FACTORS ASSOCIATED WITH PHYSICAL ACTIVITY IN EARLY CHILDHOOD

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INTRODUCTION

Worldwide trends in childhood obesity are disconcerting given the likelihood of obese children becoming obese adults (Guo *et al.*, 2002). An important publication by Tremblay and Willms (2000) exposed dramatic increases in the prevalence of overweight and obesity in Canadian children. Notably, the largest increases tended to be in the youngest (7-year-old) children (Tremblay & Willms, 2000). Whether children younger than 7 years would have demonstrated even larger increases is unknown. However, in two independent reports representing two separate regions in Canada, the estimated prevalence of overweight among 2- to 5-year-old children was ~11% (He & Sutton, 2004) and ~18% (Canning *et al.*, 2004). It is also noteworthy that prevalence of overweight and obesity has been negatively correlated with levels of physical activity (PA) in Canadian children (Tremblay & Willms, 2003). Although the importance of regular PA is indisputable, the determinants of PA among children and adolescents are not well understood. Theoretically, establishment of appropriate PA habits in early childhood should translate into positive health consequences later in life, and evidence is accumulating that increased PA in preschool-age children is associated with improved health status (e.g., Binkley & Specker, 2004; DuRant *et al.*, 1993; Saakslahti *et al.*, 2004). Therefore, identifying determinants of PA during early childhood seems particularly relevant, and this area is attracting a renewed scientific interest.

Recently, the Centers for Disease Control and Prevention (CDCP) in the United States convened an expert panel to examine the issue of measuring PA and sedentary behaviour in preschool-age children (Fulton *et al.*, 2001). From this meeting, a number of research topics were advanced, including the need to identify determinants of PA. In a

similar fashion, the purpose of this review is to identify factors that have been related with PA during early childhood. In the majority of cases, the available literature describes these relationships based on correlational analyses. Thus, inferences of cause and effect can not be confirmed.

LITERATURE SEARCH STRATEGIES

To identify relevant publications for this review, the following strategies were employed:

- A literature search performed electronically on Pubmed[1]. The keywords used and their combinations were as follows: "**physical activity**" *AND* **preschool**; "**physical activity**" *AND* **nursery**; "**physical activity**" *AND* **infants**.
- Scan of the reference lists of relevant publications derived from the above electronic search.
- Scan of *Pediatric Exercise Science* (all issues) for relevant articles on the topic.

Given the focus of this paper is on the period of early childhood, an arbitrary age range of 0 to 5 years was imposed. Consequently, studies that combined data from younger children (i.e., < 5 years) with children older than 5 years were not considered further. For interest's sake, a frequency distribution of the original articles, which served the evidence for this review, is presented by year of study publication in **Figure 1**. Although every attempt has been made to retrieve the most relevant articles, this review should not be considered comprehensive in an absolute sense. Some relevant characteristics of the studies used in this review are presented in the **APPENDIX**.

[1] Pubmed is available at http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?db=PubMed and includes Medline journals.

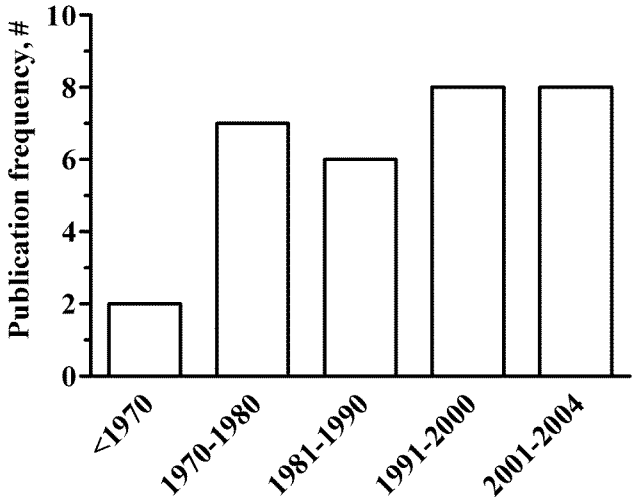

Figure 1. *Frequency distribution of publications used in this review according to year of study publication.*

