

Original Research Review

Physical Activity in Early Childhood: Current State of Knowledge

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Abstract

This paper provides findings from a review of literature relating to physical activity (PA) in the early childhood years (children aged <5 years). Activity in early childhood may confer considerable health gain, including improved bone health and a reduced risk of being overweight. Increased sedentary time may have a negative influence on physical health. Exactly how much PA is required, and what types of activity are important for health gain in young children is yet to be determined. There is a paucity of information pertaining to PA and cognitive development, insulin resistance, and cardiovascular disease risk factors for this age group. As well, there is limited information regarding the activity profiles of pre-school children, and the determinants of both PA and sedentary behaviour. It is likely that factors in both the family and early childhood centre environments are related to PA and/or sedentary behaviours. Knowledge regarding PA and early childhood health, development, and learning is limited. Longitudinal research is required to track PA patterns of young children, identify potential health outcomes, and social and environmental determinants of PA and sedentary behaviour in early childhood and beyond. Collaborative links between health and education providers and PA and health researchers are required to promote consistent PA messages.

Key Words: Physical activity; sedentary; early childhood; health

Introduction

PA is defined as any bodily movement requiring energy expenditure. Within an early childhood education centre context, this refers to both fine (e.g., painting) and gross (e.g., running, skipping) body movements. PA in early childhood (children aged <5 years) has traditionally been assessed using proxy questionnaires (Sääkslahti et al., 1999) or direct observation (Sallis et al., 1993), both of which are subjective measures that can lead to bias and inaccuracy (Sirard & Pate, 2001). More recently, motion sensors such as accelerometers have been used to gather more objective, accurate, and detailed information on the amount and level of activity in young children (Reilly et al., 2004).

The importance of PA and movement in early childhood is increasingly being acknowledged by educators, health professionals, and government departments worldwide. In New Zealand this is best exemplified with the Ministry of Health's *Healthy Eating-Healthy Action Implementation Plan* that identified the promotion of "nutrition, physical activity and obesity issues in preschools and schools including Kohanga Reo and Kura Kaupapa Maori" as a key issue requiring initial attention (Ministry of Health, 2004, p. 17). Sport and Recreation New Zealand (SPARC) has also identified the early childhood years as an important time to address PA promotion with their launch of the Active Movement initiative in 2004. This initiative is "designed to improve the quality, accessibility, and level of participation in physical activity for all children and young people in New Zealand" (Sport and Recreation New Zealand, 2005, p. 9). The tripartite Memorandum of Understanding signed in 2004 by SPARC, the Ministry of Health, and the Ministry of Education to encourage "children to be more active and make healthy choices" (Sport and Recreation New Zealand, 2005, p. 9) is further evidence of the New Zealand Government's prioritisation of PA in childhood.

Before moving forward with these goals, it is imperative to gather a sound knowledge-base from which to guide and inform decision making processes and interventions, and to consider what the practical implications of this knowledge may be for educators and health promoters alike. Accordingly, this paper provides a review of the current state of knowledge regarding the benefits and determinants of PA. Barriers to activity are also explored, with a particular focus on the New Zealand early childhood education context. The implications of these findings for early childhood researchers, educators, and health promoters are also discussed.

Method

Findings from the *Active Movement Scoping Exercise and Programme Evaluation* report (Kolt et al., 2005) formed the basis of this paper. Relevant information has been drawn from the report, which has been built upon, updated, and summarised. Computer database searches (MEDLINE, PsychInfo, Cinahl, Eric) and manual searches were conducted of articles in the English language literature from 1970 to 2006. Reference lists were also scanned for relevant literature. Inclusion criteria were as follows: a) subjects included children aged less than 5 years, and b) PA and/or concepts relating to PA were the literature focus. In line with Sallis, Prochaska and Taylor (2000) articles were excluded that had a primary focus on sports participation, laboratory studies, case studies, expert opinion, and book chapters. Because of the paucity of research in this area, a second tier of literature was searched, encompassing doctoral dissertations and websites of national and international education associations, universities, and government departments. The studies reviewed consisted of pre-school or community samples, used a variety of outcome measures and research designs, and are briefly outlined in Table 1. The terms 'young child', 'early child', and 'pre-school' refer to children aged less than 5 years, 'child' refers to school-aged children, and 'adolescent' refers to children aged 13 years and over.

TABLE 1. Descriptive Characteristics of Physical Activity and/or Obesity Studies in Early Childhood Populations

