

## Physical activity and cardiovascular disease risk factors in children and adolescents: An overview

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Currently, there is considerable interest in the physical activity and cardiovascular disease (CVD) risk factors of youth in North America and other developed countries. The central question to this paper is, what is the role of physical activity in the primary prevention of CVD? Three subquestions are explored: what are the current levels and prevalence of physical activity and CVD risk factors in North American youth?; what is the association between physical activity and CVD risk factors in children and adolescents?; and what is the influence of childhood physical activity on subsequent adult cardiovascular health? The number of youth meeting physical activity recommendations varies by measurement procedures, age and sex. In general, physical activity levels decline during adolescence. Aerobic fitness remains stable in boys and gradually declines during adolescence in girls. The prevalence of overweight and the emergence of type 2 diabetes in children and adolescents have increased over the past few decades. Although the association is weak and causal inference cannot be drawn, physical activity explains a small amount of the variance in CVD risk factors during childhood and adolescence, particularly at the extremes. Childhood overweight increases the risk of adult overweight, the clustering of other CVD risk factors, coronary artery calcification in adulthood, and all-cause and CVD mortality. Future studies should consider the measurement of physical activity, physical activity-genotype interactions, biobehavioral approaches to the prevention and treatment of obesity and comorbidities, and emerging risk factors. Prospective cohort studies are also warranted to further examine the influence of childhood physical activity on subsequent health outcomes.

**Key Words:** *Atherosclerosis; Children; Exercise; Health; Inactivity; Lipids; Obesity*

Currently, there is considerable interest in the physical activity and health-related physical fitness of youth in North America and other developed countries, particularly related to risk factors for cardiovascular disease (CVD) (1). Why is the study of physical activity and CVD risk factors in children and adolescents an important research and public health question? First, CVD is the leading cause of death in North America and other developed countries, and both physical activity and aerobic fitness are independently related to CVD mortality in adults (2). Second, although the clinical manifestations of CVD occur in middle adulthood, studies

### L'activité physique et les facteurs de risque de maladie cardiovasculaire chez les enfants et les adolescents : Un aperçu

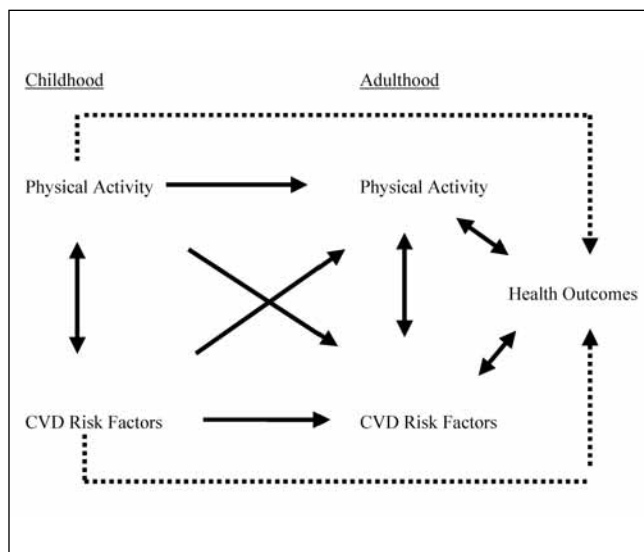
On s'intéresse beaucoup à l'activité physique et aux facteurs de risque de maladie cardiovasculaire (MCV) chez les adolescents d'Amérique du Nord et d'autres pays industrialisés. Dans le présent article, on se pose une question centrale : Quel est le rôle de l'activité physique dans la prévention primaire des MCV ? Trois sous-questions sont examinées : Quels sont les taux et la prévalence actuels de l'activité physique et de facteurs de risque de MCV chez les jeunes nord-américains ?, Quelle est l'association entre l'activité physique et les facteurs de risque de MCV chez les enfants et les adolescents ? et Quelle est l'influence de l'activité physique pendant l'enfance sur la santé cardiovasculaire adulte ? Le nombre de jeunes qui respectent les recommandations en matière d'activité physique varie selon les modes opératoires, l'âge et le sexe. En général, les taux d'activité physique diminuent pendant l'adolescence. La capacité aérobique demeure stable chez les garçons et diminue graduellement chez les filles pendant l'adolescence. La prévalence d'embonpoint et l'émergence de diabète de type II chez les enfants et les adolescents a augmenté depuis quelques décennies. Même si l'association est faible et qu'il est impossible d'établir des inférences causales, l'activité physique explique une petite partie de l'écart des facteurs de risque de MCV pendant l'enfance et l'adolescence, surtout aux extrêmes. L'embonpoint pendant l'enfance accroît le risque d'embonpoint à l'âge adulte, l'agglutination d'autres facteurs de risque de MCV, la calcification des artères coronaires à l'âge adulte ainsi que la mortalité toutes causes confondues ou secondaire aux MCV. Les prochaines études devraient tenir compte de la mesure de l'activité physique, des interactions entre l'activité physique et les génotypes, des démarches biobehavioristes pour prévenir et traiter l'obésité et ses comorbidités et des facteurs de risque émergents. Des études prospectives de cohortes s'imposent également pour examiner plus à fond l'influence de l'activité physique sur les issues de santé subséquentes.