DEFINITIONS

Among the studies included in this review, the amount and nature of PA varies considerably from one to another, with no consistent operational definition. For the purpose of this review, the term ***physical activity*** refers to any bodily movement produced by skeletal muscles resulting in energy expenditure (Malina *et al.*, 2004). Intuitively, PA performed by children 0 to 5 years of age might be described more appropriately as ***play***. Burdette and Whitaker (2005) defined play as "the spontaneous activity in which children engage to amuse and to occupy themselves" (p. 46). Thus, play can be considered a form of PA that can also represent various levels of intensity. Other definitions of relevant terms used throughout this document are listed below and are derived from Malina et al. (2004).

- ***Energy Expenditure (EE)*****:** An expression of total-body metabolism during specific time periods comprised of resting EE, diet-induced EE, and activity-induced EE.

- ***Activity Energy Expenditure (AEE)***: The amount of EE beyond that required for resting metabolism and for the digestion, absorption and storage of nutrients.
- ***Physical Activity Level (PAL)*:** The ratio between total EE and resting EE used to estimate the contribution of AEE over a given time period.

MEASUREMENT ISSUES

Measuring PA in free-living humans, in particular young children, is technically challenging. Obviously, conclusions based on PA data are only as strong as the validity of methods used to collect the information. A wide range of techniques exist to measure PA in children, and a number of different methods have been employed in the studies reviewed (see **APPENDIX**). A detailed description of each method is beyond the scope of this review. It is important to note, however, that a combination of methods is most recommended (Malina *et al.*, 2004).

FACTORS ASSOCIATED WITH PHYSICAL ACTIVITY (PA)

The following sections describe relationships between PA and various factors, which I have broadly categorized as *Biological*, *Psycho-social*, and *Environmental*. These classifications are similar to those previously described by Kohl and Hobbs (Kohl, III & Hobbs, 1998). Importantly, many of these factors are modifiable, which implies that interventions targeted at them may have positive consequences on levels of PA in growing children.

Biological Factors

Age

A well-described activity-related phenomenon during adolescence is a gradual decline in levels of PA over time (Malina *et al.*, 2004). Torun et al. (1996) also noted temporal reductions in daily energy expenditure (EE) during early childhood, apparently beginning at ~3 years of age. In contrast, activity EE (AEE) gradually increases during the first 2 years of life (Butte *et al.*, 2000). However, few data are available regarding secular trends in PA of children 0 to 5 years of age. Reilly and colleagues reported a positive correlation between PA and age in 3- to 4-year-old boys, but not girls (Jackson *et al.*, 2003) and between physical activity level (PAL) and age in 3- and 5-year-old boys, but not girls (Reilly *et al.*, 2004). Likewise, Pate et al. (2004) reported that, compared with 3-year-old children, 4- and 5-year-old boys and girls spent more time in sedentary activity. In addition, the amount of time spent in light activities was greatest in 3-year-old, intermediate in 4-year-old, and least in 5-year-old children. However, there were no differences between age groups for moderate-to-vigorous PA (MVPA) or vigorous PA (VPA). Another study by Lawson and Ingleby (1974) found a positive correlation between total play and age from ~3 months to 3 years, with the amount of total play apparently reaching a plateau by 3 years of age. However, these authors also noted a positive correlation between total play and time awake. Thus, the proportion of time spent playing actually decreased with age, when time awake was taken into consideration. Unfortunately, this study could not provide the intensity of activity during the time spent playing.

Age is also likely to influence activity behaviour. For example, Tizard et al. (1976) noted that, compared with 4-year-old children, 3-year-old children less often chose to play outside and spent more time playing on their own. These age-related differences remained even after length of attendance at their preschool was statistically controlled.

Taken together, the findings of studies describing the influence of chronological age on levels of PA during early childhood are equivocal. Although it seems reasonable to recommend that no age is too young to begin encouraging PA, it will be important to identify ages that may be of particular relevance for the development of PA behaviour.

