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CONFERENCE SUMMARY REPORT

International Conference on Physical Activity and Obesity in Children: Summary Statement and Recommendations

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Abstract
The increasing prevalence of obesity among the world's children and youth was the impetus for an international conference convened in Toronto, Canada to examine issues related to physical activity and obesity in children (June 24–27, 2007). The goal of the conference was to assimilate, interpret and share scientific evidence with key stakeholders to develop recommendations concerning effective physical activity policies and programs to address obesity in children. The conference was attended by approximately 1000 delegates from 33 countries who gathered to listen to the invited speakers and to share information on promising practices related to the promotion of physical activity with the aim to reduce the burden of obesity in children. The major topics addressed at the conference included the biological and behavioural causes of obesity, current and past levels of physical activity and sedentarism in children, the role of the social, family and built environment in addressing the physical activity deficit, and the role of legislation and industry in promoting physical activity. Promising physical activity interventions among children were presented, and important research, policy and practice recommendations to address the issue of physical inactivity and obesity were provided.

Key words: *Obesity, child, adolescent, sedentary behaviour, sedentarism, physical activity*

Introduction

The World Health Organization (WHO) has estimated that every year 1.9 million people die as a result of physical inactivity while 2.6 million people die as the result of being overweight or obese (1). The ubiquitous nature of the worldwide increases in, and excessive prevalences of, physical inactivity and obesity has garnered international attention, and has prompted the development of a "Global Strategy on Diet, Physical Activity and Health" (2). In light of the increasing prevalence of obesity among the world's children and youth (3), a scientific conference was convened in Toronto, Canada to examine issues related to physical activity and obesity in children (June 24–27, 2007). The long-term aim of this international conference is to

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*The Conference Speaker Panel includes Tom Baranowski, Claude Bouchard, Kelly Brownell, Deborah Cohen, William H. Dietz, Rod Dishman, Mary Flynn, William Haskell, James O. Hill, WPT (Philip) James, Russell Pate, John Peters, Michael Pratt, Harry Rutter, James Sallis, Jo Salmon, Chantal Simon, and Boyd Swinburn.

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inform the development of scientifically-based community intervention approaches to reduce the incidence of childhood and youth obesity through increased physical activity and sport participation. The on-site goal of the conference was to assimilate, interpret and share scientific evidence with key stakeholders to develop recommendations concerning effective physical activity policies and programs at the community level to address obesity in children and youth. The International Conference on Physical Activity and Obesity in Children was attended by approximately 1000 delegates from 33 countries. In addition to the plenary session of invited lectures, 119 scientific and 18 programmatic posters were presented by delegates attending the conference.

Eighteen invited speakers addressed the conference over the course of three days which were structured along three over-arching themes of science, policy and practice. Dr. Philip James and Dr. William Dietz opened the conference by providing a worldwide perspective on the scope of the problem of childhood obesity and the secular and behavioural trends that have contributed to the epidemic. Dr. Russell Pate and Dr. William Haskell addressed the issue of current physical activity levels of youth and trends that have occured over time. The behavioural and psycho-social determinants of physical activity levels were considered by Dr. Rod Dishman whereas the biological and genetic factors were discussed by Dr. Claude Bouchard. Dr. James Hill focused on physical activity as a contributing factor to the obesity epidemic in children and youth. The role of social and physical environments in overcoming the physical activity deficit were addressed by Dr. Tom Baranowski who talked about the role of family and parents, Dr. James Sallis who discussed modifying the social environment, and Dr. Deborah Cohen who presented on modifying the physical or built environment. Dr. Kelly Brownell discussed the role of powerful upstream influences such as food availability and marketing on the obesity epidemic. Dr. Harry Rutter examined issues related to physical activity and legislation, Dr. Boyd Swinburn discussed public health and formal education approaches, and Dr. John Peters explored the role of the private sector in addressing the physical activity deficit. The final day of the conference was devoted to highlighting promising practices and showcasing successful physical activity interventions. Dr. Mary Flynn began the session by summarizing a review of published physical activity interventions targeting obesity in children. Dr. Chantal Simon presented results from the "Intervention Centered on Adolescents' Physical Activity and Sedentary Behaviour" (ICAPS) study – a four-year physical activity promotion study in French adolescents, and Dr. Jo Salmon presented data from the Australian Switch-Play study. Finally, Dr. Michael Pratt concluded the session by summarizing interventions to increase physical activity and prevent obesity in Latin American children.

An Expert Panel was constituted under the auspices of the International Association for the Study of Obesity (IASO) Physical Activity Task Force (PATF) to review, critically evaluate, and summarize the evidence presented by the invited speakers. The Expert Panel members included Dr. Peter Katzmarzyk (Chair), Dr. Louise Baur, Dr. Steven Blair, Dr. Estelle Lambert, Dr. Jean-Michel Oppert and Dr. Chris Riddoch. This report is the main product of the International Conference on Physical Activity and Obesity in Children.

Definition of Overweight and Obesity in Childhood and Adolescence

Overweight and obesity refer to conditions of excess body weight, relative to stature, and specifically excess adipose tissue. Numerous clinical definitions of pediatric overweight and obesity are in use, leading to confusion in the epidemiological literature. These definitions have been variously based on such parameters as skinfold thickness, weight-for-age, weight-for-height, or BMI-for-age (the latter with a variety of cut-points being used). In the late 1990s, the International Obesity TaskForce (IOTF) recommended that body mass index (BMI) based on centile curves that at age 18 pass through the adult cut-points of 25 kg/m^2 and 30 kg/m^2, be used to define overweight and obesity among children and adolescents (4); a table of age- and sex- specific cut-points based upon a compilation of nationally representative cross-sectional growth studies from a number of countries has subsequently been published (5). Nevertheless, other definitions are in use for epidemiological purposes, most notably in the U.S. the CDC 2000 BMI-for-age charts using the arbitrary cut-points of the 85^{th} and 95^{th} centiles (6). The WHO has recently published its Child Growth Standards charts for children aged 0–5 years, based upon the observed growth of children who were exclusively breastfed for the first six months; these charts show minimal differences in growth between children of several different ethnic groups, at least in the first few years of life, and thus potentially represent ideal growth patterns (7). They are increasingly being used as international growth standards for children under 5 years of age. The development of an international growth reference for older children (ages 5–17 y) is awaited (8). There is also a recognition of the need for harmonization of reference data for obesity for surveillance in children and youth.

High and Increasing Prevalence of Pediatric Obesity

Pediatric obesity is increasingly prevalent in many countries. The worldwide prevalence of overweight (including obesity) in children and adolescents aged 5–17 years is approximately 10%, with that of obesity alone being 2–3% (9). Certain regions and countries have particularly high levels of pediatric obesity; for example, more than 30% of children and adolescents in the Americas, and approximately 20% of those in Europe (higher in southern Europe than in northern Europe), are overweight or obese (See Figure 1). These prevalences are projected to increase over the next few years (3). It is particularly troubling that not only is the prevalence of obesity increasing, but there is some evidence to suggest that the annualized rates of increase are also on the rise, at least in Europe (10). So not only is the actual prevalence of overweight and obesity increasing but the rate of new cases each year is rising as well. Socioeconomic differentials in the prevalence of pediatric obesity are also recognized; overweight is generally high among the poorer children in affluent countries and among the affluent children in countries undergoing economic transition (9).

