Physical Activity and Cardiovascular Disease Risk Factors in Children and Adolescents

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Cardiovascular disease (CVD) is the leading cause of global mortality, and its precursors have their origin in the first decade of life. The most recognized CVD risk factors are total and central adiposity, insulin resistance, blood lipids and lipoproteins, blood pressure, inflammatory proteins, and cardiorespiratory fitness. Low physical activity is strongly associated with a higher risk of developing CVD in adults, and there is compelling evidence indicating that this is also the case in young individuals. Epidemiologic evidence indicates that a high level of physical activity, particularly vigorous physical activity, is associated with lower total and central body fat in youth. Likewise, moderate and vigorous physical activity rather than low-intensity levels seems to be independently associated with insulin resistance, blood lipids, blood pressure, inflammatory proteins, and cardiorespiratory fitness in children and adolescents. Preventive efforts should start in the first decades of life.

Introduction

Cardiovascular disease (CVD) is the leading cause of global mortality. Although CVD events occur most frequently during or after the fifth decade of life, there is evidence that the precursors of CVD have their origin in childhood. Adverse CVD risk factors during childhood have shown to track into adulthood [1]. The most recognized CVD risk factors are total and central body fat, insulin resistance, triglycerides, high-density lipoprotein (HDL) cholesterol, total cholesterol, blood pressure, inflammatory proteins, and cardiorespiratory fitness.

Childhood and adolescence are crucial periods of life because dynamic changes in various metabolic systems, including hormonal regulation, changes in body fat content and body fat distribution, and transient changes in insulin sensitivity, are known to occur during growth and puberty. Dramatic psychological changes also occur during this period. Likewise, lifestyle and healthy/unhealthy behaviors are established during these years, which may influence adult behavior and health status.

Blair [2] recently claimed that "physical inactivity is one of the most important public health problems of the 21st century." Indeed, a sedentary lifestyle and poor diet, along with tobacco, are the leading causes of CVD and death [3]. Obesity is a major health problem that affects not only adults but also children and adolescents. Increased energy intake together with reduced energy expenditure results in the accumulation of body fat. The consequences of an excess of body fat on health are well known. Pediatric overweight/obesity is strongly associated with adult overweight. Childhood overweight confers a fivefold or greater increase in risk of being overweight in early adulthood relative to children who were not overweight at the same age [4,5]. Overweight children and adolescents have higher levels of blood lipids and lipoproteins, blood pressure, and fasting insulin in adulthood and thus are at increased risk for future CVD compared with nonoverweight children. In fact, Must et al. [6] reported that overweight in adolescence was a more powerful predictor of these risks than overweight in adulthood.

In this review, we summarize current epidemiologic evidence showing the association of physical activity and CVD risk factors in children and adolescents. We also discuss some methodologic issues concerning physical activity assessment in young people for a better understanding and interpretation of the findings presented in the review.

Assessing Physical Activity in Children and Adolescents

Physical activity under free-living conditions is difficult to assess, especially in young people, because of its complex nature. More than 30 methods of assessing physical activity are described in the literature. In short, methods for assessing physical activity in young people can be grouped into three categories: reference techniques, objective techniques, and subjective techniques.

Reference techniques

The most commonly used reference techniques are direct observation, assessment of total energy expenditure using doubly labeled water, and indirect calorimetry. Although direct observation provides valuable information about physical activity levels and patterns, it is difficult to follow a child for a full day. Furthermore, it is feasible for assessing a small number of individuals but not large numbers. The doubly labeled water method is recognized as the reference method or "gold standard" for the assessment of total energy expenditure. This technique assesses energy expenditure by estimating carbon dioxide production using an isotope dilution over at least 3 days. Although the doubly labeled water approach is a powerful tool to accurately measure daily energy expenditure, it has several limitations: the isotopes are expensive and difficult to obtain, and no information about duration, frequency, or intensity of the activity is obtained. Indirect calorimetry during rest and exercise is used extensively and considered an accurate and valid measure of short-term energy expenditure. Although smaller, lighter, and portable gas analyzers have been developed recently, this method is intrusive and cannot be used for long recording periods (the battery works for only 2–3 hours).

