Australian Government

Department of Health and Ageing

Discussion paper for the development of recommendations for children's and youths' participation in health promoting physical activity

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Prepared for the Australian Department of Health and Ageing

by

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Contents

Executive Summary

Intoduction

In March 2002, The Department of Health and Ageing commissioned researchers at the University of Queensland's School of Human Movement Studies to draft this discussion paper to facilitate the development of Australian recommendations for both children's and youths' participation in health-promoting physical activity. This discussion paper:

- provides an overview of the evidence linking physical activity to health benefits in children and adolescents;
- reviews existing guidelines for young people's participation in health-promoting physical activity;
- provides physical activity recommendations suitable for the Australian setting; and
- assesses the ability of existing measurement tools to monitor physical activity in young people.

It is intended that this discussion paper will serve two main purposes:

1. as a background document for phase two of the process in developing Australian physical activity recommendations for children and youth, in which physical activity experts and stakeholders from within Australia will be invited to a consensus conference to draft a formal set of recommendations; and
2. as a resource to assist with the development of programs and policies that promote or advocate physical activity for children and youth.

Links to health

Based on an extensive review and critical appraisal of the extant scientific literature, it was concluded that physical activity was associated with some immediate health outcomes in children and youth. Physical activity was found to have beneficial effects on:

- adiposity,
- skeletal health, and
- several aspects of psychological health.

Evidence related to physical activity and blood lipids and lipoproteins was mixed, with physical activity having a modest beneficial effect on blood triglyceride (TG) and high-density lipoprotein cholesterol (HDL-C) levels, but little consistent effect on total, low-density lipoprotein (LDL-C), and very low-density lipoprotein cholesterol (VLDL-C) levels. Physical activity did not appear to be related to resting blood pressure.

Tracking of physical activity

The issue of "tracking" or the notion that participation in physical activity in childhood and adolescence may facilitate participation in physical activity in adulthood was also examined. There was some evidence that, over short time periods (3-5 years), physical activity behaviour tracks. However, over longer periods of follow-up (6-12 years) there was little evidence that physical activity behaviour tracks during childhood and adolescence. There was no evidence to support the view that childhood physical activity is directly associated with chronic disease morbidity and mortality during adulthood.

Physical activity and other health behaviours

The impact of physical activity on other health behaviours (e.g., cigarette smoking and diet) and academic achievement was also examined. On the positive side, sport and physical activity participation appeared to be protective against:

- cigarette smoking,
- alcohol use and
- illegal drug use.

However, on the negative side, sport and physical activity appeared to increase one's risk for:

- anabolic steroid use, and
- inappropriate weight loss practices.

Participation in physical activity was not associated with increased academic performance.

Level of evidence

Of note, much of the evidence regarding the impact of physical activity on health status in children and youth is derived from observational studies (mostly cross-sectional) or uncontrolled trials. While a small number of prospective observational studies and randomised controlled trials have been conducted, they remain the exception rather than the rule. Consequently, no health outcome could be allocated a level of evidence higher than level C – evidence is from outcomes of uncontrolled or non-randomised trials or from observational studies.

Proposed physical activity recommendations

Based on the review of the existing physical activity guidelines and relationship between physical activity and health outcomes in children and youth, we endorsed the adoption of the guidelines proposed at the 1994 International Consensus Conference and the 1997 Health Education Authority Consensus Conference. For Australian children and youth we recommend that:

- **All children and youth should be physically active daily, or nearly every day, as part of play, games, sports, work, transportation, recreation, physical education, or planned exercise, in the context of family, school, and community activities.**

- **All children and youth should engage in physical activity of at least moderate intensity for 60 minutes or more on a daily basis.**
- **Children and youth should avoid extended periods of inactivity through participation in sedentary activities such television watching, video, computer games and surfing the internet.**
- **Children and youth who currently do little activity should participate in physical activity of at least moderate intensity for at least 30 minutes daily, building up to undertaking 60 minutes daily.**

Ideally, this recommendation would be supported by compelling epidemiological and experimental evidence demonstrating that 60 minutes of physical activity performed on a daily basis provides important physical and social health benefits during childhood and adolescence and is associated with maintenance of a physically active lifestyle into adulthood. However, as indicated above, there is only marginal evidence that physical activity is beneficial for health during childhood and adolescence, and there is little evidence that physical activity behaviour tracks from childhood to adulthood. Moreover, for health outcomes that demonstrate a favorable association with physical activity, the level of evidence is modest and there is little indication of a minimum dose required to derive benefit. Nevertheless, we endorse the recommendation of at least 60 minutes of physical activity per day, twice the amount recommended in guidelines for adults. Our reasons for doing so are five-fold.

1. Available evidence indicates that vast majority of children and adolescents would meet a recommendation of at least 30 minutes of at least moderate intensity per day and that very few would meet recommendations calling for continuous, sustained bouts of physical activity ($\geq$ 20 minutes).

2. There is evidence that sedentary activities such as television watching are strongly associated with excessive adiposity and displaces time for physically active pursuits.

3. Children and adolescents probably require more than 30 minutes of physical activity daily in order to learn and master the movement skills required for a physically active lifestyle later in life.

4. Ongoing surveillance of an important health indicator such as physical activity in children and youth requires that a reasonable and logically derived threshold be applied so that individuals and population groups can be classified as sufficiently or insufficiently active. Adoption of existing international guidelines facilitates useful comparisons with other countries.

5. A guideline communicating a minimum dose of physical activity will encourage health care professionals to promote physical activity participation in young people and encourage the planning and implementation of school and community-based programs to enhance young people's participation in health-promoting physical activity.

Monitoring

Valid and reliable measures of physical activity are a necessity in studies designed to: 1) document the frequency and distribution of physical activity in defined population groups; 2) determine the amount or dose of physical activity required to influence specific health parameters; 3) identify the psychosocial and environmental factors that influence physical activity behaviour in youth; and 4) evaluate the efficacy or effectiveness of health promotion programs to increase habitual physical activity in youth. To date, a wide range of methods has been used to measure physical activity in children and adolescents. These include self-report questionnaires, direct observation, doubly-labelled water, heart rate monitoring, and motion sensors such as accelerometers and pedometers.

Because of their ease of administration, low cost, and the ability to characterise activity historically, self-report measures are typically used in monitoring and surveillance studies. Available evidence indicates that self-report methods provide valid and reliable estimates of participation in physical activity in adolescents. However, the generally low validity and reliability coefficients observed for self-report instruments in young children suggest that objective measures of physical activity such as accelerometers may be more appropriate in primary school-aged children. However, for large population-representative samples of children, objective measures are likely to be too expensive and logistically difficult to administer effectively. Hence, for monitoring and surveillance studies involving children aged 10 years or younger, parent proxy self reports may be the only viable approach to measuring physical activity.

Introduction

Physical activity participation is thought to be related to the optimal development and functioning of many physical, physiological, educational, social and psychological processes in children and youth. It is also widely believed that regular physical activity participation in childhood and adolescence may facilitate participation in an active lifestyle in adulthood, and that physical activity in childhood and adolescence may help to reduce the risk of chronic diseases of adulthood. While a number of medical and public health organisations have issued position statements endorsing the promotion of lifetime physical activity in young people, there are no widely endorsed Australian recommendations regarding the dose of physical activity for children and youth.

The development of such recommendations was identified in the Strategic Inter-Governmental forum on Physical Activity (SIGPAH) work plan, and experts attending a Physical Activity Measurement Workshop in 2000 as a priority for Commonwealth action. The recommendations would be used by the Commonwealth to develop policy and as a tool to set and measure benchmarks and monitor progress toward health-related policy objectives. A more broad objective is that these recommendations, based on best available evidence, will encourage health care professionals to promote physical activity participation in young people and that the recommendations will encourage the planning and implementation of school and community-based programs to enhance young people's participation in health-promoting physical activity.

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Methodology

2.1   Literature Search

A comprehensive search of the research literature was conducted using the computer-based databases MEDLINE, PUBMED, PSYCHLIT, CURRENT CONTENTS, SOCIAL SCIENCE INDEX, and SPORTS DISCUS. Manual searches of the reference lists of recovered articles and the authors' extensive personal files were also conducted. The search targeted primary research articles, systematic reviews, guidelines and/or recommendations, and consensus statements published up to and including February 2002.

The key words used in the computer searches were physical activity, children, adolescents, youth, exercise, guidelines, recommendations, measurement of physical activity, assessment, physical education, risk factors, cholesterol/blood, insulin resistance, blood pressure, bone mineral density, obesity, growth, and maturation. We also examined the annual subject and author index of relevant journals in the field of physical activity and health which are not included in the databases listed above.

2.2   Critical Appraisal

Recovered articles were reviewed, catalogued, and evaluated for overall quality. To be included in the review the study must have:

1.   Included children and adolescents ($\leq$ 19 years).
2.   Provided an adequate description of the study population and sampling procedures.
3.   Provided an adequate description of the study design.
4.   Provided an adequate description of the measure of physical activity or surrogate measure of physical activity.
5.   Provided an adequate description of the dose or amount of physical activity or exercise allocated to experiment groups.
6.   Provided a measure of effect size or measure of association between physical activity and the outcome of interest.

Physical activity recommendations or guidelines for children and youth that were NOT evidence-based or the result of expert consultation/consensus were not included.

*   For the articles selected, the following information was evaluated:
*   Sample description
*   Study design
*   Summary of methods and measures

- Method of assessing physical activity
- Dose of physical activity
- Major outcomes
- Strengths and limitations

Consistent with the approach adopted for the 1994 International Consensus Conference on Physical Activity Guidelines for Adolescents (277), each study was categorised according to the strength of the evidence provided.

Level I - Experimental Studies

- IA Controlled randomised trial
- IB Uncontrolled or non-randomised trial

Level II - Observation Studies

- IIA Prospective observational studies
- IIB Cross-sectional or case-control observational studies

Level III - Case studies

Existing physical activity guidelines were evaluated on the quality and level of supporting evidence and appropriateness for children and adolescents taking into consideration the unique behavioural and physiological attributes of this population.

2.3   Integration of studies and proposed recommendations

For the purposes of a) evaluating the level of evidence for an association between physical activity and a given health outcome; and b) proposing evidence-based guidelines for participation in physical activity, we applied the evidence-based methodology used by the National Institutes of Health (221). This approach is consistent with the NHMRC Quality of Evidence rating scale and was employed at the 2001 evidence-based symposium on dose-response issues concerning physical activity and health sponsored by Health Canada and the U.S. Centers for Disease Control and Prevention (166).

- *Category A:* Evidence is from endpoints of well-designed randomised controlled trials (RCTs), or trials that depart minimally from randomisation that provide a consistent pattern of findings in the population for which the recommendation is made. Category A, therefore, requires substantial numbers of studies involving substantial number of participants.
- *Category B:* Evidence is from endpoints of intervention studies that include only a limited number of RCTs, post hoc or subgroup analysis of RCTs, or meta-analysis of RCTs. In general, Category B pertains when few randomised trials exist, when they are small in size, the trial results are somewhat inconsistent, or when the trials were undertaken in a population that differs from the target population of the recommendation.
- *Category C:* Evidence is from outcomes of uncontrolled or non-randomised trials, or from observation studies.

- ***Category D:*** Expert judgement is based on the synthesis of evidence from experimental research described in the literature and/or derived from clinical experience or knowledge that does not meet the above-listed criteria. This category is used only in cases where the provision of some guidance is deemed valuable, but an adequately compelling scientific literature addressing the subject of the recommendation was deemed insufficient to justify placement in one of the other categories (A through C).

Health consequences of physical activity for children and youth

3.1 Introduction

Among adults, regular participation in physical activity has been shown to provide an array of important health benefits. These include reduced risk of coronary heart disease, hypertension, Type II diabetes mellitus, obesity, certain cancers, and some mental health problems (90,224). Long-term prospective studies have consistently demonstrated that the risk of all-cause mortality is significantly lower in physically active and/or fit adults relative to their sedentary counterparts (45,235) and that mid-life increases in physical activity or fitness are associated with significant reductions in risk for all-cause mortality (44,236). This scientific evidence has prompted several medical and public health organisations to issue position statements and official recommendations endorsing promotion of physical activity for enhancement of public health (89a, 90,224,245).

Among children and adolescents, the relationship between physical activity and health is less well understood. Regular physical activity may reduce chronic disease risk in young people, but documenting this is difficult because chronic diseases such as coronary heart disease and osteoporosis rarely manifest themselves prior to the middle to late years of adult life.
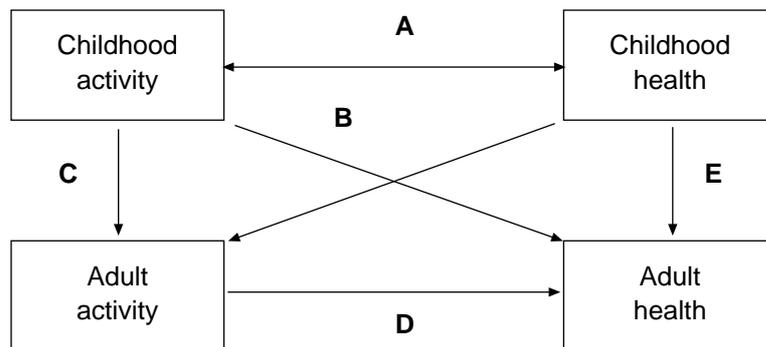
Figure 1:   Conceptual model illustrating the relationship between childhood physical activity and health status

Blair and colleagues (46) have proposed a conceptual model illustrating the relationship between childhood physical activity and health status. According to the model, childhood physical activity may influence adult health status either directly (Path B) or indirectly through its beneficial effects on childhood health outcomes (Paths A and E). Alternatively, childhood activity may indirectly influence adult health status through its positive effects on physical activity levels during adulthood (Paths C
and D). This association is commonly referred to as the tracking of physical activity from childhood to adulthood. The evidence concerning this pathway is discussed in Chapter 6.

With respect to Path B, there is little evidence to suggest that childhood physical activity is directly associated with adult health status. The Harvard Alumni Study found youth sports participation to be unrelated to morbidity and on mortality from cardiovascular disease later in life (235). In addition, prospective epidemiological data from the Coopers Institute for Aerobic Research show sports participation during youth to be unrelated to coronary risk factor status during middle age (59).

With respect to the indirect effects of childhood physical activity on adult health status (Paths A and E), there is a growing body of evidence linking childhood physical activity with childhood health outcomes, which in turn, are known to influence health status during adulthood. To date, the most frequently studied childhood health outcomes include blood pressure, blood lipid and lipoprotein levels, adiposity, skeletal health, and psychological health. The evidence linking physical activity to these outcomes during childhood and adolescence is summarised in sections 3.2 to 3.5 In addition to these outcomes, evidence related to cardiorespiratory fitness, muscular strength and endurance, other health behaviours (e.g. smoking) and academic performance is summarised in sections 3.6 to 3.9. Section 3.10 overviews some of the risks associated with participation in physical activity. An overall summary of the evidence base is provided in section 3.11.

3.2   Cardiovascular Risk Factors

The evidence relating childhood and adolescent physical activity to cardiovascular disease risk factors is summarised in Tables 1 and 2 in Appendix A. In relation to blood pressure, only two randomised controlled trials have demonstrated reductions in either systolic (SBP) or diastolic (DBP) blood pressure of ≥ 5 mm Hg in normotensive children. Participants in both the South Australian and West Australian intervention studies had significantly reduced DBP compared with controls (106,356). Two smaller trials have reported reductions in both SBP and DBP in hypertensive children (141) and in girls in the highest tertile of blood pressure (111), with moderate to vigorous aerobic exercise. Studies with normotensive children, including the large CATCH intervention trial in the US, found no differences between experimental and control groups with respect to either SBP or DBP (366). In uncontrolled trials, reductions in both SBP and DBP ranging from 5 to 16 mm Hg have been reported only in those studies involving hypertensive or obese children who participated in various forms of exercise. The studies by Hagberg et al (139,140) indicate that improvements in blood pressure which accompany training in hypertensive children are

12

reversed when training is stopped. Of the 16 observational studies which are summarised in Table 1 (in Appendix A), seven found no significant association between activity and blood pressure. The findings of the remaining studies were variable, with inverse relationships between either physical activity or fitness and SBP, DBP or both. In general, associations were in the range –0.1 to –0.3. Large population-based studies found either no association between physical activity and blood pressure (e.g., Anderson N= 2474 (13), Raitakari et al N=2358 (260)) or, in the case of the Australian Health and Fitness Survey (N= 2400) a weak correlation (r=-0.12) between fitness and SBP only (103).

In relation to blood lipids, the results of 8 randomised control trials provide little evidence of positive effects of activity or exercise. The results of the remaining intervention trials have shown similar results. Of the nine studies shown in Table 2 (in Appendix A), three reported increases in high density lipoprotein cholersterol (HDL-C) and decreases in triglycerides (TG) and one of these also reported a decrease in low-density lipoprotein cholesterol (LDL-C). The 25 observational studies shown in Table 2 report similarly diverse results. Associations with at least one blood lipid or lipid fraction were reported in most of these studies, but there appears to be little consistency among the results, except that ten of the studies reported a significant positive correlation between activity or training and HDL-C.

3.3   Adiposity, Overweight and Obesity

The evidence relating childhood and adolescent physical activity to adiposity and weight status is summarised in Table 3 in Appendix B. Overall, 56 studies meeting the inclusionary criteria were located. Of these, 14 were prospective observational studies, with the remaining 42 using cross-sectional study designs. The majority of studies reported significant inverse associations between physical activity and body composition or obesity/ overweight status. Twelve of the 14 longitudinal studies (86%) observed a significant inverse association, while 25 of the 42 cross-sectional studies (60%) reported a significant inverse association between physical activity and adiposity or overweight status.

Because the amount of physical activity required for health benefit and weight loss are likely to be different, studies evaluating the effects of physical activity or exercise training on weight loss, fat mass, or body composition were not reviewed for this report. Nevertheless, the recently published meta-analytic review by Lemura and Maziekas (181) provides some useful information about the dose of activity required for weight control in children and adolescents. Following analysis of 92 effect sizes from 30 studies meeting the stringent inclusionary criteria, significant pooled effect sizes were noted for percent body fat (ES = 0.70, 95% CI 0.21 – 1.1), body mass (ES = .34, 95% CI 0.01 – 0.46), body mass index (ES = 0.76, 95% CI 0.24 – 1.7), and fat free mass (ES = .50, 95% CI 0.21 – 1.1). Regression analyses indicated the most favorable alterations in body composition to be associated with low-intensity, long duration exercise and aerobic exercise combined with high-repetition resistance training.

3.4   Skeletal Health

The evidence relating childhood and adolescent physical activity to skeletal health is summarised in Table 4 in Appendix C. Only two randomised controlled trials (one with boys, the other with girls) have shown that children who followed a structured physical activity program for 8 – 10 months had greater increases in bone mineral density (BMD) than controls (58,215). Another randomised trial with adolescent girls found no differences in BMD between control and intervention groups following
26 weeks of resistance training (48). Despite the scarcity of level I evidence, two cohort studies have shown that the most active boys and girls develop greater bone mass over time when followed for periods of 6 and 13 years (26,137). Further evidence, from within-person studies of differences in BMD in cases where one limb is used significantly more than the other, also support the view that activity is associated with higher BMD (27,145). There is evidence from several observational studies to suggest that children who participate in weight bearing activities (e.g. running, gymnastics, soccer) develop higher BMD than those who participate in non-weight bearing activities such as swimming and cycling (72,97,116,202).

3.5   Social-Psychological Benefits

Relative to some other health outcomes, the effects of regular physical activity or exercise training on social-psychological health has been studied quite extensively. The primary outcomes most studied include depression, stress, anxiety, self-concept, and self-esteem. Table 5 in Appendix D displays the evidence relating to the association of physical activity with symptoms of depression. Of the nine studies meeting the inclusionary criteria, five used experimental study designs. Only two studies were conducted as randomised controlled trials. Collectively, the results suggest that physical activity interventions can have a positive influence on depressive symptomology; however, two studies reported non-significant effects. Cross-sectional studies confirm a protective effect for physical activity. In contrast, longitudinal studies have provided inconsistent findings.

Table 6 in Appendix D summarises the evidence pertaining to physical activity and stress and anxiety. Collectively, controlled intervention studies have shown physical activity or exercise training to be associated with lower levels of stress and anxiety. Three of the four observational studies, including one prospective study, report a significant inverse association between physical activity and stress/anxiety.

Table 7 in Appendix D displays the results of studies examining the impact of physical activity and exercise training on self-concept. Self-concept is the organised configuration of perceptions about one's attributes and qualities that are within conscious awareness. Three of the five experiment studies observed exercise to be a positive influence on self-concept. Cross-sectional observational studies have consistently reported a positive association between physical activity level and self-concept.

The evidence relating physical activity and exercise training to self-esteem is summarised on Table 8 in Appendix D. Self-esteem is the evaluation of one's self-concept and feelings associated with that evaluation. With the exception of the uncontrolled trial by Blackman et al. (43), all studies reported a significant effect on, or association with, self-esteem.

3.6   Cardiorespiratory Fitness

Cardiorespiratory fitness is defined as the ability to sustain moderate intensity, whole body activity for extended time periods (247). Cardiorespiratory fitness is thought to be an important health outcome for two primary reasons. First, because a high level of cardiorespiratory fitness is associated with an enhanced physical work capacity and reduced fatigue, cardiorespiratory fitness may influence a child's motivation or ability to engage in regular physical activity, particularly vigorous intensity activity. Second, adult studies have shown cardiorespiratory fitness to be inversely related to morbidity and mortality from cardiovascular disease. Hence, children and adolescents with low levels of cardiorespiratory fitness may be at increased risk for development of cardiovascular disease. However, as discussed earlier, there is little evidence to support this contention. Among youth, there is evidence that cardiorespiratory fitness (expressed relative to body mass) is inversely related to risk factors for cardiovascular disease (31). However, these associations tend to disappear when the confounding influence of body mass or adiposity is considered.

Among children and adolescents, the relationship between physical activity and cardiorespiratory fitness is complex. In laboratory studies, children demonstrate remarkably high levels of cardiorespiratory fitness as measured by maximal oxygen uptake (VO_2 max) (274), and yet, there is evidence that sizable percentages of children and adolescents report little or no participation in vigorous physical activity (244,341). Furthermore, during childhood and adolescence, VO_2 max expressed relative to body weight remains relatively stable in spite of the fact that, during the same period, physical activity levels decline (274). Although such findings suggest that physical activity has little influence on physical fitness in children and adolescents, such a conclusion would ignore two important findings in the youth physical activity literature. First, controlled exercise training studies involving children have shown that increases in structured physical activity can result in significant increases in physical fitness (251). Second, when children and adolescents are categorized into physical activity groups (i.e. tertiles), subjects in the highest physical activity groups consistently demonstrate higher levels of physical fitness (94,165,246). Thus, there appears to be some evidence to suggest that physical activity and physical fitness are related in children and adolescents.

To date, a sizable number of studies have examined the relationship between physical activity and physical fitness in children and adolescents. On average, these studies have reported low to moderate positive associations between activity and fitness (216). However, close inspection of the literature reveals considerable variability across studies with correlation coefficients ranging between -.16 and .74. This variation is most likely attributable to differences in the methods used to quantify physical activity and/or physical fitness, differences in sampling methodology, and differences in the population studied.

Trost (346) reviewed the peer-reviewed literature pertinent to the relationship between physical activity and cardiorespiratory fitness in children and adolescents. In order to provide a more definitive conclusion regarding the magnitude of this association, a meta-analytic approach was utilised in which effect sizes from each study were weighted and pooled to provide a global estimate of the correlation between physical activity and physical fitness in youth. In addition, to quantitatively examine the effects of gender, age, and

methodological differences on this relationship, pooled correlation coefficients were calculated for the following categories of studies: (a) girls only; (b) boys only; (c) older children (≥ 13 years); (d) younger children (< 13 years); (e) objectively measured physical activity correlated with a laboratory or quasi-laboratory measure of physical fitness; (f) self-reported physical activity correlated with a laboratory or quasi-laboratory measure of physical fitness; and (g) self-reported physical activity correlated with a field test of physical fitness.

The pooled correlation coefficients for all studies and the various categories of studies are shown in Table 10 in Appendix E. After weighting for sample size, the average correlation between physical activity and physical fitness was .17 (95% C.I. .14 - .19). Pooled correlation coefficients for the various categories of studies ranged from .11 (self-reported physical activity and laboratory measured or estimated physical fitness) to .18 (self-reported physical activity and 1.6 km run performance). The pooled correlation coefficient was higher in girls (r =.18) than boys (r = .13).

Overall, the results suggested that physical activity and physical fitness are positively related constructs in children and adolescents; however, the magnitude of this association is relatively weak. After weighting each study for sample size, the average correlation was .17, indicating that, on average, physical activity could account for less than 5% of the variance in cardiorespiratory fitness. Thus, among children and adolescents, the terms physical activity and physical fitness should not be used synonymously. Moreover, given the weak relationship between the two constructs, health practitioners and educators should focus greater attention on promoting physical activity behaviour instead of "increasing fitness". They should also avoid evaluating the efficacy of promotional strategies or intervention programs on the basis of changes in physical fitness. Finally, researchers should avoid the frequent practice of validating physical activity instruments with measures of physical fitness. A summary of the studies reviewed in this area is provided in Tables 9 and 10 in Appendix E.

3.7   Muscular Strength and Endurance

Muscular strength and endurance is an important component of health-related physical fitness in children and youth. Greater muscular strength and endurance is associated with enhanced functional capacity (ability to lift loads etc.) and may reduce the risk of low back pain and other musculoskeletal injuries (247). Muscular strength is also positively correlated with bone mineral density, an important determinant of skeletal health (26,49).

Available evidence indicates that strength training, when properly structured with respect to frequency, mode, intensity, and duration, is safe and can increase strength in preadolescents and adolescents. In preadolescents, strength training can enhance strength without concomitant increases in muscle cross-sectional area (hypertrophy). Gains in strength can be attributed to improvements in neuromuscular functioning – that is, training increases the number of motor neurons that will fire with each muscle contraction.

In Australia, the number of injuries arising from strength training in young people is not known. In North America, the U.S. Consumer Product Safety Commission estimated that, between 1991 and 1996, 20,940 to 26,120 strength training related injuries occurred in

individuals under 21 years of age (47). Muscle strains accounted for between 40% and 70% of all injuries, with the lumbar region of the back being the most commonly injured site. A small number of case studies have raised concerns about epiphyseal injuries in the wrist and apophyseal injuries in the spine from weight lifting in skeletally immature individuals. Such injuries appear to be quite rare and are believed to be largely preventable by avoiding maximal lifts and improper lifting techniques.