Ethnic Differences in Susceptibility to Obesity and Obesity-associated Complications

Ethnic differences in obesity prevalence among children are recognized. For example, in the United Kingdom, Afro-Caribbean and South Asian children tend to be heavier than white children (11). Also, data on children and adolescents 2–19 y of age from the U.S. suggest that Mexican-American males have a greater odds of being overweight than Non-Hispanic white males, while Mexican-American and Non-Hispanic Black females are at an increased odds of being overweight by comparison to Non-Hispanic white females (12). The relative contributions of external (e.g. socioeconomic status, environmental), internal (physical activity, other lifestyle factors), and inherent (e.g. genetic) or adaptive factors that may drive such observed ethnic differences remain poorly understood.

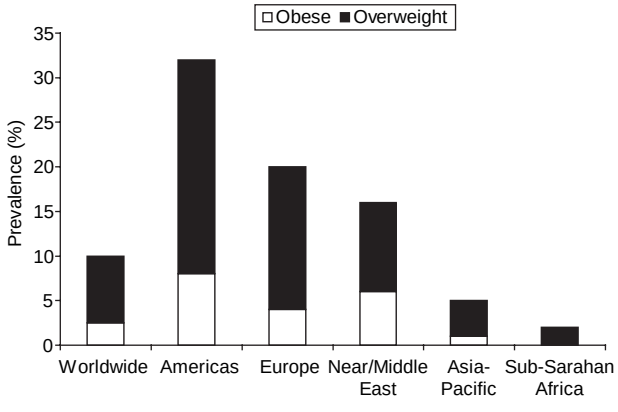

Figure 1. Prevalence of overweight and obesity among children 5–17 y of age in global regions. Adapted from reference (9).

Differences in ethnicity may also influence obesity-related health outcomes. For example, at any value of BMI, Taiwanese adults are more susceptible to obesity-related disorders such as type 2 diabetes and hypertension than are American whites and blacks (13). Recent evidence also suggests that the level of overall body fatness and the amount of fat in specific depots for a given BMI also differs among ethnic groups (14,15). The issue of ethnic differences in obesity and obesity-related health risks requires more research in order to better delineate the sources of the observed differences and the consequences, especially with respect to surveillance and the identification of children and youth at elevated health risk.

Current Physical Activity and Physical Inactivity Levels of Children and Youth

Physical activity comprises any bodily movement produced by the skeletal muscles that results in a substantial increase in energy expenditure over resting levels (16). There are several domains in which physical activity can occur, including leisure-time, occupational work (or school in the case of children), domestic chores, and active commuting. Physical activity and physical inactivity represent opposite ends of the energy expenditure continuum. At the lower end of this continuum, *sedentary behaviour* refers to a number of activities that have in common energy expenditure levels that approximate resting. Watching television, working on a computer, or playing video games – that is, time spent in front of a screen (i.e., screen time) – is a commonly used indicator of sedentary behaviour. Low accelerometer counts also represent an objective measure of sedentary behaviour. Thus, sedentary behaviour does not represent the opposite of physical activity, but corresponds to a complementary dimension of behaviour. The distinction between physical activity and sedentary behaviour has implications for both assessing and preventing obesity and related diseases (17). Furthermore, it is possible for an individual to have high levels of both physical activity and sedentary behaviour, which makes the study of these behaviours a complex endeavor. For example, a person might engage in 60 minutes of exercise per day and spend the rest of the day in a sedentary occupation. In order to best capture relationships with obesity, it is important to not only understand the types and intensities of

physical activity being performed, but also the impact on total daily energy expenditure, which is one of the key elements in the energy balance equation.

There have been several large studies of the physical activity characteristics of children and youth in North America and Europe over the last decade. The available data are from both self-report and objective measures across the energy expenditure continuum. In most studies, physical activity was characterized as moderate-to-vigorous activity (MVPA). In many studies, it is common to express the intensity of physical activity in multiples of resting energy expenditure (METs). One MET (equivalent to resting) is equal to approximately 1 $kcal \cdot kg^{-1} \cdot hr^{-1}$ of energy expenditure (18). Investigators have used different definitions of MVPA, but typically this intensity of activity refers to increases in resting metabolism of at least 3 METs. Sedentary behaviour is usually defined as activities that involve little increase in energy expenditure above resting metabolic rate, and would include activities of less than 1.5 METs. The mostly widely used compendium of MET values for common activities has been compiled using data from adults (18,19). Given the potential for wide variability in activity-specific energy expenditure values among youth (20), more research is required to determine the applicability of applying adult MET values to estimate the energy expenditure of children and youth.

The Youth Risk Behaviour Surveillance System (YRBSS) in the U.S. provides self-reported physical activity data on boys and girls in the 9^{th}–12^{th} grades (21). The report suggests that only 40% of boys and 30% of girls are meeting the physical activity recommendation of at least 60 minutes of physical activity per day. Another U.S. study, The National Longitudinal Study of Adolescent Health, is comprised of a sample of 13,157 12 to 22 year-old youth (22). The prevalence of having at least 5 sessions/week of MVPA was higher in males than in females, and both groups showed a steep inverse gradient across age groups. For example, about 50% of 12–15 year-old boys met the standard and about 25% of those in the 18–22 year old group met the standard. Proportions for females for these two age groups were markedly lower than for males, amounting to 35% and 12%, respectively.

Canadian adolescents appear to be more active than their U.S. counterparts; however, there are differences in the criteria for meeting the physical activity recommendations. Three cross-sectional surveys were conducted in Ontario in 1997, 1999, and 2001 among 5000 7^{th} to 12^{th} graders (23). The criterion for physical activity in this study was obtaining at least 20 minutes of vigorous physical activity on 3 or more days of the week. About 70% of boys met this criterion in all three surveys, and the prevalence was slightly less in girls, who also showed a slight decline over the surveys, from $\sim$60% in 1997 to $\sim$55% in 2001.

There are few international comparisons of physical activity levels of children and youth using the same survey instrument across countries. However, there are some physical activity data available from 35 countries who participate in the Health Behaviour in School-aged Children (HBSC) Study (24). In the 2001/02 HBSC survey, there was great variation in the proportion of youth who engage in 60 minutes of physical activity per day on at least 5 days of the week. On average, 34% of youth report meeting this guideline, ranging from 26% in Belgium to 57% in Ireland for boys, and from 12% in France to 44% in the United States for girls. Across countries, boys were consistently more active than girls, and there was a decline in physical activity levels with advancing age. Furthermore, the relationship between physical activity levels and the prevalence of overweight/obesity among adolescents has been shown to be quite robust across countries in the HBSC. In 88% of the countries participating in the survey, physically inactive adolescents had a significantly elevated odds of being overweight (25).

More concerning than even the self-reported prevalence data are those from physical activity levels objectively measured using accelerometry. Reports on objectively measured physical activity levels among children and youth have begun to appear (26–28). Accelerometry data from the European Youth Heart Study on 2185 9 and 15 year-old children and youth demonstrated a large drop in MVPA from 9 to 15 years of age. More recently, Ness et al. (26) collected accelerometer data on 5500 12-year old children as part of the Avon Longitudinal Study of Parents & Children. Overall, the children spent approximately 20 minutes/day in MVPA, with boys spending more time moderately active (25 min/day) than girls (16 min/day). Similarly, in the U.S., Pate et al. (28) has reported on accelerometry data from 1578 sixth grade girls from six cities. This study indicated that these girls participated in only about 24 minutes/day of MVPA, and 56% of their waking hours were spent in sedentary pursuits. Overall, the results from the objective physical activity monitoring studies confirm a relatively low level of MVPA in children and youth from Europe and North America and inconsistencies between self-reported and objectively measured physical activity levels.

