

REVIEW / SYNTHÈSE

Physical activity guidelines for children and youth¹**Ian Janssen**

Abstract: The aim of this review is to provide a scientific update on evidence related to the biological and psycho-social health benefits of physical activity in school-aged children and youth. To accomplish this aim, the first part of the paper reviews existing physical activity guidelines for school-aged children and youth, with an emphasis placed on how Canada's guidelines compare and contrast with those of other countries and organizations. The paper then provides an overview of physical activity levels of Canadian children and youth, which indicates that few Canadian youngsters meet current physical activity recommendations. The next section of the paper summarizes the literature that informs how much physical activity is required to promote health and well-being in children and youth. The paper then provides suggestions on modifications that could be made to Canada's physical activity guidelines for children and youth. Specifically, consideration should be given to setting both minimal (≥ 60 min/d) and optimal (up to several hours per day) physical activity targets. The final section identifies future research needs. In this section, a need is noted for comprehensive dose-response studies of physical activity and health in the paediatric age group.

Key words: physical activity, children, adolescents, health.

Résumé : Cette étude se propose de faire un relevé des études scientifiques qui établissent les effets bénéfiques de l'activité physique sur les plans biologique et psychosocial chez les enfants d'âge scolaire et chez les adolescents. Pour atteindre cet objectif, la première partie de cet article analyse les directives courantes en matière d'activité physique à l'intention des enfants et des adolescents et s'attarde à comparer et à distinguer les directives canadiennes de celles des autres pays et organisations. Dans un deuxième temps, l'article présente un aperçu des niveaux de pratique de l'activité physique chez les enfants et les adolescents et arrive au constat que peu de jeunes Canadiens font ce qui est recommandé en matière d'activité physique. Par la suite, l'article trace le bilan des articles scientifiques portant sur la quantité d'activité physique requise pour améliorer la santé et le bien-être chez les enfants et les adolescents. Puis l'article propose des modifications aux directives canadiennes à l'intention des enfants et des adolescents. Notamment, on devrait cibler des durées minimale (au moins 1 heure par jour) et optimale (jusqu'à quelques heures par jour) de pratique de l'activité physique. En dernière partie, l'article suggère des pistes de recherche et souligne la nécessité de faire des études détaillées sur la quantité d'activité physique à faire (dose) pour obtenir des gains (effet) sur le plan de la santé chez les jeunes au Canada.

Mots-clés : activité physique, enfants, adolescents, santé.

[Traduit par la Rédaction]

Introduction

Canada's first set of physical activity guidelines for children and youth were introduced in 2002 (Health Canada and

the Canadian Society for Exercise Physiology 2002a, 2002b). The basic recommendation within these guidelines was that children and youth, independent of their current physical activity level, should increase the time they currently spend on physical activity by 30 min/d, and progress over approximately 5 months to ≥ 90 min/d. The aim of this review is to provide a scientific update on evidence related to the biological and psycho-social health benefits of physical activity in school-aged children and youth that has accumulated since the publication of these guidelines. Specifically, this paper will explore if Canada's physical activity guidelines for children and youth are appropriate; if not, it will make suggestions on how the guidelines could be modified to reflect current knowledge.

Existing physical activity guidelines for children and youth

The publication of Canada's physical activity guidelines

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for children and youth in 2002 represented a joint effort of the Canadian Society for Exercise Physiology and Health Canada. Two sets of guidelines were published, one for children aged 6–9 y (Health Canada and the Canadian Society for Exercise Physiology 2002*b*) and a second for youth aged 10–14 y (Health Canada and the Canadian Society for Exercise Physiology 2002*a*). In addition to the physical activity guides, which highlighted the recommended physical activity levels for these two age groups, a number of other promotional and educational packages were developed, including family booklets (Health Canada and the Canadian Society for Exercise Physiology 2002*c*, 2002*d*), teacher booklets (Health Canada and the Canadian Society for Exercise Physiology 2002*e*, 2002*f*), as well as physical activity magazines for children (Health Canada and the Canadian Society for Exercise Physiology 2002*g*) and youth (Health Canada and the Canadian Society for Exercise Physiology 2002*h*).

The key recommendations within Canada's child and youth physical activity guides are as follows:

- (1) Increase the time currently spent on physical activity by 30 min/d, and progress over approximately 5 months to ≥ 90 min/d.
- (2) Physical activity can be accumulated throughout the day in periods of at least 5–10 min.
- (3) The 90 min increase in physical activity should include 60 min of moderate activity (e.g., brisk walking, skating, bicycle riding) and 30 min of vigorous activity (e.g., running, basketball, soccer).
- (4) Participate in different types of physical activities — endurance, flexibility, and strength — to achieve the best health results.
- (5) Reduce non-active time spent watching television and videos, playing computer games, and surfing the Internet. Start with 30 min/d less of such activities and progress over the course of approximately 5 months to 90 min/d less.

Many other countries and organizations have developed physical activity guidelines and recommendations for school-aged children and youth, as summarized in Table 1. Only those guidelines that make a specific recommendation about the volume of physical activity are included in the table. In addition to the specific guidelines shown in Table 1, many other organizations have recommended that children and youth be physically active, but these recommendations have been made in very general terms (e.g., youngsters need to be active) and are therefore not included in this review.

From a historical perspective, professional organizations have paid attention to the definition and measurement of physical fitness, rather than physical activity. Over the past two decades, there has been an increasing concern about the health consequences of physical inactivity, with a concurrent shift from the use of physical fitness standards towards health-based physical activity targets (Biddle et al. 1998). Before 1998, the physical activity guidelines for children and youth were, for the most part, consistent with physical activity guidelines for adults (Table 1), and were based on studies correlating physical activity with morbidity and mortality risk in adults. These early physical activity guidelines

typically recommended about 30 min of accumulated physical activity on most or all days of the week.

It was not until 1998 that a set of physical activity guidelines based specifically on studies of children and youth were developed. The first of these was published by the UK Health Education Authority (Biddle et al. 1998), who convened an international panel of experts to write their guidelines. These guidelines recommended that children and youth participate in at least 60 min of moderate-intensity physical activity on a daily basis. The physical activity guidelines that have been developed for children and youth since 1998 have, with the exception of the Canadian guidelines, been very consistent with those of the UK Health Education Authority in terms of the volume of physical activity recommended (Table 1).

Canada's physical activity guidelines for children and youth are unique in two ways. First, rather than defining participation in an absolute amount of physical activity (e.g., 90 min/d), Canada's physical activity guidelines recommend that children and youth should increase the time they currently engage in physical activity, starting with 30 min/d more and progressing to 90 min/d more over the course of several months. Second, the minimal amount of physical activity recommended in Canada's physical activity guidelines for children and youth is at least 50% higher than that recommended in any of the other guidelines. More specifically, Canada's guidelines recommend an increase of 90 min/d physical activity, whereas the other guidelines for children and youth published since 1998 have recommended a minimum physical activity level of 60 min/d (or 60 min on most days). Another distinguishing feature of the Canadian guidelines is that they pertain to a limited age span. That is, rather than deriving guidelines that cover all school-aged children and youth, the Canadian guidelines are specific to 6–14-year-olds (with different promotional materials for 6–9-year-olds and 10–14-year-olds). The 15–19-year-old age range is not covered. As explained by Hearst and Sharratt in this issue (Hearst and Sharratt 2007), the exclusion of 15–19-year-olds reflects a lack of funding to develop additional guidelines and promotional materials that would cover more than two paediatric age groups (6–9 and 10–14 y).

Physical activity levels of Canadian children and youth

In the interest of presenting current and representative data, this section is limited to results that are based on nationally representative Canadian data sets collected within the past 5 years (2002 onward). Unfortunately, standardized and consistent physical activity surveillance data are not available for Canadian children and youth. Furthermore, the surveillance data on physical activity for the paediatric population is not congruent with the physical activity recommendations contained within Canada's physical activity guidelines for children and youth. These issues are discussed to a greater extent in the review by Katzmarzyk and Tremblay, contained in this issue (Katzmarzyk and Tremblay 2007).