The American Academy of Pediatrics (11) issued the following recommendations regarding strength training in children and adolescents in 2001:

- Strength training programs for preadolescents and adolescents can be safe and effective if proper resistance training techniques and safety precautions are followed.
- Preadolescents and adolescents should avoid competitive weight lifting, power lifting, body building, and maximal lifts until they reach physical and skeletal maturity.

When paediatricians or health professionals are asked to recommend or evaluate strength training programs for children and adolescents, the following issues should be considered:

- Before beginning a formal strength training program, a medical evaluation should be performed by a pediatrician. If indicated, a referral may be made to a sports medicine physician who is familiar with various strength training methods as well as risks and benefits in preadolescents and adolescents.
- Aerobic conditioning should be coupled with resistance training if general health benefits are the goal.
- Strength training programs should include a warm-up and cool-down component.
- Specific strength training exercises should be learned initially with no load (resistance). Once the exercise skill has been mastered, incremental loads can be added.
- Progressive resistance exercise requires successful completion of 8 to 15 repetitions in good form before increasing weight or resistance.
- A general strengthening program should address all major muscle groups and exercise through the complete range of motion.

Any sign of injury or illness from strength training should be evaluated before continuing the exercise in question.

For a summary of studies in this area, see Table 11 in Appendix F.

3.8   Other Health Behaviours

Sports participation has long been thought to provide children and adolescents with a prosocial environment that fosters basic values, such as fair play, competitiveness, and achievement. Sports may also help protect participants against negative influences that can lead to juvenile delinquency and experimentation with tobacco, alcohol and illicit drugs. Most youth sports programs are offered during "at-risk" times (after-school and weekends), thus limiting participants' opportunities to engage in negative behaviours. Furthermore, participation in sports is often made contingent upon following rules and regulations that overtly discourage negative behaviours such truancy and experimentation with drugs and alcohol.

In this section, we summarise the research literature pertaining to the relationships between physical activity and selected health behaviours in children and adolescents. Because sports participation provides substantial amounts of physical activity, we overview the results of studies evaluating associations between physical activity as well as sports participation. The following health behaviours were considered: use of tobacco, alcohol, illegal drugs, anabolic steriods, dietary intake (fruit and vegetable consumption and fat consumption), weight control practices, sexual activity, and violence.

3.8.1 Physical activity and Cigarette Smoking

Results from population-based studies conducted in the United States and Finland provide consistent evidence of a significant inverse association between physical activity and cigarette smoking in adolescents. Pate et al. (252) assessed the relationship between physical activity and cigarette smoking in a population-representative sample of US high school students. After controlling for age, sex, and race/ethnicity, low active youth were found to be 1.4 times more likely than active students to have smoked in the 30 days preceding the survey. Raitakari et al. (260) prospectively examined the association between physical activity and cigarette smoking in a representative sample of Finnish youth aged 12 to 18 years. Participants who remained sedentary over the 6-year follow-up period were significantly more likely than their active counterparts to either begin smoking or smoke on a daily basis.

Winnail et al. (377) assessed the relationship between physical activity and cigarette smoking among high school students from South Carolina. Among white males, low-active students were almost twice as likely as high-active students to report cigarette smoking in the past 30 days. No association was observed among African American students. Aaron et al. (4) prospectively examined the relationship between leisure time physical activity and cigarette smoking in high schools student in a single city in the northeastern United States. After controlling for sex, race/ethnicity, and academic performance, a significant inverse association was observed among females but not males. Kelder et al. (162) reported an inverse association between cigarette smoking and physical activity participation among students participating in the Minnesota Class of 1989 study. The prevalence of cigarette smoking was 14 % higher in low-active students compared to high-active students.

A small number of studies have investigated the relationship between physical activity and cigarette smoking in preadolescent youth. Valois et al.(354) investigated the relationship between physical activity and cigarette smoking in 374 fifth grade students. No association was found between self-reported physical activity and experimentation with cigarette smoking. D'Elio et al. (81) studied the relationship between physical activity and experimentation with cigarette smoking in 303 African American fourth grade students. Students with moderate to high levels of physical activity were more likely than low active students to try cigarette smoking. However, the number of children experimenting with cigarettes was very small and none of the reported associations were statistically significant.

3.8.2 Sports Participation and Cigarette Smoking

Escobedo et al. (109) examined the relationship between participation in school sports and cigarette smoking in a population-representative sample of US high school students. After adjustments for age, sex, race/ethnicity and academic performance, students reporting participation in three or more sports teams in the previous 12 months were 2.5 times less likely than non-participants to be classified as regular smokers (smoked on 5 to 15 of the last 30 days).

Utilising data from the 1993 CDC Youth Risk Behavior Survey (YRBS), Pate et al. (250) assessed the relationship between sports participation and cigarette smoking. After controlling for age, race/ethnicity and physical activity outside of sport, students reporting participation in one or more sports teams during the previous 12 months were 1.2 to 1.3 times less likely than non-participants to report smoking in the past 30 days. This trend was observed in both genders but was only significant among females. Thorlindsson et al. (331,333) examined the association between sports participation and cigarette smoking in several population-representative samples of Icelandic youth. In two random samples aged 12 to 15 years, sports participation was inversely associated with cigarette smoking. Depending on the definition of sports participation (structured vs. non-structured), the correlation ranged from – 0.21 to – 0.28. Among 12- to 15-year-olds, both the frequency (r = -0.22) and the duration of sports participation (r = -0.24) were inversely associated with cigarette smoking.

In a secondary analysis of the 1991 and 1993 South Carolina YRBS data, Rainey et al. (259) assessed the relationship between sports participation and cigarette smoking in a representative sample of 7846 secondary school students. After controlling for race/ethnicity, sex, and participation in physical education, non sports participants were more likely to report smoking in the past 30 days than sports participants. In a further analysis of the 1993 YRBS data, Winnail et al. (377) reported sports participation to be inversely related to cigarette smoking among white males and females. However, among African American students, sports participants were approximately twice as likely as non-participants to report cigarette smoking in the past 30 days.

Baumert et al. (34) contrasted the prevalence of cigarette smoking among sports participants (n = 4036) and non-participants (n=2813) from a single high school in the south-eastern United States. After controlling for age, race/ethnicity and gender, sports participants were significantly less likely than non-participants to report smoking in the past 30 days. Oler et al. (231) compared cigarette smoking rates in school sports participants (n=243) and non-participants (n=575). After controlling for sex, race/ethnicity, and academic performance, non-participants were four times more likely than sports participants to smoke cigarettes. Davis et al. (85) examined the relationship between sports participation and cigarette smoking in 1200 high school-aged males. Sports participants were significantly less likely to be smokers than non-participants. However, when the relationship was adjusted for race/ethnicity and academic performance, the inverse association between sports participation and smoking was no longer significant. Lastly, Forman et al. (123) compared the smoking rates of 1117 male sports participants with normative data from the 1989 National Survey of American High School Seniors. Relative to the survey participants (65.7%), sports participants (27.9%) were significantly less likely to report smoking cigarettes.

In summary, studies examining the relationship between cigarette smoking and sports participation or physical activity are numerous and generally consistent in identifying an inverse association. Sport participants are about 1.2 to 4 times less likely than non-participants to smoke cigarettes. Only two of the identified studies did not report an inverse association, and both of these studies focused on primary school aged children, among whom the prevalence of cigarette smoking is low.

3.8.3 Physical Activity and Alcohol Use

Aarnio et al. (1) examined the association between leisure time physical activity and alcohol consumption among 1097 boys and 1014 girls from Finland. Participants were categorised into one of five physical activity levels ranging from sedentary (no leisure time physical activity in the previous month) to very active (vigorous physical activity 4-5 times/week). An inverse relationship was observed between physical activity level and frequency of alcohol use; however, this association was only significant among girls. Faulkner and Slattery (115) investigated the relationship between physical activity and alcohol use among 257 Canadian high school students. After placing students into gender specific activity tertiles, a significant positive association between physical activity level and alcohol consumption was observed in males but not females. Rainey and colleagues (259) studied the relationship between physical activity level, participation in school sports and alcohol use in population-representative sample of high school from South Carolina. After controlling for race/ethnicity, gender, and physical education status, sports participants with moderate and high levels of physical activity were found to be significantly more likely to report drinking on 6 to 19 of the 30 days preceding the survey. Physically active sports participants also reported drinking more frequently than non sports participants and were more likely than sedentary non sports participants to have engaged in episodes of binge drinking in the previous month. Utilising data from the 1990 YRBS, Pate et al. (252) examined the association between physical activity and alcohol consumption in a nationally representative sample of U.S. high school students. After controlling for age group, gender, and race/ethnicity, females classified as physically active were significantly less likely than their low active counterparts to report alcohol use in the 30 days preceding the survey. No association was found between physical activity and alcohol use among male high school students.

A small number of studies have investigated the association between physical activity and experimentation with alcohol in children. In a study of 381 sixth grade students, Hastad et al. (143) reported experimentation with alcohol or tobacco to be approximately 10% lower among sports participants (24.1 versus 34.0%). This difference remained intact when participants were stratified into low and high socioeconomic groups. In conflict with this finding, Felton et al. (117) reported no association between participation in moderate to vigorous physical activity and alcohol experimentation in rural fifth grade children from South Carolina. D'Elio et al. (81) evaluated the association between exercise level and alcohol experimentation in 303 African-American fourth and fifth grade students. Students reporting moderate and high levels of physical activity were more likely than their low-active counterparts to report alcohol use; however this association was not statistically significant when adjusted for gender, socioeconomic status, use of other abuseable substances, friends use, self-esteem, and academic performance.

3.8.4   Sports Participation and Alcohol Use

Buhrmann (68) examined the relationship between sport participation and alcohol use in 857 high school females from rural Iowa. After controlling for parental occupation, mother's education, cumulative grade point average, membership in out-of-school organisations, and social status, a significant inverse correlation of -.40 was observed between sports participation and alcohol use. Thorlindson (331) examined the relationship between sports participation and alcohol use in two large samples of rural Icelandic youth age 12 to 15 years old. The correlation between sports participation and use of alcohol ranged from -.04 to .12, indicating a weak to non-existent association between sports participation and alcohol use. In a further study of Icelandic youth, Thorlindsson et al. (333) examined the relationship between sports participation and alcohol consumption in a nationally-representative sample of 1200 15-16-year-olds. Both the frequency of sports participation and the hours engaged in sport were inversely associated with alcohol consumption (r = -.19 and -.17, respectively). Donato et al. (93) compared the drinking habits of 330 elite male athletes to those of 366 male high school students residing in the same area. After controlling for social class, parental education, parental alcohol use, peer alcohol use, smoking status, and judgement of alcohol as harmful, sports participation was found to have a significant inverse relationship with total alcohol intake, frequency of wine drinking, and amount of spirits consumed. Nativ and Puffer (222) contrasted the drinking practices of 109 intercollegiate athletes and 110 non athletic controls. After controlling for age, sex, race, and campus living status, athletes were significantly more likely than non-athletes to report drinking three or more alcohol beverages at a sitting. Athletes and non-athletes did not differ significantly with respect to the frequency of alcohol consumption. Aaron et al. (4) prospectively examined the relationships between leisure time physical activity, participation in competitive sports and alcohol consumption in high school students from Pittsburgh. After controlling for gender, race/ethnicity, and age, a significant positive association between leisure time physical activity and alcohol consumption was observed for male students. Furthermore, males who reported participation in competitive sports were significantly more likely than their non-sporting counterparts to report alcohol in the month preceding the survey. No associations were found between physical activity, sports participation, and alcohol use among female students.

In summary, the results of studies related to alcohol consumption and participation in sports and physical activity participation are inconsistent. Among adolescents under the age of 18, sports participation appears to be inversely associated with alcohol use. However, among older adolescents (i.e., university students), sports participation may be positively associated with alcohol use. The relationship between physical activity and alcohol consumption is even less clear. Among high school-aged males, physical activity appears to be weakly associated with greater alcohol consumption. Among high school-aged females, however, physical activity appears to be weakly associated with lower alcohol consumption.

3.8.5   Sport, Physical Activity and Illegal Drug Use

Winnail et al. (377) contrasted marijuana use in students reporting low, moderate, and high levels of physical activity. After stratifying the sample by gender and race, moderate and high levels of physical activity were found to be negatively associated with marijuana use among white males. No association was observed among African-American males and

females. Robinson et al. (269) examined the predictors of substance use in 1,447 tenth grade students. Self-reported participation in aerobic activity did not correlate significantly with use of illegal substances. Pate et al. (252) examined the relationship between physical activity status and illicit drug use in a population-representative sample of U.S. high school students. After controlling for grade level, sex, and race, students classified as physically active were significantly less likely to report using cocaine and marijuana in the 30 days preceding the survey.

Baumert et al. (34) compared the prevalence of marijuana use among sports participants (N=4036) and non-participants (N=2813). After controlling for age, race, and gender, participants were significantly less likely than non-athletes to report marijuana use. Oler et al. (231) compared illicit drug use in high school sport participants (N= 243) and non-participants (N= 575) from Kentucky. After controlling for age, sex, race, and academic performance, non-participants were found to be twice as likely as athletes to report marijuana use. No association was found between sport participation and cocaine use. Winnail et al. (377) examined the relationship between sports participation and illicit drug use in 4,800 public high school students from South Carolina. After adjusting for race and gender, sports participants were significantly less likely than non-participants to report using marijuana, cocaine, and other illicit drugs such as LSD, PCP, and heroin. Forman et al. (123) compared the prevalence rates of drug use of 1,117 male high school sport participants from the Chicago area with those reported in the 1989 National Survey of American High School Seniors. Relative to the survey participants, athletes were less likely to report use of marijuana, cocaine, amphetamines, barbiturates, heroin, PCP, and LSD.

In summary, a small number of studies have examined the relationship between physical activity or sports participation and use of illegal drugs. Most studies have focused on the potential of organised sports to prevent drug use and abuse among young people. Collectively, the results of these studies suggest an inverse relationship between sports participation and illicit drug use.

3.8.6   Sport, physical activity and anabolic steroid use

Buckley et al. (67) were the first to comprehensively examine the prevalence of steroid use among high school sport participants. They drew a sample of 12th grade male students from 150 high schools across the nation. Of those eligible, only 50.3% voluntarily participated. Eleven questions were used to establish current or previous use of steroids. Steroid users were more likely to participate in school sports programs than non-users. When examined on a sports specific basis, steroid users were more likely to participate in football and wrestling than other school sports. Of interest, it was noted that 35.2% of users did not intend to participate in school-sponsored athletics. The largest percentage of users (47%) reported their main reason for using steroids was to improve athletic performance. Using the 1993 national YRBS data, Pate and colleagues (250) found that sports participation was associated with increased steroid use, but only among African-American males. These analyses were adjusted for age and participation in regular, vigorous physical activity.

DuRant et al. (102) used the 1991 national YRBS data set (N = 12267) to assess the relationship between steroid use and sports participation, and steroid use and strength training. After controlling for age, sex, academic performance, other drug use and region of

the country, students who engaged in strength training were found to be significantly more likely to report steroid use than students who did not engage in strength training. Students who participated on a sports team were more likely than non-participants to report steroid use; however, this association did not reach statistical significance. In the midwest, both strength training and sports participation were significantly associated with increased likelihood of using anabolic steroids; while in the northeast, only strength training was significantly associated with steroid use. In the southern and western states, neither strength training nor sports participation was significantly associated with steroid use.

The 1993 South Carolina YRBS (N= 3437) showed that non-sport participants were slightly more likely to report steroid (non-significant) use in their lifetime compared to participants; however this association failed to reach statistical significance (OR = 1.17, 95% CI: 0.71-1.94) (377). When stratified by race and gender, it was found that white male and female non-participants were significantly more likely to use other drugs including steroids than their sporting counterparts. In a study conducted in seven high schools in Georgia (n = 6849), no significant difference in steroid use (ever or current) between sports participants and non-participants was found after controlling for age, race and gender (85).

Several studies conducted with non-representative samples of adolescent youth have observed a positive association between sports participation and steroid use among youth. Windsor and Dumitru (376) surveyed 901 high school students from one relatively affluent school district and one relatively lower socioeconomic status (SES) school district regarding steroid use. Five per cent of males and 1.4% of females reported that they had used steroids. In comparison, more than six per cent (6.7%) of male sport participants, and 1.8% of male non-participants took steroids. The male sport participants from the higher SES schools reported significantly greater steroid use than the male sport participants from the lower SES schools (10.2% versus 2.8%). Tanner and colleagues (319) conducted a confidential survey questionnaire to assess anabolic steroid use among 6930 students from 10 high schools in Denver, Colorado. The overall prevalence of anabolic steroid use was 2.7% (4.0% for boys and 1.3% for girls). Use was slightly higher among sports participants (2.9%) than non-participants (2.2%).

In summary, the literature examining the relationship between sports participation and steroid use is inconsistent with the strength and direction of the association varying by race/ethnicity and geographic region. A positive association may exist, but this may limited to athletes such as football players and wrestlers.

3.8.7   Sport, physical activity and dietary practices

French et al. (125) surveyed students in grades seven through ten (708 males and 786 females) in a mostly white, upper-middle class school district in Minnesota. Sports participation was assessed with a 28-item checklist representing activities of light to vigorous-intensity. Students were asked to check the activities that they performed for 20 minutes or more and indicate one of five choices as to when the activity was last performed (e.g. today, rarely or never). Dietary constructs were assessed with a 25-item questionnaire for preference (1 through 5) and recency of consumption (1 through 5) of various foods representing sweets, salty snacks, fruits and vegetables, and protein entrees. Factor analysis was used to group the activities into leisure sports, conditioning sports and

atypical sports (sports played less frequently). Factor analysis was also used to group the foods into junk food or empty calories, salty snacks, healthy foods (e.g. fruits and vegetables, yoghurt) and protein entrée (e.g. hamburger). Among both males and females, participation in leisure sports and conditioning sports was found to be correlated with recent healthy food choices (r = 0.26 to 0.36) , and healthy food preferences (r = 0.13 to 0.20). Among females, conditioning sports (r = -0.10) and atypical sports (r = -0.09) were inversely correlated with salty snack preference, while conditioning sports were inversely associated with junk food preference (r = -0.10). Among males, conditioning sports was associated with protein entrée preference (r = 0.11).

Baumert et al. (34) examined the relationship between sports participation and dietary intake in 7179 high school students from a single county in the southern United States. Compared to non-participants, sport participants were significantly more likely to report consuming breakfast, fruits and vegetables and one serving from the dairy food group on a daily basis. They were also less likely to add salt to their foods. No differences were found in reported consumption of red meats, fried foods and snack foods. Among the 14747 US high school students who completed the 1993 YRBS, sports participants were more likely to report recent consumption of fruits and vegetables than non-participants. In addition, female sports participants were less likely to report recent consumption of high fat foods than non-participants. (250)

Pate et al. (252) analysed data from the national YRBS to determine if physically active adolescents were more likely than their low-active counterparts to report consumption of fruit or vegetables on the previous day. After adjustment for age group, sex and race, students who did not eat vegetables on the previous day were almost twice as likely to be low active than students who reported eating at least one serving of vegetables. Among the Hispanic and White subgroups, students who ate no fruit on the previous day were 2.3 and 3.1 times, respectively, more likely to be low active than those who ate one or more serving of fruit on the previous day.

Aarnio et al. (1) surveyed 1097 girls and 1014 boys in Finland from 1991-1993. Physical activity behaviour was classified into one of five categories from very active to inactive based on reported frequency and intensity of physical activity performed outside of school. Saturated fat intake was estimated with a single item regarding use of spread on bread. Response choices included: 1) usually nothing; 2) mostly margarine; 3) mostly butter; 4) butter/margarine mixtures; 5) light spread; and 6) other. Results indicated that the highest activity group was significantly more likely to use no spread on their bread than the inactive group. For example, in the very active group, 15.4% of girls and 5.2% of boys reported using no spread; whereas among the inactive, only 1.6% of girls and none of the boys reported using no spread.

Raitakari et al. (260) tracked the health-related behaviours of 961 Finnish adolescents, aged 12 to 18 years. Leisure time physical activity was assessed by questionnaire. A physical activity index, ranging from 1 to 225, was calculated from the product of intensity, duration and frequency. Participants with a score greater than or equal to 85 in three examinations, three years apart (i.e. 1980, 1983, 1986) were considered constantly active. Those with an index value less than 15 over the three examinations were considered constantly sedentary.

Diet was assessed by a trained nutritionist using a 48-hour recall at the baseline examination in 1980 and again in 1986. Comparing the constantly active to the constantly sedentary, it was found that the sedentary young males consumed significantly more saturated fat and had a lower polyunsaturated to saturated fat ratio than the active males.

Lytle et al. (190) examined cross-sectional data from grades 6 through 12 of the Class of 1989 Study which was part of the Minnesota Heart Health Project. Subjects from the intervention communities were examined separately from the comparison communities. Frequency and intensity of physical activity was used to create an exercise score ranging from zero to nine. Dietary behaviour was summarised on a scale of zero to 18 with each point on the scale representing a healthier food choice. In both the intervention and control communities, students in the highest two quintiles for healthy food choices exhibited significantly higher levels of physical activity than students in lowest two quintiles. This difference was more evident among females in the intervention communities.

Terre et al. (328) studied the interrelationships among health-related behaviours in 1092 children between the ages 11 to 18 years. To examine potential developmental differences in these relationships, participants were grouped into four groups: Grade 6 (age 11), Grades 7-8 (ages 12-13), Grades 9-10 (ages 14-15) and Grades 11-12 (ages 16-18). Students completed a 35-item self-reported questionnaire designed to assess five health-related behaviours including diet and exercise. Exploratory factor analyses performed within each group revealed sedentary behaviour to be related to poor eating habits in all grade level groups with the exception of students in Grades 11 and 12.

In summary, there appears to be a positive association between physical activity and healthy dietary practices. However, this association my not be consistent for all dietary behaviours. Given the scarcity of information available and the difficulty of assessing both physical activity and dietary behaviour in youth, caution should be used when making conclusions about the relationship between physical activity and dietary behaviour in youth.

3.8.8 Sport, physical activity and weight control practices

There is evidence to suggest that those who participate in sports in which leanness is emphasised, such as ballet or gymnastics, are more likely to diet inappropriately or have eating disorders such as bulimia and anorexia nervosa (182,256). Leon (182) suggests that with the increasing participation of females in sports activities, a greater number of adolescent females may be at risk for the development of eating disorders. Others have recognised that owing to the rules of their sport, certain athletes are subject to a particular pressure to maintain a low body weight (330).

A study of 955 competitive male and female swimmers aged 9-18 years showed that girls, irrespective of actual weight, were more likely to engage in weight loss efforts, while boys were more likely to try to gain weight. (95) Girls were more likely than boys to use unhealthy weight loss methods, such as fasting (27.0% versus 16.4%), self-induced vomiting (12.7% versus 2.7%) and diet pills (10.7% versus 6.8%). Boys used laxatives and diuretics more than girls (4.1% versus 2.5%, 2.8% versus 1.5%, respectively). At least one unhealthy method of weight control was used by 15.4% of the girls (24.8% among postmenarcheal girls) and 3.6% of the boys (95).

In a sample of high school females in a midwestern US city, the eating disorder inventory (EDI) was used to assess psychological traits known to be associated with eating disorders. Female sport participants were significantly more likely than non-participants to be perfectionistic and to engage in bulimic behaviour, such as uncontrollable overeating and self-induced vomiting. Yet, no significant differences were found on current dieting practices (28% of athletes versus 25% of non-athletes were on a diet to lose weight) (322).

Among 64 female university students, athletes involved in sports that provided an advantage to those with a slim body (e.g. gymnastics, synchronized swimming, diving, figure skating, long-distance running and ballet) had greater weight concerns and diet concerns, and were more emotionally liable and dissatisfied than female athletes participating in hockey, basketball, springing, downhill skiing and volleyball (84). Analyses of the 1993 national YRBS found no association between high school sports participation and weight loss behaviour including use of vomiting or diet pills to lose weight. In fact, young girls (less than 16 years) involved in sports were less likely to report trying to lose weight than non-athletes (209).

Few studies have examined the association between physical activity and weight loss practices or eating disorders. Those that have been conducted have utilised very limited samples. French et al. (125) collected data from 708 males and 786 females in grades 7 through 10 from a suburban school district in the mid-western United States. A 21-item eating disorder checklist was developed for the study, based on previous research and DSM-III-R criteria for eating disorders. The number of affirmative responses constituted a risk score for eating disorders. Physical activity was measured using a 28-item checklist of activities. Principal components analysis resulted in three categories of activities: leisure or outdoor sports, conditioning sports and atypical sports. Among males, atypical sports participation (e.g. bowling, aerobics, softball) was a significant predictor of the risk score for eating disorders. Among females, all three categories of physical activity (conditioning sports, leisure sports and atypical sports) were significant predictors of the risk score for eating disorders.

In summary, relatively few studies have examined the relationships between sports and physical activity participation and weight loss practices in adolescent youth. The majority of studies have been conducted with small and non-representative samples. The available evidence, although limited, suggests that participation in sports that emphasise leanness and artistic ability is associated with increased risk for inappropriate weight control methods and eating disorders.

3.8.9 Sport, physical activity and violence

Levin et al. (183) examined the relationship between violent behaviours and sports participation in 2436 high school students from a single county in the southwestern United States. The violent behaviours examined included assault, trouble at school, stealing, trouble with police, damaging property, carrying a weapon to get something, and carrying a weapon for protection. Among males, sports participation was not significantly associated with any of the violent behaviours; however, when male athletes were divided into contact and non-contact sports, athletes in contact sports were significantly more likely than their non-contact counterparts to assault others, get into trouble at school and carry a weapon for

protection. Among females, participants from any sport were significantly less likely than non-participants to exhibit negative or violent behaviour. Similar to the males, females involved in contact sports were significantly more likely than their non-contact sporting counterparts to engage in assault and carry a weapon for protection.

Pate and colleagues (252) examined physical activity participation and the relative odds of being injured in a physical fight in a nationally-representative sample of US high school students. After controlling for age, sex and race/ethnicity, no association was found between physical activity level and injury from physical fighting (OR = 0.90, 95% C.I. 0.71-1.15). Aaron et al. (4) contrasted the prevalence of weapon carrying in high school students reporting low, medium and high levels of leisure time physical activity. Boys were significantly more likely than girls to report carrying a weapon in the previous 30 days; however, within gender groups, the prevalence of weapon carrying was similar across the three physical activity groups. When students were classified on the basis of participation in competitive sports, no association was found in either boys or girls; however, it is notable that the prevalence of weapon carrying among female sport participants (8%) was almost half of that observed among female non-participants (15%).

