Contents

Part G. Section 9: Youth

Introduction

Physical activity in American children and adolescents has been a concern of authorities in education, medicine and public health for more than half a century. During most of this period, experts have focused on physical fitness rather than physical activity, per se. During the post-World War II era, concerns about military preparedness led to formation of the President's Council on Physical Fitness and Sports. The Council initiated a youth physical fitness testing program that was intended to promote participation in fitness-enhancing physical activity in children and adolescents. In association with that fitness testing program and others, standards for physical fitness in young people have been developed.

Although these standards for physical fitness in youth have been available for many years, only in the past decade have professional and scientific organizations presented guidelines for physical activity in children and youth. Different groups have taken various approaches to the task of identifying recommended levels of physical activity for young persons. Some expert panels have approached this task by focusing on the health effects of controlled exercise training in youth. Other groups have considered cross-sectional and longitudinal associations between physical activity and various health-related factors.

The task of relating physical activity to indicators of health and fitness is complex. Part of the complexity relates to 3 processes that are ongoing during the first 2 decades of life: normal physical growth, biological maturation, and behavioral development. These processes occur simultaneously and interact, especially during adolescence, making their individual and combined effects difficult to evaluate. Physical activity, a behavior that has its own developmental pattern, is only one of many factors that may influence indicators of health and fitness in youth. It may be difficult to partition effects attributed to physical activity from those associated with normal growth, maturation, and development.

Review of the Science

Overview of Questions Addressed

This chapter addresses key questions related to the relation between physical activity and a select number of health-related outcomes in children and adolescents. These outcomes are physical fitness, body composition, cardiovascular and metabolic disease risk factors, bone health, and mental health. For each of the selected health outcomes, the committee considered the following questions:

1. Is there a significant relation between physical activity and the outcome?

2. If so, has a dose-response pattern been established?

3. If a relation is evident, is it influenced by age, developmental status, sex, race/ethnicity, and/or socioeconomic status?

Data Sources and Process Used to Answer the Questions

The Youth subcommittee decided to apply 3 important delimitations in performing the review of scientific literature summarized here. First, the review was limited to studies of school-aged children aged 5 to 19 years. Although it certainly would be relevant to consider studies of younger children, it was the subcommittee's judgment that the scientific literature on physical activity and health is too limited in infants and preschool-age children to support clear conclusions.

Second, the subcommittee opted to focus its review on the relation between physical activity and the modest number of health-related outcomes noted above. Third, the subcommittee focused on the effects of physical activity on health outcomes as observed **during childhood and adolescence.** The subcommittee recognized the significance of the potential long-term effects of physical activity during childhood and adolescence on health outcomes later in life. It also was concerned about the potential influence of physical activity early in life with physical activity in adulthood. However, the subcommittee judged that the scientific literature pertinent to the latter 2 relationships is currently insufficient to inform physical activity guidelines. Hence, the review presented in this chapter is limited to an examination of the relation between physical activity and selected health-related outcomes during childhood and adolescence.

For each of the aforementioned health-related outcomes, the subcommittee performed a systematic evidence-based review of the literature using the *Physical Activity Guidelines for Americans* Scientific Database as its primary resource (see ***Part F. Scientific Literature Search Methodology***, for a detailed description of the Database). The review consisted of publications from 1995 onward, with the exception of some review papers on cardiorespiratory fitness. This was due to the fact that many studies on the effects of endurance training on cardiorespiratory fitness were published before 1995. The subcommittee examined reviews, meta-analyses, randomized controlled trials (RCTs), non-randomized controlled trials, prospective cohort studies, cross-sectional studies, and additional observational studies. As needed, the subcommittee also used systematic reviews, meta-analyses, and original studies from sources other than the Scientific Database.

Question 1: Is Physical Activity Significantly Related to Cardiorespiratory Fitness Among Children and Adolescents? If So, Is There an Established Dose-Response Pattern? Is the Relation Influenced by Age, Developmental Status, Sex, Race/Ethnicity, or Socioeconomic Status?

Conclusions on Relation and Dose-Response Pattern

Physical activity is positively related to cardiorespiratory fitness in children and youth, and both preadolescents and adolescents can achieve improvements in cardiorespiratory fitness with exercise training. Endurance training has been shown to increase VO_{2max} by 5% to 15%. Due to variability across studies, the optimal dose of physical activity needed to attain improvements in cardiorespiratory fitness cannot be specified (1;2). In a recent review, Baquet and colleagues (3) summarized the dose of exercise prescribed across 22 controlled training studies. They concluded that an intensity greater than 80% of maximal heart rate, a frequency of 3 to 4 days per week, a duration of 30 to 60 minutes per session, and a length of 1 to 3 months resulted in improvements in cardiorespiratory fitness (3).

Rationale for Relation and Dose-Response Pattern

This review of the literature was based on an evaluation of 2 review articles, 1 meta-analysis, 10 cross-sectional studies (Table G9.A1, which summarizes these cross-sectional studies can be found at http://www.health.gov/paguidelines/report/), 1 prospective cohort study, and 21 experimental studies. The experimental studies can be further classified as randomized trials (n=6), group randomized trials (n=3), non-randomized trials (n=8), before and after studies (n=2), and time series studies (n=2) (Table G9.A2, which summarizes these experimental studies, can be accessed at http://www.health.gov/paguidelines/report/). Typically, most cross-sectional studies either correlated cardiorespiratory fitness with physical activity levels or compared active youth to inactive youth. Cardiorespiratory fitness was assessed with a variety of methods, including step test, cycle ergometer, 20-meter shuttle run, and treadmill test. All of the studies reported an association between physical activity and cardiorespiratory fitness. In particular, Ara and colleagues (4) reported that males who participated in 3 hours of extracurricular physical activities per week in addition to regular physical education classes had significantly greater aerobic fitness compared to males who participated only in regular physical education classes. In another study, Dollman and colleagues (5) measured both sedentary behavior and moderate to vigorous physical activity. They reported that males who watched television for more than 2 hours per day and engaged in more than 60 minutes of moderate to vigorous physical activity (MVPA) had higher cardiorespiratory fitness compared to males who watched television for more than 2 hours per day but obtained less than 60 minutes of MVPA (5). Females who engaged in more than 60 minutes of MVPA (regardless of their television viewing habits) had greater cardiorespiratory fitness levels than females who obtained less than 60 minutes of MVPA (5). In all of the remaining cross-sectional studies, the dose of physical activity was not provided. Overall, cross-sectional studies concluded that youth with higher physical activity levels tended to have higher cardiorespiratory fitness levels.

In the only prospective cohort study that met the search criteria, Ara and colleagues (6) assessed physical activity in 42 boys with an average age of 9 years, and followed them for 3 years. The boys were divided into a physical activity group (participating in at least 3 hours of extracurricular physical activities per week plus regular physical education classes) and a non-physical activity group (participating only in regular physical education classes) (6). Cardiorespiratory fitness was assessed with the 20-meter shuttle run test. At the conclusion of the 3-year period, the physical activity group maintained their cardiorespiratory fitness levels, whereas the non-physical activity group decreased their cardiorespiratory fitness levels (6).

Most of the 21 experimental studies reported increases in cardiorespiratory fitness in a range from 5% to 15% with endurance training. The most common activities were aerobics, running, cycling, using exercise machines, stair climbing, basketball, and brisk walking. The dose of endurance training varied across studies. Frequency ranged from 1 to 5 days per week, duration was between 20 and 60 minutes per session, and intensity ranged from 70% to 90% of maximum heart rate (HRmax).

Conclusions on Developmental and Demographic Influences

Both children and adolescents can increase their cardiorespiratory fitness with endurance training, and males and females respond similarly to endurance training. The literature is not adequate to support a conclusion regarding race/ethnicity. Most studies did not report the socioeconomic status of participants, thereby precluding conclusions about the influence of this demographic factor.

Rationale for Developmental and Demographic Influences

Age and/or Developmental Status

Children and adolescents can achieve improvements in cardiorespiratory fitness with physical activity. Twenty-one experimental studies examining this relation have included subjects who range in age from 5 to 18 years. In all but one study (7), physical activity produced improvements in cardiorespiratory fitness, whether preadolescents, adolescents, or both were active.

Sex

Both males and females have demonstrated their capacity to attain similar improvements, ranging from 5% to 15%, in cardiorespiratory fitness as a result of endurance training (1;2;8-12).

Race/Ethnicity

Information about the potential influence of race/ethnicity on cardiorespiratory fitness in youth is limited. Most studies have focused on white children and adolescents, but of the 4 studies that examined the effect of endurance training on cardiorespiratory fitness in African American youth, all found significant improvements in cardiorespiratory fitness of 5% to 10% (8;10;13;14). Crews and colleagues (15) implemented a 12-week intervention among Hispanic children, and reported significant improvements (16%) in cardiorespiratory fitness.

Socioeconomic Status

Most studies did not report the socioeconomic status of participants, thereby preventing conclusions about the influence of this factor on physical activity and cardiorespiratory fitness.

Question 2: Is Physical Activity Significantly Related to Muscular Strength Among Children and Adolescents? If So, Is There an Established Dose-Response Pattern? Is the Relation Influenced by Age, Developmental Status, Sex, Race/Ethnicity, or Socioeconomic Status?

Conclusions on Relation and Dose-Response Pattern

Physical activity is positively related to muscular strength. In both children and adolescents, resistance training 2 or 3 times per week significantly improves muscular strength.