Study	Sample	Ages	Measures	Results
Berenson et al. (2002)	US; cohort study of 16,000 individuals	0 at baseline (1973), now aged 38y	BMI, BP, extensive CVD risk factor profiling	CVD risk factors are exhibited in early childhood & are predictive of adult CVD risk; an upward secular trend in childhood obesity has occurred
Boldemann et al. (2006)	Sweden; 197 children	4-6y	BMI, UV radiation, ECE outdoor environment, environmental conditions	Quality of ECE outdoor environment (more trees, shrubbery etc.) was associated with increased PA and reduced UV radiation
Carter et al. (2005)	NZ; 240 children	3y	BMI, WC, 5 days accelerometry	25% of children were owt or obese; significant variation in PA levels between children was found
Dennison et al. (2002)	US; 1405 boys, 1356 girls	2-4y	BMI, TV watching, TV accessibility, maternal BMI, maternal education	OR of children being owt was 1.06 for each h/day of TV/video watching; nearly 40% had a TV in their bedroom & these children were more likely to be owt & watch more TV
Dowda et al. (2004)	US; 125 boys, 141 girls	3-5y	Centre policies, practices and quality; direct observation of PA	Quality of ECE centre was associated with less sedentary activity and higher MVPA
Finn et al. (2002)	US; 106 boys, 108 girls	3-5y	BMI, 2 days accelerometry, parental BMI & education, prematurity, participation in organised activities	Sex, prematurity, childcare centre attended, and paternal BMI influenced children's PA
Fisher et al. (2005)	Scotland; 394 children	4.2 ± 0.5y	BMI, FMS, <6 days accelerometry	Habitual PA was weakly associated with FMS

Gillis et al. (2006)	Canada; 80 boys, 117 girls	4-16y	BMI, 7-day PA recall	PA was negatively associated with BMI; girls were less active than boys; owt and non-owt children aged 4-7y had similar PA profiles; owt children had more sedentary activity
Gordon et al. (2003)	NZ; 21 boys, 20 girls	3-7y	BMI, FM, FFM, %BF, skinfolds, circumferences	34-49% of children were obese (depending on criterion); over 60% had truncal fat levels exceeding scores for NZ children
Gustafson et al. (2006)	Review of 34 international studies	3-18y (various studies)	Parental correlates of PA (various measures)	Significant correlations were found for parental support and child PA
Hancox et al. (2004)	NZ; 535 boys, 502 girls at baseline	3y at baseline, followed up at 5, 7, 9, 11, 13, 15, 18, 21, & 26yrs	BMI, BP, VO2 max, blood cholesterol, TV watching	Average weeknight TV viewing between 5-15y was associated with higher BMI, lower fitness, & raised cholesterol at 26y; in 26y individuals, 17% of owt, 15% of increased cholesterol, & 15% of poor fitness was attributed to watching TV for >2h daily
Hernandez et al. (1998)	US; 144 boys, 165 girls	3-6y	BMI, teacher reports of child behaviours & health screening tests	32% of children were obese; owt & obese children are more likely to develop risk factors for CVD & diabetes
Janz et al. (2001)	US; 179 boys, 189 girls	4-6y	BMC, BMD, 4 days accelerometry, parental report of child's usual PA & TV watching	PA was associated with BMC & BMD; VPA had strongest relationships with bone health
Janz et al. (2002)	US; 217 boys, 250 girls	4-6y	BMI, %BF, FM, FFM, TV watching, 3-4 days accelerometry	Low VPA and high TV watching were associated with fatness
Janz et al. (2004)	US; 218 boys, 249 girls	4-7y	Bone geometry, 3-4 days accelerometry, PA questionnaire	Habitual PA was associated with improved bone geometry

Khoury et al. (2004)	US; 247 children	2-4y	BMI, FM, FFM, BMD, accelerometry	PA was associated with LBM and BMI
Klesges et al. (1990)	US; 122 boys, 100 girls	3-6y	BMI, direct observation of PA	PA was associated with parental weight status, % time spent outdoors, and child's relative weight
Lucas et al. (2006)	NZ; 78 children	3-5y	BMI, >18h accelerometry, EC environment	PA was moderately associated with indoor space; hourly PA had a weak negative association with outdoor space; 76%, 18%, and 6% of time was spent sedentary, in light PA, & in MVPA, respectively
McKenzie et al. (2002)	US; 104 boys, 104 girls	4y at baseline, then 5y, 6y, & 12y	Movement skills, 7- day PA recall	No significant association between motor skills in early childhood and PA at 12y
Moore et al. (1991)	US; 63 boys, 37 girls	4-7y	8.6 ± 1.8 days accelerometry, parental PA	Children of active mothers and fathers were 2.0 and 3.5 times as likely to be active as children of inactive parents respectively; children from families with 2 active parents were 5.8 times more likely to be active than those with 2 inactive parents
Moore et al. (2003)	US; 63 boys, 40 girls	3-5y at baseline, followed up for 8y	BMI, skinfolds, 3-5 days accelerometry	More active children had significantly smaller gains in BMI and skinfolds
Pate et al. (2004)	US; 115 boys, 132 girls	3-5y	BMI; 1-11 days accelerometry	The pre-school a child attended significantly predicted VPA and MVPA; boys had more VPA and MVPA than girls
Poest et al. (1989)	US; 269 boys, 245 girls	Age not stated, children attending	Parental and teacher report of child's PA	Children were not engaged in VPA year round; parental PA correlated with child PA;

