR]	Combined:Walk+Jump+Dance	250	8	NR	N	N
Tjonna A, Stolen TO, Bye A et al. (2009)	54	26	28	14.1 [NR]	Aerobic	80	12	Vigorous	N	N
Tsang T, Kohn M, Show C et al.(2009)	20	NR	NR	NR [12–18]	Tai Chi, Karate, Yoga	180	24	NR	N	N
Wong P, Chia M, Tsou I et al. (2008)	24	24	0	14 [13–14]	Combined:Aerobic+Strength	110	12	Moderate	N	N
Yu C, Sung R, Hau K et al. (2008)	82	54	28	10.5 [8–11]	Combined:Aerobic+Strength	225	6	Moderate	Y	N
Median [Min-Max]	41 [18–120]			10.9 [8.9–16.9]		120 [80–420]	12 [6–36]			

M = Males, F = Females, LSE = Lifestyle Education (ranged from nutritional counseling, physical activity information, and/or behavior change) NR = Not Reported, N= not included, Y= included

Table 2

Summary of changes in fitness measures reported for overweight or obese youth (Note: the number of fitness tests vary across the 33 studies).

Fitness Test	Non-significant[†]	Significant[†]	% Significant
Aerobic Tests			
Distance Run test	0	3	100%
Heart response (during/post)	0	6	100%
VO _{2max} direct-Bike	1	5	83%
VO _{2max} direct-Treadmill	1	9	90%
VO _{2max} estimate-Lab test	0	8	100%
Walk test	1	1	50%
Total	3	32	91%
Muscular Strength/ Muscular Endurance			
Curl-up or Sit-up	0	1	100%
Push-up	0	1	100%
Handgrip Dynamometer	0	1	100%
RM - Lower Body	2	3	60%
RM - Upper body	1	5	83%
Weighted Ball Throw	0	1	100%
Standing Broad Jump	0	2	100%
Total	3	14	82%

[†]Based on a reported statistical test *p*-value of >0.05 (non-significant) or 0.05 (significant) within the Intervention Group or Interaction effect compared to Control Group.

VO_{2max}= Maximal Oxygen Uptake; RM= Repetition Maximum

Table 3

Summary of adverse (-), null (Ø), and beneficial (+) changes in health outcomes when a study reported **significant** improvement (p<0.05) for a component of fitness (aerobic capacity, both aerobic and muscular strength/endurance, or muscular strength/endurance). Each study could contribute multiple health outcomes but falls under one of the 3 columns. Blank cells indicate no measures reported.

Health Outcome	Improvement in Fitness Component															
	Aerobic			Aerobic and Strength			Strength/Muscular Endurance			Total						
	-	Ø	+	-	Ø	+	-	Ø	+	-	Ø	+				
Adiposity/Obesity	0	17	36	68%	0	2	3	60%	0	10	5	33%	0	29	44	60%
BMI	0	8	11	58%	0	0	2	100%	0	3	2	40%	0	11	15	58%
% Body fatness	0	5	14	74%	0	1	0	0%	0	2	2	50%	0	8	16	67%
Fat mass	0	3	4	57%					0	4	1	20%	0	7	5	42%
Visceral Fat	0	1	3	75%					0	1	3	75%	0	1	3	75%
Waist circumference	0	0	4	100%	0	1	1	50%	0	1	0	0%	0	2	5	71%
Cardiovascular	0	45	25	36%	0	3	1	25%	0	10	1	9%	0	58	27	32%
C-Reactive Protein	0	6	1	14%					0	1	1	100%	0	6	2	25%
Systolic Blood Pressure	0	6	4	40%					0	1	0	0%	0	7	4	36%
Diastolic Blood Pressure	0	6	4	40%					0	1	0	0%	0	7	4	36%
HDL-Cholesterol	0	8	4	33%	0	1	0	0%	0	2	0	0%	0	11	4	27%
LDL-Cholesterol	0	7	2	22%	0	1	0	0%	0	2	0	0%	0	10	2	17%
Total Cholesterol	0	6	4	40%	0	1	0	0%	0	2	0	0%	0	9	4	31%
Triglyceride	0	6	6	50%	0	0	1	100%	0	2	0	0%	0	8	7	47%
Musculoskeletal	1	3	5	56%	0	3	3	50%	0	3	3	50%	1	6	8	53%
Bone Mineral Content	0	0	1	100%					0	0	1	100%	0	0	2	100%
Bone Mineral Density	0	0	1	100%									0	0	1	100%
Fat-free body mass	1	3	3	43%					0	3	2	40%	1	6	5	42%
Metabolic	0	24	20	45%	0	0	3	100%	0	12	2	14%	0	36	25	41%
Adiponectin	0	2	0	0%									0	2	0	0%
Apolipoprotein A-1	0	2	1	33%									0	2	1	33%
Apolipoprotein B	0	2	1	33%									0	2	1	33%
Blood Glucose -fasting	0	7	4	36%	0	0	1	100%	0	4	1	20%	0	11	6	35%

Health Outcome	Improvement in Fitness Component															
	Aerobic			Aerobic and Strength			Strength/Muscular Endurance			Total						
	-	0	+	%+	-	0	+	%+	-	0	+	%+				
Homeostasis Model (HOMA)	0	2	3	60%	0	0	1	100%	0	2	0	0%	0	4	4	50%
Insulin-like Growth Factor 1	0	0	1	100%					0	0	1	100%	0	0	1	100%
Interleukin 6	0	2	1	33%					0	2	1	33%	0	2	1	33%
Insulin -fasting	0	4	6	60%	0	0	1	100%	0	5	0	0%	0	9	7	44%
Insulin sensitivity	0	0	1	100%	0	1	1	50%	0	1	1	50%	0	1	2	67%
Leptin	0	1	1	50%					0	1	1	50%	0	1	1	50%
Tumor Necrosis Factor- alpha	0	2	1	33%					0	2	1	33%	0	2	1	33%
Mental/Emotional	0	0	1	100%	0	2	0	0%	0	2	0	0%	0	2	1	33%
Anxiety					0	1	0	0%	0	1	0	0%	0	1	0	0%
Cognitive	0	0	1	100%					0	0	1	100%	0	0	1	100%
Depression					0	1	0	0%	0	1	0	0%	0	1	0	0%
ALL HEALTH OUTCOMES	1	89	87	49%	0	5	7	58%	0	37	11	23%	1	131	105	44%