In summary, a small number of studies have examined the relationship between sport and/or physical activity participation and violent behaviour in youth. The available evidence indicated that sports participation is not related to violent behaviour in adolescents. However, when athletes from different types of sports are compared, there is limited evidence that participants in "contact sports" exhibit a higher prevalence of violent behaviours than participants in "non-contact" sports.

3.9   Academic Performance

The relationship between physical activity and academic performance has been the subject of research and speculation for many decades. Advocates for sport and physical activity programs support the view that the values and discipline acquired on the playing field transfer positively to the classroom, and that physical conditioning improves mental performance. Conversely, teachers and school administrators are increasingly questioning the contribution of sport and physical education to the academic mission of schools. Despite the keen interest in the topic, relatively few empirical studies have addressed the question of whether physical activity improves academic performance among children and adolescents.

Studies conducted by McIntosh (204) and Smart (304) in the United Kingdom during the 1960's suggested that students of higher academic standing were significantly more likely than students of lower academic ability to participate in school and extracurricular sports. However, none of these early studies controlled for socioeconomic status or other potentially confounding factors. More recent studies conducted in the UK confirm the results of earlier studies. Williams (373) studied the sport and physical activity behaviours of 14350 students from 15 schools in London. Sports participation was positively associated with academic attainment. The effect was evident in both males and females, but was particularly strong among adolescent females.

Experimental studies have provided mixed results with respect to the effects of a physical activity program or additional physical education on academic performance. Tuckman and Hinkle (348) investigated the effects of a 12-week running program (3 days per week, 30 mins per session) on creativity and classroom behaviour in 154 children in grades four to six. Relative to controls attending regular physical education, participants randomised to the running program significantly improved cardiorespiratory fitness. However, no significant differences were observed for creativity and classroom behaviour. Bluechardt and Shephard (50) tested the effects of a 10-week physical activity program on academic performance in 45 students with learning disabilities (23 experimental and 22 controls). The experimental program provided students with three hours per week of vigorous physical activity combined with social skill training and problem solving. Controls received conventional academic instruction, but were provided with additional lessons to ensure that they received the same level of individual attention. No significant between-group differences were observed for the five measures of academic performance which included general intellectual ability and competence in spelling, mathematics, reading and writing.

The Trois Rivieres study (298) examined the effects of adding one hour per day of physical education on academic performance and health and fitness outcomes in a cohort of 546 primary school students. Control students were drawn from the immediately preceding and immediately succeeding classes at the same schools. These students received only the standard single period of physical education per week. Each student's academic performance for any given year was calculated as the average of classroom marks for French, mathematics, English, and natural science. During the first year of the study, participants in control classes demonstrated somewhat better academic performance than those in experimental classes. However, in grades 2 through 6, the experimental classrooms exhibited significantly higher levels of academic performance than controls. Again, the effect was more pronounced in girls than in boys.

The School Health, Academic Performance and Exercise (SHAPE) study involved 519 fifth grade students from seven primary schools in Adelaide, South Australia (105). At each of the seven schools, class groups were randomly assigned to one of three 14-week programs – fitness, skill, or control. Classes assigned to the fitness condition received 75 minutes of moderate to vigorous physical activity per day, 15 minutes before school and 60-minutes in normal class time. Classes assigned to the skill group had a similar time allotment, but classes emphasised skill development rather than moderate-to-vigorous physical activity. Classes assigned to the control condition received the usual three 30-minute periods of physical education. Despite a substantial reduction in classroom time for the fitness and skills groups (210 minutes per week), there were no significant group differences in gains of arithmetic performance or reading skills over the 14-week study period.

Observational studies examining the association between physical activity and academic performance have produced conflicting results. Schurr and Brookover (295) examined the association between sports participation and academic achievement in 352 eleventh grade boys. Boys were classified as participants if they reported participation in any interscholastic sport. Relative to their non-sporting counterparts, participants exhibited a

significantly higher grade point average and IQ scores. Lindner (187) investigated the relationship between sports participation and perceived academic performance in 4,690 Hong Kong children aged 9 to 18 years. A sports participation index was derived from the self-reported frequency, duration, and months of participation for up to five sports or physical activities. Student participants rated their academic performance as good, average, below average or poor. The sports participation index was significantly higher among students with high self-rated academic performance than for students with less satisfactory self rated academic performance. The association was stronger in females than in males.

Tremblay et al. (335) examined the relationship between physical activity and academic performance in sixth grade students residing in New Brunswick, Canada (N=6923). Physical activity was based on four questions assessing the weekly frequency of sustained moderate physical activity, sustained vigorous physical activity, and participation in strength and flexibility enhancing activities. Academic performance was measured by standardised scores on reading and mathematics tests administered by the Department of Education. After adjusting for socioeconomic status, family structure, and BMI, physical activity was negatively associated with math and reading scores; however the magnitude of the association was trivial and close to zero.

Dwyer et al. (104) assessed the relationship between physical activity and academic performance in a national sample of Australian children aged 7 to 15 years (N=7,961). Academic performance for each participant was measured using a 5-point rating scale completed by a school representative (principal). Physical activity was assessed by questionnaire. Students reported the frequency, duration, and intensity with which they cycled or walked to school, engaged in physical education class, engaged in school sport, and engaged in other physical activities. A further item asked students to report their usual level of activity during lunchtime. Among girls aged 7, 8, 9 and 14 years, small but statistically significant positive associations (r=0.11 – 0.19) were observed between rating of academic performance and physical activity. Among boys, physical activity was weakly associated with academic performance in all age groups, with the exception of 11-year-olds. Correlations ranged from 0.08 to 0.18.

Sallis and colleagues (282) studied the effects of an intensive 2-year health-related physical education program on academic achievement in primary school children. Seven participating primary schools were randomly assigned to one of three experimental conditions. Two schools adopted a modified physical education curriculum (Sports, Play, and Active Recreation for Kids (SPARK) taught by physical education specialists. An additional two schools adopted the same modified physical education curriculum as the first group; however, the program was taught by classroom teachers and not PE specialists. The three remaining schools served as controls. These schools maintained their usual physical education program taught by classroom teachers. The modified physical education program called for a minimum of 3 x 30-minute lessons per week for 36 weeks. Half of the class time was devoted to "health-fitness" activities (e.g., aerobic dance, running games etc.) and half devoted to "sport-fitness" (e.g., soccer, basketball). The curriculum also included a self-management program designed to teach children the behavioural skills needed to adopt and

maintain a physically active lifestyle. Academic achievement before and after the 2-year physical education program was measured via school district administered standardised academic tests.

Although the teacher-led physical education program marginally attenuated the declines in overall achievement and achievement in language and reading, the intensive physical education program had minimal effects on academic achievement. While the findings failed to support the contention that increased sport or physical activity improves academic performance, it is noteworthy that academic achievement scores within the intervention schools were not adversely affected, despite a doubling of the amount of time devoted to physical education.

3.10   Risks of Physical Activity Participation

Like most activities in life, participation in exercise or physical activity is not without risk. In the physical activity and sport domains, some of the most commonly studied risks include musculoskeletal injury, negative psychological conditions (stress, burnout, and staleness), and risks to reproductive health. Notably, these negative outcomes mostly occur in children and adolescents participating in intensive competitive sport.

According to The New South Wales Youth Sports Injury Report (227), there are 10,000 sports-related hospitalisations and 100,000 emergency department visits each year in NSW, with over half (54%) of young people who play sport experiencing some form of injury in a 6-month period. The most common types of injuries reported are bruising (36%), muscle strains (32%), joint/ligament strain (29%) and bleeding (16%). Sports which had the most injured participants included rugby union, rugby league, netball, hockey, AFL, soccer, and horse riding.

Between 1998 and 1999, the Queensland Injury Surveillance Unit collected data on 9,031 sports related injuries (258). More than 70% of the sports injury presentations were aged between 5 and 25 years with the highest prevalence occurring in the 10 to 14 years age group. Among males, rugby league dominated sports injury presentations, accounting for more than 60% of all sports related injuries. Among women, netball, basketball and soccer were the most frequent injuries. Almost two thirds of sports injuries were fractures or sprains and strains. Seventy percent of sports injuries were reported to have been caused by either a low fall or being struck by or collision with another person.

Numerous countermeasures can be employed to reduce sports-related injuries in children and youth. These include, modifications to the rules, reductions in playing areas and duration, use of protective equipment in games and training, modification to equipment, education programs for parents, coaches, sports trainers and administrators, and preparticipation medical screening.

Excessive stress, burnout, and overtraining are frequently cited negative outcomes associated with intensive participation in youth sports. In most cases, however, the cause of such outcomes can be traced back to inappropriate coaching practices, excessive physical workloads, and personal susceptibility factors (e.g. trait anxiety). Presently, the proportion

of youth sports participants who suffer negative psychological outcomes remains unknown. Gould (134) states that children and adolescents should not be discouraged from participating in competitive sport because of stress and burnout concerns. The vast majority of children engaged in competitive sport do not experience excessive levels of state anxiety and do not experience burnout. Reviews of the youth sport attrition research show that most children do not discontinue sport involvement because of excessive competitive stress or burnout. Rather, conflicts of interest and interest in other types of activities are the most consistently cited motives for sport withdrawal (134).

Several strategies have been developed to help prevent or reduce the problems of excessive stress, burnout, and overtraining. These include, monitoring of workload and indicators of fatigue (e.g., resting HR), education programs for parents, coaches, sports trainers and administrators, setting short-term goals for practices and competitions, taking relaxation breaks, and learning self-regulation skills.

There is little evidence to suggest that regular participation in physical activity poses a threat to the reproductive health of young people, particularly young women. There is, however, evidence that very intensive training in sport and physical activities, coupled with low energy intake, can have a negative impact on reproductive function in adolescent girls. The most studied reproductive health concerns among female adolescents are delays in menarche and amenhorrea.

Descriptive studies have consistently observed that female sports participants report later ages at menarche than non-participants. However, Malina (196) has been quick to point out that there is little causal evidence to support the concept that training for sport and other intensive physical activities "causes" menarche to be later than normal. The misconceptions about the influence of intense physical activity on the age at menarche stems from 3 important factors. First, the clinical definition of "delayed menarche" is far too narrow. Clinically, delayed menarche is defined as an age at menarche of 14 years or older. Such a definition fails to consider the normal human variability in age at menarche. Second, much of the evidence linking exercise training to delayed menarche has been derived from retrospective studies that: a) do not quantify the frequency, intensity, and duration of training; b) fail to distinguish between initial participation and formalised training; and c) do not control for important confounding factors that are known to influences age at menarche such as mothers age at menarche, and number of siblings etc. Lastly, because of the effects of sexual maturation on body composition in adolescent girls, it is likely that girls with later ages at menarche self-select themselves into competitive sports programs (196).

The true prevalence of amenorrhea among females sports participants is unknown. Studies conducted thus far have reported prevalence rates as low as 3.4% and as high as 66% (271). However, it is likely that the prevalence is towards the high end of this range, especially in sports in which poor nutrition habits are practiced and a lean physique is emphasised. Controlled experimental studies indicate that amenorrhea is the direct result of a reduction in the frequency of luteinising hormone (LH) pulses from the pituitary gland (271,362). The reduction in LH pulse frequency is thought to be caused by a decrease in the frequency of

gonadotrophic releasing hormone (GnRH) pulses secreted by the hypothalamus. The stimulus for this response remains an active area of investigation, but recent reports support the concept that a prolonged and severe state of negative energy balance is responsible (the energy drain hypothesis). In the presence of adequate nutrition, normal participation in sports and physical activity presents no serious long-terms threat to the reproductive health of adolescent girls.

3.11 Overall Summary of the Health Consequences of Physical Activity for Children and Youth

Table 12 provides an overall summary of the health consequences of physical activity for children and youth. There is modest evidence that physical activity has beneficial effects on adiposity, skeletal health, and psychological health. Evidence related to physical activity and blood lipids and lipoproteins is mixed, with physical activity having a modest beneficial effect on blood triglyceride and HDL cholesterol levels, but little consistent effect on total, LDL, and VLDL cholesterol levels. Among healthy children, physical activity does not appear to be related to resting blood pressure.

Table 12 also summarises the associations between physical activity and other health behaviours. On the positive side, sport and physical activity participation appears to be protective against cigarette smoking, alcohol use and illegal drug use. However, on the negative side, sport and physical activity appears to increase one's risk for anabolic steroid use and inappropriate weight loss practices. Few conclusions could be made regarding the impact of sport and physical activity participation on sexual activity and violence; however it appears that physical activity is not associated with these health behaviours. The available evidence suggests that participation in physical activity is not associated with academic performance.

Much of the evidence regarding the impact of physical activity on health status in children and youth is derived from cross-sectional observational studies or uncontrolled trials. While a small number of prospective observation studies and randomised controlled trials have been conducted, they remain the exception rather than the rule. Consequently, no health outcome could be allocated a level of evidence higher than level C – evidence is from outcomes of uncontrolled or non-randomised trials or from observational studies. For some health behaviours, the evidence base could only be categorised as level D Note that this category is used only in cases where the provision of some guidance is deemed valuable, but an adequately compelling scientific literature addressing the subject was deemed insufficient to justify placement in a higher level of evidence.

The data presented in Table 12 prompts the question – why is the evidence base so weak? Perhaps the first reason is that most children and adolescents are inherently healthy and that biological risk factors for chronic disease are generally observed to be at favourable levels in young people. Hence, the weak associations may be, in part, attributable to lack of variation with respect to physical activity and the health endpoint under examination. A second important reason is that the endpoints examined are influenced not only by physical activity, but also growth and maturation. Thus, without appropriate study designs, it is

difficult to know if changes in biological risk factors are related to physical activity participation or are the result of normal growth and maturation. A third reason is that physical activity in children and adolescents is difficult to measure. Because all measures, to varying degrees, contain random measurement error, any association between physical activity and health will be biased towards the null. Hence, the associations summarised in Table 12 are likely to be an underestimation of its true relationship with physical activity.

So on what basis should we recommend that children and adolescents be physically active on a regular basis? First and foremost, it is intuitively sensible and biologically plausible that preventive health measures such as fostering a physically active lifestyle should begin early rather than later in life. It should never be forgotten that atherosclerosis is a process that begins early in life (308). It should also not be forgotten that participation in physical activity is associated with some important health benefits in young people. There was sufficient evidence to conclude that physical activity is positively associated with bone mass and inversely associated with adiposity and overweight/obesity. Notably, these health outcomes track rather strongly from childhood into adulthood. Considering the dramatic rise in the prevalence of overweight and obesity in Australian children and adolescents over the last decade (52); and the importance of physical inactivity in development and maintenance of childhood and adolescent obesity (40,277), one could argue that it has never been more important to promote regular health-enhancing physical activity among our nation's youth.

Table 12: **Summary of the associations between physical activity and health outcomes in children and youth**

Outcome	Strength of Association	Dose of Physical Activity Required	Level of Evidence*
Blood Pressure	—	No indication	C
Blood Lipids	±	No indication	C
Adiposity	++	Long duration, moderate intensity	C
Skeletal Health	++	Weight bearing exercise important.	C
Psychological Health	+	No indication	C
Cardiorespiratory Fitness	+	Vigorous sustained activity.	C
Other Health Behaviours			
Cigarette Smoking	- -	No Indication	C
Alcohol	-	No Indication	C
Illegal Drugs	-	No Indication	C
Anabolic Steroids	+	No Indication	D
Unhealthy Diet	-	No Indication	D
Improper weight control	+	No Indication	D
Sexual Activity	?	No Indication	D
Violence	?	No Indication	D
Academic Performance	÷	No Indication	C

* See Chapter 2 for explanation of the level of evidence.

(- -) repeatedly documented inverse association;

(-) weak or mixed evidence of an inverse association;

(') evidence of no association;

(+) weak or mixed evidence of a positive association;

(+ +) repeatedly documented evidence of a positive association;

(?) insufficient data available.

Note that each health behaviour is presented as a health compromising behaviour. A negative association indicates that sports participants and/or physically active individuals are less likely to engage in that behaviour.

Physical activity in Australian children and youth

In Australia, efforts to promote physical activity in young people have been hindered by the lack of accurate population-level physical activity monitoring and surveillance data. Indeed, to date, the 1985 Australian Health and Fitness Survey (257) is the only study to have assessed physical activity behaviour in a nationally representative sample of Australian school children. Surveys conducted by the Australian Bureau of Statistics during the 90's have provided useful descriptive information regarding national participation in school-based and club sports and physical activities; however, it is important to note that these data are based entirely on parent proxy reports and provide insufficient information to assess compliance with accepted international guidelines for participation in physical activity. The NSW Schools Fitness and Physical Activity Survey provides important new information about the prevalence of health-enhancing physical activity in a large and representative sub-population of Australian youth. However, methodological differences with respect to the measurement of physical activity preclude any comparisons with the earlier Australian Health and Fitness Study or comparable activity surveys conducted in other western developed countries.

4.1   1985 Australian Health and Fitness Survey

The 1985 Australian Health and Fitness Survey (257) assessed physical fitness, physical activity, and other health-related parameters in a nationally-representative sample of Australian primary and secondary school children. The results indicated that sports participation was widespread with nearly all participants (86%) reporting participation in at least one sports team run by their school or community in the previous year. The mean number of sports played varied little by age and sex (on average, just over 2.5 teams per year). Participation in school physical education was also uniformly high with almost three-quarters of students reporting participation in physical education lessons in the preceding week. Despite the high prevalence of sports participation, only 38.3% to 50.6% of boys and 34.9% to 44.4% of girls reported participation in sustained vigorous physical activity (30 minutes at an intensity that made children "huff and puff") three to four times a week. Within each age group, boys were more likely than girls to report regular sustained vigorous physical activity; however, no age-related trends were evident.

4.2   ABS 1995 National Health Survey

The 1995 National Health Survey assessed physical activity in a national sample of young people aged 15 to 24 years (21). Almost a quarter (23%) of Australian young people reported no physical activity whatsoever in the two weeks preceding the interview. Approximately one-half (48%) of Australian young people reported walking for exercise in the previous two weeks. Of this group, 42% reported walking seven or more times in the previous two weeks, with 97% reporting an average duration of greater than or equal to 30 minutes per occasion. Fifty-one percent reported participation in moderate-intensity physical activity in the two weeks prior to the interview. Of this proportion, about a quarter (26%) reported exercising moderately seven or more times in the previous two weeks, with 86% reporting an average duration of 30 minutes or more per occasion. Almost one-third of young people in Australia reported participation in vigorous-intensity physical activity in the previous two weeks. Of this number, 20% reported exercising vigorously seven or more times in the previous two weeks, with just under 90% reporting an average duration of 30 minutes or greater per occasion.

4.3   1995-96 & 1996-97 Australian Population Survey Monitor

As part of the household-based Australia Population Survey Monitor, the ABS assessed participation in organised sports and physical activity in a nationally-representative sample of children aged 5 to 14 years (22). Data were provided by parents and not the children themselves. Across all age and gender groups, 61.5% of Australian children participated in at least one organised sport or physical activity in the 12 months preceding the survey. Boys (65.0%) were more likely to participate in sports and physical activities than girls (57.8%). Children aged 9-11 years (71.0%) and 12-14 years (68.4%) were more likely than 5-8 year olds (49.2%) to participate in sport or physical activity. Across all age and gender groups, participation in club sports and physical activities was greater than school-based programs. For boys, the 3 most commonly reported sports/activities were soccer, basketball, and swimming; while for girls, the 3 most commonly reported activities were netball, swimming, and basketball.

Children's participation in organised sports and physical activities was again examined in the 1996-97 ABS population monitoring survey, yielding almost identical results (23). Across all age and gender groups, 61.1% of Australian children participated in at least one organised sport or physical activity in the 12 months preceding the survey. Boys (64.7%) were more likely to participate in sports and physical activities than girls (57.4%). Children aged 9-11 years (70.4%) and 12-14 years (68.8%) were more likely than 5-8 year olds (48.7%) to participate in sport or physical activity. Across all age and gender groups, participation in club sports and physical activities was greater than school-based programs. For boys, the 3 most commonly reported sports/activities were soccer, Australian rules football, and cricket (outdoor); while for girls, the 3 most commonly reported activities were netball, swimming, and dancing.

4.4   New South Wales Schools Fitness and Physical Activity Survey

The NSW Schools Fitness and Physical Activity Survey assessed physical activity behaviour in a population-representative sample of NSW school students in grades 8 and 10 (51). The survey found that around 80% of year 8 and year 10 boys and girls were 'active' in summer, but that fewer girls than boys were active in the winter months (69% in year 8 and 66% in year 10).

5.5   ABS Children's Participation in Cultural and Leisure Activities

The ABS's Children's Participation in Cultural and Leisure Activities (24), released in January 2001, represents the most recent population-level survey of children's participation in sport and physical activities. In the 12-months prior to April 2000, 59.4% of Australian children aged 5 to 14 years were involved in organised sport outside of school hours. Participation was higher in boys (66.1%) than in girls (52.3%). Compared to children aged 5 to 8 years (51.0%) and children aged 12 to 14 years (62.4%), participation in organised sports was highest among 9 to 11 year olds (67.3%). On average, boys participated in organised sport on 56 occasions over the past year, while girls participated in organised sport on 52 occasions over the corresponding period. Among boys, the most frequently played sports were soccer, Australian rules football, swimming, cricket, and tennis. Among girls, the most frequently played sports were netball, swimming, tennis, and basketball. Children were more likely to participate in organised sport if they were Australian born, did not live in a capital city, came from a two-parent family, had Australian born parents, and lived in a household in which both parents were employed.

Measurement of physical activity

The development of accurate and reliable assessment tools for quantifying physical activity in children and adolescents continues to be a priority (172,345). Valid and reliable measures of physical activity are a necessity in studies designed to: 1) document the frequency and distribution of physical activity in defined population groups; 2) determine the amount or dose of physical activity required to influence specific health parameters; 3) identify the psychosocial and environmental factors that influence physical activity behaviour in youth; and 4) evaluate the efficacy or effectiveness of health promotion programs to increase habitual physical activity in youth. To date, a wide range of methods has been used to measure physical activity in children and adolescents. These include self-report questionnaires, direct observation, doubly-labeled water, heart rate monitoring, and motion sensors such as accelerometers and pedometers. Table 13 provides a summary of how each of the most popular methods compares with respect to their key attributes.

Table 13:   Summary of key attributes for current methods to measure physical activity in children and adolescents

Method	Valid	Cheap	Objective	Ease of Admin-istration	Easy to complete	Measures patterns, modes, and dimensions of physical activity	Non-reactive*	Feasible in large studies	Suitable for ages < 10 y	Suitable for ages > 10 y
Questionnaire	✓	✓✓✓	✗	✓✓✓	✓✓	✓✓✓	✓✓✓	✓✓✓	✗	✓✓✓
Interview	✓✓	✓	✗	✓✓	✓✓	✓✓✓	✓✓✓	✓✓	✓	✓✓✓
Proxy Report	✓	✓✓✓	✗	✓✓✓	✓	✓✓	✓✓✓	✓✓✓	✓✓	✓
Diary	✓	✓✓✓	✗	✓✓✓	✗	✓✓✓	✗	✓	✗	✓✓
Heart rate monitoring	✓✓	✓✓	✓✓✓	✓	✓	✓	✓	✓	✓✓✓	✓✓✓
Accelerometer	✓✓	✓	✓✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓✓	✓✓✓
Pedometer	✓✓	✓✓✓	✓✓✓	✓✓	✓✓	✗	✓	✓✓✓	✓✓✓	✓✓✓
Observation	✓✓✓	✗	✓✓	✓	✓✓✓	✓✓	✓	✓	✓✓✓	✓✓
Doubly labeled water	✓✓✓	✗	✓✓✓	✓✓	✓✓	✗	✓✓	✗	✓✓✓	✓✓

* Non-reactive – doesn't induce changes in physical activity behaviour as a result of the measurment process

✗   Poor or Inappropriate

✓   Acceptable

✓✓   Good

✓✓✓   Excellent

5.1 Self-Report Measures

A variety of self-report methods have been used to assess physical activity in children and adolescents. These include self-administered recalls, interview administered recalls, diaries, and proxy reports from parents or teachers. Depending on the purpose of the study, self-report measures vary considerably in the specificity with which mode, duration, frequency and intensity are reported. Recall time frames range from as little as one day to as much as one year.

The most frequently cited advantages of self-report measures are ease of administration, the ability to characterise activity historically, and low cost. As a result, self-reports are typically used in epidemiological research or surveillance studies where objective measurement techniques are not feasible. Although convenient, self-report methods are subject to considerable recall bias and may not be suitable for use among young children. Baranowski et al. (32) demonstrated that children under 10 years of age cannot recall activities accurately and are unable to quantify the time frame of activity. In addition, it appears likely that younger children may not fully understand the concept of physical activity. Trost et al. (339) investigated the completeness of children's understanding of the term physical activity. Approximately 60% of fourth grade students had difficulty differentiating between sedentary activities such as playing computer games and active pursuits such active games and household chores. Thus, extreme caution must be exercised when attempting to utilise self-report instruments in children aged 10 years or under.

Sallis (290) examined the validity and reliability of 23 self-report instruments used to assess physical activity behaviour in children and adolescents. Instruments were grouped into the following categories: interviewer-administered, self-administered, diary measures, and proxy report measures. For interviewer-administered measures, reliability coefficients were acceptable (r = .70 - .81), with young children demonstrating lower reliability coefficients than adolescent youth. When heart rate monitoring was used as a criterion measure of physical activity, concurrent validity coefficients ranged from .29 to .72. Validity coefficients were generally higher among adolescents than children. For self-administered recall instruments, test-retest reliability coefficients ranged from .56 to .93. All self-report instruments demonstrated acceptable evidence of validity. Again, reliability and validity coefficients were age dependent, with younger children exhibiting poorer test-retest reliability and concurrent validity than adolescent youth. Diary measures were found to be reliable (intraclass R = .91) and valid (r=.80 with physical work capacity) among youth old enough to record their physical activity behaviour. For proxy reports of physical activity, activity estimates were moderately correlated with activity monitor counts (r = .41 - .60). However, in three studies, proxy reports were not associated with directly observed physical activity or measures of resting heart and blood pressure.

In summary, available evidence indicates that self-report methods provide acceptable estimates of relative physical activity behaviour in older groups of children. However, the generally low validity and reliability coefficients observed for self-report instruments in young children support the notion that objectives measures of physical activity such as accelerometers may be more appropriate in primary school aged children. For large population-based samples of children, however, objective measures may be too expensive

and logistically too difficult to administer effectively. Hence, for proposed monitoring and surveillance studies involving children aged 10 years or younger, parent proxy reports may be the only viable approach to measuring physical activity.