		early childhood centres		teacher education level was associated with instructional time spent for motor development
Proctor et al. (2003)	US; 73 boys, 40 girls	3-5y at baseline, followed up annually to 12y	BMI, skinfolds, % calories from fat, protein, & carbohydrate, TV watching, parental BMI & PA	Children who watched the most TV during childhood had the greatest increase in body fat over time
Reilly et al. (2005)	UK; 3934 boys, 3824 girls	0y at baseline, followed up regularly to 7y	BMI at 7y, TV watching at 3y, birth weight and weight gain profiles, parental BMI, sleep hours	Parental BMI, early BMI/adiposity rebound, >8h TV watching per week at 3y, catch-up growth, weight gain in first year, birth weight, per 100g, & <10.5h sleep duration at 3y were associated with increased risk of obesity at 7y
Reilly et al. (2006)	UK; 273 boys, 272 girls	4.2 ± 0.5y at baseline	BMI, 6 days accelerometry, FMS	No change in PA or BMI at 6 or 12m post PA intervention; significant increase in FMS in intervention group
Robinson et al. (2006)	US; 42 boys, 38 girls	4-7y	BMI, TV viewing time (allowance monitor & parental report)	Children with TV in bedroom watched significantly more TV
Roemmich et al. (2006)	US; 32 boys, 27 girls	4-7y	BMI, 4 days accelerometry, neighbourhood environment, TV viewing time (allowance monitor)	Sex, age, socioeconomic status, adiposity, and TV watching explained 14% of the variance in PA, housing density a further 12%, and percentage of park plus recreation area a further 10% of PA variance

Sääkslahti et al. (1999)	Finland; 50 boys, 55 girls	3-4y	BMI, CVD risk factors, weekend PA, FMS	PA was weakly associated with FMS and negatively associated with CVD risk factors; outdoor play and MVPA were strongest predictors of improved outcomes
Sääkslahti et al. (2004)	Finland; 82 boys, 73 girls	4-5y at baseline, followed up for 3y	BMI, BP, serum total & HDL cholesterol, HDL/total cholesterol ratio, triglyceride concentration, PA diary	High PA was associated with reduced triglycerides, especially at 6y; girls' PA level was associated with improved cholesterol and triglyceride profiles at 6y; outdoor play in boys was related with improved cholesterol profiles at 4y
Sallis et al. (1988)	US; 13 boys, 20 girls	3-5y	BMI, direct observation, parental BMI, parental self-reported PA, family CVD risk	Children spent 58% of time in sedentary activities; family CVD risk, parent VPA, and paternal BMI was associated with children's PA
Sallis et al. (1993)	US; 328 families	4.4 ± 0.5y	BMI, skinfolds, social and home environment, direct observation of PA	Time spent outdoors and prompts to be active were associated with increased PA
Sallis et al. (2000)	Review of 108 international studies	Studies were categorised by age (either "children" aged 3-12y, or "adolescents" aged 13-18y)	Various measures of PA, and socio-environmental correlates of PA	Boys were more active than girls; for children aged 3-12y, PA preferences, intention to be active, perceived barriers (inverse), previous PA, healthy diet, program/facility access, time spent outdoors, and parental BMI were associated with PA level

Scantling et al. (2005)	US; 48 boys, 52 girls	4-7y	BMI, %BF, FM, FFM, 6 days accelerometry	Moderate PA & MVPA was inversely associated with body weight in girls; children in the highest tertile for MVPA weighed significantly less and had 20% less fat mass than children in the least active tertile
Sibley & Etnier (2003)	Meta analysis of 44 international studies	Studies classified by age groups (4-7y, 8-10y, & 11-13y)	Various cognitive and PA assessment measures	Larger effect sizes were found for PA and cognition in 4-7y children than the 11-13y children
Specker & Binkley (2003)	US; 178 children	3-5y	BMC, 3-day diet, 2 days accelerometry	PA was associated with BMC, which was more pronounced with calcium supplementation
Specker et al. (1999)	US; 72 infants	6m at baseline, followed up at 9, 12, 15, & 18m	BMC, 3-day diet, PA	PA was associated with BMC only in the presence of adequate calcium intake
Trost et al. (2003)	US; 118 boys, 127 girls	3-5y	BMI, direct observation, 1-11 days accelerometry	Overweight boys were significantly less active than non-overweight boys
Vaska & Volkmer (2004)	Australia; 114,669 children	4y	BMI	Rates of overweight and obesity in children increased significantly from 1995–2002; in 1995 12.8% and 10.2% of females & males were overweight or obese respectively, in 2002 21.4% and 17.3% of females & males were overweight or obese, respectively

Vásquez et al. (2006)	Chile; 12 boys, 12 girls	3-5y	FFM, FM, 3 days accelerometry, EE, energy intake	PA was negatively associated with body fat; sedentary activity was higher in day care compared with the home environment
Voss et al. (2003); Wilkin et al. (2004)	UK; 170 boys, 137 girls	5y (Year 1 at school, mean age 4.9y)	BMI, 7 days accelerometry, diet, insulin resistance, blood profiles	No information on any relationship between PA and insulin resistance has been reported to date
Worobey et al. (2004)	US; 16 boys, 26 girls	4-5y at baseline, followed up for 1y	BMI, BP, 1-day accelerometry	48% were owt or obese; EE was associated with BMI