have shown that atherosclerosis has its origins in childhood and adolescence (3-7). There is also evidence that physical activity, aerobic fitness and CVD risk factors track from childhood and adolescence into adulthood (8). Thus, adult heart disease can be predicted to some degree from childhood and adolescent CVD risk factors. Atherosclerosis is a progressive disease that has its origins in childhood and adolescence, which highlights the importance of its prevention during childhood and adolescence.

This paper addresses three questions: what are the current levels and prevalence of physical activity and CVD risk factors

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**Figure 1** Overview of the complex inter-relationships among physical activity, cardiovascular disease (CVD) risk factors and health outcomes across the lifespan. Modified and adapted from references 10 and 16

in North American youth?; what is the association between physical activity and CVD risk factors in children and adolescents?; and what is the influence of childhood physical activity on subsequent adult cardiovascular health? Although other reviews have been published on this topic (1,9-16), there is no comprehensive review that examines both the descriptive and analytical epidemiology of physical activity and CVD risk factors in children and adolescents.

### INTER-RELATIONSHIPS AMONG PHYSICAL ACTIVITY, CVD RISK FACTORS AND HEALTH OUTCOMES ACROSS THE LIFESPAN

Figure 1 illustrates the complex inter-relationships among physical activity, CVD risk factors and health outcomes across the lifespan and provides an overview of the questions addressed in this paper. The model was originally presented by Blair et al (10) and has been modified to address the question of the influence of physical activity and health-related fitness during childhood and adolescence on subsequent adult health outcomes (17).

In adults, relationships among physical activity, health-related fitness and health are well-established (18). Inter-relationships are bidirectional or reciprocal, ie, a physically inactive person will have an unfavourable CVD risk factor profile and increased risk of CVD mortality; in turn, CVD morbidity may inhibit or reduce the level of habitual physical activity. In children and adolescents, relationships between physical activity and CVD risk factors are less clear. This model also suggests that physical activity and CVD risk factors track into adulthood. Tracking refers to the stability of a characteristic or the maintenance of a relative rank within a group over time (19). It may also be possible that physical activity during childhood and adolescence impacts adult CVD risk factors, and CVD risk factors during childhood and adolescence impacts adult physical activity. Finally, it has been postulated that childhood physical activity and/or CVD risk factors directly influence adult health outcomes. This paper serves to address this model based on the proposed questions.

### WHAT ARE THE CURRENT LEVELS OF PHYSICAL ACTIVITY AND CVD RISK FACTORS IN NORTH AMERICAN CHILDREN AND ADOLESCENTS?

It is often assumed or implied that North American youth are inactive and unfit (16,20,21). What data support these claims?