Gender

One of the most consistent findings in the studies reviewed was the existence of a gender difference in PA behaviour of young children. Even as young as 18 months, boys were found to be more active than girls over a 24-hr period (Vara & Agras, 1989). Eaton and Enns (1986) have also concluded that boys are more active than girls during infancy. However, using an objective measure of PAL, Reilly et al. (2004) found a gender difference at five, but not at three, years of age. Higher activity levels in boys *versus* girls have been reported whether the method of determining PA is by parent report (Lawson & Ingleby, 1974; Telama *et al.*, 1985), direct observation (Baranowski *et al.*, 1993; Clark *et al.*, 1969; Goldberg & Lewis, 1969; Halverson & Waldrop, 1973; Harper & Sanders, 1975; McKenzie *et al.*, 1992), accelerometry (Buss *et al.*, 1980; Finn *et al.*, 2002; Jackson *et al.*, 2003; Pate *et al.*, 2004) or doubly labelled water (Reilly *et al.*, 2004).

A closer examination of these gender-related differences reveals that not only do boys engage in greater overall amounts of PA, they also tend to engage in higher intensity activities than do girls (Goldberg & Lewis, 1969; McKenzie *et al.*, 1992; Saakslahti *et al.*, 1999; Telama *et al.*, 1985). In addition, Harper and Sanders (1975) noted that boys spent more time out-doors than girls and used more play space than girls. Goldberg and Lewis (1969) reported that girls, more than boys, tended to sit and play with combinations of toys. This latter observation suggests that the nature of play and PA among children is likely to have implications for the choice of measurement instrument, since an accelerometer, for example, would not likely detect the female activities described by Goldberg and Lewis (1969).

What is less clear, however, is why such gender-related differences exist, even in infancy. The presence of gender differences in motor activity even during very early life suggests some hereditary influence (Thomas & Thomas, 1988). For the most part, however, studies have determined PA in boys and girls when they are together and share the same environmental influences. Therefore, it would be interesting to determine the nature and intensity of PA of boys and girls when they are assessed separately. Thomas and Thomas (1988) proposed that social more than biological determinants are likely to influence gender differences in PA during early childhood.

Body Fatness

Given that weight control is a delicate balance of energy intake and EE, low levels of PA could contribute to excess weight gain. Conversely, excess weight gain could contribute to low levels of PA. Recently, Trost et al. (2003) determined levels of PA in overweight (n=60) and normal weight (n=185) children (3 and 4 years of age)

attending preschool. All activity-related measures, either derived from accelerometry or direct observation, were lower in overweight *versus* normal weight boys, but similar between girls of different body weight. Likewise, Kagamimori et al. (1999) reported increased levels of physical *inactivity*, as determined by questionnaire of a caregiver, in obese *versus* non-obese 3-year-old Japanese boys and girls.

In line with these observations, the PAL of infants (Tennefors *et al.*, 2003) and young children (Atkin & Davies, 2000) has been shown to correlate inversely with their estimated body fatness. In contrast, Noland et al. (1990) did not find an effect of a child's relative weight status (% of expected weight) on their directly observed activity levels. However, activity monitoring in this last study was conducted in a church basement, and these artificial conditions probably did not reflect the children's true activity behaviour.

As alluded to earlier, it is difficult to ascertain whether physical *inactivity* is a cause or consequence of increased body fatness in young children. Li and colleagues (1995) directly observed PA in 31 infants (16 female) for six hours on three occasions, when the children were 6, 9, and 12 months of age. Activity levels at 12 months were inversely correlated with body fatness at 6 months, but PA at 6 months was not related to body fatness at 12 months. In other words, fatter babies at 6 months of age were less active later in infancy, but a low level of PA in early infancy was not a good predictor of body fatness in later infancy. This study suggested that increased body fatness may lead to physical *inactivity*, and not *vice versa*. Further support for this possibility comes from two studies. First, Klesges et al. (1986) studied children between ~2 and 4 years of age, with PA directly observed in their home. With this approach, extreme, but not minimal

or moderate, levels of PA were correlated inversely with the child's relative weight (%ile for age). In other words, children heavy for their age were less inclined to engage in high-intensity PA. Second, Pate et al. (2004) found that a child's body mass index (BMI) was a significant predictor of their VPA, but not MVPA.