BF = Body fat; BMC = Bone mineral content; BMD = Bone mineral density; BMI = Body mass index; BP = Blood pressure; CVD = Cardiovascular disease; EC = Early childhood; ECE = Early childhood education; EE = Energy expenditure; FM = Fat mass; FFM = Fat-free mass; FMS = Fundamental motor skills; h = Hours; m = Months; MVPA = Moderate-to-vigorous physical activity; NZ = New Zealand; OR = Odds Ratio; owt = Overweight; PA = Physical activity; TV = Television; US = United States of America; UV = Ultra-violet; VO2 max = Maximum oxygen consumption (fitness test); VPA = Vigorous physical activity; WC = Waist circumference; y = Years

Results

Physical Activity Benefits in Early Childhood

1. Overweight and Obesity

Weight gain, overweight status, and weight in infancy persists through the pre-school years (Mei, Grummer-Strawn, & Scanlon, 2003), and has been associated with overweight in later childhood and adulthood (Stettler, Kumanyika, Katz, Zemel, & Stallings, 2003). Overweight and obese school-aged children are more likely to develop risk factors for cardiovascular disease and diabetes (Hernandez, 1998), and are at much greater risk of developing adult obesity (Deckelbaum & Williams, 2001). Calculated as weight (kg) / height (m)², body mass index (BMI) is commonly used as an indicator of body size. Age- and sex-specific BMI cut-off points have been determined for youth aged 2-18 years that relate to overweight (25 kg/m²) and obesity (30 kg/m²) at 18 years (Cole, Bellizzi, Flegal, & Dietz, 2000). BMI is not an exact measure of adiposity, however, and so should be considered as a screening tool and for prevalence estimations only rather than as a diagnostic assessment of overweight or obesity.

A number of studies have reported a high and/or increasing prevalence of overweight and obesity in children aged less than 5 years (Gordon et al., 2003; Vaska & Volkmer, 2004), including a recent cohort study children in Dunedin, New Zealand, whereby a quarter of the 3 year old children were overweight or obese at baseline (Carter et al., 2005). Recent US

data has shown that the prevalence of obese children aged 0 to 6 years increased from 6.3% to 10.0% from 1980 to 2001, and the prevalence of overweight children increased from 11.1% to 14.4% during the same time period (Kim et al., 2006). Notably, these trends were evident for all age categories of children, including infants aged less than 6 months.

A number of cross-sectional studies have shown a negative relationship between body size (overweight, obesity, or body fatness) and PA level in young children (Khoury, Claytor, & Daniels, 2004; Trost, Sirard, Dowda, Pfeiffer, & Pate, 2003; Vásquez, Salazar, Andrade, Vásquez, & Diaz, 2006). As well, specific PA variables, such as amount of vigorous PA (Janz et al., 2002), and moderate-to-vigorous PA (Scantling, Heelan, Abbey, & Eisenmann, 2005) have been related to reduced body size in early childhood. Two studies have investigated the longitudinal relationship between PA and body size (Moore et al., 2003; Worobey, Adler, & Worobey, 2004). Children classified as 'most active' in the longitudinal Framingham Children's Study (see footnote 1) had consistently less gains in body size between 4-7 years of age compared to children classified as 'least active' (Moore et al., 2003). Nutritional intake was controlled for in the analyses, and energy intake actually increased with increasing PA level. Conversely, no difference was found between PA and weight classifications over time in another sample of US pre-school children (Worobey, Adler, & Worobey, 2004). Interestingly, no relationship between energy intake and body size was found in the latter study, indicating that there may be confounding factors influencing the relationships between body size, nutrition, and PA. One randomised controlled trial has been conducted in an attempt to increase PA and reduce obesity in pre-school children (Reilly et al., 2006). The intervention comprised a 30-minute PA programme three times per week for 24 weeks (delivered by nursery staff), and provision of materials to families promoting PA and reduced TV time. Six- and 12-month follow-up measurements showed no significant difference in PA level, sedentary behaviour or BMI as a result of the intervention. Accordingly, more comprehensive intervention may be required to improve PA levels and any subsequent influence on weight status. The longitudinal association between PA and body size requires further investigation to determine whether PA influences weight status or vice-versa, and to ascertain how much PA is required for healthy weight maintenance, while also accounting for other contributing factors to excess body size.

Inactivity has also been associated with overweight and obesity in early childhood. It is important to note that inactivity is not the exact inverse of PA. Rather, PA and inactivity are independent variables that can both have an effect on health outcomes (e.g., obesity prevalence) (Dietz, 1996). This is because inactivity is often described and quantified as a behaviour (e.g., watching TV), rather than as a reduced PA level (e.g., Gillis, Kennedy, & Bar-Or, 2006), and these behaviours have been associated with unhealthy activities such as increased consumption of fatty foods (Dietz, 1996). Objectively assessed TV watching (using TV allowance monitors) has actually been positively associated with accelerometer-determined PA in young children (Roemmich et al., 2006), demonstrating the ambiguous relationship between these variables.

Study findings have varied, but in general, screen time exposure (TV, video/dvd, computer, and/or game console use) of more than 2-3 hours daily has been associated with an increased risk of being overweight or obese in young children. For example, Reilly et al. (2005) found that, compared with children who watched under 4 hours of TV weekly, children who watched between 4-8 hours or more than 8 hours of TV per week were 1.37 and 1.55 times more likely to have BMI values categorised as overweight or obese, respectively. Dennison et al. (2002) established that, for every additional hour of TV/video watching per day, pre-school children were 1.06 times more likely to be categorised as overweight or obese by BMI. In the same study, children who had a TV in their bedroom were 1.31 times more

likely to be in overweight or obese than children without a bedroom TV. Unsurprisingly, recent research using TV allowance monitors has also shown that 4-7 year old children with a bedroom TV accumulate significantly more TV-watching time than children without a TV in their bedroom (Robinson et al., 2006).