On the opposite end of the energy expenditure continuum, several studies are also available in which physical inactivity levels in children and youth have been monitored. Ekelund et al. (29) reported

that 9 year-old children in the European Youth Heart Study spent 90–100 minutes/day watching television, with the boys watching slightly more than the girls. Further, the 15 year-old boys and girls in this study watched nearly 120 minutes of television per day. Australian youth show similar patterns; Salmon et al. (30) reported that among school children in Melbourne, 70% of boys 5–6 years of age and 80% of those aged 10–12 years watched $\geq$ 120 minutes of television/day. For the girls the corresponding figures were 65% and 85% for the respective age groups. In the U.S., data from the YRBSS have demonstrated that more than 40% of boys and girls in the 9th grade watch $\geq$180 minutes of television/day (21). This declines to about 30% watching this much television for those in the 12th grade.

Taken together, the results indicate that children and youth in much of the Western world have relatively low levels of MVPA, and spend a large percentage of their time in sedentary pursuits. However, there is a need for agreement on the definitions of adequate levels of health-enhancing physical activity for children. While technological advances have allowed for objective monitoring of physical activity levels to become more feasible for large-scale surveillance studies, it is recommended that more efforts be placed into arriving at an international consensus on defining accelerometry methods and cut-points. Clearly, international data are lacking. Further, it is recommended that a combination of accelerometry and self-report questionnaires be used to monitor physical activity levels. Accelerometry can provide objective data on intensity and amount of physical activity, while the questionnaires can provide information on the context, type of activity, location, and with whom the activity was undertaken. These data provide important insights needed to develop effective physical activity interventions.

Temporal Trends in Sedentarism and Physical Activity Levels of Children

Although the data suggest that there is currently a high level of sedentarism among children and youth, it is important to determine if there have been shifts over time, and to determine what the causes of these shifts may have been. Unfortunately there are no longitudinal trend data for physical activity energy expenditure from any country on representative samples of children and adolescents. It seems highly unlikely that total daily energy expenditure or physical activity energy expenditure can ever be measured accurately by questionnaire (at least in absolute terms), and better objective methods must be developed and applied to representative samples of children and adolescents. Within the context of the development of obesity, the major challenge is to detect a net change of no more than 20–30 minutes/day of moderate intensity activity. The resulting difference in physical activity energy expenditure could lead to substantial weight gain in as little as one year. However, some insights can be derived from data from self-reports of physical activity levels and time use studies.

Figure 2 shows the trends in physical activity and sedentary behaviour from 1999 to 2005 in the U.S. YRBSS. Approximately 70% of youth report being physically active to the extent that they engage in vigorous activity for at least 20 min/3 $\times$week and/or moderate activity for at least 30 min/5 $\times$week, while 10% of youth report engaging in no moderate or vigorous intensity physical activity over the course of the seven days prior to the survey. There appear to be no significant temporal trends in these markers of physical activity and physical inactivity between 1999 and 2005. These data are similar to those in other countries, which demonstrate no changes in the prevalence of children and youth performing moderate or vigorous physical activity (31).

Several sources of data indicate that there has been a decrease over time in walking and cycling for transportation by children and youth. For example, data from the U.S. National Personal Transportation Surveys indicate that walking to school as a percentage of trips to school made decreased from 20.2% in 1977 to 12.5% in 2001 (32). Similar trends are evident in Britain where the percentage children aged 5–10 years who walked to school decreased from 71% to 62% between 1975–76 and 1989–94 (33). Some of these trends may have occurred prior to the mid-1990s, so more recent surveys may show little change. Besides the apparent secular decline in walking to school, there is a remarkable 4–5 fold

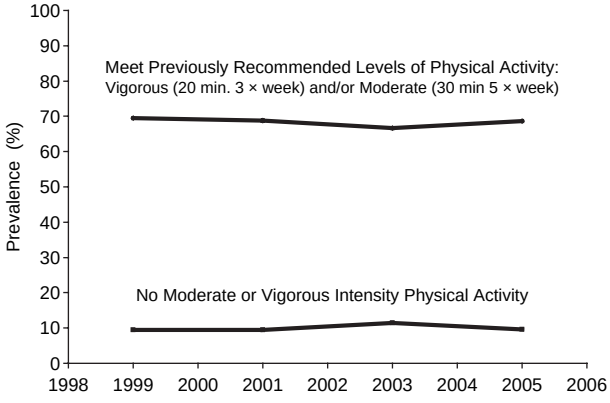

Figure 2. Trends in moderate-to-vigorous physical activity and sedentary behaviour among U.S. High School Students, 1999–2005. Data are from the National Youth Risk Behavior Surveys.

difference in the prevalence of children walking to school in the UK compared to the U.S.

The available data on time spent in sedentary activities is primarily limited to markers of television viewing. Studies generally show that the amount of time spent viewing television has not changed appreciably or has actually decreased over time (21,34); however, some trend data show increases in other "small screen recreational activities" such as video games and surfing the Internet. Due to the rapid adoption of new technologies by youth, accurate data on specific "small screen" behaviours are not available. In an era where television is being replaced by other screen activities, it is important to develop measures of "screen time" in order to better capture this component of sedentary behaviour.

Data on time use are very limited but suggest that at least in the U.S., play time and discretionary time have decreased substantially for children between 1981 and 1997 (35). Figure 3 demonstrates that the amount of discretionary time available to children has decreased by approximately 400 minutes per week in the United States. This decrease was largely the result of increased time spent in school, child care and studying and reading (35). The time use data also suggest that time spent playing decreased by approximately 500 minutes/week between 1981 and 1997. This is particularly troubling within the context of physical activity, as "active play" is often encouraged as an outlet for children to expend energy (36–38).

The available prevalence data indicates that there has been little change in sedentary behaviours *per se*, of children and youth in recent years. However, time use data suggest that there are more constraints on children's time, and thus fewer opportunities to be physically active. Given the high prevalence of children and youth that do not meet current recommendations for physical activity, every effort should be taken to re-introduce free-time and active play into the lives of our children.

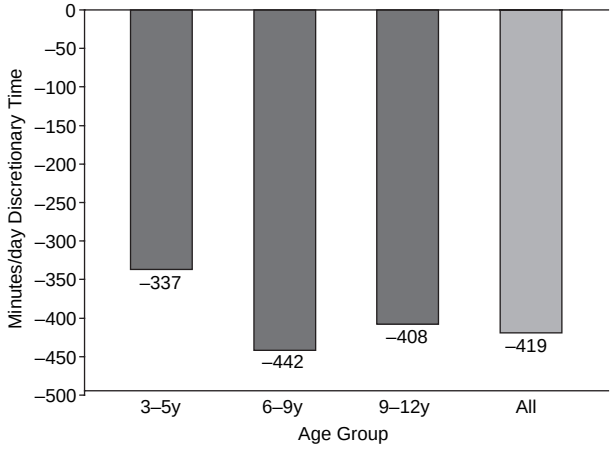

Figure 3. Changes in the amount of discretionary time for children in the USA, 1981–1997. Adapted from (35) based on data from reference (106).