#### Physical activity

Accurate measurement of habitual physical activity is essential in physical activity epidemiology (22). Physical activity and daily energy expenditure can be measured by questionnaires, surveys, diaries, motion sensors, heart rate monitors, indirect calorimetry and doubly labelled water. Each method has its own advantages and disadvantages. Thus, issues of reliability, validity and feasibility are important considerations. In general, there is an inverse relationship between validity and feasibility. For instance, a feasible method in large population studies such as a questionnaire is probably the least valid measure of physical activity; on the other hand, the most valid measures of energy expenditure, doubly labelled water or indirect calorimetry, are not practical or feasible in large studies. Given the various methodologies and limitations of measuring physical activity in youth, it is difficult to compare studies.

In an analysis of data from the first National Child and Youth Fitness Study (NCYFS I) in the United States, Blair et al (10) estimated that greater than 85% of youth expended at least 3 to 4 kcal/kg/day, which is the recommended amount of energy expenditure in physical activity for adults. In addition, 78% expended at least 6 kcal/kg/day, an amount suggested for youth (23). In a review of large population-based studies and smaller studies using objective measures of physical activity, Pate et al (24) determined that adolescents engaged in habitual physical activity for approximately 1 h per day. In addition, approximately 67% of males and 25% of females participated in moderate to vigorous physical activity for 20 min three or more times per week. Results from the 1999 United States Youth Risk Behavioral Surveillance (YRBS) indicate that approximately two-thirds (64.7%) of high school students nationwide participated in activities that made them sweat and breathe hard for at least 20 min on at least three of the seven days preceding the survey (ie, vigorous physical activity); 56.1% of high school students were enrolled in a physical education class but only 29.1% of students attended physical education class daily; and 55.1% of high school students played on sports teams during the 12 months preceding the survey. For all indicators of physical activity, participation was greater in males and Whites compared with females and ethnic minorities, respectively. Results from a quantitative review of 26 studies using heart rate data from three- to 17-year-old youth indicate that youth attained over 60 min per day of low intensity physical activity (20% to 50% of heart rate reserve) and approximately 30 min per day of physical activity using over 50% of heart rate reserve, a traditional cardiorespiratory fitness training level (25). Using uniaxial accelerometry as an objective measure of physical activity, a majority (70% to 90%) of Massachusetts students in grades one through 12 met various recommendations of 30 to 60 min of moderate activity per day (26). Using self-reported physical activity data from the 1998 Canadian National Population Health Survey, it was found that about 55% of males and 65% of females did not meet the 3 kcal/kg/day recommendation (27). Using the 6 kcal/kg/day recommendation, about 80% of 12- to 19-year-old males and

12- to 14-year-old females did not meet the recommendation, while about 90% of 15- to 19-year-old females did not meet this recommendation.

In light of the evidence provided above, it is important to recognize that the recommendations for sufficient physical activity for children and adolescents are generally based on expert opinion rather than evidence-based medicine. The need for a systematic approach to defining the required amount of physical activity necessary for optimal growth and development has recently been addressed (28). Nonetheless, if the preceding information is to be taken as evidence supporting that youth are physically active, the age-related decline in physical activity during adolescence should be seen as alarming. Adolescence (12 to 18 years) is marked by the greatest annual decline in physical activity throughout the lifespan (29,30).

Data examining the secular trend in physical activity are limited. Standardized data for physical activity are only available since 1993 through the YRBS. Among adolescents in grades nine to 12, there has been no significant change in self-reported vigorous physical activity (31). Using data from five Canadian surveys, it was found that the mean activity energy expenditure increased between the 1981 and 1988 surveys and has since (1992, 1994 and 1996) remained relatively stable (27).

#### **Aerobic fitness**

The age- and sex-associated variation in peak maximum oxygen consumption ( $\text{VO}_2$ ) during growth and maturation is well-known (32,33). In males, peak  $\text{VO}_2$  remains relatively stable (approximately 52 mL/kg/min) throughout childhood and adolescence. In females, values remain fairly stable (approximately 45 mL/kg/min) until about 12 years of age and then begin to decline through adolescence. In comparison, recommended values for adults are 38 and 35 mL/kg/min in males and females, respectively (34). In addition to the decline in peak  $\text{VO}_2$  in adolescent females, there has been an estimated secular decline of about 20% over the past few decades in 15- to 18-year-old American females (35). Based on the available data, there are no secular changes among six- to 18-year-old boys, or six- to 11- or 12- to 14-year-old girls.