A number of studies suggest that increased body fatness is associated with reduced levels of PA during early childhood. Moreover, there is some indirect evidence that low levels of PA may, in fact, be a consequence of overweight. In particular, future research should investigate the potential of body fatness to regulate intensity of PA, given the implications for AEE.

Motor Skills

One might argue that development of motor skills should allow a child to be more physically active. Conversely, a more physically active child may better develop their motor skills. Sääkslahti et al. (1999) found that parent-reported PA in 3- and 4-year-old children correlated positively with the children's measured motor skills. Clearly, more work is needed to describe a possible relationship between acquisition of motor skills in early childhood and overall levels of PA. The importance of this initiative has been advanced by the CDCP's expert panel (Fulton *et al.*, 2001), but questioned by Pate (2001).

Genetics

The influence of genetics on activity behaviour of young children has been examined by Willerman (1973). In this study of 61 sets of twins, mothers retrospectively rated the activity behaviour of both twins with a questionnaire. In children under 50 months of age, the activity levels of monozygotic (36 sets) and dizygotic (25 sets)

siblings were strongly correlated (r values of 0.9 and 0.6, respectively). Based on these results, the author concluded "a substantial heritable component to activity level" (p. 292). The findings, however, must be interpreted with caution given the potential for bias in the mothers' assessment of her children's activity level and the fact that both siblings had been exposed to the same environmental influences. Further investigations into the possible influence of genetics on activity levels, however, seem warranted.

Psycho-social Factors

Ethnicity

One might argue that socio-economic and/or cultural differences among ethnic groups could possibly impact a child's opportunity for PA. In a few instances, differences between Caucasians and ethnic minorities have been reported. In a group of 4-year-old children, Sallis et al. (1993) reported that Anglo-Americans were more active than Mexican Americans. More recently, Pate et al. (2004) reported higher MVPA and VPA in 3-, 4-, and 5-year-old black children, compared with white children. This latter observation is interesting considering that PA of all the children was determined at their preschool and not in their home environment. Given that familial influences on PA in young children do not seem to translate to external environments (e.g., preschool) (McKenzie *et al.*, 1992), these ethnic-related differences may deserve further investigation.

Parental Influence

In addition to a possible influence of a parent's genetic material on their offspring's PA, the behaviours of parents or guardians, activity or otherwise, undoubtedly sculpt the behaviours of young children. Parental influence, in a variety of forms, on PA

in young children has been examined by a number of investigations. In a group of ~2- to 4-year-old children, parental encouragement to be active did not correlate with the child's activity behaviour (e.g., running or walking), but did correlate positively with the intensity of the activity undertaken (Klesges *et al.*, 1986). In this regard, prompts (i.e., parental encouragement) to be active were correlated with extreme, but not minimal or moderate levels of PA. Kagamimori and colleagues (1999) found that the frequency of physical *inactivity* was higher among 3-year-old Japanese children mainly cared for by their mother and lower among children with a full-time working mother.

Parental influence, in terms of body weight, may also impact a child's level of PA. For example, Eck et al. (1992) assessed PA by direct observation for 60 min in the home of children with zero, one or two overweight parents. Ninety-two children (50 boys) with an approximate age of 4.5 years were grouped as high risk (one or two overweight parents) and 95 (54 boys) with a similar age were grouped as low risk (zero overweight parents). The level of stationary activity was marginally higher and total PA slightly lower in the high risk group. Consistent with these observations, Trost et al. (2003) found that overweight kids who were also relatively inactive were more likely to have at least one obese parent or adult guardian.

Another interesting parental influence described by Sallis et al. (1993) was the extent of household "rules". Children living in households with more indoor and outdoor rules (e.g., "no balls in the house" and "staying close to home") exhibited lower levels of activity than children with fewer rules, implying a direct parental control on children's level of PA.