Causes of Obesity in Children

Obesity is recognized as a chronic condition of multifactorial origin (39). Central to body weight regulation is the notion of energy balance. The gradual increase in body weight that leads to obesity is the consequence of a sustained positive energy balance (i.e., when energy intake exceeds energy expenditure). The concept of "energy gap" refers to this imbalance between intake and expenditure that explains weight gain in excess of normal growth in children (40). There are many factors that can influence energy balance and therefore that can be identified as contributors to the current obesity epidemic in children. These factors include biological, behavioural, environmental, as well as social influences. Importantly, many aspects of our behaviour and environment have changed over the last decades, and physical activity has to be seen in the context of these multiple changes. The dramatic changes in the prevalence of overweight and obesity in recent decades point to the influence of a complex array of environmental factors acting on genetically predisposed individuals. However, a precise and accurate understanding of causality is limited, partly because studies investigating these factors have often been hampered by methodological issues including cross-sectional designs, or being under-powered, or based on univariate analyses.

The relative contribution of energy intake versus energy expenditure to the obesity epidemic is a source of continuing debate. There are comparatively few longitudinal studies looking at the association between energy expenditure and weight gain. A range of endogenous factors influencing activity level (e.g. activity "temperament", "clumsiness" or sleep patterns) may predispose to, or protect against, obesity. Different types of time use by lean versus obese people may also explain some of the risk for obesity (41). Longitudinal studies show that active transport (walking and cycling) has decreased in many westernised countries while car use has increased (42). These secular trends are associated with changes in neighbourhood and transportation planning, as well as with changes in safety perception (43,44). Additional trends include the rise in electronic media use, especially by younger populations.

Some of the most studied influences on obesity relate to dietary intake and eating patterns. Marked changes in food practices in Westernised countries have occurred in recent decades. These include an increase in food availability (e.g. quick service

restaurants), "fast food" consumption (45), portion sizes, fat intake and sweetened drink (soft drink) consumption (46). Obesity is associated with a lower frequency of family meals, an increase in meal skipping (45) and restrained eating. Travel distances to fast food outlets are shorter in lower compared with higher socioeconomic neighbourhoods (47) and the cost of food is negatively related to energy density, so that energy–dense, nutrient-poor foods are cheaper than higher quality foods (48). These latter findings may partly explain the social gradient associated with obesity in westernised countries.

In order to set the stage for discussions of potential solutions to the problem of childhood physical inactivity and obesity, the biological, social and physical environmental factors related to obesity in children and youth are discussed below in greater detail.

Biological Predictors of Weight Gain

A fundamental question is whether a defective or maladaptative biology is involved in the predisposition towards sustained positive energy balance and the resulting weight gain. Several biological predictors of weight gain have been identified, including a low resting energy expenditure, low fat oxidation rate, low plasma leptin levels, and low muscle oxidative potential. Interestingly, although all of these factors have been linked to weight gain in normal weight subjects, they tend to be normalized in obese subjects. For example, a low resting energy expenditure for a given body composition is predictive of weight gain over time (49), whereas resting energy expenditure is higher in obese subjects due to a greater body mass (and fat-free mass) (50). To uncover such inter-individual differences in susceptibility to weight gain, a strong perturbation needs to be applied to the system in which these individuals live. This is the case with weight fluctuation studies such as overfeeding or negative energy balance studies (51).

Genetic Influences on Obesity

The next question is whether a defective or maladaptative biology which predisposes towards obesity is an acquired or inherited characteristic. A predisposition towards obesity appears to be unequally distributed in humans. Early studies showed that obesity tends to run along family lines (52), and several studies have indicated a "familial risk" of obesity such that a person's risk of being obese increases as the corpulence (BMI) of relatives increases (53–55). Increased rates of assortative mating for body fatness may also mediate the genetic component of obesity (56). As shown recently, mate selection appears promoted by similarity in body fatness and confers a higher risk of obesity in offspring. In Swedish subjects, obesity concordance in parents was associated with an obesity prevalence of 20.1% in adult offspring compared to 1.4% if parents were concordantly non-obese (57).

When individuals live in an "obesogenic" environment as exists in modern industrialized countries, many will gain weight. However, when individuals are exposed to a similar environment, not everyone will respond in the same manner. It is assumed that those with a high genetic predisposition for obesity will gain the most weight, an effect often referred to as gene-environment interaction. Support for this notion is provided by long-term controlled experiments on monozygotic twin pairs (58,59). In different experiments, pairs of identical male twins were subjected to approximately 100 days of overfeeding (1000 kcal/day), or 100 days of energy deficit (1000 kcal/day) through exercise training. These landmark studies showed that individuals with identical genotypes respond similarly in body mass and body composition when subjected to prolonged changes in energy balance, whereas the variability is larger among those whose genotypes differ. A more recent study has provided additional evidence for a genetic role in explaining variation in diet-induced weight loss among pairs of obese premenopausal female monozygotic twins (60).

Obesity represents a complex, multifactorial trait. As such, single gene mutations causing human obesity are extremely rare (61). To date, only a few hundred cases of human obesity due to mutations in 11 different genes have been reported. Interestingly, all of these major genes primarily relate to energy intake pathways, not energy expenditure. A frequently cited example of single-gene mutations causing obesity relates to the leptin pathway. In three of such leptin-deficient subjects with morbid obesity, treatment by recombinant leptin resulted in profound weight loss, together with increased physical activity, decreased food intake and beneficial metabolic and endocrine effects (62).

Most genes involved in more common forms of obesity are viewed as "polygenes"-those which make a relatively small contribution and explain less than 5% of the phenotypic variance. More than 400 such associations have now been reported in the literature, with 22 genes supported by at least 5 studies (61). Modern genome-wide search strategies may reveal new promising candidate genes. For example, recently an association was reported of a common variant in the FTO (fat mass and obesity associated) gene predisposing to type 2 diabetes through an effect on BMI (63). The association of the FTO

variant with BMI was replicated in 13 cohorts with 38,759 participants. Of note, the increased risk was also observed in children (from age 7 years) and reflected a specific increase in body fat.

Life-cycle Risk for Obesity and Obesity-related Complications

The U-shaped association between birth weight and later chronic disease raises the concept of a life-cycle or trans-generational escalation of obesity and of related disease (64). At one end of the birth size spectrum, low birth weight babies who then experience inadequate catch-up growth may become stunted children and adolescents. Such malnourished girls may become women who, during pregnancy, are at increased risk of having low birth weight babies due to inadequate fetal nutrition. If these babies are exposed to rapid weight gain following birth, they are at increased risk of later visceral obesity and obesity-associated complications, such as type 2 diabetes. At the other end of the birth size spectrum (and potentially more relevant for Westernised countries), high birth weight babies are at higher risk of becoming overweight children and adults. Overweight women are then more likely to have pregnancies complicated by glucose intolerance and diabetes, with resultant high birth weight babies-and thus the trans-generational cycle is perpetuated (65). This potential for a trans-generational escalation of obesity highlights the importance of intervening in adolescent girls and young women in particular, prior to pregnancy. The mechanisms linking birth size, fetal nutrition and later disease are poorly understood but involve epigenetic phenomena, whereby the expression of selected genes is altered through DNA methylation and histones (66), or programming of physiological and behavioural patterns.

Behavioural, Social and Environmental Determinants of Childhood Obesity

The biological and genetic factors that confer an increased risk of weight gain must be considered within the context of a behavioural and social milieu. Biological and genetic factors are generally difficult to change within an individual; thus, the role of changing behaviour in the context of the obesity epidemic is of paramount importance. There is a wide range of behavioural, social and environmental variables that have been linked to physical inactivity and obesity in childhood. Given the public health importance and the burden associated with physical inactivity, it is important to identify key moderators and mediators of physical activity that can guide successful interventions.