Rationale for Relation and Dose-Response Pattern

A total of 5 review articles and 2 non-randomized trials were included in this evaluation of the evidence. Malina (16) reviewed 22 experimental studies of pre- and early-pubertal youth and muscular strength training programs and reported a significant increase in muscular strength. Most of the resistance training programs were 8- or 12-week programs that consisted of 2- and 3-day sessions separated by days of rest; the range of all reviewed programs was 6 weeks to 21 months. Less than half of the studies reported intensities, but of those that did, training intensities ranged from 50% to 85% of 1 repetition maximum (1RM), with 75% 1RM being the most common. Conversely, when participants stopped the resistance training (detrained), they experienced a decrease in muscular strength. Growth and maturation were taken into account in this review, and Malina concluded that resistance training did not have a negative effect on these developmental factors among pre- and early-pubertal youth.

Blimkie and Bar-Or (17) reviewed 18 studies of adolescents and concluded that moderate to high training loads resulted in significant increases in muscular strength. However, Blimkie and Bar-Or also noted that for both preadolescents and adolescents, “the optimal combination of mode, intensity, volume and duration of training for strength increases…has yet to be determined" (p.115). Other review articles reported increases in muscular strength with resistance training among prepubertal children (18-20).

Treuth and colleagues (21) implemented a non-randomized resistance training study in a sample of obese girls aged 7 to 10 years. Over a period of 5 months, the girls trained with 6 upper body and 1 lower body exercises for 3 days per week, 20 minutes per session. The sequence of exercises for each session was leg press, bench press, military press, bicep curl, latissimus pull down, triceps extension, and sit-ups. Each participant performed 2 sets of 12 repetitions for the upper body exercises and 2 sets of 15 repetitions for the leg press. Weight was gradually increased throughout the program to 70% 1RM. At the conclusion of the trial, the intervention group significantly increased their 1RM bench press by 19.6%, 1RM leg press by 20%, and knee extensor strength by 35%.

Faigenbaum and colleagues (22) studied the effects of a 9-week non-randomized progressive resistance training study in boys aged 13 years. The program consisted of resistance training exercises 2 days per week for 90 minutes per session. A typical training session began with a 10-minute warm-up, followed by 2 or 3 types of Olympic-style lifts and then a series of resistance exercises: barbell squat, leg curl, bench press, front latissimus pull down, seated row, biceps curl, and triceps extension. For each exercise, 3 sets were performed, with 1 to 4 repetitions for the Olympic-style lifts per set, and with 12 to 15 repetitions decreasing to 8 to 10 repetitions for the resistance exercises per set. The program increased leg strength by 19% and upper body strength by 15%.

Conclusions on Developmental and Demographic Influences

Both children and adolescents can increase their muscular strength with resistance training, and males and females show similar relative increases in strength with resistance training. The literature is too limited to support conclusions about the influence of race/ethnicity and socioeconomic status.

Rationale for Developmental and Demographic Influences

Age and/or Developmental Status

Children, pre- and early-adolescents can improve their muscular strength with resistance training (16;18-20). In addition, resistance training does not have adverse effects on growth and maturation (16).

Sex

Both males and females can obtain increases in muscular strength with resistance training (21;22), although approximately half of the studies reviewed by Malina (16) were of males only.

Race/Ethnicity

Information about the potential influence of race/ethnicity on muscular strength is limited. Most studies have been conducted with white children and adolescents.

Socioeconomic Status

Most studies did not report the socioeconomic status of participants, thereby preventing conclusions about the influence of socioeconomic status on muscular strength.

Question 3: Is Physical Activity Significantly Related to Body Composition in Children and Adolescents? If So, Is There an Established Dose-Response Pattern? Is the Relation Influenced by Age, Developmental Status, Sex, Race/Ethnicity, or Socioeconomic Status?

Conclusions on Relation and Dose-Response Pattern

Among normal-weight youth, those who have relatively high levels of physical activity tend to have less adiposity than youth with low levels of physical activity. However, programs that increase physical activity in normal-weight youth typically have little effect on adiposity.

Controlled training studies with overweight/obese youth have observed reductions in overall adiposity and visceral adiposity with exposure to regular physical activity of moderate to vigorous intensity 3 to 5 times per week, for 30 to 60 minutes. The most consistent favorable effects of physical activity on adiposity were found in studies that used dual-energy x-ray absorptiometry (DXA) to estimate percent body fat and magnetic resonance imaging to estimate visceral adipose tissue (VAT), in contrast to studies based on body mass index (BMI) or skinfold estimates of percent body fat based on skinfold thicknesses. Evidence for a dose-response pattern is inconsistent in the studies reviewed.

Rationale for Relation and Dose-Response Pattern

Caveats

Indicators of body composition change with chronological age (CA) and associated changes in normal growth and maturation (18). As a result, it is difficult to partition physical activity effects from those expected with growth and maturation. On average, BMI declines during infancy and early childhood, reaches a nadir at about 5 to 7 years, and then increases through the remainder of childhood and adolescence. The timing of the increase is labeled the “adiposity rebound.” Fat-free mass (FFM) shows a growth pattern similar to that of height, with a major adolescent spurt; fat mass (FM) increases, on average, consistently with age. Percent fat (%F) increases during childhood but declines during adolescence in males and continues to increase at a slower pace in females during adolescence. Sex differences are negligible in BMI; they are small in FFM and FM during childhood and increase during adolescence (FFM males larger, FM females larger). The sex difference in %F (greater in females than males) is consistent from childhood through adolescence.

Indicators of body composition are also related to biological maturity status. On average, among youth of the same CA, those advanced in maturity status are larger in size, BMI, FFM, and FM compared to those "on time" or delayed in maturity status. With the exception of pubertal status, only one of the studies reviewed included age at peak height velocity (PHV) as a maturity indicator, while no studies incorporated skeletal age. Many studies included an estimate of pubertal status, either clinically assessed or self-reported stage of breast or pubic hair in girls, or genital or pubic hair in boys; menarcheal status is occasionally considered. Stages of breast and pubic hair and genital and pubic hair are not equivalent in girls and boys, respectively. Pubertal status so estimated simply means that the youth was in a particular stage; it provides no information about when the youth entered the stage or how long he or she had been in a stage. Further, pre-pubertal children (no overt signs of puberty) of the same CA can vary up to 3 to 4 years in skeletal age.

As an indicator of adiposity, BMI has limitations when evaluating the influence of physical activity in intervention studies. In normal-weight children, BMI is about equally correlated with FFM and FM and %F; it is a better indicator of overall body size (weight-for-height), not necessarily adiposity. In overweight and obese youth, BMI may be more highly correlated with %F, although some overweight or obese youth also have a large FFM. Activity may alter body composition without a change in BMI. In addition, BMI may have different meanings among ethnic groups, given well-established ethnic variation in body proportions (especially relative leg length and, by inference, relative upper limb length).

Measurement variability may be a factor in looking at changes in skinfolds with intervention training studies. In the studies reviewed, the change attributed to physical activity may be within the range of measurement error. Also, the standard error of estimation (SEE) of %F prediction equations from skinfolds is not considered; SEEs are in the range of 3-5%. A number of more recent studies use DXA, which should improve the precision of body composition estimates.

Evidence

This review of the evidence is based on an evaluation of 45 cross-sectional studies (Table G9.A3, which summarizes these cross-sectional studies, can be accessed at http://www.health.gov/paguidelines/report/), 21 prospective cohort studies, 21 experimental studies in normal-weight children and adolescents, and 16 training studies in the overweight and/or obese. The 37 training studies can be further classified as 13 randomized trials, 9 group randomized trials, 12 non-randomized trials, and 3 before-and-after studies. Study participants ranged in age from 3 to 18 years, and a variety of indicators of physical activity was used.

Cross-Sectional Studies

The majority of studies used correlation and regression, and samples were of mixed weight status (normal-weight, overweight, obese). Across studies, physical activity has a low and, at best, moderate relation with BMI, percent body fat, fat mass, and skinfold thicknesses. The correlations are reasonably consistent across studies considering the mix of methods used to measure and estimate physical activity. The magnitude of correlations and regression estimates indicates that physical activity accounts for a relatively small percentage of the variance in BMI and indicators of adiposity, and that other factors explain most of the variance. Nevertheless, youth who engage in more physical activity, specifically vigorous physical activity, tend to have less adiposity than those who engage in less physical activity (4;23-25).

Several analyses of cross-sectional data have suggested a number of steps per day and energy expenditure or physical activity that are necessary for maintaining normal weight in youth. Recommended cut-off points for normal weight children are 12,000 and 15,000 steps per day for girls and boys aged 6 to 12 years, respectively (26), and 13,000 and 16,000 steps per day for girls and boys aged 5 to 12 years, respectively (27). An association between 60 minutes per day of physical activity with an energy expenditure of 8 or more kcal/kg/day and acceptable levels of BMI and percent body fat also has been noted in youth aged 9-11 years (28).

Prospective Cohort Studies

The prospective cohort studies are of mixed designs and are at times difficult to interpret (Table G9.A4, which summarizes these prospective cohort studies, can be accessed at http://www.health.gov/paguidelines/report/). Several trends are apparent, however:

- The school-based CATCH intervention had no effect on BMI and skinfolds (29;30).
- The Nurses' Health Study II offspring showed smaller than expected estimated changes in BMI associated with physical activity, although the association may be of clinical relevance if the effects are cumulative (31;32).
- One study suggested that active children may have a later adiposity rebound than less active children, though it is not clear in the study whether the rebound was modeled in individual children (33).
- One study considered changes relative to estimated age at peak height velocity, with the results suggesting that an increase in physical activity may control the accrual of fat mass from childhood through adolescence in males (34).
- Other studies generally show a small relation between physical activity levels and changes in indicators of adiposity or mixed results.