Objective techniques

Objective techniques are increasingly being used. They include equipment such as heart rate monitors, pedometers, and accelerometers. The information obtained by heart rate monitoring is mainly based on the assumption of a linear relationship between the heart rate and work rate. However, the heart rate is influenced not only by physical activity but also by factors such as caffeine or medications, anxiety, emotional stress, fatigue, body position, the active muscle group, training status, state of hydration, ambient temperature, and humidity. Pedometers are relatively inexpensive, simple motion sensors that record the number of steps a person takes. On the other hand, pedometers cannot measure the intensity or pattern of the activities. They do not properly record activity during cycling (except when using ankle-mounted pedometers) or increases in energy expenditure due to carrying objects. Pedometers also are unable to distinguish walking and running or moving downhill and uphill. Accelerometers are more sophisticated motion sensors than pedometers. They record movement through piezoelectric transducers and microprocessors that convert recorded accelerations to a quantifiable digital signal referred to as a "count." This method provides an accurate measure of physical activity and valuable information about the intensity of physical activity. However, its limitations must be recognized, including insensitivity to cycling, walking and running, moving uphill or downhill, or activities such as swimming.

Combinations of objective methods, such as heart rate monitoring plus accelerometry or use of the Global Positioning System plus accelerometry, are being developed and implemented and are expected to provide more sophisticated measures of physical activity. Although technology is advancing rapidly, the intellectual and scientific developments required to make these methodologies useful and feasible (eg, the use of appropriate software for cleaning data and appropriate interpretation of the output) are still in their infancy.

Subjective techniques

Many subjective techniques are available, including self-reported questionnaires, interviewer-administered questionnaires, mail surveys, proxy reports by parents or teachers, and diaries. In epidemiologic research, self-reported questionnaires are the most common because they are easy to use and inexpensive. However, important drawbacks have been recognized with their use in children. The sporadic nature of children's physical activity makes these activities difficult to recall, quantify, and categorize. Also, the lower cognitive functioning of children compared with adults reduces the ability of children to accurately recall intensity, frequency, and especially duration of the activities.

Although the reference methods give a highly accurate measure of physical activity, they are too expensive and not feasible enough for use in large-scale studies. The subjective methods have low accuracy for the assessment of physical activity in youths, especially in children younger than 12. Among the objective methods, accelerometry has been shown to be feasible and provides accurate information about duration, frequency, and intensity of habitual physical activity under free-living conditions. Consequently, unless otherwise indicated, the studies discussed in this review are based on accelerometry.

Physical Activity and Overall Body Fat

Cross-sectional studies examining the relationship between various measures of body fat and physical activity have usually indicated a negative relationship between activity levels and body fat. A multicenter study of 1292 9- or 10-year-old European children analyzed the associations of physical activity with indicators of total body fat (ie, sum of five skinfold thicknesses and body mass index) [7]. The results suggested that the accumulated amount of time spent in moderate and vigorous physical activity is related, albeit weakly, to total body fat. Wittmeier et al. [8] investigated 251 Canadian children 8 to 11 years old and found that time spent in moderate to vigorous physical activity was inversely correlated with body mass index and skinfold-derived estimate of body fat.