Since 2000 Statistics Canada has monitored health behaviours in the population using the Canadian Community

Table 1. Existing physical activity guidelines for school-aged children and youth.

Organization	Title of recommendation	Reference	Year	Age range	Recommendation
American College of Sports Medicine	Opinion statement on physical fitness in children and youth	American College of Sports Medicine 1988	1988	Children and youth	Obtain 20–30 min of vigorous exercise each day
International Consensus Conference on Physical Activity Guidelines for Adolescents	Physical activity guideline for adolescents: consensus statement	Sallis and Patrick 1994	1994	11–21 y	Be physically active daily, or nearly daily, as part of play, games, sports, work, transportation, recreation, physical education, or planned exercise; engage in ≥3 sessions/week of moderate to vigorous activities that last ≥20 min
US National Institutes of Health	Consensus development panel on physical activity and cardiovascular health	NIH Consensus Development Panel on Physical Activity and Cardiovascular Health 1995	1995	All	Accumulate 30 min of moderate physical activity on most, preferably all, days of the week
US Surgeon General	Physical activity and health	US Department of Health and Human Services 1996	1996	≥2 y	Accumulate 30 min of moderate physical activity on most, preferably all, days of the week
UK Health Education Authority	Young people and health-enhancing physical activity: evidence and implications	Biddle et al. 1998	1998	Children and youth	Participate in physical activity that is of at least a moderate intensity for an average of 1 h/d; participate in physical activities that enhance and maintain strength in the musculature of the trunk and upper arm/girdle ≥2 d/week; the above recommendation should be met by participating in developmentally appropriate activities
Australia Department of Health and Ageing	National physical activity guidelines for Australians	Department of Health and Ageing 1999	1999	5–18 y	At least 60 min, and up to several hours, of moderate to vigorous physical activity every day; limit screen time ≤2 h/d
American Cancer Society	Guidelines on nutrition and physical activity for cancer prevention	Byers et al. 2002	2002	Children and youth	Engage in ≥60 min/d of moderate-to-vigorous physical activity at least 5 d/week
Health Canada and the Canadian Society for Exercise Physiology	Canada's physical activity guide for children and youth	Health Canada and the Canadian Society for Exercise Physiology 2002a, 2002b	2002	6–14 y	Increase time currently engaged in physical activity by at least 30 min/d (in periods of at least 5–10 min), progressing to ≥90 min/d more physical activity; the 90 min/d increase in physical activity should include both moderate (60 min) and vigorous (30 min) activities; decrease time spent doing sedentary activities (television, video games, internet), initially by 30 min/d, eventually by ≥90 min/d
Weight Realities Division of the Society for Nutrition Education	Guidelines for childhood obesity prevention programs	Weight Realities Division of the Society for Nutrition Education 2003	2003	Children	Be active for at least 60 min/d; limit screen time to <2 h/d and replace with more active activities
US National Association for Sports and Physical Education	Guidelines for appropriate physical activity for elementary school children	Corbin and Pangrazi 2004	2003	5–12 y	Accumulate at least 60 min, and up to several hours, of age-appropriate physical activity on all, or most days of the week; daily accumulation should include moderate and vigorous physical activities, with the majority being intermittent in nature
US Department of Agriculture	Dietary guidelines for Americans	US Department of Health and Human Services and US Department of Agriculture 2005	2005	Children and youth	Accumulate ≥60 min of physical activity on most, preferably all, days of the week

Table 1 (continued).

Organization	Title of recommendation	Reference	Year	Age range	Recommendation
Divisions of nutrition and physical activity and adolescent and school health of the US Centers for Disease Control	Evidence based physical activity for school-age youth	Strong et al. 2005	2005	6–18 y	Participate in ≥ 60 min/d of moderate to vigorous physical activity; activities should be developmentally appropriate, enjoyable, and involve a variety of activities

Note: Guidelines are listed in chronological order of release.

Health Survey (CCHS). The CCHS is a detailed interview (a combination of telephone and in-home interviews) conducted each year on representative samples of Canadians aged 12 and older. Physical activity levels are self-reported by the participants, including the adolescents. For each participant, total leisure-time physical activity energy expenditure is calculated based on (i) the types, frequency, and average duration of the physical activities in which they participated during the previous 3 months; (ii) the known energy expenditures associated with these physical activities; and (iii) their body mass. Based on a threshold of $12.5 \text{ kJ}\cdot\text{kg}^{-1}\cdot\text{d}^{-1}$ ($3.0 \text{ kcal}\cdot\text{d}^{-1}\cdot\text{kg}^{-1}$), the equivalent of 30 min of walking at a brisk pace (see review by Katzmarzyk and Tremblay 2007), only 48.7% of 12–19-year-old participants in the 2003 CCHS were classified as physically active (Statistics Canada 2004). Thus, despite using a conservative threshold (well below the amount of physical activity promoted in Canada's physical activity guidelines for youth), less than half of the youth population was considered physically active. Findings from the 2003 CCHS show clear gender and age differences in physical activity among Canadian youth. Using the $12.5 \text{ kJ}\cdot\text{kg}^{-1}\cdot\text{d}^{-1}$ threshold, 56.6% of male youth vs. 40.5% of female youth were physically active, and 51.9% of 12–14-year-olds vs. 46.7% of 15–19-year-olds were physically active (Statistics Canada 2004).

In the special nutrition cycle of the CCHS conducted in 2004, physical activity participation data for 6–11-year-old Canadian children was collected, based on parental reports of time spent in physical activity of at least a moderate intensity. Within this survey, 83.9% of children averaged at least 1 h/d of physical activity, and 42.6% averaged at least 2 h/d of physical activity, but only 9.8% averaged at least 3 h/d of physical activity (Statistics Canada 2005). As with adolescents, there were gender differences in the activity patterns of the children with 86.7% of males vs. 80.8% of females averaging at least 1 h/d of physical activity (48.6% vs. 36.2% for ≥ 2 h/d, 13.5% vs. 5.9% for ≥ 3 h/d) (Statistics Canada 2005).

The Health Behaviour in School-Aged Children survey (HBSC) is a cross-national study of youth in grades 6–10 (corresponding to ages 10–16 y); it is conducted across 34 countries, including Canada (Currie et al. 2001; http://www.hbsc.org/overview_studydesign.html). The latest HBSC survey with available data was conducted in 2001–2002. It assessed physical activity within a larger health behaviour questionnaire that was completed in the classroom setting. After being provided with a definition and examples of common physical activities, participants were asked how many days in the past week and in a typical week they undertook cumulative physical activity of 60 min or more (Prochaska et al. 2001). Scores on the simple physical activity questions that were used were significantly correlated with more direct measures of physical activity (accelerometers; $r = 0.40$) and were reliable ($r = 0.79$) in classifying subjects as meeting or not meeting physical activity guidelines (Prochaska et al. 2001). Based on European guidelines that recommend youth engage in 60 min of physical activity on at least 5 d/week (Biddle et al. 1998), subjects were categorized as physically inactive if they were active for 60 min on 0–4 d/week or physically active if they were active for 60 min on 5–7 days per week. In Canada, only 44.9% of youth were clas-

sified as being physically active, even though these conservative criteria were employed. Although less than half of the Canadian participants in the HBSC survey were classed as physically active, Canadian youth ranked third highest amongst the 34 countries participating in the HBSC (Janssen et al. 2005).