In general, parental encouragement to be active results in increased activity of the child. However, other parental characteristics also seem to play a role in regulating children's PA. Given the complete dependence of children ages 0 to 5 years on their parents or guardians, they are obvious targets to help increase levels of PA in their children.

Personality

Given that PA is behaviour, it would seem logical that a child's personality or attitudes may impact on the nature of their activity and play. Battle and Lacey (1972) investigated correlates of hyperactivity among infants 0 to 3 years of age. They reported that hyperactive male infants were physically bold, noncompliant toward adults and did not strive toward independence. The most active boys and girls showed little concern with physical harm. In a later study, Buss et al. (1980) determined PA in 65 boys and 64 girls using an actometer[2]. Children were tested at preschool at the ages of 3, 4, and 5 years. Two hours of activity were determined three times at age 3 and four times at age 4, with an average interval of one week separating sessions. Within each year, activity scores were combined to form a single composite score at each age. The scores determined at the ages of 3 and 4 years were further combined into a single activity index, effectively representing a one year period. Personality measures of each child at ages 3 and 4 were described by the children's nursery school teachers using a questionnaire. This study did not find an effect of gender on personality correlates with PA and therefore pooled the data. The results identified a large number of personality-related correlates with PA at 3 and 4 years of age. In general, the more active children

were observed to try to stretch the limits, take advantage of others and be the centre of attention; they liked to compete, were self assertive and somewhat aggressive; they were not obedient, compliant, shy or reserved. On the other hand, less active children were more socially withdrawn. Given that PA measures were combined to effectively represent the period between ages 3 to 4, one might argue that a child's level of PA at 3 years of age determined their personality over the next year. Conversely, it might be argued that PA during the preceding year determined the child's personality at age 4. The findings of personality correlates (most of which would be considered unacceptable) with PA are interesting, but limited. Future research would benefit from incorporating measures of personality or attitudes when attempting to identify determinants of PA in early childhood.

Environmental Factors

Dietary Intake

As determinants of energy balance, it is possible that energy intake and EE regulate each other. In this regard, Vara and Agras (1989) determined the caloric intake of 43 18-month-old boys and girls from a buffet. Within one week of the buffet, PA was determined over a 24-hr period. The children who consumed more calories were less active. Although the mechanism and significance of these results are unclear, the data may have implications for the activity levels of today's children who are exposed to calorie-dense foods. Vara and Agras (1989) suggested that the infants who consumed greater amounts from the buffet may have secreted more opioid peptides, thus becoming

[2] An actometer is described by the authors as "a modified self-winding watch which is strapped to the child's limb(s) or back. Movement activates the winding mechanism, registering motoric activity on the hands of the dial" (p. 402).

physically inactive. It is also noteworthy that some studies in preschool-age children have not found a relationship between dietary intake and body fat (e.g, Atkin and Davies (2000)), but have found a relationship between PA and body fat (see section on *body fat*). Therefore, it may be worthwhile to pursue the possibility of caloric intake and/or composition as determinants of PA in early childhood.

Outdoors versus Indoors

Perhaps not surprisingly, a child's level of PA is generally greater outdoors *versus* indoors (Baranowski *et al.*, 1993; Halverson & Waldrop, 1973; Harper & Sanders, 1975; McKenzie *et al.*, 1992; Sallis *et al.*, 1993; Telama *et al.*, 1985), and Sallis et al. (1993) noted that the variable with the strongest association to children's PA at home was their time spent outdoors. Indeed, Telama et al. (1985) reported that the majority of their 3-year-old children preferred outdoor activities to indoor activities. Both at home and at preschool, McKenzie et al. (1992) reported significant correlations between time spent outdoors and caloric expenditure. The preference for outdoor activity may also depend on gender. For example, Harper and Sanders (1975) reported that boys spent more time in outdoor areas, whereas girls spent more time in indoor areas. Likewise, Halverson and Waldrop (1973) noted that boys were more active outdoors than girls. Creating opportunities for outdoor activity may, therefore, increase children's levels of PA.