Several studies have suggested that vigorous physical activity may be more important than lower intensities in preventing obesity in children and adolescents. Gutin et al. [9] reported that only physical activity of vigorous intensity was associated with lower body fat in 16-year-old North American adolescents, which concurs with other studies involving younger participants [10,11,12•]. Dencker et al. [11] reported a strong relationship between vigorous physical activity and body fat in 8- to 11-year-old Swedish children. Likewise, Butte et al. [13] observed a strong and negative association between vigorous physical activity and percent body fat in 4- to 19-year-old children. We also observed a negative association between vigorous physical activity and body fat measured by the sum of five skinfolds in 9- and 10-year-old Estonian and Swedish children participating in the European Youth Heart Study (EYHS) [12•]. The children who engaged in more than 40 minutes of vigorous physical activity per day had lower body fat that those who engaged in 10 to 18 minutes of vigorous physical activity daily. One of the most relevant studies to date examining the association between physical activity and total adiposity is the Avon Longitudinal Study of Parents and Children, in which 5500 12-year-old children were assessed using accelerometry and dual-energy x-ray absorptiometry [14••]. The authors found a strong graded inverse association between physical activity and obesity that was stronger in boys. The results also suggested that a higher-intensity physical activity may be more important than total activity in relation to adiposity.

Longitudinal studies support the idea that youth who participate in relatively high levels of physical activity have less body fat later in life than their less active peers [15,16]. Experimental studies have been developed to obtain specific information about the influence of regular physical activity on body fat in normal-weight and/or overweight and obese children and adolescents. In overweight and obese children, beneficial effects of body fat control might be attained with 30 to 60 minutes of moderate physical activity 3 to 7 days per week [17–19]. Obese adolescents who spent more time engaged in vigorous physical activity tended to be those who decreased body fat the most [17,18]. For several reasons, it is reasonable to recommend moderate physical activity for obese children and adolescents until higher intensities can be attained. Moderate physical activity is better tolerated than vigorous physical activity [18], and tiring physical activity may lead to less physical activity on the following day, although it likely depends on the type of exercise performed. Therefore, for obese children and those who have been physically inactive, an incremental approach to the daily goal of 45 to 60 minutes of moderate physical activity at least 5 days per week is recommended [20]. However, these programs do not influence body fatness in normal-weight children and adolescents, who should engaged in more intensive and longer sessions (≥ 80 min/d) to reduce percentage body fat storages [20].

Collectively, the current literature agrees fairly consistently that the association between physical activity and obesity is stronger for vigorous physical activity than for moderate physical activity. When an individual exercises at a higher intensity, the total energy expenditure is higher than for moderate-intensity exercise for a similar amount of time. Whether it is really the intensity that matters, or whether the total energy expenditure is responsible for many of the reported outcomes, remains to be answered. In other words, we still do not know whether 30 minutes of moderate physical activity and 10 minutes of vigorous physical activity (assuming that both have the same energy cost) have different effects on body composition. Strictly, only a well-designed randomized controlled trial could accurately answer this question, but observational data can be used to address this question.

To help solve this dilemma, researchers should try to make the energy expenditure linked to vigorous and moderate physical activity equivalent so that only the intensity and not the total number of calories spent will differ. The outcomes using this study design will help us to better understand how and to what extent the intensity of physical activity matters in the management and prevention of obesity.

Physical Activity and Central Body Fat

Central adiposity is associated with a range of risk factors for CVD even in young people and is becoming increasingly important in pediatrics. Although there are accurate and sophisticated methods to evaluate central body fat, waist circumference is considered an accurate surrogate for central body fat [21].

We showed that children and adolescents who had a low level (first tertile) of vigorous physical activity had twice the odds of having a high-risk waist circumference as those who had a high level (third tertile) of vigorous physical activity [22]. When the associations were controlled for television viewing or birth weight, low vigorous physical activity was still a significant predictor of the odds of being overweight and having a high-risk waist circumference. Likewise, more recent findings in children and adolescents have shown a negative association between central body fat and physical activity assessed by accelerometers, especially with vigorous physical activity [23,24]. In contrast, we did not observe an association between waist circumference and self-reported physical activity in Spanish adolescents who took part in the AVENA (Alimentación y Valoración del Estado Nutricional en Adolescentes) study [25]. However, a study in 12-year-old French children reported a negative relationship between waist circumference and self-reported physical activity [26].