Experimental Studies in Children of Normal Weight or Mixed Weight Status

With few exceptions, experimental studies show a small increase in BMI and adiposity indicators, or no significant changes in the BMI and adiposity indicators with training (Table G9.A5, which summarizes these experimental studies, can be accessed at http://www.health.gov/paguidelines/report/). Training protocols varied among studies, but the majority focused on relatively continuous activity, primarily endurance activities. Durations of protocols also varied — less than 10 weeks (6 studies); 10 to 15 weeks (8 studies); 16 to 20 weeks (2 studies); longer than 20 weeks (7 studies) — but results do not appear to vary with protocol duration. Of the studies with durations longer than 20 weeks, results were mixed. A 10-month intervention of continuous activity (35) showed a significant reduction in percent body fat, but a 10-month intervention of brief high-impact physical activity (36) showed no effect on weight and fat mass. Results were similar when the brief high-impact physical activity intervention was extended over 2 years (37). Two interventions that extended over 1 school year had different results, with Schneider and colleagues (38) showing no effect of physical activity on percent body fat and Viskic and colleagues (39) showing a larger decrease in percent body fat in the experimental compared to the control group. One study over 2 school years showed a smaller gain in BMI in an intervention group that included parental support compared to a control group and an intervention group without parental support (40). An even longer study, which extended over 3 to 4 years, showed no influence of added physical education on fat mass (41).

Two studies (35;42;43) were conducted in which investigators did not specifically choose youth who were overweight or obese to participate. However, the youth who chose to participate had mean baseline BMIs that met the International Obesity Task Force criteria for overweight. The studies used a relatively large dose of moderate to vigorous physical activity (80 minutes per day, 5 days per week for 8 months (42) and 10 months (35)) and noted a small but significant reduction in percent body fat. Youth with better attendance had a larger decline in percent body fat (43) and a smaller increase in BMI (35) over the course of the study.

Experimental Studies in Overweight or Obese Children

Results among studies are somewhat variable, but most suggest a decline in BMI and percent body fat in overweight or obese youth with training, though there are several exceptions (Table G9.A6, which summarizes these experimental studies, can be accessed at http://www.health.gov/paguidelines/report/). The most consistent results for percent body fat and visceral adipose tissue are Gutin and colleagues (8;35;42-46). Most studies use continuous, largely aerobic activity, 3 to 5 times per week for 30 to 60 minutes. Durations vary: 8 weeks (1 study); 10 weeks (1 study); 12 weeks (4 studies); 3 to 5 months (4 studies); 6 to 10 months (4 studies). Two studies of strength training show minimal effects on adiposity in obese youth (21;47).

Conclusions on Developmental and Demographic Influences

Variations in the effects of physical activity on adiposity associated with age, sex, biological maturity status, race/ethnicity, and socioeconomic status have not been systematically considered in the literature. Studies are variable in controlling for the potential influence of age per se and maturity status in the respective analyses. No conclusions regarding the effects of age and maturity can be made at this time.

Question 4: Is Physical Activity Significantly Related to Cardiovascular and Metabolic Health in Children and Adolescents? If So, Is There an Established Dose-Response Pattern? Is the Relation Influenced by Age, Developmental Status, Sex, Race/Ethnicity, or Socioeconomic Status?

Conclusions on Relation and Dose-Response Pattern

Physical activity is positively related to cardiovascular and metabolic health in youth. A dose-response relation appears to exist, in that greater doses of physical activity are associated with higher levels of cardiovascular and metabolic health. However, the precise pattern of the dose-response relation has not yet been determined.

Rationale for Relation and Dose-Response Pattern

To examine the relation between physical activity and cardiovascular and metabolic health, a total of 43 studies were considered: 21 experimental studies, 2 prospective cohort studies, and 20 cross-sectional studies. Of the 21 experimental studies, 13 were randomized trials, 2 were group randomized trials, 2 were non-randomized trials, 2 were time series studies, 1 was a before-and-after study, and 1 was another type of study that included a comparison group.

Physical activity may exert much of its influence on cardiovascular and metabolic health by enhancing fitness and reducing fatness, which in turn influence the underlying processes leading to cardiovascular disease and type 2 diabetes. Thus, studies typically have focused on risk factors for these two diseases, namely fasting levels of insulin, lipids, and inflammatory markers. Some recent studies have gone further to determine whether physical activity influences mechanisms, such as cardiac parasympathetic activity, and end-organ parameters, such as endothelial function, left ventricular (LV) geometry and function, arterial stiffness, and carotid intima-media thickness (IMT). Because so little information is currently available on these variables, and because of the interrelations among them and the cardiovascular disease/type 2 diabetes risk factors, we have tried to draw generalizations across the entire risk profile.

Observational studies have reported that youth who engage in relatively large amounts of physical activity have more favorable risk profiles than youth who engage in relatively little physical activity (48-56). Because RCTs have shown that physical activity decreases total body and visceral fatness (35;45;46), which are themselves related to poor risk status (57), it is noteworthy that, to some degree, the association of physical activity to favorable risk profile is retained even after controlling for the possible mediating effect of body fatness (58-62). Some evidence indicates that the relation of physical activity to improved insulin sensitivity is clearer in boys than in girls (63). Evidence also suggests that the relation between level of physical activity and lipids and lipoproteins is primarily with triglycerides and HDL-cholesterol; physical activity has little influence on LDL-cholesterol. However, in children with elevated LDL-cholesterol, increased levels of physical activity may be associated with a prospective trend to lower LDL-cholesterol (64).

In recent years, a metabolic syndrome underlying cardiovascular disease and type 2 diabetes has been identified in adults, and the concept of risk factor clustering as being especially detrimental has been extended to youth (65). When investigators have derived clustering scores, they have found that youth who engaged in more physical activity had better scores than did inactive youth (53).

Investigations of physical activity and risk profiles have generally focused on aerobic physical activity. However, some evidence is available that youth with substantial muscle strength, as a proxy for strength-building physical activity, have good insulin sensitivity (66). This subject deserves further study.

Taken together, the observational results support the hypothesis that physical activity is associated with a favorable risk profile. A number of studies have tested this hypothesis using controlled interventions. Because of the potential role of fatness as a mediator of the relation between physical activity and risk profile, many RCTs have used subjects who were obese at baseline.

The information available from such intervention trials in obese youth suggests that controlled physical activity programs lasting 2 to 8 months have favorable effects on many indices of cardiovascular and metabolic health, including insulin sensitivity, lipid profile, indices of inflammation, endothelial function, cardiac parasympathetic activity, and carotid IMT (10;44;67-72). It appears that the favorable effects of physical activity on lipids are clearest in youth who exhibit an especially elevated risk status at baseline (10;69). Some studies have shown that physical activity interventions led to improvements in insulin sensitivity or lipid profile that were to some degree independent of changes in body fatness (73-75). However, obese youth who participated in a school-based physical activity intervention and who improved in fitness, fatness and fasting insulin concentration (76), lost their gains over the subsequent summer when they were not engaged in regular physical activity (77). This shows the importance of maintaining exposure to physical activity on a long-term and continuous basis.

In contrast to results from physical activity intervention studies in obese youth, studies of youth who varied over the spectrum of fatness at baseline, have generally failed to provide evidence that physical activity reduced fatness or improved risk profiles (7;78;79). This discrepancy between the results of observational and intervention studies suggests that the dose of physical activity needed in these subjects may be greater than that needed to elicit such changes in obese youth. Research is needed on the impact of physical activity interventions carried on for extended periods of time. Because of the difficulty of conducting RCTs over the periods of time needed to produce substantial changes in body fatness (i.e., years rather than months), conclusive evidence from RCTs is quite difficult to obtain.

An important aspect of the physical activity–health relationship is the dose of physical activity that is associated with favorable risk status. However, relatively little clear information is available on this matter. The limited information available from observational studies suggests that at least 360 minutes per week of moderate-to-vigorous physical activity is associated with a good risk profile (53). With respect to a desired intensity of physical activity, some evidence indicates that vigorous physical activity, such as that found in sports, may be more closely related to a favorable risk status than is moderate physical activity (51;58). This is consistent with studies showing that vigorous physical activity, more so than moderate physical activity, is associated with lower amounts of fatness (80-83).

In the general population of youth, few experimental data exist to show a beneficial effect of physical activity on fatness or risk status, perhaps because the few investigations available used relatively small doses of physical activity. It is likely that doses of controlled moderate-to-vigorous physical activity greater than 300 minutes per week are needed for such youth to prevent accretion of general and visceral fat (35). Even when an intervention that employed a dose of this size had a favorable effect on fatness, the changes in risk profile of the intervention and control groups did not reach significance (42). It may be necessary for youth to maintain the lower levels of fatness for years in order to see clear effects on the fatness-associated risk profile.

Taken together, the observational and experimental evidence supports the hypothesis that maintaining high amounts and intensities of physical activity starting in childhood and continuing into the adult years will enable people to maintain a favorable risk profile, less end-organ damage, and lower rates of morbidity and mortality from cardiovascular disease and type 2 diabetes mellitus. Taken collectively, the research suggests that moderate-to-vigorous physical activity for at least 1 hour per day would help youth to maintain a healthy cardiovascular disease and type 2 diabetes risk profile. Higher volumes or intensities of physical activity probably have greater benefit.

Conclusions on Developmental and Demographic Influences

Very little is known about the effects of age, developmental status, sex, race/ethnicity, and socioeconomic status on the relation of physical activity to cardiovascular disease and type 2 diabetes risk status.

Rationale for Developmental and Demographic Influences

Very few studies have investigated interactions of physical activity with age, developmental status, sex, race/ethnicity, or socioeconomic status. Of those that have investigated such interactions, some have reported contradictory findings. For example, a study of Danish children found that physical activity was inversely related to insulin resistance in girls, but not in boys (61) whereas a study of American youth found the opposite result, namely that greater physical activity was associated with better insulin sensitivity in boys, but not in girls (63). Thus, interactions of physical activity with these factors are an important topic for future investigations.