Season

In Canada, seasonality and climatic conditions are obvious and important considerations in the opportunity for outdoor PA. This is particularly germane, when the evidence supports that levels of PA are directly associated with being outdoors (see above). Burdette et al. (2004) found that outdoor play was highest in summer and lowest

in winter. Likewise, Baranowski (1993) reported differences in the amount of time children spent inside *versus* outside by time of year and the activity levels of boys and girls differed by time of year, particularly when outside. In addition, Harper and Sanders (1975) found that cold, rainy weather reduced outdoor play in boys and girls, despite staff permissiveness for the children to venture outdoors. Not surprisingly, season and climatic conditions seem to influence children's PA. In Canada, overcoming this challenge will require innovative approaches.

Outside versus Inside the Home

Are children as active outside as they are inside their home? Noland et al. (1990) found that PA observed during 20 min of free play in an artificial environment (church basement) did not correlate with PA observed at home or preschool in eight children. In a larger sample (n=351), McKenzie (1992) also found low correlations between children's activity at home and their outdoor activity at preschool (i.e., recess). Observations typically made on the same day found that children were more active at recess than at home (McKenzie *et al.*, 1992). The few available observations suggest that opportunities away from the home for children to increase their PA may be important.

Preschool[3]

Given the increased prevalence of Canadian children attending day-care centres[4], it is important to understand the impact of the preschool and its care-givers on children's PA. Intuitively, the physical design of a preschool should influence a child's opportunity for PA. This was highlighted by Neill (1982) who reported that playroom openness in

[3] In this document, the term ***preschool*** is used synonymously with the terms ***nursery school*** and ***day-care centre***. However, when describing a particular study, I have used the terminology in the original paper.
[4] Recent estimates of Canadian child care arrangements can be found at: http://www.statcan.ca/Daily/English/050207/d050207b.htm.

nursery schools was positively related to children's active play. Thus, children spent more time moving around and in active play when more space was available. In addition to the importance of preschool design, Tizard et al. (1976) noted that in their study only 2% of observations related to children's activity involved the staff playing with the children. Thus, active participation and interaction between the child and care-giver, more so than simply suggesting activities, may have significant consequences for the child's level of PA.

More recently, Finn et al. (2002) also observed significant differences among preschools in children's PA. Mean daily activity counts, as determined by accelerometry, and the proportion of time spent in vigorous activity varied with preschool, but no further preschool characteristics were provided. In addition, Pate et al. (2004) found that consideration of preschool explained a large proportion of the variance in children's level of PA. The latter two studies are discussed in more detail below.

To determine the influence of preschool policies and practices on children's PA, Dowda et al. (2004) recruited 266 children (126 boys) ages 3, 4, and 5 years attending a number of preschools. PA was assessed by direct observation for 60 min on 2 to 3 days. The results indicated that children who spent more time in MVPA attended preschools that offered more field trips, smaller class sizes, and college-educated teachers. Similarly, children who spent less time in sedentary activities attended preschools with college-educated teachers and higher overall quality.

Taken together, the importance of preschool on a child's level of PA can not be understated. The preschool offers a unique opportunity to assess children's PA under relatively well-controlled conditions (e.g., diet, time spent outdoors, etc.), without the

potential for child reactivity (e.g., video photography). In addition, preschools offer an excellent venue to implement prospective programs of PA.

MULTI-FACTORIAL APPROACH

So far, this review has focused on studies providing simple bivariate relationships between PA and a given factor of interest. The simplicity of this statistical approach limits the predictive power of the observed associations. Therefore, some studies have employed multiple regression analyses to identify a combination of factors, which are predictive of a child's PA. These studies will be discussed below. In most cases, factors that have been described in previous sections (e.g., preschool) will be further discussed in the next paragraphs.