Controlled trials of physical activity interventions among youth have generally produced relatively weak results, probably because of a lack of focus on theoretically-based mediators of activity. In addition, measurement properties of scales used to assess mediators often lack verification of validity. The measurement of physical activity in most studies has been by self-report, with the obvious weaknesses resulting from misclassification. Multi-level conceptual models have been used by some investigators to evaluate physical activity interventions. Highly complex models are required and much additional work needs to be done. Advanced statistical methods such as structural equation modeling and latent growth modeling may enhance precision for evaluating multi-level, theoretically-derived analyses of change in physical activity, the results of which must then be translated into meaningful interventions.

Although often limited by correlational designs and measures that do not necessarily meet high psychometric standards, the current evidence is sufficient to encourage controlled trials of physical activity in children and youth. Further research is needed to determine the importance of actual and perceived environmental and social factors in mediating changes in physical activity.

In general there is a negative relationship between measures of physical activity and adiposity in children. In addition, the available data suggest that high levels of physical activity reduce the likelihood of weight gain over time (67,68). This is consistent with data in adults (69).

A direct relationship between time spent watching television and obesity has been found in most, but not all, studies in children (68). In other words, greater screen time is associated with a higher prevalence of obesity. The assumption of the converse argument is that if screen time is limited, physical activity energy expenditure will increase, and this effect has not been well described. Although the relationship is significant from a statistical point of view, its clinical importance has been questioned due to the small effect sizes observed (70).

In addition to cross-sectional and cohort studies, physical activity interventions provide information about the role that physical activity may play in explaining variation in childhood obesity. A meta-analysis examining exercise as an option in the treatment of pediatric obesity found that low-intensity, long-duration activity was most successful at changing body composition outcomes (71). Physical activity appears to contribute less than food restriction to weight loss, but a high level of physical activity is one of the common characteristics of

individuals who are successful in long-term weight loss maintenance. Adult subjects included in the National Weight Control Registry, who are maintaining an average weight loss of more than 30 kg over an average of more than 5 years, reported engaging in 60-90 minutes daily of physical activity, with about one third in high-intensity activity (72).

Reducing sedentary time is another complementary option that has been tested in children (73). In a randomized controlled study in 9-year old children in California, reduction of time spent viewing television was associated with a reduced growth-associated body weight gain over time (74). This is of major importance, since it is one of few successful interventions in the field of prevention of childhood obesity.

The amount of physical activity needed to prevent gaining or regaining weight obviously depends on the habitual food intake among the population in question. This means that the nutritional context must be considered. It may not be possible for many individuals with low physical activity levels to achieve energy balance at healthy body weights, regardless of the diet consumed. Additionally, there may be some enhanced sensitivity of energy balance regulation that occurs at high vs low levels of energy expenditure. This could be due to increased sensitivity of different homones and substrates.

In summary, many factors contribute to the development of childhood obesity, thereby offering multiple targets for intervention. Available data, although incomplete suggests that a low level of physical activity is a high risk for development of obesity and a high level of physical activity is a low risk for development of obesity. Given current knowledge, it is difficult to see how the prevalence of childhood obesity can be reduced without increasing physical activity; therefore increasing physical activity should be a high priority for addressing obesity in youth.

Social Determinants of Childhood Physical Activity and Obesity

The child's social environment can be considered at two levels – the micro level (family and peers) and macro level (organizations, communities and cultures, news, mass media, crime and traffic, socio-economic status, policies, etc.). A broad range of such influences can act independently and synergistically to influence a child's physical activity behaviour. The addition of further more distal influences – environmental, societal and global-creates a 'socio-ecological' model of physical activity (Figure 4). With such a broad range of factors combining to influence behaviour, multi-level interventions may

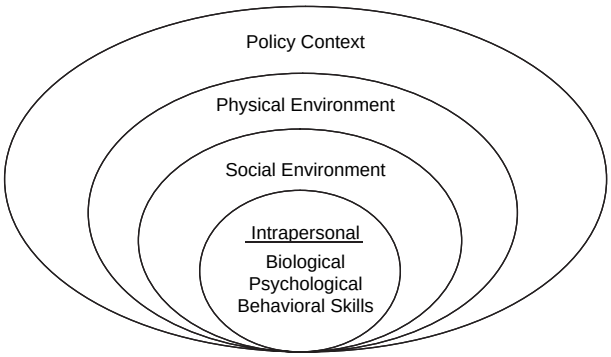

Figure 4. An ecological model of health behaviour (compliments of Dr. James Sallis, San Diego State University).

have the greatest likelihood of effectively increasing physical activity. This may be particularly true if all factors in the model are important and if there are important interactions between the levels. An important consideration is that individually-focused interventions are unlikely to succeed if the environmental conditions are not supportive. There may be a need to address the environment before attempting interventions addressing individuals.

A review by Sallis et al. (75) investigated the determinants of children's physical activity. One hundred and two studies were identified, incorporating 40 variables for children (3–12 years) and 48 for adolescents (13–18 years). For the socio-cultural variables, no determinants (out of nine studied) were significant predictors. In adolescents, four significant determinants (out of 10 measured) were identified: parent support, significant others support, sibling physical activity, and direct help from parents. For parents' activity, 50% of the findings were significant in both children and adolescents, but the results were not consistent across the age ranges in the two categories. This review has recently been updated by Van Der Horst and colleagues (76) using data from studies published from 1999 to 2005. The review included 60 studies, and the results indicate that among children 4–12 y of age, male gender, self-efficacy, parental support, and parental physical activity (for boys) were all positively associated with physical activity. Among adolescents 13–18 y of age, there was evidence that male gender, parental education, self-efficacy, attitude, goal orientation/motivation, physical education/school sports, family influences, and the support of friends were all positively associated with physical activity levels (76). Duncan et al. (77) have also reported sources and types of social support for children. Types of support were emotional (encouraging, discussing etc), and instrumental (exercising with child, transport, etc). The support of friends was the most strongly related to physical activity – friends

watching other youth being active was related to higher participation in physical activity.

In addition to overall physical activity levels, the correlates of specific components of physical activity and sedentary behaviour have also been investigated. For example, the correlates of children's vigorous activity have been reviewed (78). In both children and adolescents, parents' physical activity appears not to influence the child's activity; however, family and peer influences performed better.

The psychosocial and environmental correlates of sedentary behaviour in adolescents have also been investigated (79). Sedentary behaviours generally include television watching, computer/video games, listening to music and phone use. In the review by Norman and colleagues (79), the existence of television/video rules in the home was most strongly related to lower levels of sedentary behaviour. Rules governing television/video use were significant predictors in both boys and girls. A recent review (76) found evidence for associations between gender, ethnicity, depression, socioeconomic status, BMI, parental education and sedentary behaviours among adolescents. As noted above, television watching has received the most attention as a marker of sedentary behaviour (80). Levels of television viewing are higher in non-white populations, in low income groups, in households where parents' viewing hours are high and where the child has a television in the bedroom.

Active commuting to school is an important opportunity for improving children's activity (81). However, factors negatively affecting active commuting include parents' concerns about crime, traffic danger, walkability, distance, convenience of car transport, and child preferences. High income households demonstrate most walking to school. Income, walkability and parental concerns interact in complex ways to influence levels of active commuting. High income, high walkability and low safety concern show the strongest associations with active commuting.