The Canadian Fitness and Lifestyle Research Institute has recently obtained objective physical activity measures in a representative sample of roughly 6000 Canadian school-aged children and youth (aged 5–19 y) who were part of the Canadian Physical Activity Levels Among Youth (CANPLAY) study (Canadian Fitness and Lifestyle Research Institute 2005). The data was collected between April 2005 and March 2006. Study participants wore pedometers during waking hours over a 7 d study period. Because the motion sensors on pedometers pick up walking and other movements (e.g., play, sport), the total “step count” is a reflection of overall physical activity levels and not just walking. The CANPLAY participants took an average of 11 356 steps/d as recorded by the pedometers. Compared with the average Canadian youth, children in Quebec took fewer “steps,” whereas children in the Western and Northern regions took more “steps.” The influences of age, gender, and socioeconomic differences seen in questionnaire-based surveys were also noted in the CANPLAY study. Interestingly, there were no differences in step counts between study participants who were and were not involved in organized sports.

A minimum count of 10 000 steps/d has been widely recommended for adults (Hatano 1993). However, Tudor-Locke and colleagues (Tudor-Locke et al. 2004) have suggested that counts of 12 000 and 15 000 steps/d are more appropriate physical activity levels for maintaining a healthy body mass in girls and boys, respectively. Within the CANPLAY study, only 27% of the study participants had step counts above these thresholds. The Canadian Fitness and Lifestyle Research Institute suggested within their report that a daily step count of 16 500 was equivalent to the 90 min of physical activity recommended in Canada’s physical activity guidelines for children and youth. Only 9% of the study participants (12% of boys, 5% of girls) had step counts above these thresholds. These new findings, based on objective assessments of physical activity and stringent physical activity thresholds consistent with the amount of physical activity recommended in Canada’s physical activity guidelines, indicate that 91% of Canadians between the ages of 5 and 19 y are not active enough.

Health benefits of physical activity in children and adolescents

Overview of 2005 evidence-based report

Although not as plentiful as for adults, there is considerable knowledge about the health benefits of physical activity in children and youth. Research in this field has been the topic of numerous systematic reviews and meta-analyses, a sample of which are referenced here (Etnier et al. 2006; Kelley and Kelley 2003; Reilly and McDowell 2003; Tol-frey et al. 2000; Twisk 2001). Indeed, researchers, health care practitioners, and the general public alike recognize

that leading a physically active life is an important part of healthy living for children and youth.

A systematic evaluation of evidence linking physical activity to several health and behavioural outcomes in school-aged children and youth was published in 2005 (Strong et al. 2005). This evaluation was sponsored by the US Centers for Disease Control and Prevention (CDC) and was developed by a multidisciplinary expert panel. The co-chairs of the panel (Dr. William B. Strong and Dr. Robert M. Malina) selected 11 other panellists, based on their expertise in specific areas of child and adolescent health. These areas included adiposity, cardiovascular health, mental health, academic achievement, musculoskeletal health, fitness, injuries, and asthma. Given the extensive nature of the CDC-sponsored evaluation, its use of a multidisciplinary team of experts, and its recent publication date, the health benefits of physical activity presented in this review are based largely on the results presented by the CDC-sponsored expert panel (Strong et al. 2005).

The expert panel reviewed over 850 articles, identified by computerized database searches and by searching the bibliographies of the panellists’ own libraries (Strong et al. 2005). Although their reviews were based on studies published in 2004 or earlier, it is unlikely that sufficient evidence has been published within the past two years to change the level of evidence presented in the expert panel’s report. Based on conceptual definitions and inclusion and exclusion criteria developed by the panel, participants systematically evaluated relevant articles for each of the health and behavioural outcomes considered. On the basis of their reviews, each panellist provided a summary of the evidence for strength (strong, >60% of studies reviewed; moderate, 30%–59% of studies reviewed; and weak, <30% of studies reviewed) and the direction (positive, null, or negative) of the effects of physical activity on each of the health and behavioural outcomes. The strength of evidence was judged from the statistical significance of the outcomes; it did not include other factors sometimes considered in evidence-based reports, such as the effect sizes of physical activity and the quality and types of studies.

The expert panel reached the following conclusions: (i) evidence-based data are strong to conclude that physical activity has beneficial effects on adiposity (within overweight and obese youth), musculoskeletal health and fitness, and several components of cardiovascular health; (ii) evidence-based data are adequate to conclude that physical activity has beneficial effects on adiposity levels in those with a normal body mass, on blood pressure in normotensive youth, on plasma lipid and lipoproteins levels, on non-traditional cardiovascular risk factors (inflammatory markers, endothelial function, and heart rate variability), and on several components of mental health (self-concept, anxiety, and depression) (Strong et al. 2005). A summary of evidence concerning the health outcomes examined by the expert panel is shown in Table 2. The amount, intensity, and type of physical activity required to achieve the result, when clear, is also shown.

Based on the evidence summarized in Table 2, the 2005 CDC-sponsored expert panel recommended that school-aged children and youth accumulate 60 min of physical activity on a daily basis (Strong et al. 2005). They also recom-

Table 2. Association between physical activity and health and behavioural outcomes in children and youth.

Sample ^a	Health or behavioural outcome	Effect ^b	Amount of physical activity required for health benefit ^c
Overweight or obese	Adiposity	+	F, 3–5 d/week; I, moderate to vigorous; D, 30–40 min/d; T, variety of aerobic activities
Normal weight	Adiposity	Null	Unclear (probably similar to overweight)
Overweight or obese	Metabolic syndrome	+	Unclear
	Lipids/lipoproteins		
	Total cholesterol	Null	Unclear
	LDL-cholesterol	Null	Unclear
	HDL-cholesterol	+	Unclear (probably similar to adiposity)
	Triglycerides	+	Unclear (probably similar to adiposity)
Normotensive	Blood pressure	Null	Unclear
Hypertensive	Blood pressure	+	F, 12–32 week, 3 d/week; I, intensity to improve aerobic fitness; D 30 min/session; T, aerobic
	Endothelial function	Null	Unclear
	Inflammation	Null	Unclear
	Heart rate variability	Null	Unclear
	Coagulation	Null	Unclear
	Mental health		
	Anxiety symptoms	+	Unclear (varies with mode of activity)
	Depression symptoms	+	Unclear (varies with mode of activity)
	Self-concept		
	Global self-concept	+	Unclear
	Physical self-concept	+	Unclear
	Sport competence	+	Unclear
	Social self-concept	Weak +	Unclear
	Academic self-concept	Weak +	Unclear
	Academic performance		
	Grades, standardized tests	+	Unclear (added physical education)
	Indicators (eg, memory)	+	Unclear
Prepubertal and pubertal	Bone strength	+	F, 2–3+ times/week; I, moderate-high strain; D, 10–60 min; T, 10 min of impact, 45–60 min of general weight bearing
Postpubertal	Bone strength	Weak +	Unclear
>7 years	Aerobic fitness	+	F, >3 d/week; I, vigorous (80% VO ₂ max; D, 30–45 min; T, variety of activities
>6 years	Strength and endurance	+	F, 2–3 d/week; I, strength 70%–85% 1RM, endurance, 30%–60% 1RM, sets 2–5; D, 30–45 min; T, variety with adult supervision

Note: Table adapted from Strong et al. 2005.

^aUnless otherwise indicated, all samples are from the general child and youth population.

^b+, positive (beneficial) effect; null, insufficient evidence upon which to base a decision or no effect identified.

^cAmount of activity required to achieve the result. F, frequency; I, intensity; D, duration; T, type of activity.

mended that the activity should be developmentally appropriate, enjoyable, and involve a variety of activities. The recommendation of 60 min/d was in large measure based on the results of intervention studies demonstrating that a 30–45 min structured bout of physical activity 3–5 d/week was effective in improving a variety of health outcomes. Thus, 60 min/d was chosen as the recommended level, to allow for inter-individual variations in response (e.g., although 30–45 min may be effective for the average person, it is not necessarily effective for all individuals) and to account for intermittent activity (e.g., play, walking to school) that would not have been part of the structured interventions.