Using a more robust measure of body size than the latter studies, Janz et al. (2002) found that percentage of body fat was significantly associated with time spent watching TV. Recently, Gillis et al. (2006) also found that overweight children (categorised by percentage body fat) spent significantly more time using the computer, TV, or video games than their normal weight counterparts. Only one study, the Framingham Children's Study, reported the longitudinal influence of TV watching in early childhood on body size (Proctor et al., 2003). Findings showed that at 11 years of age, children who had watched more than 3 hours of daily TV during early childhood had significantly higher BMI, triceps skinfold, and sum of five skinfolds. Only one New Zealand study has been published that has assessed TV time and body size in children (Hancox, Milne, & Poulton, 2004). Although this relationship was assessed in participants aged 5 years and older, the New Zealand sample and longitudinal nature of the study make it worthwhile reporting. Study findings showed that increased TV weeknight watching between 5-15 years was significantly associated with BMI. In addition, the authors estimated that 17% of overweight in the sample at 26 years could be attributed to watching TV for more than 2 hours daily during childhood and adolescence.

Collectively, the above studies provide strong evidence for the positive relationship between parent-reported screen time and body size in pre-school children. This is an area for concern, particularly considering that physical inactivity has been shown to track even more strongly than PA from late childhood to early adulthood (Raitakari et al., 1994). A majority of studies found were cross-sectional and used BMI as an indicator of body size. Further studies are required to longitudinally and objectively quantify time spent being sedentary and investigate the link between screen time, sedentary time, nutritional practices, socio-environmental factors, and more sensitive measures of body size. The application of proxy reports of sedentary behaviours to date are likely to result in bias. Ideally, future research should aim to utilise objective measures of sedentary behaviour, such as accelerometry and TV allowance monitors. Although the population-wide quantification of the prevalence of participation in PA and inactivity is fundamental to understanding the role of PA in the health of young children's lives, this is an area that has not yet been explored.

2. Cardiovascular Disease and Type 2 Diabetes

Both cardiovascular disease and type 2 diabetes are often intrinsically linked with increased body fatness, a phenomenon termed the 'metabolic syndrome'. Individuals with this syndrome exhibit indicators of cardiovascular disease (e.g., increased blood pressure, cholesterol, low density lipoproteins, and triglycerides), diabetes (insulin resistance), and body fatness (Voss et al., 2003). While cardiovascular disease and type 2 diabetes are normally exhibited in adult populations, cardiovascular risk factors have been shown to begin in early childhood and be predictive of cardiovascular risk in adulthood (Berenson, 2002). Increased insulin sensitivity has also been observed in young children at 4.9 years of age (Wilkin et al., 2004).

To date, no published literature has reported the relationship between PA and type 2 diabetes in pre-school children. The Special Turku Coronary Risk Factor Intervention Project for Babies (STRIP) (see Footnote 2) has assessed the relationship between coronary heart disease risk factors (BMI, cholesterol concentrations and ratios, blood pressure, triglycerides) and parent proxy-reported PA in young children aged 4 years at baseline (Sääkslahti et al., 2004). A negative relationship between triglycerides and high PA levels

was found, especially when the children were aged 6 years. Results were also differentiated by gender – in girls a higher PA level was associated with improved cholesterol and triglyceride profiles at 6 years, whereas in boys, playing outdoors was related with improved cholesterol profiles at 4 years. This large cohort study employed in-depth objective measures of cardiovascular risk factors, but the use of proxy-report methods to assess PA is a limitation.

While there is evidence that young children may exhibit indicators of cardiovascular disease, type 2 diabetes, and the metabolic syndrome, there is a dearth of information relating to the relationship between PA and these lifestyle diseases in early childhood. Further research in this area is required before definitive conclusions can be drawn.

3. Bone Health

It is now well known that being active is related to the development and maintenance of healthy bones across the lifespan. The majority of the benefit is due to the forces applied to bone during activity, whereby mechanical loading causes adaptive bone responses resulting in improved bone density (Anderson, 2000). Achieving a peak bone density prior to puberty is integral to determining bone health (and reducing the risk of osteoporosis) in later life (Anderson, 2000).

Participating in gross motor activities (bone loading) has shown greater improvements in bone mineral density than fine motor activities (non-loading) in infants (Specker, Mulligan, & Ho, 1999) and toddlers aged 3-5 years (Specker & Binkley, 2003), however, this benefit was only observed in the presence of adequate calcium intake. The first study to investigate the influence of objectively measured habitual PA (using accelerometers) on bone density in young children was the Iowa Bone Development Study (see Footnote 3) (Janz et al., 2001). Findings indicated that physically active young children had greater site-specific bone mass, bone mass density, and total body bone mass compared to their less active peers, and that time spent in vigorous PA was most highly associated with bone measures. In more recent research (based on the Iowa Bone Development Study), Janz et al. (2004) found that bone adapted positively to increased loading during daily accelerometer-determined PA in children aged 4-7 years. Importantly, this increase in bone strength was achieved through 'everyday' activity rather than specific bone loading activities or elite sport performance. A primary limitation of the latter two studies was the absence of assessment of calcium intake in the participants.