Question 5: Is Physical Activity Significantly Related to Bone Health in Children and Adolescents? If So, Is There an Established Dose-Response Pattern? Is the Relation Influenced by Age, Developmental Status, Sex, Race/Ethnicity, or Socioeconomic Status?

Conclusions on Relation and Dose-Response Pattern

Bone-loading physical activity increases bone mineral content and density. Targeted weight-loading activities that simultaneously influence muscular strength, done 3 or more days per week are effective. It is challenging to compare mode and dose, as some studies observed or implemented jumping activities, some used weight-bearing games, and some examined resistance training activities. Intensities are reported as ground-reaction force (GRF), levels from moderate to vigorous, or as a percent of the 1RM. Rarely do doses vary within a study, supporting the need for dose-response studies.

Rationale for Relation and Dose-Response Pattern

The literature from 1995 to the present yielded 17 RCTs, 5 group randomized trials (2 of which published follow up data 9 to 12 months after study completion), and 7 prospective cohort studies that examined the relation between physical activity and bone health. Specific outcome measures included at least one of the following: bone mineral content (BMC), bone mineral density (BMD), bone area (BA), stiffness index (SI), bone geometry and strength, and periosteal circumference.

The osteogenic potential of physical activity is determined by the magnitude of the external load, the dynamic nature of the load, the rate at which the load is introduced, and the duration of the loading bout (84). Weight-bearing activities that introduce stress to the skeleton through either GRF (e.g., running, jumping) or high-intensity joint-reaction forces (e.g., weight lifting) have a greater effect on bone mineral accretion than do weight-supported activities (e.g., bicycling, swimming), and may be more effective in reducing future risk of osteoporosis (85).

Studies that report a GRF show a minimum load or dose of 3X body weight (BW) to be effective in changing BMC. Short duration bouts with GRF more than 5X BW have produced effects in the femur (86) and tibia (87), compared to growth-related changes in controls participating in usual weight-bearing activity during physical education classes, with loads less than 5X BW.

Studies that focused on high-intensity jumping (at least 3X BW) for 3 to 12 minutes at a time, at least 3 days per week, showed an effect on femoral neck or greater trochanter BMD (37;88-90). Adding high-intensity weight-bearing physical activity (12 minutes, 3 times per week) to school-based physical education classes resulted in positive gains in BMC of the spine and hip after 7 months in early pubertal girls and pre-pubertal boys and then at 20 months in pre-pubertal boys and pubertal girls (36;37;88;91). Boys also demonstrated changes in bone structural geometry (bone strength) after 20 months.

In most studies, an exercise or physical activity regimen of at least 2 days per week (35) and up to 5 days per week (87;92) resulted in positive effects on bone health. Most studies implemented the intervention 3 days per week (36;37;88;90;91). The majority of studies have been conducted over a 6 to 20 month period. A duration of only 6 months was too short to demonstrate significant changes in some of the studies (93) and yet one study showed a positive effect after just 4 months of high-intensity jumping rope (GRF=3.2 X BW) in girls aged 14 to 15 years (94).

Conclusions on Developmental and Demographic Influences

The relation between physical activity and bone health is influenced by age and developmental status. A number of studies suggest that the window of opportunity for the effects of physical activity on bone mineralization in both boys and girls is during early puberty and pre-menarchal years. During the period of peak BMC velocity (12.7 years for girls; 14.1 years for boys), a greater increase in BMC is seen for highly active than less active children. The bone health of both boys and girls is improved by physical activity. Limited information is available about the influence of race/ethnicity because most studies examined only white children and many studies did not report race at all. Most of the published studies do not routinely present data on socioeconomic status, so it is difficult to determine whether differences exist on this demographic parameter.

Rationale for Developmental and Demographic Influences

Age and/or Developmental Status

The effect of mechanical loading on the skeleton is dependent on both age and maturity (i.e., hormone levels) (95), particularly around the peak BMC velocity. A number of recent studies showing positive effects from physical activity suggest that the window of opportunity for bone mineralization effects resulting from the activity, in both boys and girls, is during early puberty and pre-menarchal years (36;90;91;96-99). Recently, MacDonald and colleagues showed an effect on distal tibia strength in pre-pubertal boys, not girls, using peripheral quantitative computed tomography (pQTC), after a 16-month intervention period (87). These studies have shown effects for trabecular bone in particular, although some have demonstrated an effect on cortical bone (87;99). Some studies in menarchal or post menarchal girls have not shown greater improvements in bone mineral content compared to controls (93;100;101), though others have shown improvement (37;94;102;103). It is difficult to put an age to the prepubescent period because increases in obesity boost adiposity, which may influence the biologic age at which it occurs and hence the window of opportunity. However, most of the prepubertal studies have examined 8-12 year olds and the pubertal/post pubertal studies have examined 12-15 year olds. Only one study examined preschoolers ages 3 to 5 years (92), and found an increase in periosteal circumference after 12 months of gross motor physical activity.

Physically inactive children may fail to realize their potential for peak bone mass during the growing years, particularly the pre-pubescent and pubertal period. Given the inadequate levels of physical activity among American youth of all ages, the long-term consequences on bone health may present a serious disease burden in future decades. Therefore, from a public health perspective it is difficult to confine the advice to youth who are verging on or at puberty.

Sex

The bone health of both boys and girls benefits from physical activity. The majority of studies focused on girls, but 4 randomized studies have shown effects in boys, all of whom were pre-pubertal at baseline (87;88;91;96).

Race/Ethnicity

Most of the studies have been performed with white children and some with Asian children (36;37;88;91), although many studies do not report race/ethnicity at all. Barbeau recently reported the gains in total body BMD in black girls ages 8 to 12 years after a 10-month physical activity program (35). This study showed a positive relation between gains in fitness and increases in total body BMD and BMC.

Socioeconomic Status

Most of the published RCT and group RCT studies did not present data on socioeconomic status so it is difficult to determine whether such differences exist.

Question 6: Is Physical Activity Significantly Related to Mental Health in Children and Adolescents? If So, Is There an Established Dose-Response Pattern? Is the Relation Influenced by Age, Developmental Status, Sex, Race/Ethnicity, or Socioeconomic Status?

Conclusions on Relation and Dose-Response Pattern

Physical activity during childhood and adolescence exerts a beneficial effect on several mental health outcomes. These include symptoms of anxiety and depression, self-esteem, and physical self-concept. The varying methodologies and insufficient numbers of intervention trials preclude inferences about dose-response patterns.

Rationale for Relation and Dose-Response Pattern

Although the burden of poor mental health is understudied in youth, the prevalence of psychiatric disorders and symptomatology is known to be substantial. The lifetime prevalence of major depression among youth has been estimated to be between 15% and 20% (104). Twice as many female as male youth have reported symptoms of major depression (105). An even broader spectrum of mental well-being is particularly relevant to youth populations, including self-esteem and academic performance.

A burgeoning body of evidence documents the effects of physical activity on neurological and psychological processes in adults, and the number of studies in children and adolescents also is growing. The evidence for the former has been described in detail elsewhere in this report in ***Part G. Section 8: Mental Health***. The quality of the evidence base for youth, especially the relatively few RCTs and longitudinal population-based cohort studies, constrain the aspects of mental health that may be examined in this brief synthesis. Although a limited number of studies have examined the association between physical activity and mental health among youth, they indicate an inverse association between physical activity and depressive symptoms (15;106-114) and anxiety (15;107;110;111;114). Studies also indicate a positive association between physical activity and self-esteem and self-concept (14;107;111;115-119). In addition, some research studies indicate an association between physical activity and academic performance (42;108;120-122). Twelve primary research articles were reviewed: 1 randomized controlled trial, 2 group RCTs, 2 prospective cohort studies, 3 non-randomized trials, and 4 cross-sectional studies. The outcomes targeted in these studies were depressive symptoms, anxiety, academic performance, and self-esteem/ self-concept.

Depressive Symptoms

Of the 6 identified studies that measured depressive symptoms, 2 were intervention trials (one randomized and one non-randomized), 1 was a prospective cohort study, and 3 were cross-sectional studies.

The randomized trial was a 12-week intervention implemented in 66 Hispanic fourth graders (15). The aerobic group participated in physical activities and maintained a mean heart rate of 134 beats per minute for 20 minutes, 3 days per week (15). The authors concluded that the moderate to vigorous physical activity obtained during the intervention reduced depressive symptoms (15). Annesi and colleagues (109) implemented a 12-week non-randomized intervention among 90 children aged 9 to 12 years, and found a significant decrease in depression and a significant improvement in mood. Too few intervention trials were found to permit assessment of dose-response or separate influences of different activity types.

Motl and colleagues (106) followed 7th graders prospectively for 2 years and assessed non-school related physical activity and depressive symptoms. They determined that changes in physical activity were inversely related to changes in depressive symptoms over the 2-year period (106). Recent longitudinal cohort studies also have suggested associations between lower levels of emotional symptoms and peer problems among boys who were physically active 3 years earlier (117).

All of the 3 cross-sectional studies found an inverse relation between physical activity and depressive symptoms. Parfitt and Eston (107) measured physical activity objectively with pedometers, and depression with the Childhood Depression Inventory among 70 children aged 10 years, and they reported an inverse correlation between physical activity and depressive symptoms ($r = -0.60$) (107). The 2 other cross-sectional studies measured sports participation and depressive symptoms of 89 youth in 12th grade (108) and 1,038 high school students (110). Field and colleagues (108) reported that youth who were more physically active had significantly less depressive symptoms than their less-active peers, and Pastor and colleagues (110) reported a negative correlation between sports participation and depressive symptoms ($r = -0.14$). A recent expert panel review also found cross-sectional data that demonstrated weak inverse associations between physical activity and scores on measures of depressive symptoms (123).