#### **Overweight and obesity**

Recent evidence suggests that the prevalences of overweight and obesity have increased substantially in Canadian children over the previous two decades (36). Further, the increases in the prevalences of both overweight and obesity have been greater in children and youth than in adults over the same time frame. Results from the 1996 Canadian National Longitudinal Survey of Children and Youth indicate that approximately 33% and 26% of seven- to 13-year-old boys and girls, respectively, are overweight (37). The corresponding values for obesity are 10% for boys and 9% for girls. Provincial variation showed a west to east trend. Results from the United States Third National Health and Examination Survey, (NHANES III, 1988 to 1994) indicate that approximately 11% of American youth are overweight and an additional 14% are obese (38). Mexican-American males and females and Black females show slightly higher prevalence rates than white males and females. Native Americans generally have the highest prevalence rates (39). The prevalence of overweight and obesity has also increased over the past few decades in the United States with the largest increase between NHANES II (1976 to 1980) and NHANES III (38).

#### **Prevalence of other CVD risk factors**

There is a paucity of data establishing prevalence rates for hypertension and dyslipidemias in North American children and adolescents, particularly Canadian youth. By definition, 5% of youth are classified as hypertensive or dyslipidemic because the clinical cutpoint is based on the 95th percentile of reference values. About 10% of 12- to 19-year-olds have total cholesterol (TC) levels exceeding 5.18 mmol/L. A secular decline in the mean TC of 7 mg/dL among 12- to 17-year-olds was observed between 1966 to 1970 (National Health Examination Survey III) and 1988 to 1994 (NHANES III) (40).

Less is known about the natural history and epidemiology of type 2 diabetes in children and adolescents due to the lack of clear criteria and population-based surveys (41). The estimated prevalence of diabetes mellitus (type unknown) is estimated to be 4.1 per 1000 among 12- to 19-year-olds in NHANES III (42). Estimates are higher in Native Americans. An increase in the prevalence of type 2 diabetes is apparent. A 10-fold increase in the incidence (number of new cases per population) of type 2 diabetes among adolescents between 1982 and 1994 has been reported in the greater Cincinnati area (43).

### **WHAT IS THE RELATIONSHIP BETWEEN PHYSICAL ACTIVITY AND CVD RISK FACTORS DURING CHILDHOOD AND ADOLESCENCE?**

Relationships between physical activity and CVD risk factors during childhood and adolescence are briefly summarized here. The association between physical activity and CVD risk factors may be assessed in cross-sectional or experimental training studies. Correlational analyses are common in cross-sectional studies and therefore causation cannot be established. Cross-sectional comparisons are often made between active and inactive youth. Few studies have used logistic regression.

#### **Physical activity and aerobic fitness**

Correlations between habitual physical activity and aerobic fitness are generally low ( $r < 0.20$ ) (44). Available data indicate relatively little trainability of maximal aerobic power in children under 10 years of age, and changes in peak  $\text{VO}_2$  per unit body weight with training in children under 13 years are generally less than 5%. Among older children and adolescents, responses of aerobic power to training improve, but results are variable between studies (45).

#### **Physical activity and blood lipids**

Correlations between physical activity and blood lipids are often low and nonsignificant (46). When youth are grouped by level of physical activity or aerobic fitness, those in the upper extremes display a better blood lipid profile, and the difference is more apparent in boys than girls. However, the data are inconsistent. TC is consistently not associated with physical activity in children and adolescents. Some studies suggest that high density lipoprotein (HDL) cholesterol and triglycerides (TG) are higher and lower, respectively, in more active than inactive youth, and low density lipoprotein (LDL) cholesterol may also be lower in more active youth (46).