5.2   Direct Observation

Physical activity behaviour has been assessed via direct observation in a variety of naturalistic settings. Although protocols vary from study to study, the formal observation typically involves observing a child at home or school for extended periods of time and recording onto either a laptop computer or coding form an instantaneous rating of the child's activity level. Activity category ratings are usually recorded on a momentary time-sampling basis at time intervals ranging from five seconds to one minute.

Relative to other methods, direct observation has a number of important advantages. Observational procedures are flexible and permit researchers to not only quantify physical activity, but also record factors related to physical activity behaviour such behavioural cues, environmental conditions, the presence of significant others, and availability of toys and equipment. Given its inherent flexibility, observation of physical activity can be used as either a process or outcome measure. Thus, direct observation can be useful to both researchers and practitioners. Direct observation is not without it's limitations, however. Because of the time required to train observers, the length of the observation period, and the tedious data-coding requirements, it is highly labour-intensive and expensive. Subject reactivity to observers is also a legitimate concern; however this problem is generally avoided by performing repeat observations.

Direct observation has been shown to be a valid and reliable tool for measuring physical activity in children. McKenzie (206) reviewed 11 different protocols for observing physical activity behaviour in children. Five of the 11 studies had documented evidence of validity using either heart rate monitoring or energy expenditure assessed by indirect calorimetry. Interobserver reliability coefficients were generally impressive, with percent agreement statistics ranging from 84% to 98%.

5.3   Doubly Labeled Water

The doubly labeled water technique represents an unobtrusive and non-invasive means to measure total daily energy expenditure in free living children and adolescents. When combined with measurement of resting energy expenditure, the doubly labeled water technique can be used to estimate energy expenditure related to physical activity. The doubly labeled method is based on the kinetics of two stable isotopes of water, ^2H_2O (deuterium labeled water) and $H_2^{18}O$ (oxygen-18 labeled water). These stable isotopes are naturally occurring compounds without known toxicity at the low doses used. Deuterium labeled water is lost from the body through the usual routes of water loss (urine, sweat, evaporative losses). Oxygen-18 labeled water is lost from the body at a slightly faster rate since this isotope is also lost via carbon dioxide production in addition to all routes of water loss. The difference in the rate of loss between the two isotopes is therefore a function of the rate of carbon dioxide production – a reflection of the rate of energy production over time (133).

The doubly labeled water technique has been validated in adults and children by comparison with indirect calorimetry. These studies generally show the technique to be accurate within 5 to 10% (133). This small amount of error has prompted several authors to view the doubly labeled water method as a potential gold standard for estimating physical activity-related energy expenditure. A major limitation associated with doubly labeled water is excessive cost. In addition, although the technique provides accurate estimates of physical activity-related energy expenditure over one- to two-week periods, it does not provide information on the pattern of physical activity behaviour – i.e., it does not provide estimates of energy expended in light, moderate, and heavy physical activity (345).

5.4   Heart Rate Monitoring

Relatively inexpensive heart rate monitors with full day storage capacity for minute-by-minute heart rates have made continuous heart rate monitoring a more feasible method for assessing physical activity in children and adolescents. Heart rate monitoring remains an attractive approach to assessing physical activity because of the linear relationship between heart rate and energy expenditure during steady state exercise. However, there are several problems associated with this method. First, it is widely recognized that factors such as age, body size, proportion of muscle mass utilised, emotional stress, and cardiorespiratory fitness influence the heart rate-VO_2 relationship. Second, because heart rate response tends to lag momentarily behind changes in movement and tends to remain elevated after the cessation of movement, heart rate monitoring may mask the sporadic activity patterns of children. Third, because a large percentage of a child's day is spent in relatively inactive pursuits (i.e., sitting in class), heart rate monitoring may be of limited use in assessing total daily physical activity. However, it is important to note that several techniques have been devised to overcome some of the limitations of heart rate monitoring. These include the use of heart rate indices that control for individual differences in resting heart rate and individualized HR-VO_2 calibration curves.

Although many relative heart rate indices can be found in the research literature, three of the most popular are the activity heart rate index (AHR), the PAHR-25, and the PAHR-50. The AHR is empirically defined as the mean of the recorded heart rate minus resting heart rate, whereas the PAHR-25 and PAHR-50 are defined as the percentage of heart rates 25% and 50% above resting heart rate. Because all three measures depend on accurate measures of resting heart rate, it should not be surprising that the operational definition of resting heart rate and the protocol used to measure resting heart rate have profound effects on the estimates of physical activity. Logan et al. (189) examined the impact of different definitions of resting heart rate on the apparent activity level of children aged 3 and 4 years. Resting heart rate was measured five different ways: 1) mean of the lowest heart rate plus all heart rates within 3 beats; 2) mean of the lowest 5 heart beats; 3) mean of the lowest 10 heart beats; 4) mean of the lowest 50 heart beats; and 5) actual resting heart rate assessed using a standardized protocol. Depending on the protocol used, the PAHR-25 varied by 10-50%, the PAHR-50 varied by 16-65%, and the AHR varied by 9-44%. The authors concluded that a consensus must be obtained for deriving or measuring resting heart rate before relative heart rate indices can be used to effectively quantify physical activity in children.

A more burdensome approach to assessing physical activity via heart rate is to calibrate heart rate and VO_2 on an individual basis. This method is especially popular among researchers conducting energy balance studies, because it provides a means of estimating total daily energy expenditure in free-living individuals. Of the various approaches to obtaining individualized HR-VO_2 relationships, the HR FLEX method is one of the most studied. This method is based on the assumption that, above a given intensity threshold, there is a linear relationship between heart rate and oxygen consumption. Below this threshold, the relationship is more variable. Therefore, in order to estimate VO_2 or energy expenditure from heart rate, the linear prediction is used above the HR FLEX point, and the average of a series of heart rate values obtained during rest are used below it. The HR Flex point is empirically defined as the average of the lowest HR during exercise and the highest during rest. Studies evaluating the validity of the HR FLEX method in children have found it acceptable for group level comparisons, but not individual level data.

Livingstone et al. (188) evaluated the accuracy of the HR FLEX method in 36 free-living children between the ages of 10 and 15. Compared with the doubly-labeled water method, heart rate based estimates of total daily energy expenditure exhibited large individual differences ranging from –16.7 to 18.8%, with mean group differences ranging from –9.2 ± 4.5% to 3.5 ± 6.6%. Similarly, Emons and co-workers (107) evaluated the validity of the HR FLEX method in children using indirect calorimetry and doubly-labeled water as criterion measures of energy expenditure. Energy expenditure predicted by 24-hr heart rate monitoring was not significantly different from that estimated by doubly-labeled water. However, relative to indirect calorimetry and doubly-labeled water, the HR FLEX method overestimated 24-hr energy expenditure by 10.4% and 12.3%, respectively.

An alternative to the HR FLEX method is to model heart rate and VO_2 continuously in a non-linear fashion. Bitar et al. (42) evaluated the validity of this approach in nineteen 10-year-old children. Individual relationships between heart rate and energy expenditure were computed during rest, light activities, and moderate to heavy exercise. Heart rate and energy expenditure were subsequently modeled using a continuous linear, polynomial, and exponential function and a discontinuous function which utilised an exponential HR-VO_2 function below the "HR flex" point and a linear HR-VO2 during exercise. The relative accuracy of each approach was tested by comparing predicted EE with observed EE measured by whole room calorimetry. Of the four modeling approaches, the best fit was obtained with the polynomial HR-VO2 relationship. The associated difference between estimated and measured EE averaged 7.62 ± 20.12%. The authors concluded that estimates of total daily energy expenditure derived from an individualized polynomial HR-VO_2 calibration curve was acceptable for group level comparisons, but lacked the precision necessary to make individual comparisons.

In an effort to improve the precision of heart rate-derived estimates of free-living energy expenditure, several investigators have used a combination of heart rate monitoring and accelerometry. In this approach, two distinct HR-VO_2 relationships are individually established, one for active periods and another for periods of inactivity. Treuth et al. (336) tested the validity of this approach in children by comparing energy expenditure estimated by a combination of heart rate monitoring and accelerometry to the energy expenditure

measured by whole room calorimetry. The mean level of error associated with the prediction of VO_2, VCO_2, and energy expenditure was $-2.6 \pm 5.2\%$, $-4.1 \pm 5.9\%$, and $2.9\% \pm 5.1\%$, respectively. Given the small magnitude of these errors, the authors concluded that the combination of heart rate monitoring and accelerometry was an acceptable method for estimating energy expenditure not only for groups of children, but for individuals as well.

5.5   Accelerometers

In recent years accelerometers have become a popular tool for quantifying physical activity in children and adolescents. Accelerometers monitor movement in a specific plane and store data as "counts". In newer models, not only are the number of movements recorded in real time, but also the intensity of the movements. The resultant data are therefore a function of the frequency and intensity of movement.

Relative to heart rate monitors, accelerometers present less burden to subjects (no electrodes or chest straps) and are capable of detecting the intermittent activity patterns characteristic of small children. However, accelerometers are insensitive to some forms of physical activity (i.e., stair climbing, swimming, and cycling), and the relationship between accelerometer counts and energy expenditure is unclear. Recently, several investigators have derived algorithms to convert accelerometer output to units of energy expenditure, but the predictive validity of these equations in children has not been determined. An additional problem related to the use of laboratory-based prediction equations or "count cut-offs" is that they assume steady-state exercise over a 1-min period. Consequently, if a child alternates between vigorous physical activity and rest within a given minute (a likely occurrence), the accumulation of counts for that minute will reflect the average activity level during that period and no credit will be given for engaging in vigorous physical activity To date, the most widely used accelerometers are the Caltrac,Tritrac-R3D and the MTI Actigraph (formerly the Computer Science and Applications Inc 7164) activity monitors. Each is discussed below.

5.5.1   Caltrac

The Caltrac accelerometer has been the most extensively used motion sensor. Its relatively small size (14 cm x 8 cm x 4 cm), light weight (400 gm), and lower cost make the Caltrac a popular choice among physical activity researchers. The Caltrac measures vertical acceleration that causes a ceramic transducer to twist, resulting in an intensity-dependent voltage output. The assumption underlying the validity of the device is that body or trunk accelerations closely reflect the energy cost of movement. The Caltrac sums and integrates the absolute value of the acceleration versus time curve and derives a numerical "count" that is displayed. The Caltrac can be programmed to provide output either in caloric expenditure units or activity counts. For the estimation of caloric expenditure, the subject's height, weight, age, and gender must be entered directly into the unit. Output appears on a liquid crystal display and several buttons on the front panel are used to program the device. Hence, the Caltrac is especially vulnerable to tampering by curious children. Another drawback of the Caltrac is its inability to store data on a minute-by-minute basis. Consequently, summated counts or kilocalories must be recorded directly from the liquid crystal display. This places additional burden on both participants and measurement personnel.

The validity and reliability of the Caltrac accelerometer has been studied quite extensively in children and adolescents. When validated against direct observation of physical activity, validity coefficients range from 0.35 to 0.62 . When validated against heart rate monitoring, validity coefficients range from 0.35 to 0.49. Reliability coefficients range from 0.30 to 0 .79 (345).

5.5.2   Tritrac-R3D

The Tritrac-R3D, measures motion horizontally, vertically, and diagonally and internally stores the motion in internal memory over intervals ranging from one to 15 minutes. The output from each plane is summed, integrated, and converted to energy expenditure units using an algorithm similar to that used with the Caltrac motion sensor. Welk and Corbin (369) evaluated the validity of the Tritrac-R3D monitor in children age 9 to 11 years (n = 35). The correlation between Tritrac counts and the activity index from heart rate monitoring was significant but moderate at 0.58.

5.5.3   MTI Actigraph

The MTI Actigraph (formerly known as the Computer Science and Applications Inc. (CSA) 7164) is a small (5.1 x 3.0 x 1.5 cm), light weight (43 g) single-axis accelerometer which can be worn at the hip, ankle, or wrist. The small size, relatively low cost, and robust design features of the MTI Actigraph make this instrument highly suitable for use in moderately large samples of children and adolescents. The MTI Actigraph can be easily initialised and downloaded on any personal computer and, in contrast with the more widely used Caltrac activity monitors, can store data continuously for up to six weeks. Other features which make the MTI Actigraph a suitable instrument for epidemiological research include the ability to specify start and stop times and an internal real-time clock which allows data to be analysed over intervals as short as one second.

A small number of studies have evaluated the validity of the MTI Actigraph in children and adolescents. Janz et al. (153) assessed the validity of the MTI Actigraph as a field measure of physical activity in children aged 7 to 15. Correlations between average Actigraph counts and various indices of heart rate were statistically significant and ranged from .50 to .74. Trost and coworkers (347) evaluated the validity of the MTI Actigraph in children aged 10 to 14 using energy expenditure assessed via indirect calorimetry as a criterion measure. Activity counts were strongly correlated with energy expenditure during treadmill walking and running (r = .87, p < .001). The intraclass correlation coefficient for two Actigraphs worn simultaneously was .87. Therefore, the MTI Actigraph appears to be a valid and reliable tool for assessing physical activity in youth.

5.5.4   Comparison of Accelerometer Types

Whether triaxial accelerometers (such as the TriTrac-R3D) provide more valid estimates of children's physical activity than uniaxial accelerometers (such as the MTI Actigraph and the Caltrac) remains a point of contention. Three-dimensional accelerometers were developed under the assumption that more is better. That is, by recording motion in more than one plane (vertical), triaxial accelerometers might be better able to quantify the non-locomotive movements produced by children during normal play. While this argument has strong intuitive appeal, field and laboratory-based studies testing the relative validity of uniaxial and triaxial accelerometers in children have produced conflicting results.

Welk and Corbin (368) compared the validity of the Tritrac and the Caltrac accelerometer in children using heart rate monitoring as an indicator of convergent validity. The correlation between heart rate and the Tritrac vector sum (r=0.58) was marginally higher than that observed for the uniaxial Caltrac accelerometer and heart rate (r=0.52). Importantly the correlation between the Tritrac and Caltrac was 0.88, suggesting that both approaches were providing similar information.

Freedson et al. (124) evaluated the validity and inter-instrument reliability of the Tritrac and the MTI/CSA Actigraph in 81 children ranging in age from 6 to 18 years. Each participant completed 3 treadmill trials consisting of walking/running at 4.4, 6.4, and 9.7 km/h, respectively. To evaluate inter-instrument reliability, participants wore two Actigraphs and two Tritracs during each trial. Consistent with previous laboratory-based validation studies, the Actigraph and Tritrac exhibited strong associations with energy expenditure measured by indirect calorimetry (r ≥ 0.90). The units did, however, differ considerably with respect to inter-instrument reliability. Across the 3 treadmill speeds, the MTI Actigraph exhibited excellent inter-instrument reliability (r= 0.89 – 0.94). In contrast, inter-instrument reliability coefficients for the Tritrac were quite poor ranging from 0.32 to 0.59.

Eston et al. (110) examined the relationships between oxygen consumption (relative to body mass raised to the power of 0.75) and output from the TriTrac and MTI Actigraph accelerometers in children during treadmill running/walking and unregulated play activities. Across all activities, the Tritrac vector sum exhibited stronger correlations with scaled oxygen consumption (r=0.91) than the MTI Actigraph (r=0.78).

Ott et al. (232) investigated the relative validity of the Tritrac and MTI Actigraph with respect to their ability to measure children's free play activities of different intensity. Twenty-eight children between the ages of 9 and 11 completed a circuit of eight free-play activities consisting of playing a video game, throwing and catching, walking, bench stepping, hopscotch, basketball, aerobic dance, and running. During the activities each participant wore a heart rate monitor, a MTI Actigraph, and a Tritrac-R3D accelerometer. Across all eight activities, both accelerometer types were significantly correlated with heart rate and an observation-based intensity score. However, correlations observed for the Tritrac vector sum (r=0.66-0.73) were greater than those observed for the MTI Actigraph (r=0.53-0.64). Similar to Welk and Corbin, outputs from both accelerometer types were strongly correlated (r=0.86), suggesting that, over a range of free-living activities, both uniaxial and triaxial accelerometers provide useful information about children's physical activity.

Based on the available evidence, it appears that three-dimensional accelerometers may provide marginally better assessments of children's physical activity than uniaxial accelerometers. However, the consistent observation that data from both types of accelerometers are strongly correlated, suggests that uniaxial accelerometers still provide useful estimates of free-living physical activity in children. There are concerns about the inter-instrument reliability of the Tritrac and this should be further investigated in other settings and study populations.

5.6   Pedometers

While accelerometers have been shown to be useful tools for quantifying physical activity in children, their relatively high cost ($USD 150 - $500 per unit) prohibit their use in feasibility studies, intervention programs, and large-scale epidemiological studies. A cost-effective alternative to accelerometers is to measure physical activity with an electronic pedometer. Pedometers have the same basic limitation as uniaxial accelerometers, in that they are insensitive to non-locomotor forms of movement. In addition to this limitation, however, these devices are unable to record the magnitude of the movement detected (movement above a given threshold is counted as a step regardless of whether it occurred during walking, running, or jumping), nor do they possess real-time data storage capabilities. Consequently, pedometers can only provide an estimate of the relative volume of activity performed over a specified time period, assuming that most of the activity performed involves locomotor movement such as walking. Many commercially-available pedometers provide users with estimates of energy expenditure; however, the algorithms used for these calculations are not appropriate for children.

To date, a small number of studies have assessed the validity of electronic pedometers as measures of youth physical activity. Leenders et al. (180) assessed the accuracy of the Yamax Digiwalker electronic pedometer in counting steps during treadmill walking at various speeds (mean=3.5, 4.2, and 5.4 km/h) in African American children between the ages of 7 and 11 years. The investigators also examined whether pedometer steps varied according to the placement of the pedometer – directly on the beltline of belt-less slacks vs. inside a soft-case pouch attached to a belt. No differences were observed between recorded and observed steps during the three treadmill speeds, nor were there significant differences in steps taken between the two pedometer placements. Importantly, steps taken differed significantly across the 3-speeds, indicating that the Yamax Digiwalker was sensitive to small increases in walking speed. Eston and colleagues (110) reported a correlation of 0.92 between steps recorded by the Yamax Digiwalker and scaled oxygen consumption during treadmill walking/running and unstructured play activities in 8- to 10-year-old children. Finally, Kilanowski et al. (167) observed correlations exceeding 0.95 between pedometer steps per minute and directly observed physical activity in 12-year-old children.

Based on the results of these studies, it appears reasonable to conclude that electronic pedometers provide valid assessments of the relative volume of physical activity in children. These devices should be especially useful in studies in which the goal is to document relative changes in physical activity or to rank order groups of children on physical activity participation. Pedometers do not, however, provide information about the frequency, intensity or duration of physical activity. What is more, because pedometer steps are influenced by factors such as body size and speed of locomotion, investigators should exercise caution when using pedometers in growing children or groups of children with different levels of maturation.

Tracking of physical activity

Tracking of a characteristic, refers to the maintenance of relative rank or position within a group over time. From a public health perspective, the concept of tracking is of considerable importance as it implies that health behaviours established early in life are carried through into adulthood. The notion that physical activity behaviour tracks from childhood into adolescence provides a strong rationale for the promotion of physical activity in children and adolescents. A small number of studies have examined the tracking of physical activity. Most studies have examined the tracking of physical activity *during* childhood and adolescence, and information about the tracking of physical activity from childhood into adulthood is scarce.

As part of the Cardiovascular Risk in Young Finns Study, Raitakari et al. (260) examined the long-term tracking of physical activity behaviour in Finnish youth. Leisure-time physical activity was assessed via self-report questionnaire in randomly selected population-representative samples of youth aged 3 to
19 years. Baseline assessments were performed in 1980, with follow-up assessments performed in 3-year intervals in 1983 and 1986. Rank order correlations between physical activity at baseline and 3-years follow-up were statistically significant and ranged from 0.33 to 0.54. Rank order correlations between physical activity at baseline and 6-years follow-up, while statistically significant, were smaller in magnitude, ranging from 0.17 to 0.43. Tracking coefficients were generally stronger among males and older age groups. To examine the stability of active and sedentary behaviour, participants were classified as active or sedentary. Forty-one percent of males and 29% females classified as active at age 12 remained active at age 18. Conversely, 56% of males and 63% of females classified as sedentary at age 12 remained inactive at age 18.

In a follow-up study of the Young Finns cohort, Telama and colleagues (326) assessed the stability of physical activity behaviour after 9 and 12 years of follow-up. This is an important study because it provides an assessment of the tracking of physical activity from childhood into adulthood. Rank order correlations for baseline physical activity (1980) and physical activity assessed 9 and 12 years later ranged from 0.18 to 0.47 and 0.00 to 0.27, respectively, indicating a low to moderate degree of tracking.

Another study that provides information about the long-term tracking of physical activity from childhood and adolescence into early adulthood is the Amsterdam Growth Study (355). The study examined both the short- and long-term tracking of total weekly energy expenditure and energy expenditure in organised sports. For time periods of approximately five years, there was suggestive evidence of tracking for total energy expenditure in both males (r =0.32 - 0.44) and females (r = 0.25 - 0.58). For weekly energy expenditure in organised sports, short-term interperiod correlations (~ 5 years) were higher at 0.53 and

0.59 for males and females, respectively. For longer periods of follow-up (10-15 years), there was little evidence of tracking for any of the physical activity variables (r < 0.20). The investigators also examined the stability of membership in the highest and lowest quintile for total weekly energy expenditure. Among males, 9 out of the 21 participants (42.8%) in the highest quintile for weekly energy expenditure at baseline (age 13) remained in the highest quintile at 4-years follow-up (age 16). Similarly, 12 of the 21 males (57.1%) in the lowest quintile for weekly energy expenditure at baseline remained in the lowest quintile at 4-years follow-up. Among females, 7 out of the 24 participants (29.2%) in the highest quintile for weekly energy expenditure at baseline (age 13) remained in the highest quintile at 4-years follow-up (age 16). Seven of the 24 females (29.2%) in the lowest quintile for weekly energy expenditure at baseline remained in the lowest quintile at 4-years follow-up.

Saris et al. (291) examined the stability of physical activity behaviour in a cohort of 217 boys and 189 girls. Data were collected every two years beginning at age six and ending at age 12. Total energy expenditure and energy expenditure in activities above 50% of aerobic capacity were estimated from 24-hour heart rate monitoring using the individual regression equation between heart rate and oxygen consumption. Interperiod correlation coefficients for total energy expenditure ranged from 0.30 to 0.42. Interperiod correlation coefficients for energy expenditure in activities above 50% of aerobic capacity were less than 0.20, indicating a low degree of tracking.

Pate et al. (241) investigated the tracking of physical activity in 47 3- to 4-year-old children over a 3-year period. Physical activity was assessed via continuous heart rate monitoring on at least two and up to four days per year. Participation in physical activity was quantified as the percentage of observed minutes between 3:00 p.m. and 6:00 p.m. during which heart rate was 50% or more above individual resting level (PAHR-50 Index). The spearman rank order correlation between the PAHR-50 index in year one and year three was 0.57 (p <.0001). In another study, Pate and colleagues (248) examined the tracking characteristics of physical activity across the fifth, sixth and seventh grades in a cohort of rural, predominantly African American children. Intraclass correlation coefficients for vigorous physical activity, moderate to vigorous physical activity, and after school energy expenditure ranged from 0.63 to 0.78, indicating a moderate to strong degree of tracking over the 3-year study period.

Sallis et al. (280) examined the tracking of physical activity at home and recess in 351 Mexican-American and Anglo-American children (mean age 4.4 years). Physical activity was directly observed over a two year period. Measurement waves occurred every six months, with each wave consisting of two days of observation within one week. Children were observed for up to 60 minutes at home on a weekday evening and up to 30 minutes during recess at preschool or school. Tracking coefficients (Pearson r's) for physical activity performed at home were .16 (based on one day of observation) and 0.27 (mean of two days observation). Tracking coefficients for activity at recess were 0.04 (one day of observation) and 0.12 (mean of two days observation), indicating a low degree of tracking.

Kelder et al. (162) studied the tracking of physical activity in adolescents residing in two communities participating in the Minnesota Heart Health Program study. Physical activity was assessed via self-report questionnaire on an annual basis, beginning in seventh grade and ending in twelfth grade. Tracking was analysed by (a) dividing baseline physical activity values into quintiles; (b) computing the mean in each quintile; and (c) ascertaining whether the mean for each activity quintile maintained its relative position over time. Tracking was most apparent in the extremes of the physical activity distribution – those with the highest (> 6 hr) and the lowest (< 1 hr) weekly exercise time.

Janz et al. (154) assessed the tracking of physical activity from childhood to adolescence in a cohort of 53 boys (*M* age at baseline = 10.8 yrs) and 57 girls (*M* age at baseline = 10.3 yrs). Vigorous physical activity, television watching and video game playing was assessed via self-report every 3-months over a 5-year follow-up period. Among boys, tracking coefficients (spearman rho's) for vigorous physical activity ranged from 0.32 (Yr 1 – Yr 5) to 0.52 (Yr 3 – Yr 5 and Yr 4 – Yr 5). Among girls, tracking coefficients for vigorous physical activity ranged from 0.43 (Yr 1 - Yr 5) to 0.65 (Yr 4 – Yr 5). Tracking coefficients for television watching and video game playing among boys ranged from 0.40 (Yr 2 – Yr 5) to 0.65 (Yr 3 – Yr 5). Among girls, tracking coefficients for television watching and video game playing ranged from 0.16 (Yr 1 – Yr 5 and Yr 3 – Yr 5) to 0.59 (Yr 4 – Yr 5). Forty-seven percent of boys and 38% of girls in the lowest tertile for vigorous physical activity baseline remained in the lowest tertile at 5 years follow-up, while 36% of boys and 42% of girls in the highest tertile for vigorous physical activity remained in the highest activity tertile at 5 years follow-up. Forty-one percent of boys and 44% of girls in the lowest tertile for television watching and video game playing at baseline remained in the lowest tertile at 5 years follow-up, while 73% of boys and 21% of girls in the highest tertile for television watching and video game playing remained in the highest activity tertile at 5 years follow-up.

In summary, relatively few studies have examined the tracking properties of physical activity during childhood and adolescence. Although studies vary considerably with respect to length, age group studied, measurement of physical activity, and method used to assess tracking, there is some evidence that, over short time periods (3-5 years), physical activity behaviour tracks. Over longer periods of follow-up (6-12 years) there is little evidence that physical activity behaviour tracks during childhood and adolescence. There is no strong evidence to support the notion that physical activity tracks from childhood to adolescence, or from adolescence into adulthood. However, future longitudinal studies using more sophisticated measures of physical activity may provide a more definitive answers to these important questions.