Whether cardiorespiratory fitness modifies the association between physical activity and abdominal fat is another matter of interest. In the first study examining how cardiorespiratory fitness can influence the associations between objectively measured physical activity and abdominal fat, we studied 1075 Swedish children and adolescents from the EYHS [27•]. We showed that the associations between physical activity and abdominal fat differ by fitness levels. In low-fit children and adolescents, time spent in vigorous physical activity seems to be the key component linked to abdominal fat. Unexpectedly though, physical activity was positively associated with waist circumference in high-fit children and adolescents. Further research examining genetic and dietary factors, in addition to objectively measured physical activity and cardiorespiratory fitness, are still needed for a better understanding of the associations between physical activity and body fat in young people.

Physical Activity and Insulin Resistance

Brage et al. [28] explored the association between measures of insulin resistance and objectively assessed physical activity in 9- and 10-year-old Danish children. They reported an inverse association between physical activity and fasting insulin after controlling for body mass index and skinfold thickness. These findings concur with other studies [29–31]. Rizzo et al. [29] observed a negative association between physical activity and a surrogate marker of insulin resistance (ie, homeostasis model assessment [HOMA]) in male and female Estonian and Swedish adolescents. The association was independent of pubertal maturity, total body fat (body mass index or skinfold thickness), or waist circumference [29]. Data on physical activity measured with questionnaires as well as with other surrogates of insulin resistance agree with these findings [32]. Longitudinal studies also indicate that declines in the volume of physical activity from childhood to adolescence are negatively associated with fasting insulin and HOMA [33].

Physical Activity and Blood Lipids and Lipoproteins

The association between objectively assessed physical activity and total cholesterol, HDL cholesterol, and triglyceride levels in children and adolescents are generally weak. Hurtig-Wennlöf et al. [34] showed bivariate correlation coefficients of total and moderate to vigorous physical activity with total cholesterol of –0.13 to 0.14, respectively, in Swedish children and adolescents. Similar findings were obtained by Andersen et al. [35••] in a large cohort of children and adolescents from Denmark, Estonia, and Portugal. However, these studies did not control for potential confounding factors such as pubertal status, fatness, and fitness. Brage et al. [36] reported a borderline significant negative association between total physical activity and triglycerides ($P = 0.052$) in 9- and 10-year-old children after controlling for age, sex, sexual maturation, ethnicity, socioeconomic status, and parental smoking. None of these studies observed a significant association between physical activity and HDL cholesterol or low-density lipoprotein cholesterol. Further studies need to examine the association between objectively assessed physical activity and blood lipids and lipoproteins in children and adolescents.

Physical Activity and Blood Pressure

Leary et al. [37] showed that higher levels of physical activity were associated with lower blood pressure in the children recruited from the Avon Longitudinal Study of Parents and Children. They also suggested that the volume of activity may be more important than the intensity. In contrast, we observed a negative significant association between physical activity of at least moderate intensity and blood pressure in 9- and 15-year-old Swedish girls and 15-year-old Swedish boys participating in the EYHS [34], but no association was observed between total physical activity and blood pressure. Likewise, Mark and Janssen [38] reported an inverse dose-response relation of total and moderate to vigorous physical activity with systolic and diastolic blood pressure in 8- to 17-year-old youth from the 2003–2004 US National Health and Nutrition Examination Survey. The likelihood of having hypertension decreased in a curvilinear manner with increasing minutes of physical activity.

Physical Activity and Inflammatory Markers

Studies reporting the effect of physical activity on low-grade inflammatory proteins in youth are scarce and mainly carried out with subjective measures of physical activity. Platat et al. [39] showed that interleukin-6 and insulin resistance were negatively associated with organized leisure-time physical activity independently of adiposity and fat localization in 12-year-old children. Similarly, Cook et al. [40] found a borderline significant negative association of C-reactive protein levels with self-reported physical activity after adjusting for the ponderal index in 10- and 11-year-old children. In contrast, Thomas et al. [41] did not observe an association between self-reported physical activity and C-reactive protein in 12- and 13-year-old schoolchildren.