Sallis et al. (1988) examined correlates of PA in young children, with an emphasis on family-related variables. On two consecutive days, activity levels of 33 4-yr-old children were determined by direct observation during an unstructured outdoor 30-min free-play session at the child's preschool. Intensity of PA was divided into sedentary, moderate, and vigorous, in which the children spent ~60%, ~31%, and ~11% of their time, respectively. Only the multiple regression model for moderate activity was statistically significant, and a combination of family cardiovascular disease (CVD) risk, parent vigorous PA, father's BMI, child's BMI, mother's BMI, and Type A behaviour of the child accounted for 39% of the variance in the child's level of moderate activity. However, only family CVD risk, parent vigorous PA, and father's BMI were significantly associated with moderate activity of the child, independently of all the other variables in the model. In this study, moderate activity was described as instances of

crawling, climbing and walking. Interestingly, time spent in vigorous activity was so sparse that reliable correlates were not found. The importance of these findings is that family-related variables could explain a large proportion of the child's activity habits in an environment away from the family and when subjected to additional environmental influences (e.g., other children).

Baranowski et al. (1993) examined the level of PA in 191 3- and 4-year-old children. During a maximum of four sessions in a single year, PA was assessed by direct observation for up to 12 hrs. A multiple regression model including a combination of gender, month (i.e., season), and location (e.g., outdoors *versus* indoors) accounted for 75% of the variance in PA. The results of this study confirm the importance of gender, season, and physical environment as determinants of PA during early childhood, as previously discussed.

Another study by Sallis and colleagues (1993) investigated correlates of PA in young children in their home environment. Children were observed on four occasions for 60 min each session. A multiple regression model including a comprehensive combination of demographic variables (gender, ethnicity, and socio-economic status), children's variables (sum of triceps and subscapular skinfolds, motor coordination, TV hrs viewed per week), social-family variables (outdoor and indoor play rules, mother's PA, an index of family relationship, family recreation, and parental control over child's PA), and environmental variables (convenient play spaces, time in play spaces, frequency in play spaces, organized activities, and PA-promoting toys) explained 25% of the variance in the children's level of PA at home. However, of the variables included in this model, only ethnicity, gender, outdoor and indoor play rules, convenient play spaces,

time in play spaces and frequency in play spaces were significant, independent predictors of the children's level of PA.

Finn et al. (2002) examined factors associated with levels of PA in 214 children, with and average age of 4 years. A multiple regression model including the combination of gender, history of preterm birth, preschool, and father's BMI accounted for 22% of the variance in the child's mean daily accelerometer counts determined over 48 hrs. These same variables explained 37% of the variance in the child's accelerometer counts between 9 AM and 5 PM (i.e., time spent at preschool). Finally, a combination of gender, history of preterm birth, preschool, and father's BMI accounted for 23% of the variance in the proportion of time the child spent in vigorous activity. That children born pre-term were less active and spent less time in vigorous activity is an interesting finding and requires further investigation. It is noteworthy that 5- to 7-year-old children born with low birth weights demonstrate reduced neuro-motor performance (Keller *et al.*, 1998) and capacity to generate anaerobic power (Keller *et al.*, 2000). Collectively, these findings lend support to the possibility that appropriate motor development during early childhood is an important determinant of PA.

Pate et al. (2004) examined the PA of 247 3-, 4-, and 5-year-old boys and girls in different preschools. Accelerometry counts (intensity of activity), determined over at least 3 days for at least 60 min each day, were categorized as light PA, MVPA, and VPA. For MVPA, a multiple regression model (MVPA-1) including the combination of the child's gender, age, ethnicity, BMI, and parent education accounted for 4.3% of the variance in their PA. By introducing preschool into the model (MVPA-2), an additional 43.3% of the variance in MVPA could be explained. In MVPA-1, only gender and parent

education emerged as significant, independent predictors of MVPA, whereas in MVPA-2, gender, ethnicity, and preschool were significant, independent predictors of MVPA. For VPA, a multiple regression model (VPA-1) including the combination of the child's gender, age, ethnicity, BMI, and parent education accounted for 7.4% of the variance in their PA. By introducing preschool into the model (VPA-2), an additional 30.9% of the variance in VPA could be explained. In VPA-1, only gender, BMI, and parent education emerged as significant, independent predictors of VPA, whereas in VPA-2, gender, ethnicity, BMI, and preschool were significant, independent predictors of MVPA.