Crime rates can also be barriers to physical activity (82,83). Results suggest that high crime rates increase television watching and prevent children from going outdoors. Interventions to reduce crime and fear have been conducted (84). Strategies included community policing, high visibility of open spaces, reduced litter and graffiti, and public spaces that encourage people onto the streets. Furthermore, walkability and crime interact – low crime and high walkability promote higher activity levels.

In summary, social factors at both the micro and macro level are significant correlates of children's physical activity levels. There is correlational evidence that parent, sibling, and peer support is related to youth physical activity, sedentary behaviour, and walking to school. Access to recreational programs in schools and communities is a consistent correlate of physical activity levels, and parents are gatekeepers of youth access opportunities for both physical activity and sedentary behaviour. Physical education classes, teacher's supervision at break time, playground markings and built sports and recreation facilities in schools, and even the school "footprint" in terms of size, may all contribute to increased levels of physical activity during school. Crime and fear of crime seem to be related to physical activity and television viewing. Although travel to school is an opportunity for physical activity in youth, parental concerns about traffic safety is a major barrier to children's active commuting to school.

The Role of the Family Environment

Physical activity levels may be affected by family norms and habits but little literature exists to support this contention. Unfortunately, even less evidence exists demonstrating the effects of family-based interventions on changing physical activity levels.

Children are undoubtedly different from adults in many ways, and effective child-focused interventions are likely to differ markedly from adult-focused interventions. Theoretically, younger children are more likely to be dependent on and influenced by their parents, whereas older children may be preparing for independence and leaving home and may be less influenced by the family. It might therefore be assumed that younger children may be easier to affect via family-focused interventions than older children. However, any intervention must be developmentally appropriate for the age and stage of development of the child.

The existing family-based intervention trials that have attempted to impact either physical activity or obesity among children and youth have used a variety of approaches to engage the family. These include 1) directly engaging the parents in a formal exercise program, 2) directly engaging the parents in an educational program, 3) simply sending educational material home. There is great variability in the quality of the existing studies in terms of design, theory base, evaluation, and statistical power, which hinders comparisons across studies.

To date, there is little evidence for effective family-based programs that have a significant impact on obesity or physical activity among children and youth; however, moderate intensity interventions seem to show some promise. In order to develop effective family-based interventions, the key

predictors of physical activity change must be incorporated into the intervention. At the present time there is a general lack of good information of determinants of physical activity changes in children and youth – thus, this is an important area for future research, as a strong scientific basis for future interventions will allow for stronger evaluations of success.

The Role of the Physical and Built Environment

The physical environment refers to everything tangible in our environment, as opposed to the social environment which would be considered intangible. The child's social environment may influence how they respond to the physical environment. We can engineer the physical environment but people might not find it acceptable, as humans have evolved to habitually save energy and much of that physical activity behaviour is 'automated' rather than planned. It may be that automated, unconscious activity is more likely to be sustainable than planned exercise. In other words, people may achieve greater success in becoming more active in situations where they pay less attention to themselves and more attention to the environment. There are mainly three settings in which the environment can have an influence on physical activity behaviour. These include the home, school and community.

The home environment has not been extensively studied in terms of its relationship with physical activity levels of children and adolescents. Affluent homes in Western society are relatively large and well equipped for physical activity. Facilities such as yards, gardens, swimming pools, bikes, dogs and treadmills can all support an active lifestyle. However, homes might also be barriers, as they are thought of as safe places to rest, rather than settings for active pursuits. Homes are also where access to the internet and television exist, which compete powerfully for children's free time. Time spent outdoors predicts higher physical activity levels and household 'rules' predict lower physical activity (85). Generally, while at home, children receive many prompts to be sedentary whereas outdoors the majority of prompts are for activity. Parents can also be a barrier, with 85% of parental prompts to boys, and 65% to girls, being to be sedentary while indoors (85). Overall, as a population strategy, the home is not a promising setting for promoting physical activity. The home is a place where sedentary behaviour prevails, and children should be encouraged to go outside. To date, there is little evidence for the effectiveness of changing the home environment, with the possible exception of television viewing (74).

Most modern schools are generally well equipped for physical activity, with opportunities for active commuting, sports facilities, physical education classes, grounds for recess and physical activity, and after-school opportunities for active pursuits. However, active commuting to school has been declining since the mid-1980s (32,86). On the other hand, intervention research has demonstrated that the school environment can be modified to improve physical activity levels. For example, school playgrounds can be modified to promote higher levels of physical activity that are relatively sustainable (87,88), and building a playground decreases sedentary time and increases physical activity (89). It should be kept in mind that the social context of playgrounds is as important as the design and construction of the playground or any modifications.

In community settings, land use, proximity to destinations and neighbourhood amenities may all influence the physical activity levels of children and youth. Urban design determines the distance people have to travel between destinations, and adults tend to walk more in more densely populated areas. However, the results for children are equivocal (90–92). Parks were originally designed to promote active recreation, and living near to a park predicts park usage. Neighbourhood and community parks seem to promote higher physical activity levels. Amenities within a park may also influence physical activity positively (providing shade, availability of water or fluids, lighting, etc.). The existence of a commercial physical activity amenity in proximity to home is associated with higher activity levels in boys and girls. Cycleways can improve physical activity levels including new users (i.e. not displaced users from roads). However, results in this area are variable (93,94). In most cases, it is not sufficient to make alterations to the built environment, rather there needs to be some motivation and public education to activate the use of the changed element.

In summary, there is evidence that the built environment can influence physical activity levels. However, the role of the built environment as a determinant of physical activity levels in children and youth does not have a weight of evidence behind it as yet, and this may be a more long term research focus that nevertheless may yield important results. Future research could incorporate the use of geographic information systems (GIS) to better assess the objective features of the built environment, and the use of global positioning systems (GPS) to better monitor children's actual movements within their physical environment. The ability to modify physical

activity behaviour by intervening in the built environment within which children live is an important area that requires further research.

Can the Physical Activity Deficit be Addressed Through Legislation?

Much of the Western world lives in an era of abundance, convenience and choice. Within this context, obtaining adequate amounts of physical activity on a daily basis becomes an increasingly difficult proposition. Although obesity is an outcome determined by a disruption in energy balance that is ultimately controlled by the individual, and to some extent their genetic make-up, there is increasing evidence that there are environmental and societal constraints on the ability to live a healthy lifestyle – one that is conducive to maintaining body weight. These constraints are compounded during childhood, which is a time when external factors are often controlled more tightly by an adult (parent, teacher, etc.). It is apparent that childhood obesity is a complex problem, and will require a complex, system-wide approach to addressing the issue.

Potential legislation to address the physical activity deficit in childhood can take two main forms – direct and indirect. Direct approaches include such things as legislating increased time allotted for physical education or daily physical activity during the school day, or subsidizing fitness club memberships and providing tax incentives for participating in organized or social sports programs. Indirect approaches include invoking legislation that alters or controls aspects of the built environment that promote physical activity. Examples of indirect legislation that can have a positive impact include altering building codes to include mandatory, appealing and visible stairwells or altering traffic flow patterns and access to car parking to allow for active transportation to be an easy option.

In short, legislation has a role to play in addressing the physical activity deficit by making the healthy choice the easy choice. This can only be accomplished by altering the social milieu through a combination of direct and indirect forms of legislation. There is currently little research available to guide the development of healthy policies; however, this should not lead to lack of action. Commonsense approaches to legislating increased physical activity levels should proceed within a strong research framework which will allow the evaluation of the different approaches used.