Owing to the high prevalence of obesity (1 in 4 children are now overweight or obese) and a rapid increase in the number of overweight and obese children and youth in Can-

ada (the prevalence of obesity has tripled in the last 20 years) (Tjepkema and Shields 2005), this review has given special consideration to the amount of physical activity associated with a healthy body mass during childhood. As indicated in the review of adult populations (this issue of the journal, Warburton et al. 2007), the volume of physical activity required to prevent weight gain and maintain weight loss is higher than the volume of physical activity required to reduce overall morbidity and mortality risk. Thus, although 30 min of moderate-intensity physical activity on most or all days of the week is appropriate to prevent many diseases in adults, it may not be sufficient for weight control; most adults may require upwards of 60 min/d to prevent age-related weight gain. The evidence in children and youth, although not as strong as for adults, also supports this contention.

For example, although the prescription of 30 min of aerobic exercise 3 d/week is effective in reducing blood pressure in hypertensive children and youth, aerobic exercise interventions lasting 30–40 min/session on 3–5 d/week are needed to improve adiposity in obese children and youth (Strong et al. 2005). Nonetheless, physical activity guidelines should focus on prevention rather than treatment. In this regard, the volume of physical activity required to prevent excessive weight gain in children and youth is unclear.

Although body weight control is an important outcome of participation in regular physical activity, it is necessary to consider numerous other health benefits in the absence of any effects on weight. By comparison with overweight and obese youth who are inactive and unfit, overweight and obese youth who are physically active and fit have less body fat (Nassis et al. 2005), an improved cardiovascular risk factor profile (Andersen et al. 2006; Eisenmann et al. 2005), and better psycho-social health (Janssen et al. 2004). Thus, current evidence suggests that physical activity has many important benefits other than weight regulation for overweight and obese children and youth.

Dose–response relationship between physical activity and health in children and youth

Dose–response studies are particularly useful for determining the minimal and optimal amount of physical activity required for good health, and for developing physical activity guidelines. In adults, the scientific community generally holds that a positive parabolic curve describes the relationship between physical activity and most health outcomes (Kesaniemi et al. 2001; Pate et al. 1995). That is, large health benefits occur with increases of physical activity at the low end of the physical activity scale, but minimal benefits in health are seen with further increases in physical activity at the upper end of the physical activity scale. Thus, existing guidelines for physical activity in adults are quite modest, with a recommendation of 30–60 min of moderately intense physical activity on most or all days of the week (Health Canada and the Canadian Society for Exercise Physiology 1998; Pate et al. 1995). There is no such consensus on the dose–response relationship between physical activity and health in children and youth, reflecting a lack of comprehensive dose–response studies in this age group. Literature reviews and evidence-based guidelines of physical activity and health in children and youth have consistently acknowledged the lack of studies examining the dose–response relationship between physical activity and health in this age group (Biddle et al. 1998; Etnier et al. 2006; Sallis and Patrick 1994; Strong et al. 2005; Tolfrey et al. 2000; Twisk 2001). The lack of dose–response studies has made it difficult to set minimal and maximal physical activity targets for children and youth.

A few studies have adequately measured the dose–response relationship between physical activity and health in youngsters, as reviewed below.

Raitakari and colleagues published a study based on cross-sectional data collected in 1986 on the association between physical activity and cardiovascular risk factors in 2358 young Finns (aged 9–24 y) (Raitakari et al. 1997). A physical activity index was created, based on the product of

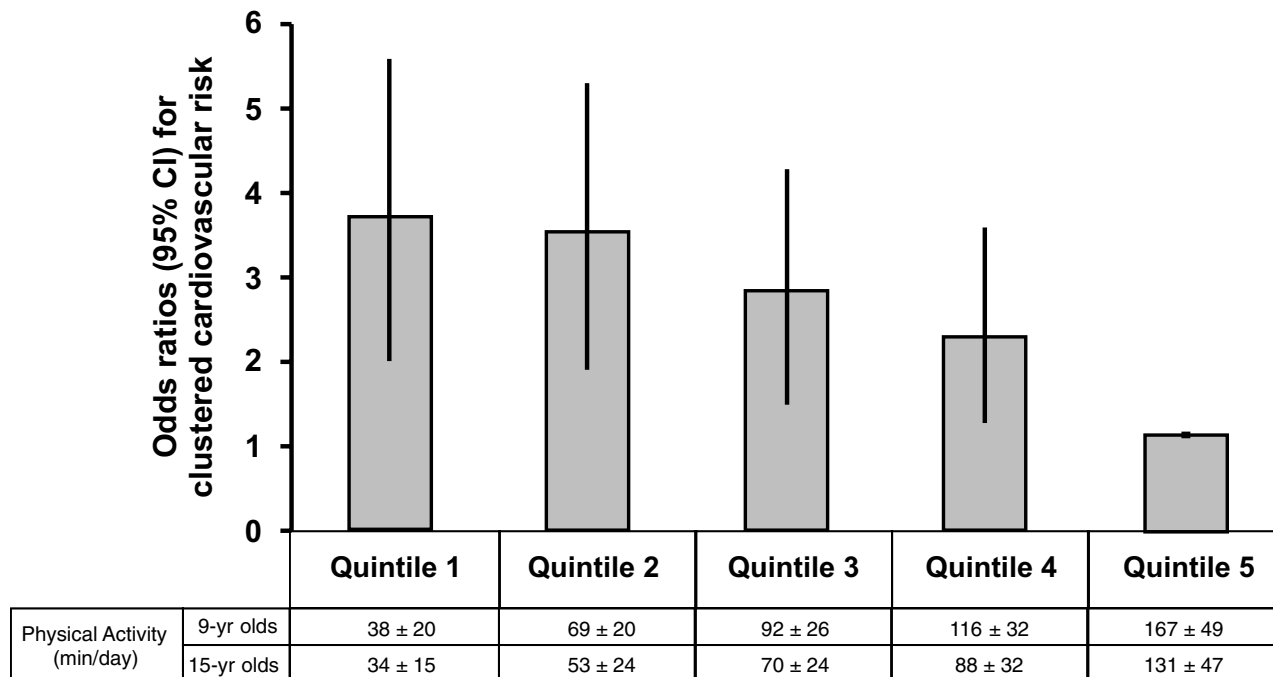
intensity, duration, and frequency of self-reported participation in structured physical activities. This index was subsequently divided into tertiles and risk factors were compared amongst the 3 groups. The authors concluded from their findings that “physical activity is associated with a favourable serum lipid profile during childhood and early young adulthood in a dose-related manner”. There were numerous limitations to this study, some of which are as follows: (i) the age range crossed from childhood into adulthood, and it is plausible that the gradation of response was driven by data from the young adults; (ii) only three physical activity categories were compared, and each of these categories included a wide range of physical activity scores, making it impossible to discern the pattern of the dose–response relationship and to determine minimal and maximal threshold for health benefits; (iii) because a derived physical activity index was used, the findings cannot easily be extrapolated to yield a clear practical recommendation such as daily minutes of physical activity; and (iv) the study was cross-sectional in design.

In 2004, Tolfrey and colleagues published the results of a 12 week intervention study conducted on a small sample ($n = 36$) of 10–12-year-olds (Tolfrey et al. 2004). Participants engaged in either low- (~60 min/week) or moderate- (~78 min/week) volume exercise programmes. Given the small (~18 min/week) differences in duration of physical activity across groups, the researchers not surprisingly failed to find dose–response or threshold effects on blood cholesterol and lipids. It is important to note that even their moderate-volume exercise program (~78 min/week) would be considered insufficient by most physical activity guidelines.