Studies employing multiple regression analyses have identified a number of factors, which in combination explain between 22 and 75% of variance in a child's PA. These studies also highlight the complexity of PA and emphasize the need for a multi-dimensional approach to studying factors associated with the nature and level of children's PA.

SUMMARY AND CONCLUSIONS

The purpose of this review was to identify factors that have been related with PA during early childhood. Although not entirely comprehensive, a number of publications describing modifiable and unmodifiable factors have been examined. The nature, amount, and intensity of PA and the methods employed to determine PA varied widely across studies. It is also important to note that studies were conducted in a variety of countries. Obviously, this has implications for possible effects of inherent cultural differences, which would not have been specifically addressed by the research design. In

conclusion, some important themes emerged from the presented evidence and these are outlined below.

- Advancing chronological age is associated with reduced levels of PA beginning as young as 3 years of age.
- Children with increased body fatness tend not to engage in higher intensity PA.
- Boys are generally more active than girls.
- Proficiency of certain motor skills is associated with higher levels of PA.
- Parents and/or guardians exert direct and indirect influences on the activity behaviour of their children, and a child's PA at home is not related to their activity levels away from home.
- A child's personality is associated with the level and nature of their PA.
- Children's PA is associated with the design, policies and practices of their preschool.

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APPENDIX. *Characteristics of studies reviewed, including method of determining PA.*

Study	Number of subjects	Age, years	Method of determining PA
Atkin & Davies (2000)	39 M 38 F	1.5-4.5	Doubly labelled water
Baranowski et al. (1993)	90 M 101 F	3 & 4	Direct observation
Battle & Lacey (1972)	37 M 27 F	0-3	Direct observation
Burdette et al. (2004)	147 M 103 F	2-4	RT3 accelerometer; parent questionnaire and interview
Buss et al. (1980)	65 M 64 F	3 & 4	Actometer (early version of accelerometer)
Clark et al. (1969)	18 M 22 F	3-5	Direct observation
Dowda et al. (2004)	126 M 140 F	3-5	Direct observation
Eck et al. (1992)	104 M 83 F	4.5	Direct observation
Finn et al. (2002)	106 M 108 F	3-5	Actiwatch accelerometer
Goldberg & Lewis (1969)	32 M 32 F	0.5 & 1	Direct observation
Halverson & Waldrop (1973)	33 M 25 F	2.5	Actometer; direct observation
Harper & Sanders (1975)	16 M 16 F	3-5	Direct observation
Jackson et al. (2003)	52 M 52 F	3-4	CSA accelerometer
Kagamimori et al. (1999)	8834; gender NP	3	Parent questionnaire

***APPENDIX** continued…*

Klesges et al. (1986)	15 M 15 F	2-4	Direct observation
Lawson & Ingleby (1974)	NP	0.25-3	Mother interview
Li et al. (1995)	15 M 16 F	0.5, 0.75 & 1	Direct observation
McKenzie et al. (1992)	182 M 169 F	4	Direct observation
Neill (1982)	10 M 10 F	3-5	Direct observation
Noland et al. (1990)	11 M 10 F	4-5	Direct observation
Pate et al. (2004)	115 M 132 F	3-5	Actigraph accelerometer
Reilly et al. (2004)	77 M 73 F	3 & 5	CSA accelerometer; doubly labelled water
Sääkslahti et al. (1999)	50 M 55 F	3-4	Parent questionnaire
Sallis et al. (1993)	347; gender NP	4	Direct observation
Sallis et al. (1988)	13 M 20 F	4	Direct observation
Telama et al. (1985)	NP	3	Parent questionnaire
Tennefors et al. (2003)	36 M 29 F	0.75 & 1.2	Doubly labelled water
Tizard et al. (1976)	57 M 52 F	3 & 4	Direct observation
Trost et al. (2003)	118 M 127 F	4	Actigraph accelerometer; Direct observation
Vara & Agras (1989)	19 M 24 F	1.5	Portable motion sensor

APPENDIX *continued…*

Willerman (1973)	122; gender NP	< 4	Mother questionnaire

M, males; F, females; NP, not provided.