Further, the same expert panel review found quasi-experimental studies that showed strong positive effects of physical activity in decreasing anxiety scores (123). Too few intervention trials were found to permit assessment of dose-response or separate influences of different activity types, however. Several recent cross-sectional studies have linked higher levels of physical activity to higher mental health scores and fewer feelings of sadness and suicidal ideation in ethnically and/or socioeconomically diverse samples, although evidence is insufficient to draw conclusions about differential sociodemographic effects (124;125).

Anxiety

Of the 3 identified studies that measured anxiety, 1 was a randomized trial, and 2 were cross-sectional studies. One of the cross-sectional studies, which focused on children aged 10 years (107), found an inverse association between objectively measured physical activity and anxiety ($r = -0.48$). In the other, which examined a large sample of high school students (n=1,038), Pastor and colleagues (110) reported a small, but significant inverse relation between sports participation and anxiety (r = −0.07). Conversely, a randomized trial of 66 Hispanic children in 4th grade did not produce changes in anxiety symptoms (15). The recent expert panel review mentioned previously found cross-sectional data to have demonstrated weak inverse associations between physical activity and scores on measures of anxiety symptoms (123).

Academic Performance

Four studies assessed the relation between physical activity and academic performance: 2 group RCTs, 1 prospective cohort study, and 1 cross-sectional study. Sallis and colleagues (120) administered the SPARK physical education program among 754 children in 4th to 6th grade, using 2 levels of implementation (Physical Education Specialists and Trained Teachers) compared to a control group (standard physical education). The SPARK program consisted of 30-minute sessions at least 3 times per week. Academic performance was measured with the Metropolitan Achievement Tests (120). The authors concluded that the SPARK program had a favorable effect on academic achievement. The students in the Specialist condition had significantly higher reading scores compared to the control group, and the students in the Trained Teacher condition had significantly higher language, reading, and basic battery scores compared to the control group (120). In addition, the SPARK program had no detrimental effects on academic performance even though it involved a significant investment of time (2 times the amount of instruction per week compared to the control group) (120).

Yin and colleagues (42) implemented the Georgia FitKid Project among 525 children in 3rd grade. The program consisted of 80-minute physical activity sessions 3 days per week, and academic performance was assessed with criterion-referenced competency tests. The authors reported no differences in academic scores between the intervention group (with 40%+ attendance) and the control group (42).

The 2 remaining studies found a positive relation between physical activity and academic performance. A total of 214 children in 6th grade were observed prospectively, and youth who met the Healthy People 2010 vigorous physical activity standards had higher academic scores compared to their peers who did not meet the standards (121). Field and colleagues (108) reported a cross-sectional positive association between physical activity and grade point average.

These findings are consistent with recent reviews of the literature. Although observational studies have consistently found relationships between physical fitness and grades and test scores, those between physical activity and direct measures of academic achievement often have had null findings (126;127). Similarly, intervention studies have been few in number, often had design weaknesses, and infrequently demonstrated improvements in academic achievement (126;127). They have, however, generally found no decrements in academic outcomes, despite substitution of activity time for didactic instruction (126). Salutary effects on indirect measures of academic performance, such as on-task behavior, disruptiveness, memory, concentration, and homework completion, have more consistently been linked to physical activity (123;126;128).

Self-Esteem and Self-Concept

DeBate and colleagues (115) assessed the impact of the *Girls on the Run* program on self-esteem of 322 girls aged 8 to 12 years. The program consisted of 60-minute sessions 2 days per week, and self-esteem was measured with the Rosenberg self-esteem scale (115). The authors concluded that self-esteem increased significantly (115). In a cross-sectional study of 70 children aged 10 years, physical activity (assessed by pedometry) was positively associated with global self-esteem ($r = 0.66$) (107). Annesi and colleagues (14) implemented a non-randomized trial among 570 African American children that consisted of physical activity sessions for 45 minutes, 3 days per week for 12 weeks. They determined that exercise self-efficacy increased among girls aged 9 to 12 years, but no changes were detected in boys or younger girls (14). Lastly, Dishman and colleagues (116) reported a positive association between physical self-concept and physical activity among 1,250 girls in 12th grade.

Conclusions on Developmental and Demographic Influences

It is difficult to draw conclusions about age and sex because most relevant studies have included children or adolescents within a narrow range of ages and a single sex, precluding sub-group analyses by age or sex. Favorable influences have been reported across age groups, but within-study comparisons have not generally been reported. Similarly, most studies do not analyze data by race/ethnicity or socioeconomic status; therefore, it is difficult to make conclusions about their influence on the relation between physical activity and mental health.

Overall Summary and Conclusions

The subcommittee's review of the scientific literature supports the overall conclusion that physical activity provides important health benefits for children and adolescents. This conclusion is based on findings of observational studies in which higher levels of physical activity were found to be associated with more favorable health parameters as well as experimental studies in which exercise treatments caused improvements in health-related factors. The documented health benefits include increased physical fitness (both cardiorespiratory fitness and muscular strength), reduced body fatness, favorable cardiovascular and metabolic disease risk profiles, enhanced bone health, and reduced symptoms of depression and anxiety.

The types and amounts of physical activity required to produce health benefits vary across the health outcomes. Also, because of limitations in the scientific evidence base, it is not possible to draw definitive conclusions regarding the minimal or optimal doses of physical activity needed to provide health benefits in young persons. Nonetheless, considering all the evidence, the subcommittee concluded that important health benefits can be expected to accrue to most children and youth who participate daily in 60 or more minutes of moderate to vigorous physical activity. Further, the subcommittee concluded that certain specific types of physical activity must be included in an overall physical activity pattern in order for children and youth to gain comprehensive health benefits. These include regular participation in each of the following types of physical activity on 3 or more days per week: resistance exercise to enhance muscular strength in the large muscle groups of the trunk and limbs, vigorous aerobic exercise to improve cardiorespiratory fitness and cardiovascular and metabolic disease risk factors, and weight-loading activities to promote bone health. It is the subcommittee's judgment that these specific types of physical activity can be appropriately performed to create a 60 minute or more per day activity pattern.

The subcommittee was not charged with considering the scientific literature on behavioral and programmatic interventions to provide and promote physical activity in children and youth. Nonetheless, the subcommittee feels strongly that young persons should obtain their health-promoting physical activity in ways that will allow them to attain health benefits over the short term as well as encourage them to maintain a physically active lifestyle over the long term. Experiences that are consistent with these goals involve participation in physical activities that are developmentally appropriate, that minimize the potential risks of overtraining and injuries, and that provide participants with opportunities for enjoyable participation in a wide range of specific forms of physical activity.

Research Needs

In reviewing the scientific literature, it became apparent that many research needs exist regarding the health benefits of physical activity among youth. Specifically, the subcommittee recommends that research be conducted to:

- Determine the types and amounts of physical activity that are needed to prevent the development of excessive adiposity during childhood and adolescence;
- Establish the dose-response pattern for the relation between physical activity and bone health in children and adolescents;
- Identify the optimal types and amounts of physical activity to maintain cardiovascular and metabolic health during childhood and adolescence;
- Determine whether physical activity affects classroom behavior and academic achievement in children and adolescents; and
- Determine the extent to which age, developmental status, sex, race/ethnicity, and socioeconomic status influence the effects of physical activity on body composition, cardiovascular and metabolic health, bone health, and mental health.

Reference List

1. Shephard RJ. Effectiveness of training programmes for prepubescent children. Sports Med. 1992 Mar;13(3):194-213.

2. Payne VG, Morrow JR, Jr. Exercise and VO2 max in children: a meta-analysis. Res.Q.Exerc.Sport 1993 Sep;64(3):305-13.

3. Baquet G, van PE, Berthoin S. Endurance training and aerobic fitness in young people. Sports Med. 2003;33(15):1127-43.

4. Ara I, Vicente-Rodriguez G, Jimenez-Ramirez J, Dorado C, Serrano-Sanchez JA, Calbet JA. Regular participation in sports is associated with enhanced physical fitness and lower fat mass in prepubertal boys. Int.J.Obes.Relat Metab Disord. 2004 Dec;28(12):1585-93.

5. Dollman J, Ridley K. Differences in body fatness, fat patterning and cardio-respiratory fitness between groups of Australian children formed on the basis of physical activity and television viewing guidelines. J.Phys.Act.Health 2006;3(2):191-9.

6. Ara I, Vicente-Rodriguez G, Perez-Gomez J, Jimenez-Ramirez J, Serrano-Sanchez JA, Dorado C, Calbet JA. Influence of extracurricular sport activities on body composition and physical fitness in boys: a 3-year longitudinal study. Int.J.Obes.(Lond) 2006 Jul;30(7):1062-71.

7. Stoedefalke K, Armstrong N, Kirby BJ, Welsman JR. Effect of training on peak oxygen uptake and blood lipids in 13 to 14-year-old girls. Acta Paediatr. 2000 Nov;89(11):1290-4.

8. Gutin B, Cucuzzo N, Islam S, Smith C, Stachura ME. Physical training, lifestyle education, and coronary risk factors in obese girls. Med.Sci.Sports Exerc. 1996 Jan;28(1):19-23.

9. McManus AM, Armstrong N, Williams CA. Effect of training on the aerobic power and anaerobic performance of prepubertal girls. Acta Paediatr. 1997 May;86(5):456-9.

10. Ewart CK, Young DR, Hagberg JM. Effects of school-based aerobic exercise on blood pressure in adolescent girls at risk for hypertension. Am.J.Public Health 1998 Jun;88(6):949-51.