#### **Physical activity and blood pressure**

Only five of 15 cross-sectional studies have reported an inverse relationship between physical activity and blood

**TABLE 1**  
**Summary of tracking coefficients for cardiovascular disease risk factors from childhood and adolescence to adulthood**

Variable	Tracking coefficient
Physical activity	0.05 to 0.45
Aerobic fitness	0.30 to 0.82
Body fatness	0.04 to 0.84
Blood pressure	0.30 to 0.60
Blood lipids and lipoproteins	0.40 to 0.70

Data from references 16, 17 and 19

pressure (BP) (1). Training studies are generally ineffective in lowering BP among normotensive or hypertensive youth, whereas exercise training studies may reduce BP in hypertensive adolescents (47).

#### Physical activity and blood glucose and serum insulin

Studies examining the association between physical activity or aerobic fitness and blood glucose and/or insulin in children and adolescents are limited. In the Young Finns Study (48), lower fasting insulin levels were observed in active males compared with inactive males. The same finding was not observed in females. Fasting insulin, but not glucose, is related to aerobic fitness but not physical activity (49). In the same study, an eight-week exercise training program resulted in a greater reduction in insulin in children who improved aerobic fitness compared with those who did not improve aerobic fitness (49). Self-reported physical activity as a teenager is also associated with type 2 diabetes during adulthood (50).

#### Physical activity and adiposity

Although some cross-sectional studies suggest that obese children are less active than nonobese children, a relationship between physical activity, or inactivity (ie, television watching), and adiposity in the general pediatric population is not clearly established (51). A recent meta-analysis suggests a small to moderate relationship between physical activity and body fatness in children and adolescents, but the magnitude of the relationship depends on the method of measurement of physical activity (eg, motion sensors, questionnaire, etc) (52). Results from two American population-based studies indicate that moderate or vigorous physical activity is related to the body mass index and overweight status in children and adolescents (53,54). However, the results for television viewing and weight status have been shown to be more convincing than those for physical activity and weight status in American children and adolescents from national surveys (53-56). Dietz and Gortmaker (57) have hypothesized that increased television viewing is attributed to increasing pediatric obesity due to its potential effects on physical activity and nutritional habits (ie, consumption of calorically dense food).

The role of physical activity in the treatment of childhood obesity suggests that exercise alone is not an effective treatment for weight loss; exercise and dietary changes result in greater weight loss than dietary change alone; and lifestyle exercise intervention may be more effective in producing long term reductions in weight and percentage overweight than aerobic or calisthenics exercise intervention (58). Interventions aimed at decreasing sedentary behaviours (television and

computer games) appear to be more effective in reducing weight and body fat than interventions aimed at increasing physical activity (58). It is also important to note that physical activity is likely to maintain body weight regulation associated with normal growth and maturation.

#### Physical activity, physical fitness and CVD risk factors in youth: A multivariate approach

The associations between physical activity and CVD risk factors reviewed above have relied on univariate statistical methods. It has been argued that a multivariate approach may be preferable because physical activity and CVD risk factors cannot be quantified with a single measurement (59). Using a multivariate analysis, Katzmarzyk et al (59) examined the relationships among physical activity, physical fitness and CVD risk factors in youth nine to 18 years of age from the Québec Family Study. Physical activity and physical fitness, respectively, explained 5% to 20% and 11% to 30% of the variance in CVD risk factors (mean arterial pressure, TG, LDL, HDL and glucose). The physical activity domain (estimated daily energy expenditure, moderate to vigorous physical activity, inactivity and television time) and physical fitness domain (submaximal work capacity, muscle strength, sit-ups and sum of six skinfolds) were characterized by negative associations with mean arterial pressure, LDL, TG and glucose, and a positive association with HDL. The results indicate that a habitual physical activity profile, characterized by greater amounts of total daily energy expenditure, moderate to vigorous physical activity, and lower amounts of inactivity and television viewing is associated with a more favourable CVD risk profile.

### WHAT IS THE INFLUENCE OF CHILDHOOD PHYSICAL ACTIVITY AND CVD RISK FACTORS ON SUBSEQUENT ADULT CARDIOVASCULAR HEALTH?

#### Tracking of physical activity and CVD risk factors

It is often assumed that a physically active and fit child will become a physically active and fit adult, thus influencing adult health outcomes (60). Such an assumption prompts the promotion of a physically active lifestyle during childhood. One approach to this question is tracking. Tracking is statistically expressed as either a correlation coefficient between a measurement of a characteristic at two points in time, or the percentage of subjects that maintain a relative rank over time (ie, 35% remained in upper quartile).