Determinants of physical activity in children and youth

The purpose of this section is to summarise the current state of knowledge regarding the determinants of physical activity in children and adolescents. First, theories or models of health behaviour used to identify potential determinant variables will be discussed. This will be followed by an overview of the demographic, physiological, psychosocial, and environmental factors that have been associated with physical activity in children and adolescents.

7.1 Behavioural Theories

7.1.1 Social cognitive theory

The majority of studies investigating the determinants of physical activity in youth have utilised social cognitive theory as a conceptual framework. Social cognitive theory posits that behaviour, personal factors (e.g., psychological, biological), and environmental factors (social and physical) interact bi-directionally with each other in a manner known as reciprocal determinism (254). A central tenet of social cognitive theory is the concept of self-efficacy or confidence in one's ability to perform a specific behaviour. Perceived self-efficacy is hypothesised to be the critical mediator determining: (a) whether or not an individual attempts a given behaviour; and (b) how hard individuals try to adopt a given behaviour before giving up (254). According to Bandura (30), an individual's self-efficacy beliefs are formed by past experiences, vicarious learning, verbal persuasion, and interpretation of one's physiological state.

7.1.2 Theory of Reasoned Action and Theory of Planned Behaviour

The theory of reasoned action states that performance of a given behaviour is primarily determined by an individual's intention to perform that behaviour (6). The intent to perform this behaviour is, in turn, influenced by the individual's attitude toward the behaviour (i.e., the beliefs about the outcomes of the behaviour and the value of these outcomes) and the influence of the individual's social environment or subjective norm (i.e. perceived expectations of salient individuals or groups, as well as the motivation to comply with these expectations). Another element of Fishbein and Ajzen's basic model is the assumption that external variables are related to behaviour only when they have an impact on the variables specified in the model. Accordingly, the theory of reasoned action recognises that personal and environmental factors do influence behaviour, however, their influence is thought to be a function of attitudinal and normative considerations.

To accommodate behaviours not fully under volitional control, Ajzen (7) added the concept of perceived behavioural control to the reasoned action model. This model, known as the theory of planned behaviour, specifies that intention to perform a given behaviour is not only influenced by attitude and subjective norm, but also perceived behavioural control. Perceived behavioural control is also hypothesised to influence behaviour in a direct fashion in parallel with its influence on intention. According to Ajzen (7), perceived behavioural control reflects personal beliefs as to how easy or difficult adoption of the behaviour is likely to be. It is an overall assessment of factors internal to the individual such as skills, ability, will power, knowledge, and adequate planning; as well as external factors such social support, opportunity, and time.

7.1.3 Harter's Self-Esteem Model

Harter's model of self-esteem is another conceptual framework that has been used to understand the factors that motivate children to participate in sport and physical activity. Adapted for the physical domain by Weiss et al. (367), the model views self-esteem as the key mediator of physical activity behaviour in children and adolescents. As shown in Figure 2 below, self-esteem in the physical domain is thought to be a function of both perceived competence/adequacy and social support from parents, instructors, and peers. Notably, social support from parents, instructors and peers is also a determinant of children's competence perceptions. In turn, self-esteem in the physical domain is hypothesised to influence participation in physical activity either directly or indirectly via its influence on enjoyment of physical activity.
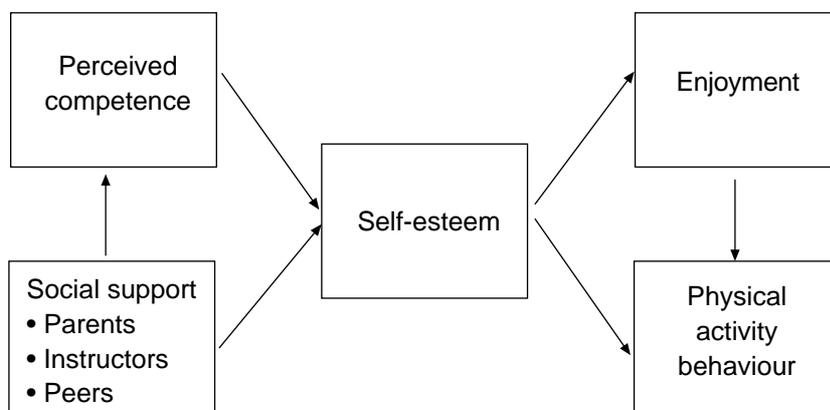
Figure 2:   Harter's Self-Esteem Model

Just as self-efficacy perceptions are of central importance in Bandura's Social Cognitive Theory, perceived competence is of key significance in Harter's model. Perceived competence refers to individuals' judgement about their ability in a particular area. In the physical domain children make judgements about their physical activity based from outcome, social, and internal sources. Outcome sources include external rewards (e.g., trophies and ribbons), event outcomes (e.g., winning, final standings), test results, and game statistics. Social sources include feedback and reinforcement from parents, teachers, and coaches, as well as evaluation by and comparison to peers. Internal sources including self-referencing such as improvement in relation to past performances and achievement of personal goals. The sources of information used to construct perceptions of competence

vary by developmental stage. Younger children (ages 5-9 yrs) tend to use mastery of simple tasks, level of effort, and feedback from parents to judge physical ability. Youth aged 10 to 15 years tend to use performance outcomes relative to their peers and verbal and non-verbal feedback from teachers and coaches to judge physical ability. In later adolescence, (ages 16-18 yrs), internal sources of information such as personal improvement and attainment of goals are used to judge physical ability (367).

7.2   Factors Influencing Physical Activity Behaviour in Youth

Existing evidence indicates that physical activity behaviour in children and adolescents is associated with a diverse set of factors. For ease of discussion, these factors are classified as either demographic, physiologic, psychosocial, and environmental influences.

7.2.1   Demographic Influences

Age and gender are the strongest and most consistent predictors of physical activity among youth. Population-based descriptive studies conducted in the western industrialised countries have demonstrated that participation in physical activity is lower in females than males; and that physical activity declines with age, particularly among adolescent females. Race/ethnicity is also associated with physical activity behaviour in youth. Data from the CDC's Youth Risk Behaviour survey (74) indicate that African-American and Hispanic youth are less active than White children. There are no comparable data for Indigenous or ethnic Australian youth.

7.2.2   Physiological Influences

Physical fitness and obesity status are the most frequently studied physiologic determinants of physical activity in youth. Numerous studies have reported physically active youth to be more physically fit than their less active counterparts (197). However, the association between physical activity and physical fitness in children and adolescents is generally weak, with an average correlation of 0.17 (216). Obesity has long been viewed as negative determinant of physical activity behaviour. In support of this assertion, numerous studies have found obese children to exhibit lower participation in physical activity than their lean counterparts (33). However, for children and adolescents within the normal healthy range for body fatness, adiposity is not consistently associated with physical activity behaviour (33). Heredity is also hypothesised to be determinant of physical activity in youth. In support of this notion, familial aggregation of physical activity behaviour has been observed in families of various racial/ethnic backgrounds (325). Bouchard and co-workers (55), utilising path analysis techniques, estimated genetic factors to account for 29% of the variance in the transmission of physical activity behaviour across generations.

7.2.3   Movement Skills

Motor proficiency or fundamental movement skills are also hypothesised to be a strong influence on youth physical activity participation.

Relatively few studies have examined the association between physical activity participation and motor proficiency or movement skills. The available evidence, which consists almost entirely of cross-sectional studies, suggests a weak but positive association between physical activity and motor proficiency. Currently, there is no definitive evidence

from prospective longitudinal studies showing a causal relationship between physical activity participation and fundamental movement skills/motor proficiency (289).

Schmucker et al. (294) evaluated the association between motor ability and habitual physical activity in 25 sixth grade children (*M* age = 12.4 years). Physical activity was measured via a questionnaire requiring students to recall their leisure time physical activities during a single week and two weekend periods. Fundamental movement skills were assessed via the Schilling Body Coordination Test for Children. Participants were rated on a 5-point scale on their ability in running, jumping, catching, throwing, climbing, and crawling. The authors also subjectively evaluated the participant's level of coordination during a basketball game. Habitual physical activity was positively and significantly correlated with performance of fundamental movement skills (r=0.51) and level of coordination during basketball (r=0.48).

Watson and O'Donovan (363) quantified the relationships between habitual physical activity and motor ability in 85 Irish school boys aged 17 and 18 years. The number of hours of physical activity performed by participants over the previous month was estimated from responses to an activity questionnaire, supplemented by an interview. Motor ability was assessed via four items – alternate hand wall toss, standing long jump, agility run, and sitting basketball throw. Motor ability was strongly associated with habitual physical activity, accounting for approximately 39% of the variance.

Ulrich (350) assessed participation in organised sport and motor competence in 250 children in kindergarten through grade four (25 boys and 25 girls from each grade level). With the assistance of parents, children recalled their participation in sport and physical activity over the previous year. Children were classified as "participants" if they reported participation in at least one organised sport in the previous 12 months. Motor competency was assessed in nine activities – broad jump, flexed arm hang, sit-up test, side-step test, sixty yard shuttle run (motor ability items) and playground ball dribble, soccer ball dribble, softball repeated throw, soccer ball throw (sport skill items). Participants exhibited significantly better performance than non-participants on the four sports skills. No significant differences were observed on the motor ability items. Discriminant function analysis indicated that performance in the soccer ball dribble was the most powerful discriminator between participants and non-participants. While the results of this study provide some support for the concept that sport participation is associated with greater motor competence, the validity of the study is severely limited by the fact that 66% of the participants were involved in youth soccer.

Butcher and Eaton (70) examined the relationship between gross and fine motor proficiency in physical activity level in 31 preschool children (*M* age = 5.1 years). Physical activity during indoor free play sessions was quantified by direct observation and motion sensors worn on the ankle. Motor proficiency was assessed using the Bruininks-Oseretsky Test of Motor Proficiency which assessed running speed and agility, strength, balance, bilateral limb coordination, upper limb coordination, response speed, visual motor control, and upper limb speed/dexterity. Participation in highly active free play was associated with better performance on the running speed/agility task (r=0.38), but with poorer performance on the balance, visual-motor control, and upper limb speed/dexterity tasks (r= -0.26 to –0.44).

Marshall and Bouffard (199) used a completely randomised factorial study design to evaluate the effects of a quality daily physical education program on movement competency in obese and non-obese Canadian elementary school children. Movement competency was assessed via Ulrich's Test of Gross Motor Development (TGMD). Relative to controls participating in the regular physical education program, quality daily physical education was found to have a significant impact on motor competency in non-obese girls and obese males. However, no effects were observed in obese girls and non-obese boys.

Okely et al. (230) evaluated the relationship between physical activity and fundamental movement skills in a representative sample of New South Wales school students in grades 8 and 10. Physical activity was assessed using a self-report questionnaire requiring students to recall the type, duration, and frequency of organised sport and non-organised physical activities during a "typical week" in winter and summer. The investigators assessed proficiency in six fundamental movement skills – running, vertical jump, catch, overhand throw, forearm strike, and kick. Girls and boys in the highest quintiles for movement skills reported significantly greater time in organised sport than those in the lowest quintiles. However, it should be noted that the explanatory power of the fundamental movement skills was small, accounting for only 3% of the variance in sport participation. Furthermore, no relationship was observed between fundamental movement skills and participation in non-organised physical activity.

7.2.4   Psychosocial Influences

Physical activity self-efficacy (i.e., one's confidence in one's ability to be physically active on a regular basis) has been shown to be a consistent predictor of physical activity behaviour in children and adolescents (9,264,340,342,343,344,380). Perceived physical competence (39,41,63,64,119,374) and perceived behavioural control (79,218) have also been shown to be associated with physical activity behaviour in youth. Positive expectations or beliefs about the outcomes of exercise are also salient influences on youth activity participation (130,135,329,342). Of particular importance is the belief that physical activity is fun or enjoyable (54,311).

Perceived barriers to physical activity are yet another important influence on youth physical activity behaviour (10,126,320). Available research indicates that, among youth, the major barriers to exercise are time constraints, poor weather conditions, homework obligations, and lack of interest or desire. Other studies indicate that intentions to be active, attitude towards physical activity, and social influences regarding physical activity are salient influences of youth physical activity participation (288,289).

7.2.5   Environmental Influences

With respect to the social environment, parental physical activity behaviour appears to be an important determinant of physical activity in children and adolescents (213,286). Support and encouragement from parents and other significant adults are also strong influences on youth physical activity (14,89,208,279). The physical environment is also an important influence on youth physical activity behaviour. Studies conducted to date have identified opportunities for physical activity, time spent outdoors, convenience of play spaces, and availability of equipment and facilities at home as key environmental determinants (169,283,287).

Watching television and/or playing video games is frequently cited as a negative environmental determinant of physical activity behaviour in children and adolescents. However, the literature examining this association is mixed. While several studies have found weak inverse relationships between television watching and physical activity (98,99,249), many have failed to observe any association (265,266,321).

In summary, the available evidence indicates that physical activity behaviour in children and adolescents is associated with a multitude of demographic, physiological, psychosocial, and environmental factors. These factors are summarised in Table 14. While the table lists an impressive array of factors, it should be noted that much of the variance in youth physical activity remains unexplained. Consequently, additional studies are needed to identify other potential important physiological, psychosocial, and environmental determinants of physical activity in youth.

Table 14:   Determinants of Physical Activity in children and adolescents

	Children	Adolescents
Demographic determinants		
Age	—	—
Gender (female)	—	—
Cultural background (non-white)	— (girls)	— (girls)
	*** (boys)	*** (boys)
Physiological determinants		
Aerobic fitness	+	+
Obesity	—	—
Motor skill development	+	+
Heredity	+	+
Psychosocial determinants		
Personality traits	***	***
Knowledge	***	***
Self-efficacy	+ +	+ +
Perceived competence	+ +	+ +
Perceived benefits	+ +	+ +
Perceived barriers	+	+ +
Enjoyment of physical activity	+ +	+
Attitude towards physical activity	+ +	+ +
Positive outcome expectancies	+	+
Intentions	+ +	+ +
Social Influences	+	+
Environmental determinants		
Parental activity	+	+
Parental support	+ +	+ +
Peer support	+	+
Access to facilities and equipment	+ +	+ +
Television watching	~	~
Time spent outdoors	+ +	+

+ + = repeatedly documented positive association with physical activity

+ = weak or mixed evidence of a positive association with physical activity

*** = weak or mixed evidence of no association with physical activity

— = repeatedly documented negative association with physical activity

~ = weak or mixed evidence of negative association with physical activity

? = no data available

Description of the intended purpose of the recommendations

The intended purpose of developing recommendations for physical activity for children and youth is to identify the minimum level of physical activity required for good health in young people. They would not be intended to guide high level fitness or sports training. The defined minimum level of physical activity would then inform the monitoring of current prevalence and trends in physical activity among children and youth. They would also be used to focus efforts on increasing population levels of physical activity and helping to prevent the development of overweight and obesity in young people.

Description and critique of existing physical activity guidelines for young people

In developing guidelines for children's and youths' participation in health promoting physical activity, several considerations should be applied:

1. There should be sufficient empirical evidence that the amount of physical activity recommended is associated with desirable status on a range of physical and social health outcomes. Ideally, there should also be evidence that the amount of physical activity recommended is associated with continued participation in physical activity during adulthood.

2. Guidelines for participation in physical activity should be sound from a behavioural perspective. That is, the type and amount of physical activity recommended should be conducive to enhancing factors known to be associated with physical activity behaviour in youth, such as perceived competence and enjoyment.

3. Physical activity guidelines should be consistent with the patterns of physical activity typically exhibited by children and adolescents. Objective monitoring studies conducted in North American and the United Kingdom indicate that relatively few children engage in sustained bouts (≥ 20 minutes) of physical activity (243,302,341). Conversely, the majority of children and youth exhibit numerous 5- and 10-minute bouts of physical activity. Therefore, physical activity recommendations for children and youth should emphasise the accumulation of intermittently performed physical activity rather than sustained continued bouts.

A number of medical, public health, and professional organisations have issued recommendations and/or guidelines for children's and youths' participation in physical activity. Until recently, most of the recommendations have failed to address the considerations discussed above. Indeed, prior to 1997, most of the physical activity recommendations were similar, if not identical, to those proposed for adults.

The 1994 International Consensus Conference on Physical Activity Guidelines for Adolescents (277) represents one of the most extensive efforts to develop guidelines on the types and amounts of physical activity needed by young people. Based on an extensive review of the pertinent scientific literature, a panel of leading scientists, health care providers, and public health officials issued the following recommendations for physical activity participation during adolescence.

- All adolescents should be physically active daily, or nearly every day, as part of play games, sports, work, transportation, recreation, physical education, or planned exercise, in the context of family, school, and community activities.
- Adolescents should engage in three or more sessions per week of activities that last 20 minutes or more at a time and that require moderate to vigorous levels of exertion.

This guideline was adopted by the National Heart Foundation of Australia in their 2001 publication *Physical Activity and Children: A Statement of Importance and Call to Action from the Heart Foundation* (300). Along with this recommendation, this document outlined the broad health benefits associated with physical activity in young people, the perils of sedentary activities, and the role parents, schools, local governments, planners, transportation officials, sport and recreation departments, and health professionals can take in promoting physical activity in Australian young people.

Healthy People 2010 (352) which describes the health promotion and disease prevention goals for United States of America in the year 2010, includes a number physical activity objectives pertinent to young people. Of the five objectives related to physical activity and young people, objectives 22-6 and 22-7 serve as "guidelines" as to the amount and type of physical activity in which young people should participate. Notably, they differ little from adult physical activity guidelines.

22-6   Increase to at least 30% the proportion of adolescents who engage in moderate physical activity for at least 30 minutes on 5 or more of the previous 7 days.

22-7   Increase to at least 85% the proportion of adolescents who engage in vigorous physical activity that promotes cardiorespiratory fitness 3 or more days per week for 20 or more minutes per occasion.

Another approach to forming quantitative physical activity guidelines for youth has been to examine the type and amount of physical activity recommended for the adult population and extrapolate this amount back to children and adolescents, taking into consideration the decline in physical activity that occurs from childhood to adulthood. Blair and co-workers (46), working from the epidemiological literature linking physical activity to health benefits in adults, estimated that a daily energy expenditure in physical activity of 12.6 kilojoules per kilogram of body weight (3 kcals/kg/day) was an appropriate target. This level of activity, when extrapolated to children, corresponds to 20-30 minutes of moderate to vigorous physical activity per day. To account for the hypothesised decline in physical activity between childhood and adulthood, the authors suggested applying a 33% adjustment, yielding an activity recommendation of 16.8 kilojoules per kilogram of body weight (4 kcals/kg/day) (approximately 30 – 40 minutes of moderate-to-vigorous physical activity per day).

In similar fashion, Corbin, Pangrazi, and Welk (78), proposed a "lifetime physical activity" guideline based on daily energy expenditure. It recommended that, at a minimum, children and adolescents accumulate 30 minutes of moderate physical activity daily (3-4 kcal/kg/day). For optimal benefit, however, the authors recommended an accumulation of 60 minutes of moderate to vigorous physical activity daily (6-8 kcal/kg/day). The

emphasis on the accumulation of moderate to vigorous physical activity throughout the day differed from traditional prescription-based activity guidelines which stressed the importance of sustained bouts of physical activity.

In 1997, the Health Education Authority (HEA) in England initiated a process of expert consultation and review of evidence surrounding the promotion of health-enhancing physical activity for young people (40,73). A primary objective of the project was to establish expert consensus on the recommended level and type of physical activity for young people. After taking into consideration the current physical activity patterns of young people and the scientific evidence linking physical activity to health outcomes in young people, the following recommendations were made:

- all young people should participate in physical activity of at least moderate intensity *for one hour per day;*
- young people who currently do little activity should participate in physical activity of at least moderate intensity for *at least half an hour a day;* and
- *at least twice a week,* some of these activities should help enhance and maintain muscular strength and flexibility, and bone health.

The National Association for Sport and Physical Education (NASPE) in the United States has issued two sets of physical activity guidelines for young people: one for children birth to 5-years-of age and another for elementary school children aged 5 to 12 years (219,200).

In 1998 NASPE issued the following recommendations for elementary school aged children (5-2 years) (219).

- Elementary school aged children should be active at least 30 to 60 minutes on all, or most days of the week.
- An accumulation of more than 60 minutes, and up to several hours per day is encouraged.
- Some of the child's activity each day should be in periods lasting 10 to 15 minutes or more and include moderate to vigorous physical activity.
- Extended periods of inactivity are inappropriate for children.
- A variety of physical activities selected from the Physical Activity Pyramid is recommended for elementary school children.

In 2002 NASPE released *Active Start: A Statement of Physical Activity Guidelines for Children Birth to Five Years* (220) recommends that all children birth to age five should engage in daily physical activity that promotes health-related fitness and movement skills. Guidelines are issue for infants, toddlers, and preschoolers, respectively. For infants NASPE recommends the following:

1. Infants should interact with parents and/or caregivers in daily physical activities that are dedicated to promoting the exploration of their environment.
2. Infants should be placed in safe settings that facilitate physical activity and do not restrict movement for prolonged periods of time.
3. Infants' physical activity should promote the development of movement skills.

4. Infants should have an environment that meets or exceeds recommended safety standards for performing large muscle activities.

5. Individuals responsible for the well-being of infants should be aware of the importance of physical activity and facilitate the child's movement skills.

For toddlers, NASPE recommends the following:

1. Toddlers should accumulate at least 30 minutes daily of structured physical activity.

2. Toddlers should engage in at least 60 minutes and up to several hours of daily, unstructured physical activity and should not be sedentary for more than 60 minutes at a time except when sleeping.

3. Toddlers should develop movement skills that are building blocks for more complex movement tasks.

4. Toddlers should have indoor and outdoor areas that meet or exceed recommended safety standards for performing large muscle activities.

5. Individuals responsible for the well-being of toddlers should be aware of the importance of physical activity and facilitate the child's movement skills.

For preschoolers, NASPE recommends the following:

1. Preschoolers should accumulate at least 60 minutes daily of structured physical activity.

2. Preschoolers should engage in at least 60 minutes and up to several hours of daily, unstructured physical activity and should not be sedentary for more than 60 minutes at a time except when sleeping.

3. Preschoolers should develop competence in movement skills that are building blocks for more complex movement tasks.

4. Preschoolers should have indoor and outdoor areas that meet or exceed recommended safety standards for performing large muscle activities.

5. Individuals responsible for the well-being of preschoolers should be aware of the importance of physical activity and facilitate the child's movement skills.

Canada's Physical Activity Guidelines for Children, released in 2002 (71) represents the most recent, and perhaps the most innovative approach to providing guidelines for children's participation in physical activity. Accompanied by a state-of-the-art social marketing campaign, the guidelines take an "individualised" approach to recommending a dose of physical activity for children and youth. It states that children should *increase* time currently spent on physical activity, starting with 30 minutes *more* per day (20 minutes of moderate activity and 10 minutes of vigorous activity). Consistent with the behavioural attributes of children's physical activity, the guide recommends building up physical activity throughout the day in periods of at least 5 to 10 minutes. In addition, the guide calls for children to reduce "non-active" time spent on TV, video, computer games, and surfing the internet, starting with 30 minutes less per day. Importantly, the guide provides a progressive stepwise 5 month program to increase daily physical activity and decrease "non-active" pursuits. At the end of the 5-months, it is recommended that children accumulate at least 60 minutes of moderate physical activity daily (e.g., brisk walking,

skating, bike riding, swimming, playing outdoors), 30 minutes of vigorous activity (e.g., running, soccer), and reduce "non-active" time by 90 minutes.

In lieu of stating a minimum amount of physical activity required for health benefit, other health organisations have focused on "policy oriented" guidelines or recommendations to promote physical activity in children and adolescents. The U.S. Centers for Disease Control and Prevention has provided 10 recommendations for school and community programs to promote lifelong physical activity among young people (75). These are displayed in Table 15.

Table 15:   CDC Guidelines for School and Community Programs to Promote Lifelong Physical Activity Among Young People

RECOMMENDATION 1

Policy: Establish policies that promote enjoyable, lifelong physical activity among young people.

- Require comprehensive, daily physical education for students in kindergarten through grade 12.
- Require comprehensive health education for students in kindergarten through grade 12.
- Require that adequate resources, including budget and facilities, be committed for physical activity instruction and programs.
- Require the hiring of physical education specialists to teach physical education in kindergarten through grade 12, elementary school teachers trained to teach health education, health education specialists to teach health education in middle and senior high schools, and qualified people to direct school and community physical activity programs and to coach young people in sports and recreation programs.
- Require that physical activity instruction and programs meet the needs and interests of all students.

RECOMMENDATION 2

Environment: Provide physical and social environments that encourage and enable safe and enjoyable physical activity.

- Provide access to safe spaces and facilities for physical activity in the school and community.
- Establish and enforce measures to prevent physical activity-related injuries.
- Provide time within the school day for unstructured physical activity.
- Discourage the use or withholding of physical activity as punishment.
- Provide health promotion programs for school faculty and staff.

RECOMMENDATION 3

Physical Education: Implement physical education curricula and instruction that emphasize enjoyable participation in physical activity and that help students develop the knowledge, attitudes, motor skills, behavioural skills, and confidence needed to adopt and maintain physically activity lifestyles.

- Provide planned and sequential physical education curricula from kindergarten through grade 12 that promote enjoyable, lifelong physical activity.
- Use physical education curricula consistent with the national standards for physical education.
- Use active learning strategies and emphasize enjoyable participation in physical education class.
- Develop students' mastery of and confidence in motor and behavioural skills for participating in physical activity.
- Provide a substantial percentage of each student's recommended weekly amount of physical activity in physical education classes.
- Promote participation in enjoyable physical activity in the school, community, and home.

RECOMMENDATION 4

Health Education: Implement health education curricula and instruction that help students develop the knowledge, attitudes, behavioural skills, and confidence needed to adopt and maintain physically active lifestyles.

- Provide planned and sequential health education curricula from kindergarten through grade 12 that promote lifelong participation in physical activity.
- Use health education curricula consistent with the national standards for health education.
- Promote collaboration among physical education, health education, and classroom teachers as well as teachers in related disciplines who plan and implement physical activity instruction.
- Use active learning strategies to emphasize enjoyable participation in physical activity in the school, community and home.
- Develop students' knowledge of and positive attitudes towards healthy behaviours, particularly physical activity.
- Develop students' mastery of and confidence in the behavioural skills needed to adopt and maintain a healthy lifestyle that includes regular physical activity.