11. Williford HN, Blessing DL, Scharff-Olson M, Brown J. Injury rates and physiological changes associated with lateral motion training in females. Int.J.Sports Med. 1996 Aug;17(6):452-7.

12. Adiputra N, Alex P, Sutjana DP, Tirtayasa K, Manuaba A. Balinese dance exercises improve the maximum aerobic capacity. J.Hum.Ergol.(Tokyo) 1996 Jun;25(1):25-9.

13. Williford HN, Blessing DL, Duey WJ, Barksdale JM, Wang N, Olson MS, Teel S. Exercise training in black adolescents: changes in blood lipids and Vo2max. Ethn.Dis. 1996;6(3-4):279-85.

14. Annesi JJ, Westcott WL, Faigenbaum AD, Unruh JL. Effects of a 12-week physical activity protocol delivered by YMCA after-school counselors (Youth Fit for Life) on fitness and self-efficacy changes in 5-12-year-old boys and girls. Res.Q.Exerc.Sport 2005 Dec;76(4):468-76.

15. Crews DJ, Lochbaum MR, Landers DM. Aerobic physical activity effects on psychological well-being in low-income Hispanic children. Percept.Mot.Skills 2004 Feb;98(1):319-24.

16. Malina RM. Weight training in youth-growth, maturation, and safety: an evidence-based review. Clin.J.Sport Med. 2006 Nov;16(6):478-87.

17. Blimkie CJR, Bar-Or O. Trainability of muscle strength, power and endurance during childhood. In: Bar-Or O, editor. The Child and Adolescent Athlete. Oxford: Blackwell Science; 1996. p. 113-29.

18. Malina RM, Bouchard C, Bar-Or O. Growth, maturation, and physical activity. Champaign, Ill: Human Kinetics; 2004.

19. Mahon AD. Exercise training. In: Armstrong N, van Mechelen W, editors. Paediatric Exercise Science and Medicine. Oxford: Oxford University Press; 2000. p. 201-22.

20. Bar-Or O, Rowland TW. Pediatric exercise medicine : from physiologic principles to health care application. Champaign, IL: Human Kinetics; 2004. p. 46-59.

21. Treuth MS, Hunter GR, Pichon C, Figueroa-Colon R, Goran MI. Fitness and energy expenditure after strength training in obese prepubertal girls. Med.Sci.Sports Exerc. 1998 Jul;30(7):1130-6.

22. Faigenbaum AD, McFarland JE, Johnson L, Kang J, Bloom J, Ratamess NA, Hoffman JR. Preliminary evaluation of an after-school resistance training program for improving physical fitness in middle school-age boys. Percept.Mot.Skills 2007 Apr;104(2):407-15.

23. Forshee RA, Anderson PA, Storey ML. The role of beverage consumption, physical activity, sedentary behavior, and demographics on body mass index of adolescents. Int.J.Food Sci.Nutr. 2004 Sep;55(6):463-78.

24. Kawabe H, Murata K, Shibata H, Hirose H, Tsujioka M, Saito I, Saruta T. Participation in school sports clubs and related effects on cardiovascular risk factors in young males. Hypertens.Res. 2000 May;23(3):227-32.

25. Schmidt GJ, Stensel DJ, Walkuski JJ. Blood pressure, lipids, lipoproteins, body fat and physical activity of Singapore children. J.Paediatr.Child Health 1997 Dec;33(6):484-90.

26. Tudor-Locke C, Pangrazi RP, Corbin CB, Rutherford WJ, Vincent SD, Raustorp A, Tomson LM, Cuddihy TF. BMI-referenced standards for recommended pedometer-determined steps/day in children. Prev.Med. 2004 Jun;38(6):857-64.

27. Duncan JS, Schofield G, Duncan EK. Step count recommendations for children based on body fat. Prev.Med. 2007 Jan;44(1):42-4.

28. Wittmeier KD, Mollard RC, Kriellaars DJ. Objective assessment of childhood adherence to Canadian physical activity guidelines in relation to body composition. Appl.Physiol Nutr.Metab 2007 Apr;32(2):217-24.

29. Luepker RV, Perry CL, McKinlay SM, Nader PR, Parcel GS, Stone EJ, Webber LS, Elder JP, Feldman HA, Johnson CC, et al. Outcomes of a field trial to improve children's dietary patterns and physical activity. The Child and Adolescent Trial for Cardiovascular Health. CATCH collaborative group. JAMA 1996 Mar 13;275(10):768-76.

30. Nader PR, Stone EJ, Lytle LA, Perry CL, Osganian SK, Kelder S, Webber LS, Elder JP, Montgomery D, Feldman HA, et al. Three-year maintenance of improved diet and physical activity: the CATCH cohort. Child and Adolescent Trial for Cardiovascular Health. Arch.Pediatr.Adolesc.Med. 1999 Jul;153(7):695-704.

31. Berkey CS, Rockett HR, Field AE, Gillman MW, Frazier AL, Camargo CA, Jr., Colditz GA. Activity, dietary intake, and weight changes in a longitudinal study of preadolescent and adolescent boys and girls. Pediatrics 2000 Apr;105(4):E56.

32. Berkey CS, Rockett HR, Gillman MW, Colditz GA. One-year changes in activity and in inactivity among 10- to 15-year-old boys and girls: relationship to change in body mass index. Pediatrics 2003 Apr;111(4 Pt 1):836-43.

33. Moore LL, Gao D, Bradlee ML, Cupples LA, Sundarajan-Ramamurti A, Proctor MH, Hood MY, Singer MR, Ellison RC. Does early physical activity predict body fat change throughout childhood? Prev.Med. 2003 Jul;37(1):10-7.

34. Mundt CA, Baxter-Jones AD, Whiting SJ, Bailey DA, Faulkner RA, Mirwald RL. Relationships of activity and sugar drink intake on fat mass development in youths. Med.Sci.Sports Exerc. 2006 Jul;38(7):1245-54.

35. Barbeau P, Johnson MH, Howe CA, Allison J, Davis CL, Gutin B, Lemmon CR. Ten months of exercise improves general and visceral adiposity, bone, and fitness in black girls. Obesity.(Silver.Spring) 2007 Aug;15(8):2077-85.

36. MacKelvie K, McKay HA, Khan KM, Crocker PR. A school-based exercise intervention augments bone mineral accrual in early pubertal girls. J.Pediatr. 2001 Oct;139(4):501-8.

37. MacKelvie KJ, Khan KM, Petit MA, Janssen PA, McKay HA. A school-based exercise intervention elicits substantial bone health benefits: a 2-year randomized controlled trial in girls. Pediatrics 2003 Dec;112(6 Pt 1):e447.

38. Schneider M, Dunton GF, Bassin S, Graham DJ, Eliakim AF, Cooper DM. Impact of a school-based physical activity intervention on fitness and bone in adolescent females. J.Phys.Act.Health 2007 Jan;4(1):17-29.

39. Viskic-Stalec N, Stalec J, Katic R, Podvorac D, Katovic D. The impact of dance-aerobics training on the morpho-motor status in female high-schoolers. Coll.Antropol. 2007 Mar;31(1):259-66.

40. Haerens L, Deforche B, Maes L, Stevens V, Cardon G, De B, I. Body mass effects of a physical activity and healthy food intervention in middle schools. Obesity.(Silver.Spring) 2006 May;14(5):847-54.

41. Sundberg M, Gardsell P, Johnell O, Karlsson MK, Ornstein E, Sandstedt B, Sernbo I. Peripubertal moderate exercise increases bone mass in boys but not in girls: a population-based intervention study. Osteoporos.Int. 2001;12(3):230-8.

42. Yin Z, Gutin B, Johnson MH, Hanes J, Jr., Moore JB, Cavnar M, Thornburg J, Moore D, Barbeau P. An environmental approach to obesity prevention in children: Medical College of Georgia FitKid Project year 1 results. Obes.Res. 2005 Dec;13(12):2153-61.

43. Yin Z, Moore JB, Johnson MH, Barbeau P, Cavnar M, Thornburg J, Gutin B. The Medical College of Georgia Fitkid project: the relations between program attendance and changes in outcomes in year 1. Int.J.Obes.(Lond) 2005 Sep;29 Suppl 2:S40-S45.

44. Gutin B, Owens S, Slavens G, Riggs S, Treiber F. Effect of physical training on heart-period variability in obese children. J.Pediatr. 1997 Jun;130(6):938-43.

45. Gutin B, Barbeau P, Owens S, Lemmon CR, Bauman M, Allison J, Kang HS, Litaker MS. Effects of exercise intensity on cardiovascular fitness, total body composition, and visceral adiposity of obese adolescents. Am.J.Clin.Nutr. 2002 May;75(5):818-26.

46. Owens S, Gutin B, Allison J, Riggs S, Ferguson M, Litaker M, Thompson W. Effect of physical training on total and visceral fat in obese children. Med.Sci.Sports Exerc. 1999 Jan;31(1):143-8.

47. Treuth MS, Hunter GR, Figueroa-Colon R, Goran MI. Effects of strength training on intra-abdominal adipose tissue in obese prepubertal girls. Med.Sci.Sports Exerc. 1998 Dec;30(12):1738-43.

48. Raitakari OT, Taimela S, Porkka KV, Telama R, Valimaki I, Akerblom HK, Viikari JS. Associations between physical activity and risk factors for coronary heart disease: the Cardiovascular Risk in Young Finns Study. Med.Sci.Sports Exerc. 1997 Aug;29(8):1055-61.

49. Matsui I, Nambu S, Baba S. Evaluation of fasting serum insulin levels among Japanese school-age children. J.Nutr.Sci.Vitaminol.(Tokyo) 1998 Dec;44(6):819-28.