The above studies provide cumulative evidence for a positive relationship between objectively assessed PA variables (vigorous PA, everyday/habitual PA) and bone health in young children. This relationship may be attenuated somewhat by calcium intake, and therefore any future related studies must take this variable into account.

4. Motor Skill Development

Fundamental motor skills comprise the basic skills (e.g., jumping, hopping, skipping, throwing, catching) that provide the foundation for more complex movement patterns. The development of fundamental motor skills results from a dynamic interaction between the growing and maturing child, their environment, and the task requirements of physical activities performed by that child (Malina, 2004). A basic mastery of these skills in early childhood has been cited as a key factor in lifelong participation in PA, recreational pursuits, and/or sports (Booth et al., 1999).

In their study of children aged 3-4 years, Sääkslahti et al. (1999) found only a weak association between PA and fundamental motor skills; however, PA was assessed

subjectively with a proxy-report diary completed by parents. More recently, Fisher et al. (2005) investigated the relationship between objectively measured PA (using 6 days of accelerometry) and fundamental movement skills. Findings showed significant positive relationships between fundamental motor skill development and both total PA and percentage of time spent in moderate-to-vigorous PA. The study of Reilly et al. (2006) also reported improved fundamental movement skills in pre-school aged children as a result of a 24-week PA intervention, although no significant change in accelerometer-determined PA was found. While evidence exists for a positive relationship between PA and fundamental motor skill development, further work is required to understand this relationship and to establish whether PA promotes fundamental motor skill development, or vice-versa.

Increased PA may be related to fundamental motor skill development in early childhood. This relationship is still not well understood as cross-sectional study designs and self-reported PA measures have been commonly applied in this area. More research is required to assess this relationship over time, to determine whether PA influences level of motor skill development, or vice-versa.

5. Cognitive Functioning

Improved cognitive functioning has also been suggested as a benefit of PA in early childhood (Leppo, Davis, & Crim, 2000; Pica, 1997). Developmental biology has provided an insight into environmental influences (including some forms of movement) on the developing brain architecture in early childhood (Leppo, Davis, & Crim, 2000; National Scientific Council on the Developing Child, 2005), with physiological changes in the brain and developmental and learning changes occurring in response to activity (Sibley & Etnier, 2003). Activities that require crossing of the midline have been promoted as being particularly important to activate both brain hemispheres in a balanced way (Hannaford, 1995). No research has yet been published that has investigated cognitive development and objectively measured PA in children aged less than 5 years, and so this relationship is still not well understood.

Physical Activity Patterns and Correlates in Early Childhood

Exactly how much activity, and what type of activities, are required for health benefits in young children are yet to be fully determined. As well, our understanding of how active (or inactive) young children actually are is limited. A number of small studies have objectively quantified the PA levels of children using accelerometers, pedometers, and other motion sensors which have provided some indication of the PA patterns of this population, and are outlined in Table 1. Significant differences in PA can already be observed in children younger than 5 years, with the following shown to be positively related to one or more PA variables: male gender (Pate, Pfeiffer, Trost, Ziegler, & Dowda, 2004), full term birth (Finn, Johannsen, & Specker, 2002), outdoor play time (Sääkslahti et al., 1999), the family environment (Gustafson & Rhodes, 2006), quality of early childhood education setting (Finn, Johannsen, & Specker, 2002; Pate, Pfeiffer, Trost, Ziegler, & Dowda, 2004), and neighbourhood environment (Roemmich et al., 2006).

The studies of Finn et al. (2002) and Pate et al. (2004) provided convincing evidence for the importance of early childhood education environments in encouraging PA, with the pre-school centre setting being the strongest individual predictor of PA in their samples. Specific education setting variables such as amount of time spent outdoors, quality of outdoor environment (Boldemann et al., 2006; Sallis, Prochaska, & Taylor, 2000), staff qualification level (Dowda, Pate, Trost, & Sirard, 2004), and overall centre quality (Dowda, Pate, Trost, & Sirard, 2004) have been associated with increased PA in young children.

The family environment also appears integral to encouraging PA in early childhood. Parental variables such as prompting and encouragement for their child to be physically active (Sallis et al., 1993), parental PA level (Moore et al., 1991; Poest, Williams, Witt, & Atwood, 1989), parental vigorous PA (Sallis, Patterson, McKenzie, & Nader, 1988), and a lower parental BMI (Finn, Johannsen, & Specker, 2002; Klesges, Eck, Hanson, Haddock, & Klesges, 1990) have been related to the PA level of their pre-school child. The first study to consider the built environment in relation to PA in young children showed that increased proximity between homes (density) and a greater proportion of park area in the neighbourhood was related to increased PA in their sample of 4-7 year old children, even after controlling for sex, age, family socioeconomic status, overweight status, and TV watching time (Roemmich et al., 2006). Unique strengths of the latter study were the utilisation of a combination of objective measurement and analysis tools such as accelerometers, TV allowance monitors, and spatial mapping software.

