Title: Physical Activity Levels and Patterns of 19 Month Old Children

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Abstract:

Purpose: It is a commonly held perception that most young children are naturally active and meet physical activity recommendations. However, there is no scientific evidence available on which to confirm or refute such perceptions. The purpose of this study was to describe the physical activity levels and patterns of Australian toddlers.

Methods: Physical activity and demographic data for 295 19-month old children from the Melbourne InFANT Program were measured using accelerometers and parent surveys. Validated cut-points of 192-1672 and >1672 counts per minute (CPM) were used to determine time spent in light (LPA) and moderate-to-vigorous (MVPA) intensity physical activity respectively. To be included in the analysis children were required to have four valid days of accelerometer data to provide an acceptable (>0.70) reliability estimate of LPA and MVPA. Physical activity data for different periods of the day were examined.

Results: On average, toddlers engaged in 184 minutes of LPA and 47 minutes of MVPA daily, and 90.5% met the current Australian physical activity recommendations for 0-5 year olds (180 mins LMVPA/day). Physical activity levels during mid-morning and mid-afternoon were higher than the other periods. Physical activity patterns for boys and girls were similar, though boys engaged in more physical activity during the morning hours than girls.

Conclusion: Most children meet the physical activity recommendations, though the majority of activity undertaken was of light intensity. Boys were more active than girls in the morning hours, but there were no differences between sexes over the entire day. Certain periods of the day may hold more promise for intervention implementation than others.

Keywords: toddler, active play, accelerometer, measurement, movement, early childhood
Introduction

*Paragraph Number 1* Physical activity is beneficial for young children’s health. Positive associations between cardiovascular risk factors (26), bone health (16), motor development (9) and children’s physical activity have been reported in the literature, and recent evidence suggests that physical activity behaviours established during early childhood may track into later childhood (15) and even adolescence (17), highlighting the need to focus on physical activity promotion from a young age. Furthermore, the main form of physical activity for young children is active play, which has been shown to improve social, emotional and cognitive skills (4, 10, 18). As such, a number of governments in countries around the world have recently developed physical activity recommendations for children under age five (1, 29). While these guidelines differ slightly in their recommendations, both encourage participation in 180 minutes of physical activity every day, including light, moderate and vigorous intensity activity.

*Paragraph Number 2* It is a common belief among parents and caregivers that young children are naturally active and that most will easily meet physical activity recommendations (12, 14). This does not appear to be the case for preschool children (3-5 years old) (6) and no evidence exists with regard to children in the first few years of life (namely toddlers aged 1-3 years). It is not currently known how much physical activity young children regularly participate in, and whether or not children engage in more or less physical activity during different periods of the day. This lack of information concerning physical activity levels in very young children is likely due, in part, to the many challenges associated with assessing physical activity in this population group (20). However, the uptake of accelerometers to measure physical activity has offered a promising means by which to objectively measure physical activity in young children. These devices are desirable as they capture movement in
real time and enable objective examination of physical activity levels and patterns throughout the day (8).

**Paragraph Number 3** Identifying current physical activity levels and the proportion of children of this age meeting the physical activity recommendations is important as it will allow us to determine if intervention strategies to promote increased physical activity are needed in this population group, or if our efforts should be focused elsewhere. Examining patterns of physical activity engagement will provide us with more information on when young children’s activity is (and is not) occurring so that we are able to identify potential “critical windows” for intervention implementation. Furthermore, understanding the influence of demographic characteristics on physical activity levels and patterns is key to the design of intervention strategies. Sex of the child and parent employment status have the potential to impact physical activity, as boys are consistently more active than girls (13) and parental employment status largely dictates the environmental structure of a child’s day (whether children are in care or not). Thus it is desirable to examine children’s activity behaviours in light of these characteristics.

**Paragraph Number 4** The purpose of this study was to describe the current physical activity levels and patterns of toddlers in Melbourne, Australia. A secondary aim was to determine compliance with existing Australian physical activity recommendations for this age group.