50. Eisenmann JC, Katzmarzyk PT, Perusse L, Bouchard C, Malina RM. Estimated daily energy expenditure and blood lipids in adolescents: the Quebec Family Study. J.Adolesc.Health 2003 Sep;33(3):147-53.

51. Boreham CA, Ferreira I, Twisk JW, Gallagher AM, Savage MJ, Murray LJ. Cardiorespiratory fitness, physical activity, and arterial stiffness: the Northern Ireland Young Hearts Project. Hypertension 2004 Nov;44(5):721-6.

52. Platat C, Wagner A, Klumpp T, Schweitzer B, Simon C. Relationships of physical activity with metabolic syndrome features and low-grade inflammation in adolescents. Diabetologia 2006 Sep;49(9):2078-85.

53. Andersen LB, Harro M, Sardinha LB, Froberg K, Ekelund U, Brage S, Anderssen SA. Physical activity and clustered cardiovascular risk in children: a cross-sectional study (The European Youth Heart Study). Lancet 2006 Jul 22;368(9532):299-304.

54. Wennlof AH, Yngve A, Nilsson TK, Sjostrom M. Serum lipids, glucose and insulin levels in healthy schoolchildren aged 9 and 15 years from Central Sweden: reference values in relation to biological, social and lifestyle factors. Scand.J.Clin.Lab Invest 2005;65(1):65-76.

55. Ondrak KS, McMurray RG, Bangdiwala SI, Harrell JS. Influence of aerobic power and percent body fat on cardiovascular disease risk in youth. J.Adolesc.Health 2007 Aug;41(2):146-52.

56. Krekoukia M, Nassis GP, Psarra G, Skenderi K, Chrousos GP, Sidossis LS. Elevated total and central adiposity and low physical activity are associated with insulin resistance in children. Metabolism 2007 Feb;56(2):206-13.

57. Gutin B, Johnson MH, Humphries MC, Hatfield-Laube JL, Kapuku GK, Allison JD, Gower BA, Daniels SR, Barbeau P. Relationship of visceral adiposity to cardiovascular disease risk factors in black and white teens. Obesity.(Silver.Spring) 2007 Apr;15(4):1029-35.

58. Craig SB, Bandini LG, Lichtenstein AH, Schaefer EJ, Dietz WH. The impact of physical activity on lipids, lipoproteins, and blood pressure in preadolescent girls. Pediatrics 1996 Sep;98(3 Pt 1):389-95.

59. Schmitz KH, Jacobs DR, Jr., Hong CP, Steinberger J, Moran A, Sinaiko AR. Association of physical activity with insulin sensitivity in children. Int.J.Obes.Relat Metab Disord. 2002 Oct;26(10):1310-6.

60. Bunt JC, Salbe AD, Harper IT, Hanson RL, Tataranni PA. Weight, adiposity, and physical activity as determinants of an insulin sensitivity index in pima Indian children. Diabetes Care 2003 Sep;26(9):2524-30.

61. Brage S, Wedderkopp N, Ekelund U, Franks PW, Wareham NJ, Andersen LB, Froberg K. Features of the metabolic syndrome are associated with objectively measured physical activity and fitness in Danish children: the European Youth Heart Study (EYHS). Diabetes Care 2004 Sep;27(9):2141-8.

62. Hussey J, Bell C, Bennett K, O'Dwyer J, Gormley J. Relationship between the intensity of physical activity, inactivity, cardiorespiratory fitness and body composition in 7-10-year-old Dublin children. Br.J.Sports Med. 2007 May;41(5):311-6.

63. Imperatore G, Cheng YJ, Williams DE, Fulton J, Gregg EW. Physical activity, cardiovascular fitness, and insulin sensitivity among U.S. adolescents: the National Health and Nutrition Examination Survey, 1999-2002. Diabetes Care 2006 Jul;29(7):1567-72.

64. Gidding SS, Barton BA, Dorgan JA, Kimm SY, Kwiterovich PO, Lasser NL, Robson AM, Stevens VJ, Van HL, Simons-Morton DG. Higher self-reported physical activity is associated with lower systolic blood pressure: the Dietary Intervention Study in Childhood (DISC). Pediatrics 2006 Dec;118(6):2388-93.

65. Goodman E, Dolan LM, Morrison JA, Daniels SR. Factor analysis of clustered cardiovascular risks in adolescence: obesity is the predominant correlate of risk among youth. Circulation 2005 Apr 19;111(15):1970-7.

66. Benson AC, Torode ME, Singh MA. Muscular strength and cardiorespiratory fitness is associated with higher insulin sensitivity in children and adolescents. Int.J.Pediatr.Obes. 2006;1(4):222-31.

67. Rimmer JH, Looney MA. Effects of an aerobic activity program on the cholesterol levels of adolescents. Res.Q.Exerc.Sport 1997 Mar;68(1):74-9.

68. Ferguson MA, Gutin B, Le NA, Karp W, Litaker M, Humphries M, Okuyama T, Riggs S, Owens S. Effects of exercise training and its cessation on components of the insulin resistance syndrome in obese children. Int.J.Obes.Relat Metab Disord. 1999 Aug;23(8):889-95.

69. Kang HS, Gutin B, Barbeau P, Owens S, Lemmon CR, Allison J, Litaker MS, Le NA. Physical training improves insulin resistance syndrome markers in obese adolescents. Med.Sci.Sports Exerc. 2002 Dec;34(12):1920-7.

70. Meyer AA, Kundt G, Lenschow U, Schuff-Werner P, Kienast W. Improvement of early vascular changes and cardiovascular risk factors in obese children after a six-month exercise program. J.Am.Coll.Cardiol. 2006 Nov 7;48(9):1865-70.

71. Balagopal P, George D, Patton N, Yarandi H, Roberts WL, Bayne E, Gidding S. Lifestyle-only intervention attenuates the inflammatory state associated with obesity: a randomized controlled study in adolescents. J.Pediatr. 2005 Mar;146(3):342-8.

72. Rosenbaum M, Nonas C, Weil R, Horlick M, Fennoy I, Vargas I, Kringas P. School-based intervention acutely improves insulin sensitivity and decreases inflammatory markers and body fatness in junior high school students. J.Clin.Endocrinol.Metab 2007 Feb;92(2):504-8.

73. Kahle EB, Zipf WB, Lamb DR, Horswill CA, Ward KM. Association between mild, routine exercise and improved insulin dynamics and glucose control in obese adolescents. Int.J.Sports Med. 1996 Jan;17(1):1-6.

74. Hanai T, Takada H, Nagashima M, Kuwano T, Iwata H. Effects of exercise for 1 month on serum lipids in adolescent females. Pediatr.Int. 1999 Jun;41(3):253-9.

75. Nassis GP, Papantakou K, Skenderi K, Triandafillopoulou M, Kavouras SA, Yannakoulia M, Chrousos GP, Sidossis LS. Aerobic exercise training improves insulin sensitivity without changes in body weight, body fat, adiponectin, and inflammatory markers in overweight and obese girls. Metabolism 2005 Nov;54(11):1472-9.

76. Carrel AL, Clark RR, Peterson SE, Nemeth BA, Sullivan J, Allen DB. Improvement of fitness, body composition, and insulin sensitivity in overweight children in a school-based exercise program: a randomized, controlled study. Arch.Pediatr.Adolesc.Med. 2005 Oct;159(10):963-8.

77. Carrel AL, Clark RR, Peterson S, Eickhoff J, Allen DB. School-based fitness changes are lost during the summer vacation. Arch.Pediatr.Adolesc.Med. 2007 Jun;161(6):561-4.

78. Rowland TW, Martel L, Vanderburgh P, Manos T, Charkoudian N. The influence of short-term aerobic training on blood lipids in healthy 10-12 year old children. Int.J.Sports Med. 1996 Oct;17(7):487-92.

79. Tolfrey K, Jones AM, Campbell IG. Lipid-lipoproteins in children: an exercise dose-response study. Med.Sci.Sports Exerc. 2004 Mar;36(3):418-27.

80. Gutin B, Yin Z, Humphries MC, Barbeau P. Relations of moderate and vigorous physical activity to fitness and fatness in adolescents. Am.J.Clin.Nutr. 2005 Apr;81(4):746-50.

81. Patrick K, Norman GJ, Calfas KJ, Sallis JF, Zabinski MF, Rupp J, Cella J. Diet, physical activity, and sedentary behaviors as risk factors for overweight in adolescence. Arch.Pediatr.Adolesc.Med. 2004 Apr;158(4):385-90.

82. Ruiz JR, Rizzo NS, Hurtig-Wennlof A, Ortega FB, Warnberg J, Sjostrom M. Relations of total physical activity and intensity to fitness and fatness in children: the European Youth Heart Study. Am.J.Clin.Nutr. 2006 Aug;84(2):299-303.

83. Stallmann-Jorgensen IS, Gutin B, Hatfield-Laube JL, Humphries MC, Johnson MH, Barbeau P. General and visceral adiposity in black and white adolescents and their relation with reported physical activity and diet. Int.J.Obes.(Lond) 2007 Apr;31(4):622-9.

84. Turner CH, Robling AG. Designing exercise regimens to increase bone strength. Exerc.Sport Sci.Rev. 2003 Jan;31(1):45-50.

85. Heaney RP, Abrams S, wson-Hughes B, Looker A, Marcus R, Matkovic V, Weaver C. Peak bone mass. Osteoporos.Int. 2000;11(12):985-1009.

86. McKay HA, MacLean L, Petit M, Kelvie-O'Brien K, Janssen P, Beck T, Khan KM. "Bounce at the Bell": a novel program of short bouts of exercise improves proximal femur bone mass in early pubertal children. Br.J.Sports Med. 2005 Aug;39(8):521-6.