New Zealand Research

To date, there are two studies that have objectively investigated PA in New Zealand pre-schoolers (Carter et al., 2005; Lucas & Schofield, 2006). The FLAME study is a 4 year investigation of the risk factors for obesity in 3 year old Dunedin children (Carter et al., 2005). This study has assessed PA using accelerometers over 5 days and will also investigate sedentary behaviour and family attitudes towards activity and nutrition. Baseline findings showed considerable variation in PA levels between children which were not associated with gender; however, follow-up assessments have not yet been conducted so it is unclear whether this is an age-related finding. Data collection will occur annually for the next 3 years with the aim of identifying specific factors related to excessive weight gain in young children to inform intervention development. Another study focused on PA patterns and environmental factors that may be related to PA in Auckland children aged 3-5 years utilising accelerometers (Lucas & Schofield, 2006). Associations between PA (sedentary, light, moderate-to-vigorous PA) and early childhood education setting environment variables (space and furnishings, programme structure, activities) were determined. Indoor space was moderately associated with increased accelerometer counts per hour and total counts, while outdoor space had a weak negative association with accelerometer counts per hour. Lucas and Schofield (2006) suggested these differing activity levels based on indoor and outdoor space may have been related to scheduled activities within the education settings. Interestingly, inactivity accounted for 76% of the time measured, with 18% of time spent in light activity, and only 6% in moderate-to-vigorous PA. These findings provide evidence for the potentially significant role inactivity may play in young children's lives, and the importance of investigating sedentary time further.

While both of the above studies are important in contributing to the New Zealand evidence base of PA research in early childhood, there still remain a number of unanswered questions. For example, the FLAME study is measuring parental attitudes towards PA, however, this is a subjective assessment that will not provide any objective evidence of the parental role in their pre-school child's PA behaviours. Further, a monitoring period of 5 days may be inadequate to provide an accurate assessment of PA in this population (Sirard, Trost, Dowda, & Pate, 2001). Similarly, the Lucas and Schofield (2006) study involved PA monitoring over 5 pre-school days only, and no assessment of weekend PA or PA outside the pre-school environment was assessed. Neither of the New Zealand studies assessed the relationship between the neighbourhood built environment and PA in early childhood. Consequently, more in-depth data collection of PA patterns and potential correlates of PA in New Zealand pre-schoolers is required, to add to, and improve on, the current state of knowledge in this field. The primary author is currently embarking on a cross-sectional

study with children aged 3-5 years in an attempt to answer some of these questions. The study will measure PA in young children and one or both of their parents using accelerometers over 7 full consecutive days. Measures of potential socio-environmental correlates of children's PA will be assessed using a questionnaire (e.g., number of televisions in household), and perceptions about parental and child PA levels will be assessed. This will be the first study in New Zealand (and only the second study worldwide), to investigate the relationship of objectively determined PA in children aged less than 5 years in relation to their built neighbourhood environment using spatial mapping. Aims of the study are to: quantify and describe in detail the PA and inactivity of 3-5 year old Auckland children and their parents; determine the relationships between PA, inactivity, and weight status; and to identify social and environmental factors that can be targeted for intervention.

Barriers to Activity Participation and Promotion in Early Childhood

A number of researchers have conducted qualitative research to identify barriers to the encouragement of PA and PA participation in young children via focus groups and interviews with parents, educators, health professionals, and government representatives (Goodway & Smith, 2005; Irwin, He, Bouck, Tucker, & Pollett, 2005; Kolt et al., 2005; O'Connor & Temple, 2005). Results have been consistent amongst studies and participants, with overwhelming agreement that PA is important in early childhood, for physical, psychological, and social wellbeing and development. While the importance of PA was acknowledged, reports of active encouragement of young children to be physically active or participating in PA with children were minimal. A number of reasons for this phenomenon were proposed by the participants of these studies, as follows: 1) some felt that children were sufficiently active without any need for further prompting or encouragement; 2) there was insufficient space, and/or a lack of covered outdoor area, for PA in the home or centre environment; 3) caregivers and educators reported lacking confidence, skills and/or knowledge required to promote PA; 4) there was a lack of logistical support for PA promotion, in terms of appropriate teacher education and funding for equipment; and 5) government regulations (noise limitations, playground safety) and centre policies (rules regarding types of activities performed indoors and outdoors, restricted planning for PA, access to TV, scheduled outdoor time, policies regarding outdoor excursions) significantly limited opportunities for PA promotion. As well, parents reported insufficient time, perceived lack of neighbourhood safety (road safety and 'stranger danger', especially in underserved communities), expense of structured programmes, lack of community role models, and children's preferences for sedentary activities as key barriers to PA in early childhood.