Developing a political agenda around physical activity for healthy living is a difficult and daunting prospect. Strategies that align public health priorities with priorities in other sectors will have the greatest chance of succeeding. For example, global warming is a major issue facing the modern world; thus, public health policies that address increasing physical activity within the context of reducing the reliance on fossil fuels and the reduction of greenhouse gas production is an enormous opportunity for advancing the physical activity agenda. The vision of a healthy, active society can only be realized with cohesive legislative efforts that change the cultural norm.

Can the Physical Activity Deficit be Addressed Through Public Health and Formal Education Approaches?

In the absence of an abundance of evidence on which to base the development of public health strategies, decisions must be made on the best available evidence. One could consider public health strategies based on this level of evidence as evidence-informed rather than evidence-based. At the present time, most intervention research being conducted does not mesh well with the way that public health problems are approached. For example, most research studies are tightly controlled, follow a standardized mode of delivery, and are self-contained. This is in contrast to most public health approaches in which programs are invested in the community, use multiple complementary delivery strategies, and are modified based on feedback from the stakeholders. In order to better inform the development of health policy, it is imperative that researchers work more closely with decision makers. Given the urgency to act on the problem of childhood obesity, the evaluation of existing practice-based interventions should become a priority.

Although clear evidence exists that there is a problem related to physical inactivity and obesity in children, the specific action that needs to be taken remains elusive. The International Obesity TaskForce has developed an evidence framework for obesity prevention, which is a useful tool to prioritize those strategies in which to invest (95). The best or more promising strategy for action will most likely differ across societies, cultures and specific contexts. The best interventions must be highly contextual which means local situations must be considered. It is important to increase physical activity levels of children and youth; however, the current evidence base suggests only modest effects on adiposity. Whatever strategy is chosen, it should be developed within a framework that allows for the effective evaluation of meaningful outcomes. Just as the

strategy may differ across context, so might the outcome of interest (i.e. increase in physical activity versus obesity reduction).

Can the Physical Activity Deficit be Addressed by the Private Sector?

Addressing the issue of physical inactivity in childhood will take the concerted effort of both the public and private sectors. Currently the investment in the promotion of physical activity is dwarfed by investment made in products designed to increase sedentary behaviour. For example, although the sales of sports products have been increasing over time, they remain a fraction of the amount spent on televisions (96). In order to get buy-in from industry to promote physical activity, it is important to frame the problem within the context of rising rates of obesity, disease and its impact on the economy. A business model is required in order to achieve changes in physical activity. Unfortunately, there are no compelling short-term incentives or disincentives for promoting physical activity – the benefits have to be viewed as long term.

In North America, industry has played a role in shaping our current environment. For example, by responding to consumer demand for time-saving, energy-conserving technologies, the private sector has allowed for the engineering of a physically inactive society. The central question that needs to be addressed now is how to change the culture to make a physically active lifestyle the norm. The private sector is a powerful player in a consumer-driven society, and has a role to play in shifting the culture in a positive direction.

There are several ways in which the private sector can aid in the promotion of healthy lifestyles. For example, industry can make an active lifestyle an expectation in the workplace, and support it with worksite wellness programs. Further, industry can innovate to fill demand for products and services that promote active lifestyles, and channel demand toward healthier choices, if the demand is present. On a broader scale, industry can help set principles and codes of conduct for marketing and advertising to best encourage healthy lifestyle choices, and partner with other sectors to create an environment that supports healthier choices. This in turn will increase demand for healthier alternatives and will in the long run feed back into further profits. Engaging the private sector in the promotion of physical activity will not be easy in the absence of a solid business model; however they represent an important component of society that needs to be engaged in this endeavor.

Are There Successful, Innovative, Community-based Physical Activity Interventions?

There are several types of interventions that have shown promise in increasing physical activity levels. In broad terms, informational approaches include community-wide education and point-of-decision prompts, behavioral and social approaches include school-based physical education, social support programs, and individually adapted behavior change, and environmental and policy approaches include changes to urban design and land use, as well as enhanced access to opportunities to be physically active (97). Several successful community-based interventions, using a variety of these approaches, have been identified through systematic and narrative reviews.

A multidisciplinary team of researchers recently conducted a comprehensive systematic review of best practices for reducing obesity and related chronic disease risk factors in children and youth (98). While no single intervention emerged from the review as a model for "best practice", several elements were identified across successful interventions that can be used to guide the development of future intervention efforts. The interventions were centered on elementary schools, high schools, communities, and in clinics. Many of the programs that were reviewed included physical activity as a component of the intervention, and physical activity seemed to be a key factor in the success of many interventions. For example, changes in body composition occurred most frequently in interventions that also demonstrated an actual change in physical activity levels. Further, physical activity was a key component of 75% of the interventions that showed improvements in chronic disease risk factors. In general, improvements in body composition were greatest in the short-term interventions compared to longer-term interventions, which highlights the issue of whether the observed benefits of the programs are sustainable over longer time frames (98). A narrative review (99) has suggested that physical activity interventions in the school setting are most effective if they include a focus on physical education, activity breaks and family strategies.

An important contribution to the International Conference on Physical Activity and Obesity in Children was the presentation of two specific examples of recently evaluated interventions which have been shown to be effective, the French ICAPS Study (Intervention Centered on Adolescent's Physical Activity and Sedentary Behavior) (100,101) and the Australian Switch-Play study (102).

ICAPS is a 4-year randomized controlled trial (randomized at school level) targeting 6th grade adolescents in Eastern France. A theory-based multilevel intervention was built upon the dynamic interplay among personal behaviors and broader social and environmental factors. The program included an educational component, coupled with new opportunities to be physically active during the school day. Through regular meetings, parents and educators were also encouraged to provide support to enhance the adolescents' physical activity. The full 4-year results are currently being tabulated; however, after 6 months of follow-up, adolescents in the intervention schools had significantly higher levels of leisure-time supervised physical activity and lower levels of sedentary behavior relative to youth in the control schools (100,101). The two-year results also demonstrated a reduced risk of being overweight in the adolescents in the intervention group relative to the control group (103). The components of parent and teacher involvement, increased opportunities for physical activity, increased social support and education are factors common to other successful school-based interventions (98).

The Switch-Play study is an Australian intervention aimed at preventing excess weight gain, increasing time spent in physical activity, and reducing sedentary behavior among 10-year old children (102). The intervention consisted of a behavioral modification program, a fundamental motor skills group, or a combination of behavior modification and fundamental motor skills. After 6 and 12 months of follow-up, the combined behavior modification / fundamental motor skills group had a significantly lower age-adjusted BMI and lower prevalence of overweight compared with controls (104). Work is on-going to test the effectiveness of these physical activity interventions in both ideal and real-world settings within the context of the Switch-Play design, and the Switch-Play program has recently been developed for delivery in Canada. Examination of the mediators of this intervention will provide important information on the tailoring of this program to suit both genders, and make it more widely available for use in other settings.