RECOMMENDATION 5

Extracurricular Activities: Provide extracurricular physical activity programs that meet the needs and interests of all students.

- Provide a diversity of developmentally appropriate competitive and noncompetitive physical activity programs for all students.
- Link students to community physical activity programs, and use community resources to support extracurricular physical activity programs.

RECOMMENDATION 6

Parental Involvement: Include parents and guardians in physical activity instruction and in extracurricular and community physical activity programs, and encourage them to support their children's participation in enjoyable physical activities.

- Encourage parents to advocate for quality physical activity instruction and programs for their children.
- Encourage parents to support their children's participation in appropriate, enjoyable physical activities.
- Encourage parents to be physically active role models and to plan and participate in family activities that include physical activity.

RECOMMENDATION 7

Personal Training: Provide training for education, coaching, recreation, health care and other school and community personnel that imparts knowledge and skills needed to effectively promote enjoyable, lifelong physical activity among young people.

- Train teachers to deliver physical education that provides a substantial percentage of each student's recommended weekly amount of physical activity.
- Train school and community personnel how to create psychosocial environments that enable young people to enjoy physical activity instruction and programs.
- Train school and community personnel how to involve parents and the community in physical activity instruction and programs.
- Train volunteers who coach sports and recreation programs for young people.

RECOMMENDATION 8

Health Services: Assess physical activity patterns among young people, reinforce physical activity among young people, counsel inactive young people about physical activity, and refer young people to appropriate physical activity programs.

- Regularly assess the physical activity patterns of young people, reinforce physical activity among active young people, counsel inactive young people about physical activity, and refer young people to appropriate physical activity programs.
- Advocate for school and community physical activity instruction and programs that meet the needs of young people.

RECOMMENDATION 9

Community Programs: Provide a range of developmentally appropriate community sports and recreation programs that are attractive to all young people.

- Provide a diversity of developmentally appropriate community sports and recreation programs for all young people.
- Provide access to community sports and recreation programs for young people.

RECOMMENDATION 10

Evaluation: Regularly evaluate school and community physical activity instruction, programs and facilities.

- Evaluate the implementation and quality of physical activity policies curricula, instruction, programs, and personnel training.
- Measure students' attainment of physical activity knowledge, achievement of motor skills and behavioural skills, and adoption of healthy behaviours.

The *U.S. Surgeon General's Call To Action To Prevent and Decrease Overweight and Obesity* released in 2001 (351) contains the following "policy-oriented" recommendations for school-aged children and youth:

- Provide age-appropriate and culturally sensitive instruction in health education that helps students develop the knowledge, attitudes, skills, behaviours to adopt, maintain, and enjoy healthy eating habits and a physically active lifestyle;

- Provide all children, from pre-kindergarten through grade 12, with quality daily physical education that helps develop the knowledge, attitudes, skills, and behaviours needed to be physically active for life;

- Provide daily recess periods for elementary school students, featuring time for unstructured but supervised play;

- Provide extracurricular physical activity programs, especially inclusive intramural programs and physical activity clubs; and

- Encourage the use of school facilities for physical activity programs offered by school and/or community-based organisations outside of school hours.

While "policy-oriented" guidelines or recommendations provide the health sector with a extremely useful "blueprint" or "action plan" for promoting physical activity in young people, they tend to resonate rather poorly with the general public and health practitioners. In simple terms, the general public and the health professionals that serve them want guidance as to how much activity is needed for health. Moreover, in the absence of a

recommended dose of physical activity for children, it is extremely difficult to implement and sustain a youth physical activity monitoring and surveillance system. One can see the impact of having national childhood overweight and obesity data on health policy. Thus, from the perspective of putting youth physical activity firmly on the national health agenda, a quantitative physical activity guideline may be preferable.

Consideration of potential age categories and special population groups

In conceptualising their lifespan approach to human motor development, Payne and Isaacs (253) list several "developmental stages" that have potential relevance to formulating developmentally-appropriate physical activity guidelines and recommendations. The first developmental period of interest is infancy which spans birth to the onset of independent walking. On average, onset of independent walking occurs at around the age of one. Once children have begun to walk independently, they are considered toddlers. Children are considered toddlers up to the age of four. From age four to age seven, children are considered to be in the early childhood stage. From the age of seven to nine, children are considered to be in middle childhood. Late childhood begins at age nine and terminates at the onset of puberty which commonly occurs in girls at approximately age 11 and boys at age 13. Adolescence is proposed to last until the end of the "teen years" or cessation of growth which occurs at approximately age 19 and 21 for girls and boys, respectively. It should be noted that "developmental stages" based on chronological age are somewhat arbitrary and one would expect to encounter considerable inter-individual variability in growth and maturation within each stage.

The existence of developmental stages or age groupings with different interests, behavioural patterns, and contrasting movement capabilities would suggest that "age-group" specific guidelines are warranted. As discussed in Chapter 9, NASPE has produced separate but related guidelines for infants, toddlers, preschoolers, and elementary school children. Notably, however, these age-group specific guidelines differ more on the type of activities performed rather than the amount or dose of physical activity required. Thus, it could be argued that all children could meet a unified dose of physical activity by engaging in activities that are appropriate for their age and level of development.

It is also important to consider the notion of providing specific guidelines for children who currently do very little physical activity. The HEA and Canadian guidelines propose that currently inactive children start with an accumulation of 30 minutes per day rather than 60 minutes per day.

At this point in time, there appears to be no practical or scientific justification for the formulation of separate physical activity guidelines for population groups defined by gender, ethnicity, or cultural background.

Proposed recommendations

As stated previously, this discussion paper is intended to represent the first step toward the development of consensus on Australian recommendations of children's and youths' physical activity. Consequently, the recommendations listed below are not an agreed set of recommendations, but rather a preliminary set proposed by the authors to be considered at a consensus conference, for adoption in Australia.

Based on the review of the existing physical activity guidelines and relationship between physical activity participation and health outcomes in children and youth, the authors endorse the adoption of guidelines proposed at the 1994 International Consensus Conference (277) and the 1997 Health Education Authority Consensus Conference (40,73). For Australian children and youth we recommend that:

- **All children and youth should be physically active daily, or nearly every day, as part of play, games, sports, work, transportation, recreation, physical education, or planned exercise, in the context of family, school, and community activities.**
- **All children and youth should engage in physical activity of at least moderate intensity for 60 minutes or more on a daily basis.**
- **Children and youth should avoid extended periods of inactivity through participation in sedentary activities such television watching, video, computer games and surfing the internet.**
- **Children and youth who currently do little activity should participate in physical activity of at least moderate intensity for at least 30 minutes daily, building up to undertaking 60 minutes daily.**

While there is very limited evidence linking physical activity to health benefits during early childhood, we acknowledge the utility of the NASPE guidelines for infants, toddlers, and preschoolers. We note that the dose of activity nominated in the NASPE guidelines are consistent with our suggested guidelines.

- Infants should interact with parents and/or caregivers in daily physical activities that are dedicated to promoting the exploration of their environment.
- Infants should be placed in safe settings that facilitate physical activity and do not restrict movement for prolonged periods of time.
- Infants' physical activity should promote the development of movement skills.
- Infants should have an environment that meets or exceeds recommended safety standards for performing large muscle activities.
- Individuals responsible for the well-being of infants should be aware of the importance of physical activity and facilitate the child's movement skills.

- Toddlers should accumulate at least 30 minutes daily of structured physical activity.

- Toddlers should engage in at least 60 minutes and up to several hours of daily, unstructured physical activity and should not be sedentary for more than 60 minutes at a time except when sleeping.

- Toddlers should develop movement skills that are building blocks for more complex movement tasks.

- Toddlers should have indoor and outdoor areas that meet or exceed recommended safety standards for performing large muscle activities.

- Individuals responsible for the well-being of toddlers should be aware of the importance of physical activity and facilitate the child's movement skills.

- Preschoolers should accumulate at least 60 minutes daily of structured physical activity.

- Preschoolers should engage in at least 60 minutes and up to several hours of daily, unstructured physical activity and should not be sedentary for more than 60 minutes at a time except when sleeping.

- Preschoolers should develop competence in movement skills that are building blocks for more complex movement tasks.

- Preschoolers should have indoor and outdoor areas that meet or exceed recommended safety standards for performing large muscle activities.

- Individuals responsible for the well-being of preschoolers should be aware of the importance of physical activity and facilitate the child's movement skills.

The term "moderate-intensity physical activity" refers to activity requiring an energy expenditure three to six times greater than resting metabolic rate. Examples of activity of this level include brisk walking, cycling, swimming, most sports, or dance. The guideline may be met through participation in structured physical activities such as organised sports or physical education or unstructured physical activities such as free play in the backyard/ playground and cycling or walking to and from places for fun and transportation. Young children would be expected to meet the guideline mostly through free play and other forms of unstructured physical activity, while adolescents would be expected to meet the guideline through participation in more structured form of physical activity such as school or club sports. Consistent with the current physical activity guidelines for adult Australians, physical activity may be performed in a continuous fashion or intermittently accumulated throughout the day. At this point in time, there appears to be no practical or scientific justification for the formulation of physical activity guidelines for special population groups.

Ideally, this recommendation would be supported by compelling epidemiological and experimental evidence demonstrating that 60 minutes of physical activity performed on a daily basis provides important physical and social health benefits during childhood and adolescence and is associated with maintenance of a physically active lifestyle into adulthood. However, there is only marginal evidence that physical activity is beneficial for health during childhood and adolescence, and there is little evidence that physical activity behaviour tracks from childhood to adulthood. Moreover, for health outcomes that

demonstrate a favorable association with physical activity, the level of evidence is modest and there is little indication of a minimum dose required to derive benefit. Nevertheless, we endorse the recommendation of at least 60 minutes of physical activity per day, twice the amount recommended in guidelines for adults.

Our reasons for doing so are five-fold.

1. Available evidence indicates that vast majority of children and adolescents would meet a recommendation of at least 30 minutes of at least moderate intensity per day and that very few would meet recommendations calling for continuous, sustained bouts of physical activity ($\geq$ 20 minutes) (15,243,302,341).

2. There is evidence that sedentary activities such as television watching are strongly associated with excessive adiposity and displaces time for physically active pursuits (122,267,268).

3. Children and adolescents probably require more than 30 minutes of physical activity daily in order to learn and master the movement skills required for a physically active lifestyle later in life.

4. Ongoing surveillance of an important health indicator such as physical activity in children and youth requires that a reasonable and logically derived threshold be applied so that individuals and population groups can be classified as sufficiently or insufficiently active. Adoption of existing international guidelines facilitates useful comparisons with other countries.

5. A guideline communicating a minimum dose of physical activity will encourage health care professionals to promote physical activity participation in young people and encourage the planning and implementation of school and community-based programs to enhance young people's participation in health-promoting physical activity.

Next steps

This discussion paper represents the first step towards what we hope will be the creation of practical and widely endorsed set of Australian guidelines for children's and youths' participation in physical activity. While we have gone to some lengths to propose suggested guidelines, we view them as preliminary in nature. Ideally this discussion paper will serve as a "background document" for a consensus conference in which physical activity experts and stakeholders from within Australia are invited to draft a formal set of guidelines or recommendations for children and youths participation in physical activity.

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Cardiovascular risk factors

Table 1:   **Evidence related to physical activity and blood pressure in children and adolescents**

Study	Study Design	Sample	Physical Activity Dose/Measure	Dependant Variable	Effects
Dwyer et al (106)	1A	Participants in the South Australian Daily PE Trial. > 500 grade 5 students.	14 weeks of fitness training or skills training 75 mins/d 5 d/wk. Controls: skills training 30 min/day 3 d/wk.	SDP/DBP	Fitness group SBP ↓ 1 mmHg DBP ↓ 4 mmHg Skill group SBP ↓ 1 mmHg DBP ↓ 5 mmHg Control group SBP ↓ 1 mmHg DBP ↓ 2 mmHg
Hanson et al (141)	1A	68 normotensive and 69 hypertensive children aged 9 – 11 yrs.	150 mins/wk of moderate to vigorous activity over an 8 month period.	SBP/DBP	Normotensive boys SBP ↓ 4 mmHg * DBP no change Normotensive girls SBP ↓ 3 mmHg DBP ↑ 4 mmHg * Controls SBP no change DBP no change Hypertensive boys SBP ↓ 6 mmHg * DBP ↓ 4 mmHg Hypertensive girls SBP ↓ 1 mmHg DBP ↑ no change Controls SBP no change DBP no change

Study	Study Design	Sample	Physical Activity Dose / Measure	Dependant Variable	Effects
Eriksson et al. (108)	IA	Boys 11-13 yrs - 9 in the exercise group and 16 controls.	F=3 d/wk D=1 hr/d I="hard running" 4 month training period	SBP/DBP	SBP ↑ 4 mm Hg DBP no change
Ewart et al. (111)	IA	99 Grade 9 girls with BP above 67th %ile.	Aerobic exercise classes – controls did normal PE.	SBP/DBP	Aerobic exercise group SBP ↓ 6.0 mmHg * DBP ↓1.3 mmHg Normal PE controls SBP ↓ 3.7 mmHg DBP ↓ 1.4 mmHg
Hofman et al. (148)	IA	309 boys (M age=9.1 y) 324 girls (M age=9.0 y	Participants randomly assigned to CHD risk reduction program or control. Emphasis on endurance training – not quantified.	SBP/DBP	5-yr change in SBP and DBP was greatest in those with the greatest change in aerobic fitness. Change was less than 1.5 mmHg for SBP and DBP, respectively.
Linder et al. (186)	IA	50 males aged 11 – 17 yrs.	8 weeks progressive exercise program. F=4 d/wk D=30 min/d	SBP/DBP	Training group SBP ↓ 1.3 mmHg DBP ↑ 0.5 mmHg Control group SBP ↑ 1.8 mmHg DBP ↑ 0.5 mmHg

(Table 1 continued overleaf)

105

Table 1: Evidence related to physical activity and blood pressure in children and adolescents (continued)

Study	Study Design	Sample	Physical Activity Dose / Measure	Dependant Variable	Effects
Vandongen et al. (356)	IA	1,147 children from Western Australia aged 10-12 yrs.	RCT testing effects of nine month nutrition and fitness intervention. Classroom instruction and daily 15 minutes fitness programs. Target intensity 150-170 bpm.	SBP/DBP	Intervention arms that included fitness training had significantly reduced DBP (~ ↓ 5mmHg) relative to controls. NS effect on SDP.
Bryant et al. (66)	IB	9 girls, 7 boys aged 6-16 yrs.	12 weeks aerobic exercise training. F=3 d/wk D=60 min	SDP/DBP	SBP ↓ 4 mmHg DBP ↓ 4 mmHg
Danforth (82)	IB	12 hypertensive children. M age = 11.5 yrs	Endurance training F=3 d/wk D= 30 min/d I=60 to 80 HR max	SBP/DBP	SBP ↓ 9 mmHg * DBP ↓ 9 mmHg *
Hagberg et al. (139)	IB	25 hypertensive children 19 boys and 6 girls. M age = 15.6 yrs	6 months of aerobic exercise followed by 9 months of detraining. F= 3d/wk I=60-65% VO2 max D=30-40 min/day	SBP/DBP	Training SBP ↓ 8.0 mmHg * DBP ↓5.0 mmHg 9-month detraining SBP ↑ 10.0 mmHg * DBP ↑ 5.0 mmHg

106

Study	Study Design	Sample	Physical Activity Dose / Measure	Dependant Variable	Effects
Hagberg et al. (140)	IB	6 children (M age = 15)	5 months of endurance training. F= 3d/wk I=60-75% VO2 max D=30-50 min/day Followed by ~ 5 months of resistance training consisting of 14 exercises 12-15 reps. Followed by 12-month detraining.	SBP/DBP	Endurance Training SBP ↓ 13.0 mmHg * DBP ↓3.0 mmHg Weight Training SBP ↓ 4.0 mmHg * DBP ↓ 4.0 mmHg Detraining SBP ↑ 16.0 mmHg * DBP ↓ 1.0 mmHg
Harrell et al. (142)	IB	1274 children in grades 3 and 4. Intervention study to reduce CVD risk factors.	8-week aerobic exercise training program. At least 3 sessions per week of 20-mins of endurance training.	SBP/DBP	Program increased self-reported PA. Children in the intervention group reported smaller rise in DBP over the study period.
McKenzie et al. (205)	IB	35 obese boys (M age = 13.2 yr)	Summer camp Exercise 5-6 hrs/d combined with low calorie diet.	SDP/DBP	SBP ↓ 6 mmHg * DBP ↓ 11 mmHg *

Table 1: Evidence related to physical activity and blood pressure in children and adolescents (continued)

Study	Study Design	Sample	Physical Activity Dose / Measure	Dependant Variable	Effects
Rocchini et al. (270) treatment	IB	72 obese children aged 10 –17 yrs. 10 non-obese controls aged 10-14 y.	Aerobic exercise F= 3 d/wk D=60 min Combined with dietary and behaviour change program.	SDP/DBP	non-obese, no SBP ↑ 4 mmHg DBP ↓ 1 mmHg Obese, treatment SBP ↓ 16 mmHg * DBP ↓ 13 mmHg * Reduction significantly greater than diet and behavioural therapy
alone					and control.
Webber et al. (366)	IB	4019 children participating in the CATCH intervention. 2.5 year follow-up. M age at baseline was 8.8 yrs	Multicomponent school based intervention which included strategies to increase physical activity in PE and outside of school.	SBP/DBP	NS difference between experimental group and controls with respect to SBP and DBP.
Al-Hazzaa et al. (8)	IIB	91 preadolescent boys aged 7 to 12 yrs.	HR monitoring. Time with HR > 159 bpm.	SBP/DBP	Significant inverse association between PA and BP. SBP r=-0.27 * DBP r=-0.30 *
Andersen (13) between BP.	IIB	2474 boys, 3535 girls M age = 17.1 yrs	Self report of weekly participation in sport and other activities.	SDP/DBP	No association physical activity and
Armstrong et al. (16) between BP.	IIB	199 boys and 164 girls aged 11 – 16 yrs.	HR monitoring	SDP/DBP	No association physical activity and
Boreham et al. (53)	IIB	Random sample of 1015 schoolchildren aged 12 – 15 yrs.	Cardiorespiratory fitness determined by 20-m shuttle run.	SBP/DBP	After controlling for fatness, NS relationship between fitness and SBP/DBP.

Study	Study Design	Sample	Physical Activity Dose / Measure	Dependant Variable	Effects
Craig et al. (80)	IIB	49 prepubertal girls aged 8 to 11 yrs.	PAEE using the DLW technique and self-report questionnaire.	SBP/DBP	Self-reported PA positively associated with DBP (r=0.32). NS associated with SBP
deMan et al. (88)	IIB	183 boys and 216 girls aged 7 – 11 yrs.	Assessed VO2 max as proxy for PA.	SBP/DBP	Boys SBP r = -0.10 DBP r = -0.13 Girls SBP r = -0.10 DBP r = -0.29 *
Dwyer et al. (103)	IIB	2400 participants from the Australian Health and Fitness Survey: 400 boys and 400 girls from the 9, 12, and 15 y age group.	Cardiorespiratory fitness as measured by the PWC 170 cycle ergometer protocol.	SBP/DBP	SBP inversely associated with fitness (r=-0.12). NS association with DBP.
Jenner et al. (158)	IIB	681 boys and 630 girls in grade 7 from Perth WA.	Self-reported PA via questionnaire.	SBP/DBP	BP inversely associated with PA in girls but not boys.
Katzmarzyk et al. (161)	IIB	324 males and 268 females aged 9 –18 yrs.	Self-report using Bouchard PA recall.	Mean Arterial Pressure (MAP)	EE and MVPA and low TV time was inversely associated with MAP.
Klesges et al. (170)	IIB	222 preschool children between the ages of 3 to 6 years (M age = 4.4 yrs).	Multimethod approach – latent physical activity variable derived from a combination of direct observation, motion sensor, and various parent reports.	SDB/DBP MAP	NS association between physical activity and measures of blood pressure.

(Table 1 continued overleaf)

109

Table 1: Evidence related to physical activity and blood pressure in children and adolescents (continued)

Study	Study Design	Sample	Physical Activity Dose / Measure	Dependant Variable	Effects
Macek et al. (191)	IIB	54 trained (swimmers and track and field athletes) and 38 untrained children aged 16 – 18 yrs.	Training status as a marker of different levels of physical activity.	SBP/DBP	Trained children had significantly lower SBP (11 mmHg) and DBP (10 mmHg) than untrained children.
Marti et al. (200)	IIB	565 boys and 577 girls aged 15 yrs.	Self report PA based on a scale of 1 to 5.	SDP/DBP	No association between physical activity and BP.
Panico et al. (237)	IIB	743 boys and 598 girls aged 7 to 14 yrs.	Cardiorespiratory fitness as measured by Harvard Step Test.	SBP/DBP	SBP inversely related to fitness quartile. NS association with DBP.
Raitakari et al. (260)	IIB	2358 children and young adults aged 9 to 24. Participants in the Young Finns Study.	Self reported PA via questionnaire.	SBP/DBP	No association between PA and SBP and DBP.
Sallis et al. (278)	IIB	148 boys (M age = 11.9 y) 142 girls (M age = 11.8 y)	Self-report PA measured by 7-day recall and global activity rating.	SDP/DBP	No association between physical activity and BP.
Strazzullo et al. (310)	IIB	153 boys and 119 girls (M age 11 yrs).	Leisure time PA measured via self-report questionnaire.	SDP/DBP	Active children had significantly lower SBP and DBP than low active children. SBP ↓ 6- 8 mmHg DBP ↓ 2-5 mmHg
Tell et al. (327)	IIB	413 boys 372 girls aged 10 to 14 yrs.	Self report PA from questionnaire.	SDP/DBP	No association between physical activity and BP.

Table Abbreviations

BP	Blood Pressure
SBP	Systolic Blood Pressure
DBP	Diastolic Blood Pressure
MAP	Mean Arterial Pressure
MmHg	millimeters of mercury
PA	Physical Activity
EE	Energy Expenditure
PAEE	Physical Activity Energy Expenditure
F	Frequency of exercise or physical activity
I	Intensity of exercise or physical activity
D	Duration of exercise or physical activity
HR	Heart Rate
VO_2 max	Maximal Oxygen Consumption
RCT	Randomised Controlled Trial
M	Mean or Average
NS	Non-significant
*	Indicates significant difference

Table 2: Evidence related to physical activity and blood lipids and lipoproteins in children and adolescents

Study	Study Design	Sample	Physical Activity Dose/Measure	Dependent Variable / Effect
Champaigne et al. (76)	IA	9 children aged 12-19 yr in exercise training group. 5 children aged 14-16 yrs served as controls.	12 week training program F = 3 days/wk I = 80% of Hrmax D = 45 min/d	NS between-group differences for TC, TG, and HDL-C. Significant ↓ in LDL-C by training.
Dwyer et al (106)	IA	Participants in the South Australian Daily PE Trial. > 500 grade 5 student.s.	14 weeks of fitness training or skills training 75 mins/d 5 d/wk. Controls: skills training 30 min/day 3 d/wk	NS difference in TC, TG, or HDL-C.
Fisher et al. (120)	IA	38 children in grade 7.	12 week aerobic training program. F = 5 d/wk I = "vigorous" D = 30 mins/session	Significant ↑ in HDL.-C. Significant ↓ in TC and TC:HDL.
Gutin et al. (138)	IA	21 obese girls aged 7-11 yrs (M age=9.2 yrs). 11 exercise, 10 controls.	10-wk aerobic training F= 5days/wk I = > 70% HR max D = 30 mins/session	NS group difference for TC, HDL-C TC:HDL-C, TG, LDLC, Lp(a).
Linder et al. (186) C,	IA	50 boys aged 11 – 17 yrs. 29 in training and 21 in control.	8 weeks of aerobic training. F = 4 d/wk I = running @ 80% HRmax on 3 days, soccer or rugby game on 1 day. D = 25 –30 min/d	NS between-group differences for TC, TG, HDL-C, VLDL-C, LDL:HDL, TC:HDL.

Study	Study Design	Sample	Physical Activity Dose/Measure	Dependent Variable / Effect
Linder et al. (185)	IA	103 male and female African American children aged 7 – 15 yrs.	4 week aerobic training program.	NS between-group differences for TC, TG, HDL-C, LDL-C, VLDL-C, LDL:HDL.
Vandongen et al. (356)	IA	1,147 children from Western Australia aged 10-12 yrs.	RCT testing effects of nine month nutrition and fitness intervention. Classroom instruction and daily 15 minutes fitness programs. Target intensity 150-170 bpm.	Significant ↑ in TC in groups. ↑ was greater in the controls relative to the intervention groups.
Webber et al. (366)	IA	4018 children participating in the CATCH intervention study.	2.5 year intervention aimed at increasing PA in physical education and at home. Dietary component included.	NS change in TC HDL-C, and apo-B.
Bryant et al. (132)	IB	7 boys M age = 9.4 yr 9 girls M age = 11.8 yr	12 week training program. F = 3 d/wk I = 75% Hrmax D = 1 hr/d – optional 30 mins of swimming	NS difference for TC.
Deveaux et al. (91)	IB	12 boys aged 14 – 17 yrs	8 week training program. F= 4 d/wk I= "moderate" soccer training D= 75 mins/d	NS between-group differences for TC, TG, HDL-C, LDL-C, VLDL-C HDL:TC.

(Table 2 continued overleaf)

113

Table 2: Evidence related to physical activity and blood lipids and lipoproteins in children and adolescents (continued)

Study	Study Design	Sample	Physical Activity Dose/Measure	Dependent Variable/Effect
Gilliam et al. (128)	IB	23 children M age = 8.5 yrs. 11 experimental and 10 controls.	12 week fitness training program. F= 4 days/wk I = "moderately high" D= 25 mins/session	NS group differences for TC and TG.
Harrell et al. (142)	IB	1274 3rd and 4th grade children.	Classroom based intervention to reduce CVD included 8 week PA program. 3 sessions per week of aerobic activity for 20 mins per session.	Significant ↓ in TC relative to controls.
Hunt et al. (150)	IB	40 males M age = 18.1 yrs. 15 subjects heavy exercise, 15 moderate exercise, and 10 controls.	10-week training program. F = 5 d/wk Hard I = 16 METs Mod I = 13 METs D = 50 mins/d (including warm-up and cool down)	NS between group differences for TC, TG, HDL-C and LDL-C.
Nizankowska-Blaz et al. (225)	IB	38 children in training group (M age = 14.5) and 35 controls (M age = 14.5).	3 years of school sport. F=10 sessions/wk I = not reported D = 45 mins/session	NS between-group differences for TC and LDL-C. Significant difference for HDL-C and TG.
Rowland et al. (273)	IB	20 girls, 11 boys aged 10-12 yrs.	13 weeks of aerobic training. F=3 days/wk I=170-180 bpm 85% HR Max D=25 mins/session	NS differences in TC, HDL-C, LDL-C, and TG.