A summary of interage tracking coefficients for physical activity and CVD risk factors is provided in Table 1. It should be noted that age span, age at first observation, significant environmental change and measurement variability need to be considered in the interpretation of tracking coefficients. Unlike physical activity, CVD risk factors track reasonably well from childhood and adolescence to adulthood. Using a composite risk factor index, the 12-year follow-up of eight- to 18-year-old youth in the Québec Family Study showed a tracking coefficient of 0.51 for males and 0.46 for females (61). Tracking is usually better when examined at the extremes. For example, 43% of subjects remained above 90th percentile, and 62% remained above 75th percentile when examined for blood lipids between ages eight and 18 years and re-examined between ages 20 and 25 years or 26 and 30 years (62).



### Childhood physical activity and adult cardiovascular health

Despite the supposition that physical activity during childhood reduces the risk of future CVD, few studies have examined the long term impact of childhood physical activity on adult cardiovascular health outcomes. Recently, two follow-up studies of Canadian children have shown similar results. Subjects in the Trois-Rivières Growth and Development Study (63), which examined the effect of daily physical education in primary school on several biological and psychosocial variables, were re-examined 20 years later. Results indicate no difference in adult levels of aerobic fitness, blood lipids, BP or body composition between experimental or control subjects. In 60 male subjects of the Saskatchewan Growth and Development Study (64), no significant association was observed between adolescent physical activity and adult TC to HDL-C ratio, but there was a trend for less active and aerobically fit males to have a larger waist-to-hip circumference ratio in adulthood.

In a recent series of papers involving the follow-up of European and North American longitudinal growth studies (65-67), it was concluded that physical fitness, but not physical activity, during youth is associated with a 'healthy' CVD risk profile later in life (68). Few significant relationships between adolescent physical activity and adult CVD risk factors were found.

### SUMMARY AND FUTURE DIRECTIONS

In summary, the number of youth that meet recommendations for physical activity varies by measurement tool and recommendation. It is clear that physical activity levels decline dramatically during adolescence. The increasing prevalence of overweight and obesity, and the emergence of type 2 diabetes in children and adolescents are of concern. Childhood overweight increases the risk of adult overweight, the clustering of other CVD risk factors, coronary calcification in adulthood, and all-cause and CVD mortality (69). The association

between physical activity and CVD risk factors in youth is generally weak to moderate at best, suggesting that other factors (genes, normal growth and maturation, other environmental factors) exert an influence on CVD risk factors. The role of physical activity on subsequent adult health outcomes may also relate to the regulation of body weight and the modification of CVD risk factors through their influence on body weight regulation. Despite the lack of causal evidence supporting the value of physical activity for the present and future cardiovascular health of children and adolescents, an important question to ask is the following: is there a scientific rationale that supports the value of being sedentary or low fitness for the present and future cardiovascular health of children and adolescents? (70).

Future directions of pediatric exercise epidemiology are numerous. Establishing reliable, valid and feasible measurements of physical activity and energy expenditure continues to be essential. Prospective cohort (follow-up) studies are required to examine the natural history of physical activity and CVD risk factors from childhood to adolescence to adulthood. In particular, the transition from adolescence to young adulthood presents a time period that reflects marked changes in behavioural (alcohol and tobacco use, dietary and physical activity patterns), sociodemographic (independence or autonomy from family, marriage, employment) and biological (body fatness, aerobic fitness) factors that are associated with an increased risk of CVD (71,72). National surveys examining the physical activity and CVD risk factors in youth are also warranted. The role of physical activity on the prevention and treatment of pediatric obesity and comorbidities also requires further exploration, preferably from a biobehavioural standpoint. Finally, the interaction of genes, physical activity, and traditional and emerging (ie, endothelial function, lipoprotein [a], homocysteine, C-reactive protein, etc) CVD risk factors may be a promising area to understand individual differences and the preclinical atherosclerotic condition.

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