We showed no association between objectively assessed physical activity (total, moderate, vigorous, and moderate to vigorous) and low-grade inflammatory proteins (ie, C-reactive protein, fibrinogen, complement factors C3 and C4) in prepubertal Swedish children participating in the EYHS [42]. Levels of low-grade inflammatory markers (C-reactive protein and C3) were negatively associated with cardiorespiratory fitness and positively associated with body fat. One could be hypothesize that physical activity could have a positive impact on low-grade inflammation through reducing body fat and enhancing cardiorespiratory fitness.

Physical Activity and Cardiorespiratory Fitness

Physical activity and cardiorespiratory fitness are closely related in that fitness is partially determined by physical activity patterns over recent weeks or months. Cardiorespiratory fitness has received special attention in recent decades because it has been shown to be an important health marker in all age groups [43,44]. Furthermore, high cardiorespiratory fitness during childhood is associated with a healthier cardiovascular profile later in life [45].

Cardiorespiratory fitness is influenced by several factors, including body fatness, age, sex, health status, and genetics, but its principal modifiable determinant is habitual physical activity. There is a positive association between objectively assessed physical activity and cardiorespiratory fitness in children and adolescents [9,12•]. Data from the Swedish part of the EYHS indicated that children who engaged in more than 40 minutes of vigorous physical activity daily had better cardiorespiratory fitness than those who accumulated less than 18 minutes per day of vigorous physical activity [12•]. We also observed that adolescents devoting at least 1 hour to moderate or vigorous physical activity daily had a healthier cardiorespiratory fitness level, independent of maturation status and adiposity [46]. Intervention studies indicate that it is possible to improve cardiorespiratory fitness levels in youth by about 10% through aerobic training [47].

Physical Activity and Clustering of CVD Risk Factors

In adults, the aggregation of multiple CVD risk factors was observed almost a century ago [48]. More recently, similar clusterings received renewed attention, and terms such as *syndrome X, insulin resistance syndrome,* and *metabolic syndrome* have been proposed to describe the connection between obesity, insulin resistance, hypertension, dyslipidemia, and diabetes [48].

Attempts have been made to extrapolate adult risk-based values into age-appropriate levels to define unfavorable risk factors in children and adolescents [48], and although this approach may be clinically useful, it ignores the continuum of CVD risk. Andersen et al. [35••,49] should be acknowledged for being among the first researchers to compute a continuum CVD risk score for children and adolescents. Such a risk score seems a better indicator of cardiovascular health in children than single risk factors [49] and may also compensate, to a certain extent, for the known fluctuations in the single risk factors [35••]. In a cross-sectional multicenter study of 1732 children and adolescents from Denmark, Estonia, and Portugal enrolled in the EYHS, Andersen et al. [35••] showed that the risk of having clustered risk factors (systolic blood pressure, triglycerides, ratio of total cholesterol to HDL cholesterol, HOMA, sum of four skinfolds, and cardiorespiratory fitness) decreased in a dose-gradient manner with increased physical activity. Previous studies in Danish children showed similar results [36]. We computed a similar risk score in Swedish children and adolescents and observed that both total and vigorous physical activity was inversely associated with CVD risk score in the group with the lowest levels of physical activity (female adolescents), whereas both fitness and fatness had a stronger impact in the other groups (children and male adolescents) [50].

Conclusions

In this article, we have reviewed and summarized current epidemiologic literature examining the association between physical activity and CVD risk factors in children and adolescents. Cross-sectional studies using objective measures of physical activity support that a high level of physical activity, particularly vigorous physical activity, is associated with lower total and central body fat in children and adolescents. Likewise, the longitudinal studies reviewed herein have shown similar associations between activity levels during childhood and adolescence and overall fat or central fat later in life. Moderate and vigorous physical activity rather than lower-intensity levels seems to be independently associated with insulin resistance, blood lipids, blood pressure, inflammatory proteins, and cardiorespiratory fitness in children and adolescents. Preventive efforts should start in the first decades of life.

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Disclosure

No potential conflicts of interest relevant to this article were reported.

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