114

Study	Study Design	Sample	Physical Activity Dose/Measure	Dependent Variable / Effect
Sasaki et al. (292)	IB	20 girls and 21 boys aged 11-13 yrs.	Training program 2 yrs. F = 7 d/wk I= running at lactate threshold D=20 minutes	NS change in TC. Significant ↑ HDL-C. Significant ↓ TG.
Smith et al. (305)	IB	Training group: 15 boys aged 9.5 – 15 yrs 13 girls aged 9.5 – 15 yrs Controls: 13 males and 11 girls	Running training 7 – 49 miles/wk, M=27 miles. "Control" 75 mins/day, 3 days/wk	Significant 32% increase in HDL-C, 13% decrease in LDL-C, and 38% decrease in TG. NS for TC.
Hofman et al. (148)	IB	3388 children from 37 schools from New York City.	1590 students received CVD risk reduction intervention and 693 students as controls. Intervention promoted increased physical activity.	Intervention did not change physical activity as estimated by change in aerobic fitness. Significant ↓ in TC in schools from 1 geographic area. NS changes for HDL-C and TC:HDL-C.
Raitakari et al. (260) association between PA and TG only.	IIA	Cohort of 2,358 Finnish children followed from 1980 to 1986.	Physical activity measured by self-report questionnaire.	Males exhibited significant associations between PA and HDL-C, TG. Girls exhibited significant
Al-Hazzaa et al. (8)	IIB	91 preadolescent boys aged 7 to 12 yrs.	HR monitoring. Time with HR > 159 bpm	Sig association reported between PA and TG, and HDL-C.
Armstrong et al. (16)	IIB	199 boys age 11-16 yrs 164 girls and 11-16 yrs	3 days of 12-h HR monitoring. VO_2 at 2.5 mmol lactate	Significant inverse association with TC and TC:HDL (r=-.24 - -.28). NS association between PA/fitness and HDL-C.

(Table 2 continued overleaf)

115

Table 2: Evidence related to physical activity and blood lipids and lipoproteins in children and adolescents (continued)

Study	Study Design	Sample	Physical Activity Dose/Measure	Dependent Variable / Effect
Armstrong et al. (18)	IIB	23 girls and 25 boys M age = 12.8 yrs.	12 hr HR monitoring Peak VO2	NS association with TC and HDL-C.
Atomi et al. (20)	IIB	21 trained boys and 31 untrained boys (n=21) and girls (n=10).	Soccer training 3 yrs or more. F=6 d/wk I= HR >160 D= 3 hr/d	NS TG. TC and HDL significantly higher in trained than untrained.
Boreham et al. (53)	IIB	Random sample of 1015 schoolchildren aged 12 and 15 yrs of age.	Physical activity and sports participation measured via self-report questionnaire.	PA significantly associated with TC:HDL-C in 15 year old boys, but no other group.
Craig et al. (80)	IIB	49 prepubertal girls aged 8 to 11 yrs.	PAEE using the DLW technique and self-report questionnaire.	Significant association between self-reported PA and LDL-C and apo B concentrations.
DuRant et al. (100)	IIB	50 boys aged 11 – 17 yrs.	Self-reported PA via questionnaire and VO2 max from cycle ergometry.	Significant inverse association with self-reported PA and measures of sedentary behaviours and HDL-C, TC:HDL, LDL:HDL.
DuRant et al. (101)	IIB	37 African American children aged 11 – 17 yrs.	Self-reported PA via questionnaire and interview.	NS for TC, LDL-C, TG, VLDL-C. Significant inverse association with LDL:HDL-C, TC:HDL-C. Significant positive with HDL-C.
Dwyer et al. (103)	IIB	2400 participants from the Australian Health and Fitness Survey: 400 boys and 400 girls from the 9, 12, and 15 y age group.	Cardiorespiratory fitness as measured by the PWC 170 cycle ergometer protocol.	NS association between fitness and TC, TG, and HDL-C.
Hickie et al. (147)	IIB	613 Australian males aged 11 – 18 yrs.	Cardiorespiratory fitness as a measure of physical activity.	NS association with fitness and TC and TG.

116

Study	Study Design	Sample	Physical Activity Dose/Measure	Dependent Variable / Effect
Ilmarinen et al. (152)	IIB	37 boys M age = 18.5 yr.	HR monitoring and self report PA diary.	NS association between PA and TC.
Katzmarzyk et al. (161)	IIB	324 males and 268 females aged 9 –18 yrs.	Self-report using Bouchard PA recall.	PA significantly associated with TG, LDL-C and HDL-C.
Lee (179)	IIB	46 boys and 72 girls aged 12 –19 yrs.	Self-reported PA via questionnaire. Ratio of work metabolic rate to basal metabolic rate (WMR/BMR).	NS relationship with TG, VLDL-C. Significant inverse association between TC and LDL-C in boys only.
Macek et al (191)	IIB	29 trained males and 26 trained females (M age=16.3) 20 untrained males and 18 untrained females (M age=18.1).	Trained group had 6 to 8 yrs of training. F=5 d/wk I=140–200 bpm D=5 hr/d	NS difference for TC. Compared to untrained group trained exhibited significant ↑ HDL-C, ↓ LDL-C, ↑ HDL:TC, ↓ TG.
Macek et al. (192)	IIB	20 girls M age = 11.9 yrs 21 girls M age = 16.1 yrs 22 boys M age = 12.0 yrs 23 boys M age = 16.0 yrs	Self-report questionnaire on sports participation. VO$_2$ from cycle ergometry.	NS association with LDL-C, TG. VO$_2$ inversely associated with TC and HDL-C in boys only. (r = -.30 - .33)
Montoye et al. (212)	IIB	44 girls and 285 boys aged 10 to 19 yrs.	Cardiorespiratory fitness as a measure of physical activity.	NS association with fitness and TC and TG.
Parizkova et al. (240)	IIB	22 boys and girls between the ages of 3.5.	Physical activity measures via direct observation.	HDL-C significant ↑ in active than inactive. NS differences observed for TC and LDL-C.
Schmidt et al. (293)	IIB	784 boys and 897 girls from Singapore.	Self-report physical activity – adaptation of the CDC Youth Risk Behaviour Survey.	Children classified as active had significantly different TC ↓, LDL-C ↓, TG ↓, TC:HDL-C↓. NS for HDL-C.

(Table 2 continued overleaf)

117

Table 2:   Evidence related to physical activity and blood lipids and lipoproteins in children and adolescents (continued)

Study	Study Design	Sample	Physical Activity Dose/Measure	Dependent Variable / Effect
Stewart et al. (309)	IIB	15 boys and 21 girls aged 12 – 19 yrs with parents with CVD. 13 boys and 16 girls aged 12 – 19 yrs controls.	Self-reported PA via questionnaire.	NS association between PA, TC and LDL-C. Significant associations between PA and TG and HDL-C.
Suter et al. (315)	IIB	39 boys and 58 girls aged 10-15 yrs.	Self-reported physical activity measured by 7-day recall.	PA significant predictor of HDL-C, TG, and VLDL-C.
Takada et al. (317)	IIB	457 Japanese 5th grade children aged 10 yrs.	Self-report: rating of involvement in sports score range 1 – 4.	PA inversely associated with HDL-C levels, NS association with TC, TG, and LDL-C.
Tell et al. (327)	IIB	372 females and 413 males age 10 – 14 yrs.	Self-reported PA via questionnaire.	Females in the highest PA tertile had significantly ↓ TG than bottom PA tertiles. No other associations with PA.
Valimaki et al. (353)	IIB	31 trained boys and 7 trained females 11-13 yrs. 11 untrained boys and 4 untrained girls 11-13 yrs.	Trained vs. untrained. Trained – participants in athletics at least 1 yr.	NS between-group differences TC. HDL-C significantly higher in trained than untrained.
Verschurr et al. (357)	IIB	215 girls aged 13-14 yrs. 195 boys aged 13-14 yrs.	Self reported PA via questionnaire. 48 h of HR monitoring and pedometer monitoring. Fitness via VO2max.	NS differences for TC, TC:HDL. High active and high fit females (based on VO$_2$) had significantly higher HDL-C than lower 2 groups.
Wanne et al. (360)	IIB	Trained group 14 boys, 16 girls 14-16 yrs. Untrained group 14 boys, 16 girls 14-16 yrs.	Trained group trained ≥ 8 hr per week for a min of 1 year.	NS difference for TC, VLDL, LDL-C, HDL:TC. Trained males significantly ↑ HDL-C and ↓ TG than untrained.

118

Study	Study Design	Sample	Physical Activity Dose/Measure	Dependent Variable / Effect
Wilmore et al. (375)	IIB	399 boys age 8 – 15 yrs.	Cardiorespiratory fitness as a measure of physical activity.	NS association with fitness and TC, HDL-C, LDL-C, HDL:TC. Significant inverse association between fitness and TG (r = -0.20).

Table Abbreviations

TC	Total Cholesterol
VLDL-C	Very-low density lipoprotein Cholesterol
LDL-C	Low-density lipoprotein Cholesterol
HDL-C	High-density lipoprotein Cholesterol
TG	Triglyceride
PA	Physical Activity
F	Frequency of exercise or physical activity
I	Intensity of exercise or physical activity
D	Duration of exercise or physical activity
HR	Heart Rate
Hrmax	Age predicted maximal heart rate
VO$_2$ max	Maximal Oxygen Consumption
M	Mean or Average
NS	Non-significant

Adiposity, overweight and obesity

Table 3: Evidence related to the association between physical activity and adiposity, overweight, and obesity in youth

Study	Study Design	Sample	Physical Activity Dose / Measure	Dependent Variable	Effects
Berkey et al. (36)	IIA	Cohort of 6149 girls and 4620 boys between the ages of 9 – 14 yrs.	Self-report. Participation in sport and PA over the previous year.	Change in BMI.	PA inversely associated with 1-yr change in BMI.
Berkowitz et al. (37)	IIA	Cohort of 52 children aged 4 – 8 yrs.	Motion sensors.	Triceps skinfolds.	Children's daytime PA significantly associated with childhood adiposity.
Beunen et al. (38)	IIA	64 boys aged 12-19 years from Leuven Growth Study.	Self-report of participation in sports over a 3-yr period.	Skinfolds (Subscapula, suprailiac,triceps, calf)calf circumference	NS body composition differences between active (> 5 hrs/wk) and inactive (£ 1.5 hrs/wk).
Goran et al. (132)	IIA	75 children (35 girls and 40 boys) aged 5.2 years at baseline.	TEE and AEE derived from DLW.	Fat mass, fat free mass and % body fat using DXA.	None of the components of daily EE were associated with change in fat mass relative to fat free mass.
Klesges et al. (171)	IIA	Cohort of 146 preschool children (age 3-5 yrs) followed over a 3-yr period.	Self-report: Parent's rating of child's level of PA.	Change in BMI.	Baseline level of PA was significantly inversely associated with change in BMI.
Ku et al. (177)	IIA	Cohort of 43 boys and 47 girls followed from 6 months to 8 years of age.	1-day activity records completed by parents.	% body fat from underwater weighing, skinfolds and circumerences.	In boys, activity level at age 3 and 4 were inversely associated with adiposity at age 8. NS association was found in girls.
Li et al. (184)	IIA	31 infants aged 6 – 12 months.	Direct Observation.	% Body fat from DXA.	% body fat significantly inversely associated with PA.

Study	Study Design	Sample	Physical Activity Dose / Measure	Dependent Variable	Effects
Maffeis et al. (194)	IIA	Cohort of 112 prepubertal children (M age = 8.6 at baseline) 4-yr follow-up.	Self-report completed by parent.	Change in relative BMI based on the age and sex specific 50th %ile for weight for height.	Obese children (120% above ideal wt) reported less PA at baseline than non-obese. PA not associated with change in relative BMI over the 4-yr study period.
Moore et al. (214)	IIA	97 children aged 3-5. Participants in the Framingham Children's Study. Mean length of follow-up 2.5 yrs.	Accelerometer Counts.	BMI Triceps and Subscapular skinfolds.	Active children were 2.6 times more likely than in-active children to exhibit stable or decreasing slope for triceps skinfold thickness.
Parizkova et al. (239)	IIA	Cohort of 96 boys followed from age 11 to 15 yrs.	Self report questionnaire recording sports club PA and frequency and intensity of unorganised sport activity.	Hydrostatic weighing.	Boys in the lowest PA group gained significantly greater amounts of body fat over the 5 year study period than those in the highest physical activity group.
Raitakari et al. (260)	IIA	6-year follow-up of participants in the Young Finns Study (N = 3,596). 6 cohorts of children aged 3, 6, 9, 12, 15, and 18 yrs	PA Index based on self-reported frequency and duration of activities in the past month weighted by an intensity factor.	Subscapular skinfold thickness and BMI.	Significant difference in subscapular skinfold thick-ness between those who remained active seden-tary over and the 6-year period. NS differences observed for BMI.
Shapiro et al. (297)	IIA	Cohort of 227 boys and 223 girls followed from age 6 months to 9 yrs.	Parent recorded activity diary.	5 circumferences (head, chest, waist, biceps, calf) and 4 skinfolds (triceps, subscapular, suprailiac, and chest).	Significant but weak inverse association between sum of skinfolds and activity score for 6 months to 9 yrs range: -0.04 to -0.16 Significant at 6 months and 9 years. NS at other ages.

Table 3: Evidence related to the association between physical activity and adiposity, overweight, and obesity in youth (continued)

Study	Study Design	Sample	Physical Activity Dose / Measure	Dependent Variable	Effects
Vuille et al. (359)	IIA	Cohort of 550 children followed from age 7 to 10 yrs.	Parent report of PA.	Obesity Status based on % of normal weight for height.	PA a significant predictor of change in relative weight from age 7 to 10 yrs.
Wells et al. (370)	IIA	26 infants aged 9-12 months followed up at 2 years of age.	TEE from DLW.	Skinfold thickness. Fat mass from total body water.	Lower levels of infant PA were associated with greater skinfold thickness in childhood.
Aaron et al. (2)	IIB	100 adolescents aged 15-18 yrs. Random sample from the Adolescent Injury Control Study.	Self-reported PA over the past year. Modification of the Minnesota Leisure Time Activity Survey.	BMI	Significant inverse association in girls ($r = -0.43 - -0.47$). NS association in boys ($r = -0.13 - -0.20$).
Al-Hazzaa et al. (8)	IIB	91 preadolescent boys age 7- 12 yrs (All tanner Stage 1) M age = 9.6 yrs.	HR monitoring over 7 week period. Time spent with HR > 159.	% body fat from skin-folds (triceps and sub- scapular) using slaughter equation.	NS correlation between PA and % body fat ($r = -0.12$).
Ball et al. (28)	IIB	106 children aged 6 – 9 yrs. (M age = 7.8).	TEE/REE (PAL) using DLW.	Fat mass assessed from the (18)O dilution space and BMI.	BMI and %BF sig. correlated with PAL in boys but not girls. BMI ($r = -0.37$). % body fat ($r = -0.50$).
Bandini et al. (29)	IIB	28 nonobese and 35 obese adolescents aged 12-18 y.	EE measured by DLW.	Obesity status derived from body fatness assessed via stable isotope dilution.	Total EE was significantly greater in the obese than nonobese but ratios of total energy expenditure/ BMR (PAL) were NS different in the two groups (1.79 +/- 0.2 versus 1.68 +/- 0.19, nonobese and obese males and 1.69 +/- 0.28 versus 1.74 +/- 0.19 nonobese and obese females, respectively).

Study	Study Design	Sample	Physical Activity Dose/Measure	Dependent Variable	Effects
Boreham et al. (53)	IIB	Random sample of 1015 school children aged 12 and 15 yrs in N. Ireland.	Self-reported frequency, duration and intensity of daily activities to derive activity score (0-100). Weekly sessions of organised sport.	% body fat from skinfolds from 4 sites Durnin and Rahaman equation.	Sports participation inversely associated with %BF in girls aged 15. PA and sports participation not associated with %BF in any other population group.
Bradfield et al. (57)	IIB	4 obese girls (M age = 16.6 yrs and 6 non-obese girls (M age = 16.9 yrs).	EE (kcal/min) form continuous HR monitoring.	Obesity status derived from triceps skinfold and arm circumference.	NS relationship between EE and weight status.
Bullen et al. (69)	IIB	109 obese and 72 lean girls attending summer camp.	Activity level during 3 sports (swimming, volleyball, tennis) recorded on film.	Obesity status based on weight for height.	Obese girls were significantly less active in all activities.
Davies et al. (83)	IIB	93 preschool children between 1.5 and 4.5 years of age.	TEE/BMR (PAL) and TEE-BMR (AEE) using DLW.	Body fatness assessed via stable isotope dilution.	Significant inverse correlation between percentage body fat and PAL (-0.52) and AEE (-0.51).
Davison et al. (86)	IIB	197 girls ages 5 and 7 yrs.	Parents rating of activity level.	BMI	NS relationship between relative PA and BMI (r = 0.02).
Deheeger et al. (87)	IIB	86 French children aged 10 yrs.	Interview-administered self-report. Frequency and duration of commonly performed activities to estimate hours/wk of activity over the past year.	BMI Triceps and subscapular skinfolds, arm circumference.	NS in the anthropometric variables between girls and boys with "low" (1st and 2nd tertile) and "high" activity (3rd tertile).

(Table 3 continued overleaf)

Table 3: Evidence related to the association between physical activity and adiposity, overweight, and obesity in youth (continued)

Study	Study Design	Sample	Physical Activity Dose / Measure	Dependent Variable	Effects
Dotson et al. (94)	IIB	National probably sample from the US National Children and Youth Fitness Survey (NCYFS). 4,539 boys grades 5-12. 4,262 girls grades 5-12	Self-reported frequency and duration of commonly performed PA over the last 12 months. Number of days in PE.	Triceps and subscapular skinfolds.	Number of activities and frequency of PE associated with lower skinfolds. NS relationships were reported.
Fogelholm et al. (121)	IIB	129 obese children and 142 normal weight controls.	Self-report: 3-day PA record.	Obesity status. Obesity defined as > 20% age-specific median for weight for height.	Obese children exhibited significantly lower PA than normal weight children. Active children 1.13 times less likely to be obese than low-active children.
Goran et al. (131)	IIB	101 children (M age = 5.3 yrs) and 68 children (M age = 6.3 yrs).	TEE and AEE derived from DLW. Self report questionnaire.	% body fat: fat mass and fat-free mass from bioelectrical impedance	AEE measured by DLW was not associated with fat mass. Significant association between self-reported PA and fat mass r = -.24 to -.32) .
Hernandez et al. (146)	IIB	461 children aged 9 – 16 yrs from Mexico City.	Self-reported: 15 item questionnaire – hrs/day of moderate and vigorous PA.	BMI and triceps skinfold. Obese if BMI or triceps SF ≥ 85th percentile from NHANES 1.	Children reporting more than 2.5 hours/day of MVPA were 1.4 times less likely to be obese than those reporting less than 1 hour/day.
Huttunen et al. (151)	IIB	31 obese and 31 normal weight children matched for age and sex. Age ranged from 5.7-16.1 yrs	Parent reported PA questionnaire. Type, frequency, and duration of activities on a daily basis.	Obesity status defined as ≥ 2 sd for weight for height.	NS difference in daily PA between obese and non-obese. Obese children reported less frequent participation in training at sports clubs.

Study	Study Design	Sample	Physical Activity Dose/Measure	Dependent Variable	Effects
Janz et al. (156)	IIB	76 randomly selected children and adolescents aged 6 – 17 yrs. 40 girls (M age = 10.8) and 36 boys (M age = 11.0).	HR monitoring 12-hr recall Global assessment	% body fat from triceps and subscapular skinfolds – slaughter equation.	Significant inverse association between total activity and % BF r = -0.31 in girls; r = -0.33 in boys.
Johnson (159)	IIB	Grade 7 and 8 students: 371 boys, 372 girls,	Number of days of PE.	Triceps skinfold	Lower body fatness in boys and girls participating in 5 versus 2 or 3 PE lessons per week. Differences were NS.
Johnson et al. (160)	IIB	31 children (M age = 8.3 yrs (14 girls, 17 boys).	Activity Energy Expenditure (AEE) Total Daily EE – resting prosprandial metabolic rate.	% body fat - Fat mass derived from total body water as measured by isotope dilution & BMI.	AEE positively associated with fat mass in boys (r = .50) and BMI in boys and girls combined (r=0.38).
Klesges et al. (170)	IIB	222 preschool children between the ages of 3 to 6 years (M age = 4.4 yrs).	Multimethod approach – latent PA variable derived from a combination of direct observation, motion sensor, and various parent reports.	Skinfolds; girls triceps, suprailiac, and abdomen; boys – triceps, subscapular and chest. Waist circumference.	Skinfolds were weakly inversely associated with the composite activity variable. Only the correlation between the boy's chest skinfold was significant (r = -0.24).
Klesges et al. (169)	IIB	222 preschool children (122 boys, 100 girls). M age = 4.4 yrs.	Direct observation at child's home.	Child's relative weight compared to age-specific median for weight for height.	Child's relative weight was positively associated with physical activity.
Maffeis et al. (195)	IIB	13 obese children and 16 non-obese children aged 8 – 10 yrs.	TEE estimated from continuous HR monitoring.	Obesity status	NS differences between obese and non-obese for PAL or time spent in MVPA.

(Table 3 continued overleaf)

Table 3: Evidence related to the association between physical activity and adiposity, overweight, and obesity in youth (continued)

Study	Study Design	Sample	Physical Activity Dose/Measure	Dependent Variable	Effects
Maffeis et al. (193)	IIB	12 obese and 12 non-obese prepubertal children (M age = 9.3 yrs).	TEE from continous HR monitoring. Individual HR-VO2 relationships established. TEE/RMR ratio used as a measure of PA.	Obesity status defined as > 20% above ideal weight for height, age and gender.	Obese children exhibited significantly greater values for TEE. NS differences for the TEE/RMR ratio suggesting no PA differences.
Moussa et al. (217)	IIB	220 obese and 220 age and sex matched controls ages 6 – 18 yrs.	Self report questionnaire.	Obesity Status BMI > 90th % tile for age and sex.	PA was significantly associated with obesity status.
Obarzanek et al. (229)	IIB	2379 African American and white girls aged 9-10 y enrolled in the National Heart, Lung, and Blood Institute Growth and Health Study.	Self report questionnaire.	BMI and sum of three skinfolds.	PAEE significantly associated with adiposity.
Parizkova et al. (240)	IIB	22 preschool children aged 3 – 5 yrs.	Observation by teacher and parents.	Sum of 4 skinfolds.	Children classified as active had significantly lower body mass, body fatness, and arm cirumferences.
Reybrouck et al. (263)	IIB	15 obese children aged 4-16 yrs and age- and gender-matched controls.	Self-report questionnaire (Interview). PA score in hours/wk.	Obesity status: >90th %tile for weight for height.	PA was 27% lower in the obese children compared to healthy controls.
Romanella et al. (272)	IIB	21 obese and 19 non-obese children 8 – 12 yrs.	Accelerometer counts over 2 days.	Obesity status. > 80th %ile for sum of two skinfolds.	NS difference in activity counts for obese and non-obese children.

128

Study	Study Design	Sample	Physical Activity Dose/Measure	Dependent Variable	Effects
Rowlands et al. (275)	IIB	34 children (17 boys, 17 girls) ages 8.3 to 10.8 yrs.	Accelerometer, Pedometer, and HR monitoring.	Sum of 7 skinfolds.	Significant inverse correlation between PA and skinfolds r = -0.42 for accelerometer and pedometer. No association with HR indices.
Sallis et al. (285)	IIB	148 boys (M age 11.9 yrs). 142 girls (M age 11.8 yrs). Diverse sample of Mexican American and white children.	Self-report: 7-day recall Global rating of activity.	BMI (kg/m²)	Global rating inversely associated with BMI in males (r = -0.28); no association in females
Schmidt et al. (293)	IIB	1681 children (784 boys and 897 girls) from 8 primary and 7 secondary schools in Singapore	Self-report questionnaire.	Sum of skinfolds. fatness.	PA significantly inversely associated with body
Stunkard et al. (312)	IIB	15 obese and 15 non-obese girls (median age 12).	Pedometer readings during 2-week camp and 1-week at home.	Obesity status determined from ht and wt tables.	NS difference in PA between obese and non-obese girls.
Sunnegardh et al. (313)	IIB	A random sample of 682 8- and 13-year-old Swedish children.	Self report: frequency and duration of common activities weighted by energy cost.	% Body fat derived from triceps and subscapular skinfolds.	Active children tended to have a lower body fat content than less active children. Difference was NS.
Suter et al. (315)	IIB	97 children (39 boys and 58 girls) aged 10-15 yrs.	Self report: 7-day recall.	BMI and sum of 10 skinfolds.	PA inversely associated with BMI. Only the association between activity and skinfolds in boys reach statistical significance (r = -0.38).
Takada et al. (316)	IIB	457 Japanese 5th grade children aged 10 yrs.	Self-report: rating of involvement in sports score range 1 – 4.	BMI	PA rating not associated with BMI.

(Table 3 continued overleaf)

Table 3: Evidence related to the association between physical activity and adiposity, overweight, and obesity in youth (continued)

Study	Study Design	Sample	Physical Activity Dose/Measure	Dependent Variable	Effects
Taylor et al. (324)	IIB	93 high adiposity and 93 low adiposity children ages 8 – 13 yrs.	Direct Observation over a 2-day period.	Sum of 3 skinfolds (triceps, subscapula and suprailiac). High adiposity > 42.9 mm (median split) & BMI.	Significant inverse correlation between SF and PA (r = -0.54) and BMI (r = -0.50).
Tell et al. (327)	IIB	413 boys and 372 girls aged 10 – 14 yrs. Participants in the Oslo Youth Study.	Self reported frequency of exercise lasting at least 30 min in duration that made you breathe and sweat.	Triceps skinfold thickness and BMI.	Higher levels of PA associated with significantly lower skinfolds and BMI values among boys. NS differences observed among girls.
Trost et al. (338)	IIB	54 obese and 133 non-obese grade 6 students (M age = 11.4).	Accelerometer readings: daily total counts, daily moderate PA, daily vigorous PA, weekly 5-, 10-, and 20-min bouts of MVPA.	Obesity status: ≥ 95th tile for BMI from NHANES-1.	Compared to their non-obese counterparts, obese children exhibited significantly lower daily accumulations of total counts, moderate PA and vigorous PA as well as significantly fewer 5, 10 and 20 min bouts of MVPA.
Ward et al. (361)	IIB	54 obese and 96 non-obese African American girls (M age = 10.7 yrs).	Self-report: Previous Day Physical Activity Recall on 3 consecutive days.	Obesity status: ≥ 85th percentile for BMI or triceps skinfold from NHANES-1.	Obese girls reported sig. fewer 30-min blocks of vigorous PA and MVPA blocks than non-obese girls. MVPA significantly associated with BMI (r = -0.17) and Tricep SF (r = -0.19). VPA sig. associated with BMI (r = -0.19) and Tricep SF (r = -0.22).
Watson et al. (363)	IIB	85 boys 17-18 yrs from Ireland.	Self-report: 7-day recall.	% body fat from upper arm, chest, thigh and calf circumferences.	NS relationship between PA and % body fat.