Two recent cross-sectional studies have examined the dose–response relationship between physical activity and obesity in school-aged youth. In these studies, the volume of physical activity was assessed directly, by accelerometer, a clear strength relative to the vast majority of epidemiological studies in this field, which have relied on self-reported questionnaire measures. Lohman et al. examined 1530 girls in grade six (Lohman et al. 2006). The mean percentage of body fat (as determined by skinfold thicknesses) decreased in a dose–response manner (from 29.4 to 25.3%) on moving from the lowest to the highest physical activity quintile. The trends for body mass index (BMI) were similar (with changes from 21.7 to 19.8 kg/m² across physical activity quintiles). Ness et al. examined 5500 12-year-olds (Ness et al. 2007). The odds ratio for having a high body fat content (as determined by dual-energy X-ray absorptiometry) between the top and bottom physical activity quintiles was 0.03 in boys and 0.36 in girls. The associations between physical activity and trunk fat were very similar to those observed for total fat. The findings of Ness et al. speak to the strength of the association between physical activity and adiposity when variables are measured by objective and accurate techniques. Although there has been some debate about the utility of physical activity as a strategy for obesity control in children and youth (Wareham et al. 2005), this may reflect the poor measures of physical activity and obesity and consequent lack of significant findings in many studies.

Andersen and colleagues (2006) published what is arguably the best dose–response study on physical activity and

Fig. 1. Odds ratio for clustered cardiovascular risk by physical activity quintiles. Error bars represent 95% confidence intervals. Average \pm SD minutes of physical activity (min/d) for each physical activity quintile, by age, are shown in the table at the bottom of the figure. Figure created from data presented in Andersen et al. (2006).



health in youth. Their cross-sectional study included 1732 randomly selected 9- and 15-year-old students from three European countries. The volume of physical activity was directly assessed by accelerometry. The health outcome examined was a composite score based on several cardiovascular risk factors (blood pressure, triglycerides, total cholesterol/HDL ratio, insulin resistance, the sum of four skinfolds, and aerobic fitness). The likelihood of having a high cardiovascular risk factor score increased in a clear dose-response manner when moving from the lowest to the highest physical activity quintile (Fig. 1). Given the two-fold difference in risk between the 4th (mean of \sim 100 min/d of physical activity) and 5th (mean of \sim 150 min/d of physical activity) quintiles, there was no apparent health threshold. This suggests that although some health benefits are observed at lower levels of physical activity, higher levels of physical activity will result in additional health benefits. The limitations of this study (Andersen et al. 2006) were its cross-sectional design, and a statistical analysis that did not model the dose-response relationship optimally by using a cubic spline approach (Royston 2000). The range of physical activity in the highest physical activity quintile was quite large, with a mean and standard deviation of approximately 150 min/d and 50 min/d, respectively. It is not clear from the results presented whether maximal benefit was achieved within the highest quintile of physical activity, and a cubic spline model could have been used to determine if the effects of increasing physical activity on the cardiovascular risk score eventually reached a plateau within the upper physical activity quintile.

Other considerations

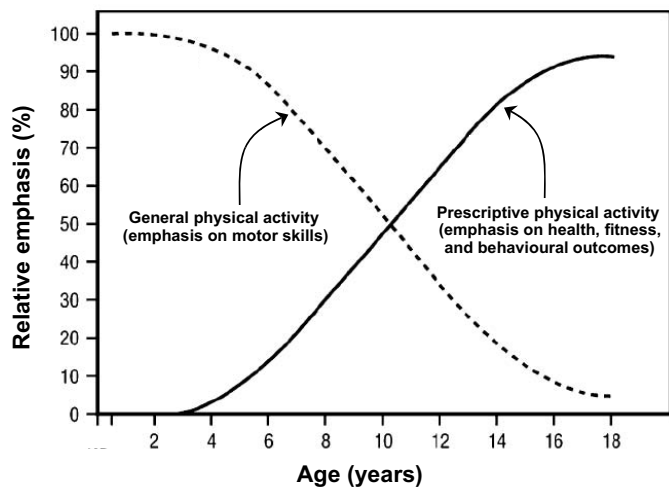
Physical activity guidelines for children and youth should

be consistent with the patterns of physical activity that are typical in this age group. Studies wherein physical activity patterns of youngsters were continuously and objectively monitored using accelerometers have shown that few young people, particularly young children, engage in bouts of physical activity lasting for 15 min or longer. However, most children and youth engage in many 5–10 min bouts throughout a typical day (Armstrong et al. 1990; Pate et al. 1994). Accordingly, a physical activity guideline that recommends the accumulation of smaller bouts of physical activity throughout the course of the day is practical and realistic for children and youth. This is entirely consistent with Canada's physical activity guidelines for children and youth, wherein it is indicated that physical activity can be accumulated in 5–10 min bouts throughout the course of the day.

As outlined in Table 2, participation in strength-training activities has beneficial effects on bone density, as well as on muscular strength and endurance. Conversely, participation in aerobic activities has beneficial effects on cardiorespiratory fitness, adiposity, and numerous cardiovascular risk factors. These points emphasize the importance of participating in both aerobic and anaerobic activities (Strong et al. 2005). This requirement has been captured in Canada's existing physical activity guidelines for children and youth. The guidelines stress that endurance, flexibility, and strength activities should be combined to achieve the best results.

Some of the health outcomes associated with physical activity in children and youth, including reductions in adiposity and blood pressure, and increased bone health, are greater with vigorous- than with moderate-intensity activities (Strong et al. 2005). Based on these findings, and the fact that it is unrealistic to expect young people to participate every day in more than 90 min of vigorous physical ac-

Fig. 2. Changing emphasis of different types of physical activity during childhood and adolescence. Figure modified from Malina (1991).



tivity, both moderate- and vigorous-intensity activities should be recommended for children and youth. Canada's current physical activity guidelines for children and youth indicate that the 90 min increase in physical activity includes approximately 60 min of moderate-intensity activities and 30 min of vigorous activities.

The physical activities in which children and youth engage, as well as the patterns of these activities, vary considerably with age. The activities that younger children elect are largely anaerobic; they help the children learn movement patterns and skills. Once the basic movements and skills have been developed, the fitness, health, and behavioural aspects of physical activity become more important (Strong et al. 2005). Thus, as illustrated in Fig. 2, the emphasis on general physical activities (games, play, etc.) and prescriptive physical activities (including many activities and organized sport) should change over the developmental years; less emphasis should be placed on general activities and more emphasis given to prescriptive activities as youngsters age. By the time late adolescence is reached (15–19 years), physical activity programmes can be very structured, similar to what would be prescribed for adults. Within the general and prescriptive physical activity domains illustrated in Fig. 2, the activities themselves should also vary across the age spectrum. For example, strength-building activities that are appropriate for younger children may include climbing, gymnastics, and callisthenics. Adolescents, on the other hand, can participate in structured resistance-training programs under appropriate adult supervision (Blimkie and Bar-Or 1996). These concepts are well captured in Canada's physical activity guidelines, as the types and examples of activities promoted in the child guide are different from those promoted in the youth guide.

Finally, when dealing with children and youth it is important to consider that the physical activities should be enjoyable. This will help ensure that youngsters will develop positive attitudes towards physical activity that will continue into adulthood. Although not stated in the physical activity recommendations, the concepts that physical activity should

be “fun, enjoyable, and cool” are stressed in Canada's physical activity guides for children and youth, and in the accompanying promotional materials (teacher and family guides, child and youth magazines). Studies of children and youth indicate that having fun is a key reason for participation in physical activity and sport (Olga et al. 2006; Salguero et al. 2003). Conversely, an overly competitive and stressful atmosphere is believed to contribute to dropout from sport during the developing years (Olga et al. 2006; Salguero et al. 2003). The vast majority of children and youth do not value the long-term health benefits of physical activity, and many of these health benefits may not be apparent for years or even decades. Physical activity messages developed for children and youth need to be informative (e.g., focussing on the immediate and short-term benefits of physical activity), relative (e.g., stressing things that are important for this age group), and persuasive. These messaging concepts are discussed at length by Brawley and Latimer (2007).