87. MacDonald HM, Kontulainen SA, Khan KM, McKay HA. Is a school-based physical activity intervention effective for increasing tibial bone strength in boys and girls? J.Bone Miner.Res. 2007 Mar;22(3):434-46.

88. MacKelvie KJ, Petit MA, Khan KM, Beck TJ, McKay HA. Bone mass and structure are enhanced following a 2-year randomized controlled trial of exercise in prepubertal boys. Bone 2004 Apr;34(4):755-64.

89. Fuchs RK, Snow CM. Gains in hip bone mass from high-impact training are maintained: a randomized controlled trial in children. J.Pediatr. 2002 Sep;141(3):357-62.

90. McKay HA, Petit MA, Schutz RW, Prior JC, Barr SI, Khan KM. Augmented trochanteric bone mineral density after modified physical education classes: a randomized school-based exercise intervention study in prepubescent and early pubescent children. J.Pediatr. 2000 Feb;136(2):156-62.

91. MacKelvie KJ, McKay HA, Petit MA, Moran O, Khan KM. Bone mineral response to a 7-month randomized controlled, school-based jumping intervention in 121 prepubertal boys: associations with ethnicity and body mass index. J.Bone Miner.Res. 2002 May;17(5):834-44.

92. Specker B, Binkley T. Randomized trial of physical activity and calcium supplementation on bone mineral content in 3- to 5-year-old children. J.Bone Miner.Res. 2003 May;18(5):885-92.

93. Blimkie CJ, Rice S, Webber CE, Martin J, Levy D, Gordon CL. Effects of resistance training on bone mineral content and density in adolescent females. Can.J.Physiol Pharmacol. 1996 Sep;74(9):1025-33.

94. Arnett MG, Lutz B. Effects of rope-jump training on the os calcis stiffness index of postpubescent girls. Med.Sci.Sports Exerc. 2002 Dec;34(12):1913-9.

95. Bailey DA, McKay HA, Mirwald RL, Crocker PR, Faulkner RA. A six-year longitudinal study of the relationship of physical activity to bone mineral accrual in growing children: the university of Saskatchewan bone mineral accrual study. J.Bone Miner.Res. 1999 Oct;14(10):1672-9.

96. Bradney M, Pearce G, Naughton G, Sullivan C, Bass S, Beck T, Carlson J, Seeman E. Moderate exercise during growth in prepubertal boys: changes in bone mass, size, volumetric density, and bone strength: a controlled prospective study. J.Bone Miner.Res. 1998 Dec;13(12):1814-21.

97. Fuchs RK, Bauer JJ, Snow CM. Jumping improves hip and lumbar spine bone mass in prepubescent children: a randomized controlled trial. J.Bone Miner.Res. 2001 Jan;16(1):148-56.

98. Morris FL, Naughton GA, Gibbs JL, Carlson JS, Wark JD. Prospective ten-month exercise intervention in premenarcheal girls: positive effects on bone and lean mass. J.Bone Miner.Res. 1997 Sep;12(9):1453-62.

99. Iuliano-Burns S, Saxon L, Naughton G, Gibbons K, Bass SL. Regional specificity of exercise and calcium during skeletal growth in girls: a randomized controlled trial. J.Bone Miner.Res. 2003 Jan;18(1):156-62.

100. Witzke KA, Snow CM. Effects of plyometric jump training on bone mass in adolescent girls. Med.Sci.Sports Exerc. 2000 Jun;32(6):1051-7.

101. Heinonen A, Sievanen H, Kannus P, Oja P, Pasanen M, Vuori I. High-impact exercise and bones of growing girls: a 9-month controlled trial. Osteoporos.Int. 2000;11(12):1010-7.

102. Nichols DL, Sanborn CF, Love AM. Resistance training and bone mineral density in adolescent females. J.Pediatr. 2001 Oct;139(4):494-500.

103. Stear SJ, Prentice A, Jones SC, Cole TJ. Effect of a calcium and exercise intervention on the bone mineral status of 16-18-y-old adolescent girls. Am.J.Clin.Nutr. 2003 Apr;77(4):985-92.

104. Birmaher B, Ryan ND, Williamson DE, Brent DA, Kaufman J, Dahl RE, Perel J, Nelson B. Childhood and adolescent depression: a review of the past 10 years. Part I. J.Am.Acad.Child Adolesc.Psychiatry 1996 Nov;35(11):1427-39.

105. Kessler RC, Walters EE. Epidemiology of DSM-III-R major depression and minor depression among adolescents and young adults in the National Comorbidity Survey. Depress.Anxiety. 1998;7(1):3-14.

106. Motl RW, Birnbaum AS, Kubik MY, Dishman RK. Naturally occurring changes in physical activity are inversely related to depressive symptoms during early adolescence. Psychosom.Med. 2004 May;66(3):336-42.

107. Parfitt G, Eston RG. The relationship between children's habitual activity level and psychological well-being. Acta Paediatr. 2005 Dec;94(12):1791-7.

108. Field T, Diego M, Sanders CE. Exercise is positively related to adolescents' relationships and academics. Adolescence 2001;36(141):105-10.

109. Annesi JJ. Correlations of depression and total mood disturbance with physical activity and self-concept in preadolescents enrolled in an after-school exercise program. Psychol.Rep. 2005 Jun;96(3 Pt 2):891-8.

110. Pastor Y, Balaguer I, Pons D, Garcia-Merita M. Testing direct and indirect effects of sports participation on perceived health in Spanish adolescents between 15 and 18 years of age. J.Adolesc. 2003 Dec;26(6):717-30.

111. Kirkcaldy BD, Shephard RJ, Siefen RG. The relationship between physical activity and self-image and problem behaviour among adolescents. Soc.Psychiatry Psychiatr.Epidemiol. 2002 Nov;37(11):544-50.

112. Nabkasorn C, Miyai N, Sootmongkol A, Junprasert S, Yamamoto H, Arita M, Miyashita K. Effects of physical exercise on depression, neuroendocrine stress hormones and physiological fitness in adolescent females with depressive symptoms. Eur.J.Public Health 2006 Apr;16(2):179-84.

113. Tao FB, Xu ML, Kim SD, Sun Y, Su PY, Huang K. Physical activity might not be the protective factor for health risk behaviours and psychopathological symptoms in adolescents. J.Paediatr.Child Health 2007 Nov;43(11):762-7.

114. Larun L, Nordheim LV, Ekeland E, Hagen KB, Heian F. Exercise in prevention and treatment of anxiety and depression among children and young people. Cochrane.Database.Syst.Rev. 2006;3:CD004691.

115. DeBate RD, Thompson SH. Girls on the Run: improvements in self-esteem, body size satisfaction and eating attitudes/behaviors. Eat.Weight.Disord. 2005 Mar;10(1):25-32.

116. Dishman RK, Hales DP, Pfeiffer KA, Felton GA, Saunders R, Ward DS, Dowda M, Pate RR. Physical self-concept and self-esteem mediate cross-sectional relations of physical activity and sport participation with depression symptoms among adolescent girls. Health Psychol. 2006 May;25(3):396-407.

117. Sagatun A, Sogaard AJ, Bjertness E, Selmer R, Heyerdahl S. The association between weekly hours of physical activity and mental health: a three-year follow-up study of 15-16-year-old students in the city of Oslo, Norway. BMC.Public Health 2007;7(147):155.

118. Daley AJ, Copeland RJ, Wright NP, Roalfe A, Wales JK. Exercise therapy as a treatment for psychopathologic conditions in obese and morbidly obese adolescents: a randomized, controlled trial. Pediatrics 2006 Nov;118(5):2126-34.

119. Ekeland E, Heian F, Hagen KB, Abbott J, Nordheim L. Exercise to improve self-esteem in children and young people. Cochrane.Database.Syst.Rev. 2004;(1):CD003683.

120. Sallis JF, McKenzie TL, Kolody B, Lewis M, Marshall S, Rosengard P. Effects of health-related physical education on academic achievement: project SPARK. Res.Q.Exerc.Sport 1999 Jun;70(2):127-34.

121. Coe DP, Pivarnik JM, Womack CJ, Reeves MJ, Malina RM. Effect of physical education and activity levels on academic achievement in children. Med.Sci.Sports Exerc. 2006 Aug;38(8):1515-9.

122. Davis CL, Tomporowski PD, Boyle CA, Waller JL, Miller PH, Naglieri JA, Gregoski M. Effects of aerobic exercise on overweight children's cognitive functioning: a randomized controlled trial. Res.Q.Exerc.Sport 2007 Dec;78(5):510-9.

123. Strong WB, Malina RM, Blimkie CJ, Daniels SR, Dishman RK, Gutin B, Hergenroeder AC, Must A, Nixon PA, Pivarnik JM, et al. Evidence based physical activity for school-age youth. J.Pediatr. 2005 Jun;146(6):732-7.

124. Brosnahan J, Steffen LM, Lytle L, Patterson J, Boostrom A. The relation between physical activity and mental health among Hispanic and non-Hispanic white adolescents. Arch.Pediatr.Adolesc.Med. 2004 Aug;158(8):818-23.

125. Larson RW, Hansen DM, Moneta G. Differing profiles of developmental experiences across types of organized youth activities. Dev.Psychol. 2006 Sep;42(5):849-63.

126. Taras H. Physical activity and student performance at school. J.Sch Health 2005 Aug;75(6):214-8.

127. Tomporowski PD, Davis CM, Miller PH, Naglieri JA. Exercise and children's intelligence, cognition, and academic achievement
40. Educ.Psychol.Rev. 2007.

128. Mahar MT, Murphy SK, Rowe DA, Golden J, Shields AT, Raedeke TD. Effects of a classroom-based program on physical activity and on-task behavior. Med.Sci.Sports Exerc. 2006 Dec;38(12):2086-94.