Especially pertinent to the New Zealand context, findings from consultation with stakeholders in early childhood education and health (early childhood and tertiary educators, government representatives, health promoters, parents, researchers) for the *Active Movement Scoping Exercise and Programme Evaluation* showed that people and general society were fundamental barriers to PA promotion and encouragement in early childhood (Kolt et al., 2005). At the macro level, societal attitudes towards prioritisation of academic learning and achievement over play and PA, and a general culture shift towards inactivity and a preference for sedentary pursuits were identified as constraints to promoting activity in young children. Limited information and support for early childhood educators was highlighted, particularly in terms of pre-service and in-service professional development, and to a lesser degree, funding for equipment and training. While a number of programmes were identified that facilitated PA in early childhood education settings, these programmes were not being rigorously evaluated, nor were they being efficiently disseminated

throughout the early childhood community. At an individual level, the attitudes, behaviours, knowledge and available time of both parents and early childhood educators were identified as key barriers to PA promotion. Specifically, parental prioritisation of academic (literacy and numeracy) learning outcomes and less regard for the potential learning opportunities and social and holistic benefits gained from PA posed a considerable challenge for early childhood educators. Concurrently, educators themselves felt ill-equipped to promote PA appropriately, and many reported being inactive themselves.

Summary and Implications

PA may confer a multitude of benefits to the young child. There is sufficient evidence to suggest a negative relationship between PA and body size, and strong evidence for a positive association between sedentary activity and body size in early childhood. PA has also been associated with improved bone density in young children, particularly in the presence of adequate calcium intake. A positive relationship has been exhibited between PA and fundamental motor skill development in toddlers.

A number of questions remain unanswered. There is a dearth of research investigating the interactions between PA and cognitive development, insulin resistance, and cardiovascular disease risk factors in early childhood. The influencing variables in the relationships between PA and health outcomes need to be determined in longitudinal research, and whether these relationships track over time is yet to be established. Understanding the overall prevalence of PA and sedentary behaviours in young children is essential. Future research is necessary to objectively quantify time spent being physically active and sedentary, and to investigate associations between PA, screen time, sedentary time, nutritional practices, and health outcomes in early childhood. The level of PA required for health gain in young children, and variables that can either be modified or targeted for PA intervention in this population group need to be identified.

The current state of knowledge indicates that important PA variables to assess are amount of vigorous PA and sedentary time. Family and early childhood education settings appear important environments to investigate further in terms of influencing PA and being amenable to change. More work is required to understand the influence of the built environment on PA in early childhood. Early childhood educators require ongoing logistical support to promote and encourage PA, including pre-service and in-service training, and government legislation and centre policies that encourage PA promotion and participation. Improved societal knowledge and attitudes regarding the fundamental role of PA in healthy development and learning is integral. Inter-sectoral approaches (between health, education, and researchers) and effective lines of communication are required to disseminate best practice approaches and research findings throughout the early childhood education community, and to ensure a consistent PA message is promoted. The SPARC Active Movement Initiative is an ideal means by which to meet some of these needs, particularly in terms of teacher training and societal education, advocacy, and improved communication and collaboration between agencies and disciplines.

This issue is of importance to all New Zealanders at an individual, community, and national (policy) level. Given the current dearth of robust research in this area, it is imperative that carefully conducted research to improve our knowledge and understanding of PA in the early childhood years is considered a priority area for educators and health promotion researchers in New Zealand and internationally.

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Footnotes

1. The Framingham Children's Study is a longitudinal study of determinants of nutrition and physical activity in early childhood. The study began in 1987 with 106 children aged 3-5 years from the Framingham region. Data collection has occurred on an annual basis since 1987.
2. The STRIP Study began in Finland in 1990 with the aim to curb atherosclerosis development by providing lifestyle intervention to 1062 children aged 7-36 months and their families. The intervention has continued and follow-up measurements will be conducted biannually until the children are 20 years.
3. The Iowa Bone Development Study investigated the relationship between PA and bone health in 470 children from Iowa. The Study is a sub-study of the Iowa Fluoride Study, a longitudinal study of fluoride intake and dental fluorosis of 890 families.

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The support of Sport and Recreation New Zealand is acknowledged in funding the *Active Movement Scoping Exercise and Programme Evaluation* project (Kolt et al., 2005). The research was conducted to understand the importance of physical activity and movement in early childhood, and issues surrounding the barriers to, and motivations for, young people's participation in activity. Melody Oliver is supported by a Tertiary Education Commission Top Achiever Doctoral Scholarship.

ABOUT THE AUTHORS

Melody Oliver is currently completing her PhD investigating physical activity and inactivity patterns in children aged 3-5 years, and the social and environmental factors that may be related to children's activity patterns. Research findings will help to inform and guide interventions and policy in health promotion and obesity prevention in early childhood.

Associate Professor Grant Schofield has expertise in health promotion, physical activity measurement, and determinants of physical activity. His research spans most groups across the lifespan from pre-schoolers to older adults as well as whole community approaches to understanding and increasing physical activity.

Professor Gregory Kolt has a background in psychology and physiotherapy and has worked extensively across research, clinical and teaching areas in these disciplines. His current research focuses on health-related physical activity, the ageing population, and physical activity interventions.

Associate Professor Claire McLachlan is the coordinator of the postgraduate programme in Early Years Education at Massey University College of Education. Claire's research interests, in addition to physical activity in young children, include early childhood education, teacher education, teachers' beliefs about curriculum, emergent literacy and open, distance and flexible learning.