**Methods**

**Sampling**

**Paragraph Number 5** Data were drawn from the Melbourne InFANT (Infant Feeding Activity and Nutrition Trial) Program. Described in detail previously (5), the Melbourne InFANT Program was a cluster randomized controlled trial that recruited first-time parents from within existing parents groups within the Melbourne area, when children were 3-4
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months of age. The intervention ran for 15 months (with the first groups recruited in June 2008 and the last groups finishing the intervention in February 2010), until the children were 18-19 months of age. Over six 2-hour sessions, the intervention took an anticipatory guidance approach to targeting early health behaviours including diet, physical activity and sedentary behaviour, and provided parents with knowledge, skills and strategies to promote positive behaviours. Ethics approval for the study was obtained from the Deakin University Ethics Committee and from the Victorian Government’s Office for Children. Informed consent to participate in the study was obtained from 542 parents during the baseline phase of the intervention (June 2008- December 2008). At completion of the intervention (August 2009 to February 2010), 417 (77%) wore an accelerometer to assess differences in physical activity level between the groups. Average time spent in light, moderate and vigorous intensity physical activity was compared between intervention and control groups using a linear regression analysis, controlling for average accelerometer wear time and the mother’s group attended. As no intervention effect was observed on physical activity between intervention and control groups (225.3 ± 41.0 mins vs. 237.4 ± 38.6 mins, p>0.19), the data from both arms of the intervention were combined for the analyses reported below.

Measures

Paragraph Number 6 Physical activity was measured every 15 seconds for seven consecutive days using ActiGraph accelerometers (Model GT1M, Pensacola, Florida, USA). Children were required to wear the accelerometers over their right hip during all waking hours, except when swimming and bathing. Parents were asked to record any time that the child did not wear the monitor, and the reason for removal.

Paragraph Number 7 Parent surveys were completed by the child’s main carer (all of whom were the child’s mother in this analysis), and describe the characteristics of that parent only.
Child (e.g. age, sex) and parent (e.g. maternal education, current employment status) demographic characteristics were obtained through the parent survey distributed at the time of accelerometer allocation. Maternal education level was used as a proxy measure of socioeconomic status, and was classified as low (secondary school or below), medium (trade and certificate qualifications) or high (university degree or higher). Maternal employment status was considered “employed” if the child’s mother worked full time or part time and “not employed” if the child’s mother was on maternity leave or was currently engaged in unpaid home duties.

Accelerometer data reduction

**Paragraph Number 8** Accelerometer data were downloaded using ActiLife Software and initially screened for compliance with the protocol. Validated cut-points of 192-1672 and >1672 counts·minute\(^{-1}\) (CPM) were used to determine time spent in LPA and MVPA per day (28). Twenty minutes of consecutive zero counts were considered to be indicative of non-wear time. For a day to be considered valid, children were required to have produced counts for 444 minutes (7.4 hours), representing non-missing counts for at least 80% of a standard measurement day, defined as the length of time that at least 70% of the sample wore the monitor (7). This wear time is similar to the frequently used wear time of 10 hours/day in older children (22), after taking into account nap times of these younger children (approximately 2 hours per day). It also corresponded to approximately 70% of parent-reported awake time.

**Paragraph Number 9** To date, no studies have reported the number of days needed to reliably determine physical activity levels in young children. As such, reliability was estimated for LPA, MVPA and CPM, using the Spearman-Brown prophecy formula. An ICC value was computed using random valid days from each participant to eliminate possible
biases associated with selecting particular days from which to run the reliability analysis. For each participant with ≥ 2 valid days of data, a random number was assigned to each valid day. Five ICC values were calculated for LPA, MVPA and CPM by comparing random, valid days with a) at least 2 days of data, b) at least 3 days of data, c) at least 4 days of data, d) at least 5 days of data, e) at least 6 days of valid data. As the ICC values changed (albeit slightly) when different combinations of random days were chosen, the reliability analyses were run 10 times each and only the average ICC value (for 2, 3, 4, 5 and 6 days in each intensity) was recorded. These five ICC values were then averaged to give a final ICC value, which was used in the Spearman-Brown prophecy formula to determine the number of days of monitoring needed to achieve an acceptable reliability of >0.70 (19). It is important to note that while the average values for 2, 3, 4, 5 and 6 days were taken, the values that were averaged differed very little, and thus did not substantially influence the number of days of monitoring needed to reliably estimate physical activity in this sample.