130

Study	Study Design	Sample	Physical Activity Dose/Measure	Dependent Variable	Effects
Waxman et al. (365)	IIB	4 obese boys, 4 non-obese male siblings, and 4 non-obese peers .	Direct observation at school and home over a 4-5 month period.	Obesity status based on weight for height.	Obese boys were less active than their non-obese counterparts inside and outside the home, but equally active at school.
Wilkinson et al. (372)	IIB	20 obese and 20 non-obese children 12 years of age.	Pedometer readings for a 24 hr period.	Obesity status: > 90th percentile for weight for height.	NS difference in PA between obese and non-obese children.
Wolf et al. (378)	IIB	Multiethnic sample of 552 girls in grades 5 –12.	Self-report : Godin Shephard PA survey.	Obesity status ≥ 85th %ile for age- and sex from NHANES 1.	Significant inverse association between PA and age- and sex-adjusted BMI.

Table Abbreviations

BMI Body Mass Index
PA Physical Activity
EE Energy Expenditure
TEE Total Energy Expenditure
AEE Activity Energy Expenditure
PAEE Physical Activity Energy Expenditure
REE Resting Energy Expenditure
BMR Basal Metabolic Rate
PAL Physical Activity Level
MVPA Moderate to Vigorous Physical Activity
DXA Dual X-ray Absorptiometry
SF Skin Folds
HR Heart Rate
VO$_2$ max Maximal Oxygen Consumption
NS Non-significant

131

Skeletal health

Table 4: **Summary of studies examining physical activity and skeletal health**

Study	Study Design	Sample	Physical Activity Dose / Measure	Dependent Variable	Effects
Blimkie et al. (48)	IA	35 females aged 14 – 18 yrs.	26 wks of resistance training. F = 3 sessions/wk I= 4 sets of 13 exercises	Whole body and spine bone mineral density (BMD).	NS difference between training and control groups.
Bradney et al. (58)	IA	38 boys (M age = 10.4 yrs).	8-month exercise program consisting of weight bearing activity 3 times per week, 30 minutes a session.	Total body, femoral, and lumbar BMD.	Exercise group had significantly greater increased in BMD relative to controls.
Morris et al. (215)	IA	71 girls aged 9-10 yrs	10-month exercise training program. F= 3 session/wk D= 30 mins/session Played sports and completed a 20 station weight bearing circuit weight training program.	BMD of the total body, lumbar spine, proximal femur, and femoral neck.	Exercise group exhibited significantly greater total body, lumbar spine, and femoral BMD relative to non-training control group.
Bailey et al. (26)	IIA	53 girls and 60 boys followed for 6 years.	Self-report PA.	Peak BMC velocity total body, lumbar spine and femoral neck.	Boys and girls who remained active over the 6-yr follow-up had sig. Greater total body BMC than those who remained inactive.
Groothausen et al. (137)	IIA	83 boys and 99 girls followed from age 13 to 27. Amsterdam Growth Study.	Peak Strain Score based on self-reported PA.	Lumbar BMD.	Peak strain PA during childhood positively associated with Lumbar BMD at age 27.

134

Study	Study Design	Sample	Physical Activity Dose / Measure	Dependent Variable	Effects
Marguilies et al. (198)	IIA	286 male army recruits aged 18-21 yrs.	Basic training – extremely demanding: 8 hrs/day 6/days/wk 14 week duration	Tibia and fibula bone mineral content (BMC).	5-11 % increase in BMC.
Bailey et al. (27)	IIA[1]	14 males and 4 females with unilateral Legg-Calve-Perthes Disease.	Restricted weight bearing activity on affected limb.	Hip BMD	Mean difference of 5.6% in BMD between hips.
Faulkner et al. (114)	IIA[1]	234 children aged 9 to 16 yrs.	PA levels within the normal range.	Whole body, arm, and leg BMD.	BMD significantly greater in dominant arm for all ages and males and females. NS difference in BMD in legs.
Hendersen et al. (145)	IIA[1]	24 males and 14 females aged 2 to 15 yrs.	Immobization study due to fracture of tibia or femur.	Hip BMD	> 8 wks of immobilisation 4.3% difference in hip BMD.
Watson et al. (364)	IIA[1]	202 male little league baseball players aged 9 to 19 yrs.	Participation in structured baseball league – throwing.	Humerus and radius BMC.	Significantly higher BMC in dominant humerus in all age groups, NS difference for radius.
Cassell et al. (72)	IIB	56 females aged 7 to 10 yrs. 25 gymnasts, 21 swimmers, and 10 controls.	Elite level training in swimming and gymnastics.	Whole body BMD.	Gymnasts significantly higher BMD in gymnasts compared to swimmers and controls.

(Table 4 continued overleaf)

Table 4: **Summary of studies examining physical activity and skeletal health** (continued)

Study	Study Design	Sample	Physical Activity Dose/Measure	Dependent Variable	Effects
Duncan et al. (97)	IIB	75 adolescent female sports participants and non-athlete controls (n=15).	Participation in elite level swimming, cycling, triathlons, and running. Combination of weight bearing and non-weight bearing sports.	BMD of the total body, lumbar spine, and femoral neck.	Runners had significantly higher BMD than controls, swimmers, and cyclists.
Fehily et al. (116)	IIB	189 males and 182 females.	Self-reported sports participation at age 12.	BMC of the distal and proximal radius.	Sports participation at age 12 positively correlated with BMC in females but not males.
Grimston et al. (136)	IIB	22 youth sports participants 11 swimmers and 11 gymnasts.	Elite level age group training in swimming and gymnastics.	Hip and spine BMD.	Gymnasts had significantly higher BMD in the hip and spine compared to swimmers.
Janz et al. (157)	IIB	179 boys and 189 girls. M age=5.2 yrs.	CSA accelerometer. Parent report of usual physical activity.	BMC of total body hip and spine.	PA significant predictor of BMC. Significant difference between the least and most active quartiles.
Kriska et al. (175)	IIB	223 postmenopausal females.	Retrospective self-reported PA at different life stages including adolescence.	BMD of the radius. BMD across different	NS difference in levels of PA between ages 14 and 21 years.
Kroger et al. (176)	IIB	40 males and 44 females aged 6 – 19 yrs.	Self-reported PA via questionnaire.	Hip and spine BMD	Active subjects exhibited greater hip BMD than non-active subjects. NS effect for spine BMD.
McCulloch et al. (201)	IIB	43 youth swimmers and soccer players and 25 controls.	Participation in elite level training in swimming and soccer.	Trabecular BMD and radial BMC.	Soccer players had sig. higher trabecular BMD than controls and swimmers. NS difference in radial BMC.

Study	Study Design	Sample	Physical Activity Dose/Measure	Dependent Variable	Effects
McCulloch et al. (202)	IIB	101 females between the ages of 20 and 35 yrs.	Retrospective self-reported PA during adolescence.	Trabecular BMD.	Women classified as active during adolescence had significantly higher BMD than other groups.
Slemenda et al. (303)	IIB	118 children ages 5.3 to 14 yrs.	Self-reported PA via questionnaire.	Hip, spine BMD and radial BMC.	PA positively associated with BMD at hip and radius. NS association with spine BMD.
Talmage et al. (318)	IIB	Subsample of 25 women from 1200 aged 19 to 98 yrs.	Retrospective self-reported PA during adolescence.	Radius BMC.	Positive association between adolescent PA and radial BMC.
Tylavsky et al. (349)	IIB	705 high school and college-age females between the ages of 17 and 23.	Self-reported PA via questionnaire.	BMC of the distal and mid radius.	PA positively associated with BMC of the distal radius.

Table Abbreviations

BMD   Bone Mineral Density
BMC   Bone Mineral Content
PA   Physical Activity
F   Frequency of exercise or physical activity
I   Intensity of exercise or physical activity
D   Duration of exercise or physical activity
HR   Heart Rate
M   Mean or Average
NS   Non-significant

Social-psychological benefits

Table 5: The association between physical activity or exercise training and depression in children and adolescents

Study	Study Design	Sample	Physical Activity Dose / Measure	Dependent Variable	Effects
Brown et al. (62)	IA	11 females M age = 15.6 yrs 16 males M age = 15.6 yrs	PA Intervention	Depression	Significant effect in females but not in males.
Norris et al. (226)	IA	31 boys and 29 girls. M age = 16.7 yrs	PA intervention	Depression	NS
Dua et al. (96)	IB	37 girls and 13 boys. Mean Age 16 yrs	PA intervention	Depression	NS
Koniak-Griffin (174)	IB	58 females M age = 16.6 yrs	PA Intervention	Depression	Significant effect
MacMahon et al. (207)	IB	98 males M age = 16.3 yrs	PA Intervention	Depression	Significant effect
Glyshaw et al. (129)	IIA	530 students in grades 7 to 11.	Self-reported PA	Depression	NS
Milligan et al. (211)	IIA	301 boys and 301 girls. M age = 18 yrs	Self-reported PA	Depression	Significant association in boys but NS in girls.
Brown & Lawton (61)	IIB	220 females aged 11-17 yrs.	Self-report of PA and sports participation.	Depression	Significant association
Thorlindsson et al. (332)	IIB	1131 children aged 15-16 yrs.	Self-reported participation in sports.	Depression	Significant association

Table 6: The association between physical activity or exercise training and stress/anxiety in children and adolescents

Study	Study Design	Sample	Physical Activity Dose / Measure	Dependent Variable	Effects
Brown et al. (62)	IA	11 girls 16 boys. M age = 15.6 yrs.	PA intervention	Anxiety	Significant effect in girls but NS in boys.
Norris et al. (226)	IA	31 boys and 29 girls. M age = 16.7 yrs.	10 week intervention Vigorous Intensity F= 2 days/wk I = 70-75% Hrmax Moderate Intensity D=25-30 mins F=2 days/wk I = 50-60% HRmax D=25-30 mins	Anxiety	Significant effect with vigorous intensity group.
Bahrke et al. (25)	IB	35 girls and 30 boys. M age = 10.6.	1 exercise session – walk/run 15 mins compared to reading or busy work for 15 mins.	Anxiety	NS change.
Brown & Siegel (60)	IIA	212 girls. M age = 13.1 yrs.	Self-report of 14 physical activities.	Stress	Significant Association.
Brown & Lawton (61)	IIB	220 girls aged 11 – 17 yrs. M age = 14yrs.	Self report of PA and participation in sports.	Stress	Significant Association.
Glyshaw et al. (129)	IIB	530 boys and girls in Grades 7 to 11.	Self-reported PA.	Anxiety	NS effect or association.
Thorlindsson et al. (332)	IIB	1131 children aged 15-16 yrs.	Self-report of sports participation.	Anxiety	Significant association.

141

Table 7: The association between physical activity or exercise training and self-concept in children and adolescents

Study	Study Design	Sample	Physical Activity Dose / Measure	Dependent Variable	Effects
MacMahon et al. (207)	IA	54 boys M age = 9.7 yrs.	PA intervention.	Self concept	Significant ↑ on self-concept relative to controls.
Blackman et al. (43)	IB	16 girls M age = 14.8 yrs.	Dance team	Self concept	NS association with self-concept.
Hatfield et al. (144)	IB	11 girls and 3 boys aged 9 – 11 yrs.	PA training program (jump rope program).	Self concept	Significant effect on self concept.
MacMahon et al. (207)	IB	98 boys M age = 16.3 yrs.	Physical activity intervention.	Self concept	Significant ↑ on self-concept relative to controls.
Parish-Plass et al. (238)	IB	43 boys M age = 10.9 yrs.	PA intervention	Self concept	NS effect.
Overbay et al. (233)	IIB	23 boys and 38 girls aged 6 – 12 yrs.	Parent report of child's PA.	Self concept	Significant association with self-concept and PA. Self concept not related to fitness measures.
Sherrill et al. (299)	IIB	393 children in grades 4 and 5.	Physical Fitness Battery.	Self concept	Significnt positive association between fitness and self-concept.
Young (379)	IIB	75 girls in grades 7 to 10.	Physical Fitness Battery	Self concept	Significant association between fitness and self-concept.

142

Table 8: The association between physical activity or exercise training and self-esteem in children and adolescents

Study	Study Design	Sample	Physical Activity Dose / Measure	Dependent Variable	Effects
McGowan et al. (203)	IA	37 grade 7 boys.	Endurance training F=3-4 times/wk I = 70-75% MHR D=25-30 mins/session	Self-esteem	Significant ↑ in self concept relative to controls not enrolled in PE.
Blackman et al. (43)	IB	16 girls M age – 14.8 yrs.	Dance team	Self-esteem	NS effect on self-esteem.
Boyd et al. (56)	IB	181 girls aged 9 to 16 yrs.	Physical activity intervention.	Self-esteem	Significant effect on self-esteem.
Holloway et al. (149)	IB	59 girls M age = 16 yrs.	12 week weight training program.	Self-esteem	NS effect.
Koniak-Griffin (174)	IB	58 girls M age = 16.6 yrs.	Exercise training program.	Self-esteem	Significant effect self-esteem.
Somstroem et al. (307)	IIA	98 high school-aged boys.	Swim performance	Self-esteem	Significant association with self esteem.

Abbreviations

PA	Physical Activity
NS	Non-significant effect
F	Frequency of exercise or physical activity
I	Intensity of exercise or physical activity
D	Duration of exercise or physical activity
Hrmax	Age predicted heart rate maximum (220-age)

143

Cardiorespiratory fitness

Table 9: Studies examining the relationship between physical activity and cardiorespiratory fitness in children and adolescents

Study	Sample	Physical Activity Measure	Physical Fitness Measure	Strength of Association
Aaron et al. (3)	47 boys (15-18 y)	self-report questionnaire (MET-hrs/week)	1.6 km run	r = -.20 †*
	53 girls (15-18 y)			r = -.47 †*
Aaron et al. (2)	608 boys (12-16 y)	self-report questionnaire (MET-hrs/week)	1.6 km run	r = -.15 †*
	567 girls (12-16 y)			r = -.23 †*
Andersen et al. (12)	27 boys (13-17 y)	interviewer administered questionnaire (sports activity score)	cycle VO$_2$ max	r = .31*
	25 girls (13-17 y)			r = .19*
Armstrong et al. (17)	85 boys (11-16 y)	heart rate monitoring	treadmill & cycle VO$_2$ max	r = .01 - .26 median r = .10
	111 girls (11-16 y)			

Study	Sample	Physical Activity Measure	Physical Fitness Measure	Strength of Association
Atomi et al. (19)	11 boys (9-10 y)	heart rate monitoring (individual calibration to VO_2)	treadmill VO_2 max	$r = .74^*$
Fenster et al. (118)	5 boys (6-8 y) 13 girls (6-8 y)	LSI accelerometer	treadmill peak VO_2	$r = .59^*$ $r = .20$
Sallis et al. (278)	148 boys 142 girls	self-report questionnaire 7-day recall & global activity rating	HR predicted cycle VO_2 max	$r = .03$ recall $r = .00$ recall $r = .13$ act. rating $r = .11$ act. rating
Sallis et al. (281)	274 boys 254 girls (4th grade)	six measurements of physical activity combined via principal components factor analysis.	1.6 km run	$r = -.16^{\#}$†

147

Table 9: Studies examining the relationship between physical activity and cardiorespiratory fitness in children and adolescents (continued)

Study	Sample	Physical Activity Measure	Physical Fitness Measure	Strength of Association
Sunnegardh et al. (314)	20 boys (8 y) 1. boys (13 y) 20 girls (8 y) 29 girls (13 y)	self-reported questionnaire (daily activity score)	cycle VO_2 max	r = .41 - .48*
Janz et al. (155)	26 boys (6-17 y) 32 girls (6-17 y)	heart rate monitoring	cycle VO_2 max	r = -.06 r = .36*
LaPorte et al. (178)	22 boys (12-14 y)	LSI accelerometer self-report questionnaire LSI accelerometer self-report questionnaire	1.6 km run 1.6 km run treadmill VO_2 max treadmill VO_2 max	r = .10 † r = .02 † r = -.16 r = -.10

148

Study	Sample	Physical Activity Measure	Physical Fitness Measure	Strength of Association
Pate et al. (242)	1,150 boys 1,202 girls (3rd - 4th grade)	self-report questionnaire	1.6 km run	r = -.17 †*
Taylor et al. (323)	100 boys (8-13 y) 86 girls (8-13 y)	observational system (CARS)	PWC 170 cycle ergometer	r = .24*
Tell et al. (327)	413 boys (11-14 y) 372 girls (11-14 y)	self-report questionnaire	HR predicted cycle VO$_2$ max	r = .11* r = .12*

Legend
† = negative correlation indicates that more active youth exhibit better 1.6 km run performance
* = indicates that this correlation was statistically significant

Table 10: Pooled correlations coefficients for the relationship between physical activity and cardiorespiratory fitness

Pooling Category	Studies	N	Range	Pooled r	95% C.I.
All Studies	27	6,244	-.16 - .74	.17	.14 - .19
Girls	8	1,391	.00 - .47	.18	.12 - .23
Boys	12	1,544	-.16 - .31	.13	.08 - .18
Older children	15	2,493	-.16 - .47	.16	.12 - .20
Younger children	12	3,761	-.06 - .74	.16	.13 - .19
Objective physical activity measure correlated with laboratory or quasi laboratory measure of physical fitness.	9	751	-.16 - .36	.14	.08 - .19
Self-report physical activity questionnaire correlated with laboratory or quasi laboratory measure of physical fitness.	9	1,283	-.10 - .31	.11	.04 - .18
Self-report physical activity questionnaire correlated with field measure of fitness.	7	4,177	.02 - .47	.18	.15 - .21
Objective physical activity measure correlated with laboratory measure of VO_2 max.	5	294	-.06 - 74	.15	.03 - .26
Objective physical activity measure correlated with quasi laboratory measure of physical fitness (PWC 170).	4	989	.11 - .24	.14	.08 - .20
Self-report physical activity questionnaire correlated with laboratory measure of VO_2 max.	3	74	-.10 - .31	.22	-.02 - .47
Self-report physical activity questionnaire correlated with quasi laboratory measure of physical fitness (PWC 170).	6	677	.00 - .40	.10	.02 - .17

Muscular strength and endurance

Table 11:   Summary of the studies examining strength training in children and adolescents

Study	Study Design	Group	Age (y)	Sex	Length	Training Programme F-I-D-T	Effects
Blimkie et al. (49)	1A	E	16.3	F	23 wks	F = 3 d/wk; I = max. effort; D = 3-4 sets x 10 reps x 13 exercises; T = hydraulic resistance	Hydraulic resistance biceps curl, knee extension/flexion, triceps press and squat press strength↑ more in E versus C.
		C	16.1	F			
Clarke et al. (77)	1A	E	8.5	M	3 mths	F = 3 d/wk; I = ?; D = 90 min/d; T = wrestling training	Isometric leg press ↑, more in E versus C.
		C	8.4	M			
Docherty et al. (92)	1A	E	12.4	M	4 wks	F = 3 d/wk; I = high resistance, low reps; D = 2 x 6 exercises	No significant training effect in either E group.
		E		M	4 wks	F = 3 d/wk; I = low resistance, high reps; D = 2 x 6 exercises	
		C		M			
Faigenbaum et al. (112)	1A	E	10.8	M/F	8 wks	F = 2 d/wk; I = 50%, 75% and 100% 10 RM; D = 35 min/d (3 sets x 10-15 reps x 5 exercises); T = child-size equipment	10 RM leg extension and curl, chest press, biceps curl and overhead press strength ↑ more in E versus C.
		C	9.9	M/F			
Falk et al. (113)	1A	E	6.4	M	12 wks	F = 2 d/wk; I = ?; D = 40 min/d; T = push-ups, sit-ups, stance/kicking, martial arts, & flexibility	Sit-ups reps and long jump distance ↑ more in E versus C.
		C	7.1	M			

Study	Study Design	Group	Age (y)	Sex	Length	Training Programme F-I-D-T	Effects
Gillam (127)	1A	E E E E E	HS HS HS HS HS	M M M M M	9 wks	F = 1 d/wk F = 2 d/wk; I = 1 RM; D = 18 sets x 1 RM; F = 3 d/wk; T = barbell F = 4 d/wk F = 5 d//wk	1 RM bench press strength ↑ more in 5 d/wk group versus all others; bench press strength ↑ more in 4 d/wk group versus 1 d/wk group; bench press strength ↑ more in 3 d/wk group versus 1 and 2 d/wk groups.
Komi et al. (173)	1A	E C	14.0 14.0	M/F M/F	12 wks	F = 4 d/wk; I = maximal; D = 5 x 3-5 s; T = isometric knee extension	Isometric knee extension strength ↑ more in E versus C.
Nielsen et al. (223)	1A	E C	6 6	F F	5 wks	F = 3 d/wk; I = maximal; D = 18-20 min/d; T = each weight group was divided into: Isometric knee extension, vertical jump or sprint training.	Isometric knee extension and vertical jump ↑ more in E versus C; isometric knee extension ↑ more in isometric group than other groups.
Ozmun et al. (234)	1A	E C	10.0 10.5	M/F M/F	8 wks	F = 3 d/wk; I = ?; D = 3 sets x 7-11 reps	Isokinetic and isotonic elbow flexion strength ↑ more in E versus C.
Pfeiffer et al. (255)	1A	E C C E C	10.3 9.7 12.5 19.8 19.6	M M M M M	9 wks	F = 3 d/wk; I = 50-100% of 10 RM; D = 3 sets x 10 reps for 4 primary exercises; (all E groups)	Isokinetic elbow flexion/extension strength ↑ more in all E versus all C; isokinetic elbow flexion/extension strength ↑ more in young E versus two older E groups .

153

Table 11: Summary of the studies examining strength training in children and adolescents (continued)

Study	Study Design	Group	Age (y)	Sex	Length	Training Programme F-I-D-T	Effects
Ramsey et al. (262)	1A	E	10.0	M	20 wks	F = 3 d/wk; I = 70-75% 1 RM 1st 10 wks; 880-85% 1 RM 2nd 10 wks; D = 3-5 sets x 5-12 reps x 5 exercises	1 RM bench and leg press, isometric and isokinetic elbow flexion and knee extension strength ↑ more in E versus C.
		C	10.0	M			
Sailors et al. (276)	1A	E	12.6	M	8 wks	F = 3 d/wk; I = 50-100% of 5 RM; D = 3 sets x 5-10 reps; T = barbell/dumbbell (both E groups)	5 RM squat, bench press and biceps curl↑ in E groups versus C groups; no difference between E groups.
		C		M			
		E	24.0	M	8 wks		
		C		M			
Sewall et al. (296)	1A	E	10.5	M/F	9 wks	F = 3 d/wk; I = 50%, 80% and 100% of 10 RM; D = 25-30 min/d (3 sets x 10-max reps x 3 exercises; T = Nautilus and Cam II	Isometric shoulder flexion strength ↑ more in E versus C.
		C	10.5	M/F			
Siegel et al. (301)	1A	E	8.4	M	12 wks	F = 3 d/wk; I = ?; D = 30 min/d (exer/rest: 30/30 s to 45/15 s); T = hand wts, stretch tubing and self-supported movement	Rt. handgrip strength ↑ E (M/F) but not C; isometric elbow flexion/extension strength ↓ F; chin-up and flex arm hang ↑ in E but not C.
		E	8.5	F			
		C	8.6	M			
		C	8.4	F			
Vrijens (358)	1A	E	10.4	M	8 wks	F = 3 d/wk; I = 75% max; D = 1 set x 8-12 reps x 8 exercises; T = concentric isotonic (both groups)	Isometric elbow flexion/extension, knee flexion/extension, abdomen and back strength ↑ in older group; abdomen and back strength ↑ in younger group.
		E	16.7	M	8 wks		

Study	Study Design	Group	Age (y)	Sex	Length	Training Programme F-I-D-T	Effects
Weltman et al. (371)	1A	E	8.2	M	14 wks	F = 3 d/wk; I = all-out; D = 30 min/d (3 sets x 10 stations [exer/rest: 30/30 s]); T = concentric hydraulic resistance	Isokinetic knee flexion/extension, elbow flexion/extension strength and vertical jump ↑ more in E versus C.
		C		M			

Abbreviations
E Experimental Group
C Control Group
F Frequency of Training
I Intensity of Training
D Duration of Training
T Type of Training
M Male
F Female
RM Repetition Maximum

155

Future research needs

To advance our understanding of the amount or dose of physical activity required for health among children and adolescents, the status of physical activity participation among young Australians, and the factors that influence youth participation in physical activity, the following research priorities should be pursued.

- Establishment of a national surveillance system for measuring physical activity and other health behaviours in Australian children and adolescents.

- Development and refinement of methods to measure physical activity in representative samples of Australian children aged 10 years and younger.

- Prospective epidemiological studies with sufficiently detailed measures of physical activity and adequate sample sizes to evaluate dose-response relationships for physical activity and short- and long-term health outcomes in young people. Such studies will need to control for the confounding effects of growth and maturation.

- Randomised controlled trials testing the effects of different doses of physical activity on carefully targeted health outcomes in children and adolescents.

- Prospective observational and experimental studies investigating the determinants (mediators and moderators) of physical activity behaviour in Australian children and adolescents. Particular emphasis should be placed on examining the interplay between social-cognitive factors and environmental influences.

- Longitudinal studies quantifying the tracking of physical activity behaviour within and between key developmental stages should be extended to include the tracking or stability of favorable attitudes towards physical activity, self-efficacy perceptions, positive affect for physical activity (i.e. enjoyment), and adaptive motivational profiles.

- Lastly, if guidelines are adopted (whatever shape or form), then awareness and use of the guidelines by medical practitioners and allied health professionals should be routinely evaluated.