Considerations for Canada's physical activity guidelines for children and youth

The next section of this review is intended to be one part of the process involved in moving forward on the review and potential revision of Canada's physical activity guidelines for children and youth. These are not physical activity recommendations per se, but rather areas that warrant consideration in the next phase of the guideline modification process.

There is strong evidence to suggest that participating in 60 min/d of physical activity will have meaningful health benefits in most children and youth (Strong et al. 2005). Indeed, with the exception of Canada, all other physical activity guidelines for children and youth that have been developed since 1998 have used 60 min/d (or on most days) as a minimal physical activity target for children and youth. The current recommendation of an increase in activity of 90 min/d may be quite intimidating, particularly for children and youth who are very inactive. From a behavioural perspective, having a target that seems out of reach may actually discourage physical activity participation. In light of this evidence, as the review process for Canada's guidelines continues, consideration should be given to including a minimal physical activity target. Current evidence suggests that a minimal target of 60 min/d may be appropriate.

That being said, the limited amount of dose–response evidence available suggests that more physical activity will be better, and additional health benefits can still be achieved in children and youth even when they are already undertaking 90 min/d of physical activity. Both the US National Association for Sports and Physical Education (Corbin and Pangrazi 2004) and the Australia Department of Health and Ageing (Department of Health and Aging 1999) have recommended that children and youth participate in at least 60 min, and up to several hours, of moderate- to vigorous-intensity physical activity every day. In this way, they have set both minimal and optimal targets. Canada's physical activity guidelines for children and youth may want to consider adopting a similar approach. That is, recommend a minimal amount of physical activity of 60 min/d, but also

note that substantial benefits can be achieved with more activity, indicating that most Canadian children and youth are not active enough, and that children and youth should be encouraged to increase their current physical activity levels up to several hours per day. This type of message should encourage children and youth who are very inactive to engage in at least a modest amount of physical activity, and also encourage moderately active children and youth to achieve even greater benefits by becoming more active. Such a message would thus remain consistent with the current child and youth guidelines for Canada that recommend undertaking more activity at higher intensities.

Although from a biological and health perspective high levels of physical activity should be recommended to children and youth, from a behavioural perspective it would require considerable efforts to bring about changes in population behaviour for most people to achieve these goals. The reader is referred to the review by Brawley and Latimer in this supplement for more discussion of these behavioural issues (Brawley and Latimer 2007). The physical and social environments within most Canadian communities, homes, and schools also make it challenging for many children and youth to achieve these targets. The built environment (an inability to walk and play in many neighbourhoods, an inadequacy of community facilities for physical activity, etc.), safety issues around letting children play unsupervised outdoors, the lack of daily physical education and qualified physical education teachers within most Canadian schools, and the poor parental role models that most young people have, all influence the ability of children and youth to meet the levels of physical activity recommended in the Canadian guidelines. Further discussion of these variables is beyond the scope of this review, but they warrant consideration when discussing both the development of physical activity guidelines and the ability of the population to adhere to the guidelines.

Other issues that should be addressed are the lack of physical activity guidelines for pre-school children (covered in this issue by Timmons and colleagues 2007), and for 15–19-year-olds, currently not addressed within the Canadian youth (ages 10–14) or adult (ages 20+) guidelines. Present evidence suggests that the amount of physical activity appropriate for health and well-being in younger adolescents is also appropriate for older adolescents (Strong et al. 2005). The 15–19-year-old age range is an important transition period, when youth are becoming increasingly independent, are no longer required to take physical education at school, are becoming less reliant on active forms of transportation, and, in most cases, are moving out of their parents' homes. Physical activity levels decline sharply during adolescence (Canadian Fitness and Lifestyle Research Institute 2006). Thus, stressing the importance of physical activity and recommending high levels of physical activity, consistent with Canada's physical activity guidelines for 10–14-year-olds, would seem appropriate for the 15–19-year-old age group as well.

With these suggestions in mind, a number of positive aspects of Canada's physical activity guides for children and youth were noted in this review. The guides recommended different types of activity (e.g., aerobic, strength, flexibility), both moderate- and vigorous-intensity activities, develop-

mentally appropriate activities, the enjoyable nature of physical activity, the finding that children and youth can accumulate the required activity in 5–10 min bouts over the course of a day, and the fact that most children and youth in Canada are quite inactive and need to increase their current physical activity level vastly.

Recommendations for future research

Existing physical activity guidelines for children and youth have been based on available evidence, which is less than ideal in amount and type. Dose–response studies are particularly useful in determining the minimal and optimal amounts of physical activity required for good health, and subsequently for developing physical activity guidelines. Few studies of children and youth have examined dose–response relationships between physical activity and health adequately. This has hampered the development of physical activity guidelines. There is a dire need for comprehensive dose–response studies of physical activity and its many health outcomes in the paediatric age group.

Most research on the health benefits of physical activity in school-aged children and youth has focused on biological health outcomes. More research is needed to determine the dose of physical activity required for several domains of mental and emotional health in this age group. Considerable research in adult populations has examined the impact of physical activity on emerging cardiovascular risk factors such as inflammatory markers, measures of vascular health (e.g., endothelial function), and autonomic function (e.g., heart rate variability) (Jurca et al. 2005), but these are still understudied areas in the paediatric age group (Strong et al. 2005).

One of the biggest limitations to studies of physical activity and health in children and youth has been the almost sole reliance on self-reported measures of physical activity, the limitations of which are highlighted by Esliger and Tremblay (2007) in this issue of the journal. Recent studies in school-aged children and youth suggest that self-reported physical activity measures over-predict actual physical activity (Bender et al. 2005; Wong et al. 2006). This is particularly problematic when the findings from self-reported studies are extrapolated to make public health recommendations about the volume of physical activity required for good health. The necessary volume of physical activity may be substantially underestimated if it is based simply on self-reported measures of physical activity. More studies of children and youth are needed in which objective physical activity measures have been obtained. Accelerometry data are now being collected as part of the US National Health and Nutrition Examination Survey and the Canadian Health Measures Survey (data collection started in March 2007). The availability of these objective measures of physical activity on large samples of the population will open up a number of exciting investigations of relationships between physical activity and health in children and youth.

Experimental (intervention) studies provide the strongest evidence of a cause-and-effect relationship. Such studies are important in all age groups in confirming evidence of the health benefits of physical activity, and in determining the volume of physical activity that is appropriate for health

and well-being. Experimental studies of physical activity and health in children and youth have typically been based on 30–45 min bouts of structured exercise performed 3–5 d/week. Such types of studies have little relevance to the way most youngsters, particularly young children, engage in physical activity. Children and youth tend to accumulate their physical activity in shorter bouts (e.g., 10 min at recess) throughout the day. There is a need for intervention studies that target making changes in physical activity throughout the course of the day, and an analysis of how these changes influence health outcomes. Nonetheless, until the environment in Canadian communities becomes more favourable to physical activity, more structured interventions may be the only reliable approach to ensure that youngsters are sufficiently active.

This review has been limited to physical activity. However, in addition to physical activity a number of physical activity guidelines for children and youth make recommendations about curtailing sedentary behaviours, particularly screen-time behaviours (television, computer, and video games) (see Table 1). The Canadian guidelines, for example, suggest reducing screen time by 90 min/d in conjunction with the 90 min/d increase in physical activity (Health Canada and the Canadian Society for Exercise Physiology 2002a, 2002b). There is a need to examine the relationship between screen time and health in children and youth more specifically and to determine the volume of screen time associated with poor health and lack of physical activity in this age group.

Finally, Canada's physical activity guidelines for children and youth, as well as this review, have been targeted towards healthy youngsters. There is also a need for research to determine whether the volume, intensity, and type of physical activity required for health and well-being in healthy children and youth is appropriate for children and youth with disease (e.g., cystic fibrosis and leukemia), physical disabilities (e.g., spinal cord disorders), and mental disabilities (e.g., Down syndrome and autism).