Much of the evidence for effective community-based interventions comes from developed countries in North America, Europe and Australia. A key question that remains to be addressed is whether these intervention strategies can be applied in transitional and developing countries. Further, it is also unclear whether important interventions from Latin America and other regions may have been missed by the existing systematic and narrative reviews that have been conducted (97–99). An important project that is tackling this issue is GUIA (Guide for Useful Interventions in Brazil and Latin America), a Special Interest Project being conducted at Saint Louis University School of Public Health, funded by the U.S. Centers for Disease Control and Prevention (105). The results of this project to date indicate that there is a strong need for rigorous evaluation of promising physical activity interventions for children in developing countries, and that school-based physical education was the only intervention that demonstrated strong evidence of effectiveness based solely on Latin American data.

Community-based interventions show promise for increasing physical activity levels among children and adolescents. There are several strategies that should be employed by practitioners to increase the effectiveness of their interventions. First, local surveillance is important to determine the baseline levels of physical activity, and to better understand the social and environmental contexts of the area which will guide the development of an effective program. Second, it is important to design interventions that are sustainable over time; thus, a focus on policy and environmental changes is important. It is frustrating to see effective interventions flourish and then fade out after an initial investment in the program runs its course and is discontinued. Third, it is important to link with researchers at academic centers for technical assistance where needed, and for input into the design and evaluation of the program. Finally, thought should be given to how the knowledge and experience gained in the intervention will be shared with others. There is much to be learned from both successful and unsuccessful interventions that must be disseminated so that future interventions can be informed from past efforts.

Recommendations

Several recommendations can be gleaned from the proceedings of the International Conference on Physical Activity and Obesity in Children. These are framed below under the headings of Research, Policy and Practice. It is hoped that evidence presented at the conference will help shape the agenda in each of these three domains in the coming years to reduce the prevalence of childhood obesity through the promotion and adoption of healthy physically active lifestyles for all children and youth.

Research Recommendations

- There is a need for ongoing work on the definitions of overweight and obesity in children and youth, particularly studies that investigate

the influence of ethnicity on the utility of BMI-for-age cut-points for identifying obesity-related health risks.
- Research that quantifies the energy imbalance responsible for recent changes in population weight distribution among children is an important step that can provide targets for population intervention.
- There is a need for further research on compensatory physical activity behaviour that may occur as the result of an intervention. In other words if new physical activity is introduced as part of a lifestyle intervention, do children compensate for this by reducing physical activity levels in other aspects of their life?
- Given the evidence that physical inactivity may be an important determinant of weight gain in children, consideration should be given to the development of guidelines or recommendations on sedentary behaviour.
- There is a need for an international consensus on accelerometry in order to standardize methods and the cut-points used to define physical activity and physical inactivity.
- Given the questionable utility of applying adult MET values in studies of children and adolescents, more research is required to better understand the amount of energy expended by children and adolescents when performing specific activities.
- To better characterize physical activity levels, studies should begin to incorporate multiple methodologies such as accelerometry and self report questionnaires to obtain a better picture of not only the amount of physical activity but the context in which it is performed.
- Given the complex relationship between physical activity and weight gain, it is important to develop complex models that allow for the measurement of the effects of confounders rather than simply adjusting or controlling for them.
- Given the importance of energy balance in the development of obesity, more research is required to understand the effects of the total volume of energy expenditure (i.e. area under the curve) rather than moderate-to-vigorous physical activity *per se* on the development of obesity.
- Physical activity and dietary intake are the key components of energy balance; thus more attention should be paid to incorporating both of these domains in research studies.
- More research is required on the role of physical activity in weight gain prevention, weight loss and in the maintenance of weight loss in children and youth.
- More research is required on the effectiveness of family-based physical activity interventions and the role of parenting style on the development of obesity.
- More research is necessary in the areas of gender and ethnic differences in parenting and its influences on physical activity to develop culturally appropriate interventions.
- There is a need to develop research models to better understand parent mediating variables, and on changing parenting behaviours might affect physical activity and obesity in children.
- In order to develop age-appropriate interventions, more research is required on the determinants of physical activity in children at different ages. The knowledge base needs to include documented causal relationships, and models that account for a substantial proportion of the variance in order to inform the development of effective interventions.
- More research is required on the effects of the components of the built environment as a determinant of childhood physical activity and obesity. More research is required to determine the effects of the home, school and community environment on physical activity levels.
- Given the evidence that simply changing the built environment may not be effective in changing physical activity behaviour in children and youth, more research on the effectiveness of combinations of social and built environment interventions is required.
- The monitoring of children's movement patterns through the built environment and level of physical activity using global positioning systems is an important area of future research.
- There is a need for more research into the biological determinants of physical inactivity and obesity in children and youth. The causes and prevalence of a defective or maladaptive biology will inform the expected effectiveness of behavioural interventions.
- More research is needed to develop a business case for physical activity. Studies addressing the economic burden of physical inactivity and the economic benefits associated with the promotion of physical activity are required.
- More research is needed to understand the parent and child decisional factors as they pertain to active play and active commuting. Such information can lead to targeting specific barriers in family interventions to increase physical activity and decease screen time.

- Multi-disciplinary, multi-sectoral research is difficult to conduct; however, more research is required that better aligns with policy and practice. Thus, policy-makers and practitioners should be integrated in research teams.

Policy Recommendations

- There is a need for ongoing surveillance and monitoring of overweight and obesity in child, adolescent and adult populations.
- Research funding is required to support observational cohort studies of predictors of change in physical activity in children in order to delineate the determinants of physical activity that are amenable to intervention.
- Research funding is required to support studies to evaluate the effectiveness of physical activity interventions among children in different social and environmental contexts.
- There is a need to advocate for public health policies that make the healthy choice the easy choice. The opportunity to be physically active should be the optimal default.
- There is a need to advocate for the development of both direct and indirect legislation that allows for the promotion of physical activity. Innovative approaches to increase opportunities for physical activity are required.
- There is a need for innovative approaches to align public health objectives related to physical activity with the objectives in other sectors, such as transportation, education and the environment.
- Schools should implement interventions that promote physical activity, as there is good evidence that the school environment is a good setting to achieve positive outcomes.
- In order to better inform public health policies related to physical activity and obesity in children and youth, it is imperative that researchers work more closely with decision makers.
- The private sector is encouraged to make an active lifestyle an expectation in the workplace, and support it with worksite wellness programs.
- The private sector is encouraged to pursue innovations to fill the demand for products and services that promote physically active lifestyles, and to channel demand toward healthier choices wherever possible.

Practice Recommendations

- Physical activity is an important component of the energy balance equation. Thus, interventions aimed at reducing obesity in children and youth should include physical activity as a key component of the strategy. The amount of physical activity required to prevent or treat obesity depends on the level of dietary energy intake, so physical activity interventions need to consider the nutritional context of the population.
- There is promising evidence for the role of parents and specifically, certain types of parenting behaviour, in encouraging physical activity behaviour in children. These innovative strategies should be evaluated and adopted.
- There is a need to consider crime reduction and traffic control strategies as components of physical activity promotion.
- Efforts should be made to increase access to physical activity opportunities and programs at schools and in community settings, especially for low-income youth.
- The best interventions are context specific, so they must be developed locally. Implementation of local interventions should be informed by promising practices that have been developed by local experience in combination with published evidence of effectiveness.
- Efforts should be made to invest in environmental changes and policy development that will ensure the longer term success and sustainability of promising interventions
- Evaluation is a key component that needs to be built into any intervention. It is recommended that public health practitioners partner with local researchers to ensure that their physical activity interventions are properly documented and evaluated.
- Standardized research and evaluation systems are required in order to achieve coordinated prevention that builds upon existing knowledge, and to avoid the duplication of efforts at the local level.

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