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References

- American College of Sports Medicine. 1988. Opinion statement on physical fitness in children and youth. *Med. Sci. Sports Exerc.* **20**: 422–423. doi:10.1249/00005768-198808000-00022.
- Andersen, L.B., Harro, M., Sardinha, L.B., Froberg, K., Ekelund, U., Brage, S., and Anderssen, S.A. 2006. Physical activity and clustered cardiovascular risk in children: a cross-sectional study (The European Youth Heart Study). *Lancet*, **368**: 299–304. doi:10.1016/S0140-6736(06)69075-2. PMID:16860699.
- Armstrong, N., Balding, J., Gentle, P., Williams, J., and Kirby, B. 1990. Peak oxygen uptake and physical activity in 11- to 16-year-olds. *Pediatr. Exerc. Sci.* **2**: 349–358.
- Bender, J.M., Brownson, R.C., Elliott, M.B., and Haire-Joshu, D.L. 2005. Children's physical activity: using accelerometers to validate a parent proxy record. *Med. Sci. Sports Exerc.* **37**: 1409–1413. doi:10.1249/01.mss.0000174906.38722.2e. PMID:16118590.
- Biddle, S., Sallis, J., and Cavill, N. 1998. Policy framework for young people and health-enhancing physical activity. *In* Young and active? Young people and health-enhancing physical activity: evidence and implications. Edited by S. Biddle, J. Sallis, and N. Cavill. Health Education Authority, London, UK. pp. 3–16.
- Blimkie, C.J.R., and Bar-Or, O. 1996. Trainability of muscle strength, power, and endurance during childhood. *In* The child and adolescent athlete. Edited by O. Bar-Or. Blackwell Science, Oxford, UK. pp.113–129.
- Brawley, L., and Latimer, A. 2007. Physical activity guidelines for Canadians: messaging strategies and realistic expectations for change and evaluation. *Appl. Physiol. Nutr. Metab.* **32**(Suppl. 2): this issue.
- Byers, T., Nestle, M., McTiernan, A., Doyle, C., Currie-Williams, A., Gansler, T., and Thun, M. 2002. American Cancer Society guidelines on nutrition and physical activity for cancer prevention: Reducing the risk of cancer with healthy food choices and physical activity. *Calif. Cancer J. Clin.* **52**: 92–119. PMID:11929008.
- Canadian Fitness and Lifestyle Research Institute. 2005. 2005 Physical activity monitor. Canadian Fitness and Lifestyle Research Institute, Ottawa, Ont.
- Canadian Fitness and Lifestyle Research Institute. 2006. 2006 Physical activity monitor. Canadian Fitness and Lifestyle Research Institute, Ottawa, Ont.
- Corbin, C.B., and Pangrazi, R.P. 2004. Physical activity for children: a statement of guidelines for children aged 5–12. 2nd ed. National Association for Sport and Physical Education, Reston, Va.
- Currie, C., Samdal, O., Boyce, W., and Smith, B. 2001. Health behaviour in school-aged children: a World Health Organization cross-national study. Research protocol for the 2001/02 survey. Child and Adolescent Health Research Unit, University of Edinburgh, Edinburgh, UK. Available from http://www.hbsc.org/overview_studydesign.html.
- Department of Health and Ageing. 1999. National physical activity guidelines for Australians. Commonwealth of Australia, Canberra.
- Eisenmann, J.C., Katzmarzyk, P.T., Pérusse, L., Tremblay, A., Després, J.P., and Bouchard, C. 2005. Aerobic fitness, body mass index, and CVD risk factors among adolescents: the Quebec family study. *Int. J. Obes.* **29**: 1077–1083. doi:10.1038/sj.ijo.0802995.
- Esliger, D.W., and Tremblay, M.S. 2007. Physical activity and inactivity profiling: the next generation. *Appl. Physiol. Nutr. Metab.* **32**(Suppl. 2E): this issue.
- Etnier, J.L., Nowell, P.M., Landers, D.M., and Sibley, B.A. 2006. A meta-regression to examine the relationship between aerobic fitness and cognitive performance. *Brain Res. Brain Res. Rev.* **52**: 119–130. doi:10.1016/j.brainresrev.2006.01.002.
- Hatano, Y. 1993. Use of pedometer for promoting daily walking exercise. *ICHPER*, **29**: 4–8.
- Health Canada and the Canadian Society for Exercise Physiology. 1998. Handbook for Canada's physical activity guide to healthy active living. Cat. No. H39-429/1998-2E. Health Canada, Ottawa, Ont.
- Health Canada and the Canadian Society for Exercise Physiology. 2002a. Canada's physical activity guide for youth. Cat. No. H39-611/2002-IE. Minister of Public Works and Government Services Canada, Ottawa, Ont.
- Health Canada and the Canadian Society for Exercise Physiology. 2002b. Canada's physical activity guide for children. Cat. No.

- H39-611/2002-2E. Minister of Public Works and Government Services Canada, Ottawa, Ont.
- Health Canada and the Canadian Society for Exercise Physiology. 2002c. Family guide to physical activity for youth 10–14 years of age. Cat. No. H39-646/2002-2E. Minister of Public Works and Government Services Canada, Ottawa, Ont.
- Health Canada and the Canadian Society for Exercise Physiology. 2002d. Family guide to physical activity for children 6–9 years of age. Cat. No. H39-646/2002-1E. Minister of Public Works and Government Services Canada, Ottawa, Ont.
- Health Canada and the Canadian Society for Exercise Physiology. 2002e. Teacher's guide to physical activity for youth 10–14 years of age. Cat. No. H39-647/2002-2E. Minister of Public Works and Government Services Canada, Ottawa, Ont.
- Health Canada and the Canadian Society for Exercise Physiology. 2002f. Teacher's guide to physical activity for children 6–9 years of age. Cat. No. H39-647/2002-1E. Minister of Public Works and Government Services Canada, Ottawa, Ont.
- Health Canada and the Canadian Society for Exercise Physiology. 2002g. Gotta move! Magazine for children 6–9 years of age. Cat. No. H39-648/2002-1E. Minister of Public Works and Government Services Canada, Ottawa, Ont.
- Health Canada and the Canadian Society for Exercise Physiology. 2002h. Let's get active! Magazine for youth 10–14 years of age. Cat. No. H39-648/2002-2E. Minister of Public Works and Government Services Canada, Ottawa, Ont.
- Hearst, W., and Sharratt, M. 2007. Canada's physical activity guides: background, development, and process. *Appl. Physiol. Nutr. Metab.* **32**(Suppl. 2E): this issue.
- Janssen, I., Katzmarzyk, P.T., Boyce, W.F., and Pickett, W. 2004. The independent influence of physical inactivity and obesity on health complaints in 6th to 10th grade Canadian youth. *J. Phys. Act. Health.* **1**: 331–343.
- Janssen, I., Katzmarzyk, P.T., Boyce, W.F., Vereecken, C., Mulvihill, C., Roberts, C., Currie, C., and Pickett, W. 2005. Comparison of overweight and obesity prevalence in school-aged youth from 34 countries and their relationships with physical activity and dietary patterns. *Obes. Rev.* **6**: 123–132. doi:10.1111/j.1467-789X.2005.00176.x. PMID:15836463.
- Jurca, R., LaMonte, M.J., and Durstine, L.J. 2005. Physical activity and nontraditional CHD risk factors: new pathways for primordial prevention of coronary heart disease. *Pres.Counc. Physical Fitness Sport Res. Dig.* **6**: 1–8.
- Katzmarzyk, P.T., and Tremblay, M.S. 2007. Limitations of Canada's physical activity data: implications for monitoring trends. *Appl. Physiol. Nutr. Metab.* **32**(Suppl. 2E): this issue.
- Kelley, G.A., and Kelley, K.S. 2003. Exercise and resting blood pressure in children and adolescents: a meta-analysis. *Pediatr. Exerc. Sci.* **15**: 83–97.
- Kesaniemi, Y.K., Danforth, E., Jr., Jensen, M.D., Kopelman, P.G., Lefebvre, P., and Reeder, B.A. 2001. Dose–response issues concerning physical activity and health: an evidence-based symposium. *Med. Sci. Sports Exerc.* **33**: S351–S358. doi:10.1097/00005768-200106001-00003. PMID:11427759.
- Lohman, T.G., Ring, K., Schmitz, K.H., Treuth, M.S., Loftin, M., Yang, S., Sothorn, M., and Going, S. 2006. Associations of body size and composition with physical activity in adolescent girls. *Med. Sci. Sports Exerc.* **38**: 1175–1181. doi:10.1249/01.mss.0000222846.27380.61. PMID:16775560.
- Malina, R.M. 1991. Fitness and performance: adult health and the culture of youth. *In* New possibilities, new paradigms? Edited by R.J. Park and H.M. Eckert. Human Kinetics, Champaign, Ill. pp. 30–38.
- Nassiss, G.P., Psarra, G., and Sidossis, L.S. 2005. Central and total adiposity are lower in overweight and obese children with high cardiorespiratory fitness. *Eur. J. Clin. Nutr.* **59**: 137–141. doi:10.1038/sj.ejcn.1602061. PMID:15454973.
- Ness, A.R., Leary, S.D., Mattocks, C., Blair, S.N., Reilly, J.J., Wells, J., et al. 2007. Objectively measured physical activity and fat mass in a large cohort of children. *PLoS Med.* **4**: e97. doi:10.1371/journal.pmed.0040097.
- NIH Consensus Development Panel on Physical Activity and Cardiovascular Health. 1995. Physical activity and cardiovascular health. *NIH Consens. Statement*, **13**: 1–33.
- Olga, M., Salguero, A., Conception, A., and Aduarde, M. 2006. Dropout reasons in young Spanish athletes: relationship to gender, type of sports and level of competition. *J. Sport Behav.* **29**: 255–269.
- Pate, R.R., Long, B.J., and Heath, G.W. 1994. Descriptive epidemiology of physical activity in adolescents. *Pediatr. Exerc. Sci.* **6**: 434–447.
- Pate, R.R., Pratt, M., Blair, S.N., Haskell, W.L., Macera, C.A., Bouchard, C., et al. 1995. Physical activity and public health. A recommendation from the Centers for Disease Control and Prevention and the American College of Sports Medicine. *JAMA*, **273**: 402–407. doi:10.1001/jama.273.5.402. PMID:7823386.
- Prochaska, J.J., Sallis, J.F., and Long, B. 2001. A physical activity screening measure for use with adolescents in primary care. *Arch. Pediatr. Adolesc. Med.* **155**: 554–559. PMID:11343497.
- Raitakari, O.T., Taimela, S., Porkka, K.V., Telama, R., Valimaki, I., Akerblom, H.K., and Viikari, J.S. 1997. Associations between physical activity and risk factors for coronary heart disease: the Cardiovascular Risk in Young Finns Study. *Med. Sci. Sports Exerc.* **29**: 1055–1061. PMID:9268963.
- Reilly, J.J., and McDowell, Z.C. 2003. Physical activity interventions in the prevention and treatment of paediatric obesity: systematic review and critical appraisal. *Proc. Nutr. Soc.* **62**: 611–619. doi:10.1079/PNS2003276. PMID:14692597.
- Royston, P. 2000. A strategy for modelling the effect of a continuous covariate in medicine and epidemiology. *Stat. Med.* **19**: 1831–1847. doi:10.1002/1097-0258(20000730)19:14<1831::AID-SIM502>3.0.CO;2-1. PMID:10867674.
- Salguero, A., Gonzalez-Boto, R., Tuero, C., and Márquez, S. 2003. Identification of dropout reasons in young competitive swimmers. *J. Sports Med. Phys. Fitness*, **43**: 530–534. PMID:14767416.
- Sallis, J.F., and Patrick, K. 1994. Physical activity guidelines for adolescents: consensus statement. *Ped. Exerc. Science*, **6**: 312–314.
- Statistics Canada. 2004. Health Indicators. Cat. No. 82-221-XIE. Statistics Canada, Ottawa, Ont.
- Statistics Canada. 2005. Health Indicators. Cat. No. 82-620-MIE. Statistics Canada, Ottawa, Ont.
- Strong, W.B., Malina, R.M., Blimkie, C.J., Daniels, S.R., Dishman, R.K., Gutin, B., et al. 2005. Evidence based physical activity for school-age youth. *J. Pediatr.* **146**: 732–737. doi:10.1016/j.jpeds.2005.01.055. PMID:15973308.
- Timmons, B.W., Naylor, P.-J., and Pfeiffer, K.A. 2007. Physical activity for pre-school children — how much and how? *Appl. Physiol. Nutr. Metab.* **32**(Suppl. 2E): this issue.
- Tjepkema, M., and Shields, M. 2005. Measured obesity: overweight Canadian children and adolescents. Cat. No. 82-620-XWE2005001. Statistics Canada, Ottawa, Ont.
- Tolfrey, K., Jones, A.M., and Campbell, I.G. 2000. The effect of aerobic exercise training on the lipid–lipoprotein profile of children and adolescents. *Sports Med.* **29**: 99–112. doi:10.2165/00007256-200029020-00003. PMID:10701713.
- Tolfrey, K., Jones, A.M., and Campbell, I.G. 2004. Lipid–lipoproteins in children: an exercise dose–response study. *Med. Sci.*

- Sports Exerc. **36**: 418–427. doi:10.1249/01.MSS.0000117132.70711.2B. PMID:15076783.
- Tudor-Locke, C., Pangrazi, R.P., Corbin, C.B., Rutherford, W.J., Vincent, S.D., Raustorp, A., Tomson, L.M., and Cuddihy, T.F. 2004. BMI-referenced standards for recommended pedometer-determined steps/day in children. *Prev. Med.* **38**: 857–864. doi:10.1016/j.ypmed.2003.12.018. PMID:15193909.
- Twisk, J.W. 2001. Physical activity guidelines for children and adolescents: a critical review. *Sports Med.* **31**: 617–627. doi:10.2165/00007256-200131080-00006. PMID:11475323.
- US Department of Health and Human Services. 1996. Physical activity and health: a report of the surgeon general. Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion, Atlanta, Ga.
- US Department of Health and Human Services and US Department of Agriculture. 2005. Dietary guidelines for Americans 2005. Publication No. HHS-ODPHP-2005-01-DGA-A. US Department of Health and Human Services, Washington, D.C.
- Warburton, D., Katzmarzyk, P.T., Rhodes, R., and Shephard, R. 2007. Evidence-based physical activity guidelines for Canadian adults. *Appl. Physiol. Nutr. Metab.* **32**(Suppl. 2E): this issue.
- Wareham, N.J., van Sluijs, E.M., and Ekelund, U. 2005. Physical activity and obesity prevention: a review of the current evidence. *Proc. Nutr. Soc.* **64**: 229–247. doi:10.1079/PNS2005423. PMID:15960868.
- Weight Realities Division of the Society for Nutrition Education. 2003. Guidelines for childhood obesity prevention programs: promoting healthy weight in children. *J. Nutr. Educ. Behav.* **35**: 1–4. doi:10.1016/S1499-4046(06)60318-7. PMID:12596730.
- Wong, S.L., Leatherdale, S.T., and Manske, S.R. 2006. Reliability and validity of a school-based physical activity questionnaire. *Med. Sci. Sports Exerc.* **38**: 1593–1600. doi:10.1249/01.mss.0000227539.58916.35. PMID:16960520.