Paragraph Number 10 Table 1 shows the number of days of monitoring needed to reliably estimate toddlers’ physical activity. Four days of monitoring provided acceptable (>0.70) reliability for LPA and CPM and high (>0.80) reliability for MVPA, while maintaining a reasonable sample size (n=295). Four valid days of data was therefore set as the inclusion criteria for the physical activity levels and pattern analysis in this study. As this study focused on time spent in LPA and MVPA rather than CPM, the number of days of monitoring needed to reliably estimate toddlers’ physical activity using CPM was calculated to inform future studies interested in using CPM as a main outcome measure.

Paragraph Number 11 Complete data were obtained from 295 children (158 boys, 137 girls). The main reasons for exclusion from the analyses were no data available (n=69) or insufficient valid data available (n=53). Time spent in LPA and MVPA per day were determined for each child as described above, and averaged across the number of valid days.
In addition, accelerometer data were analyzed using customized Excel macros in order to examine the data by hourly periods. This allowed for the determination of the time spent in LPA and MVPA for each hour between the hours of 6 am to 8 pm. The time frame of 6 am to 8 pm was chosen because it represented the hours during which a minimum of 20% of the sample would be included in the analyses (as determined from the examination of a random sub-sample of children), and represents logical times during the day for interventions to be implemented. To be included in the pattern analyses, children were required to have worn the accelerometer for 50% of each hour (i.e., 30 minutes) (24) and have valid accelerometer data for the whole day (i.e.: a wear time of >444 minutes). A 30 minute wear time criteria was established for the pattern analyses to attempt to reduce the potential underestimation of toddlers’ physical activity associated with napping, a characteristic of this young population. The time that each child spent in LPA and MVPA during the same valid hourly period (e.g. 9:00 am-10:00 am) was averaged over all valid days; the average value was used in the final analysis.

**Data analyses**

**Paragraph Number 12** Descriptive statistics were initially calculated for all measured variables. To assess differences in LPA, MVPA, child age, child sex and maternal education, exploratory one-way analyses of variance (LPA, MVPA, child age) and chi-square analysis (sex, maternal education) were conducted to assess differences between children included and excluded from the analysis. The main analysis consisted of a one-way analysis of variance, where differences in daily and hourly LPA and MVPA were examined, with sex and maternal employment status as the independent variables. Data were analysed using SPSS version 17.0. Statistical significance was set at p<0.05.
Results

Descriptive characteristics

Paragraph Number 13 Table 2 reports the demographic and physical activity characteristics of the study population. There were no significant differences in demographic variables and MVPA between included and excluded children, though included children engaged in approximately 40 mins more of LPA a day than excluded children, and were on average, one month younger than their excluded counterparts (19.1 months vs. 20.1 months).

Physical activity level

Paragraph Number 14 Table 3 outlines the minutes spent in LPA and MVPA for boys and girls. There were no significant differences in time spent being physically active between boys and girls and between children whose mothers were employed or not employed, for either intensity. In total, 90.5% of the children met the physical activity guidelines.

Physical activity patterns

Paragraph Number 15 Figure 1 depicts the time spent in LPA and MVPA for this sample between 6 am and 8 pm. The periods during the day with the highest physical activity were between 8 am and 10 am and between 4 pm and 5 pm. The most active hour was 4 pm- 5 pm, with children spending $20.3 \pm 4.5$ minutes in LPA and $5.4 \pm 2.6$ minutes in MVPA. Children were least active in the early morning (6 am to 8 am), around midday and after 5 pm.

Paragraph Number 16 Figure 2 illustrates the time spent in LPA and MVPA per hour for boys and girls separately. Boys engaged in significantly more LPA than girls between 6-7 am (13.4 mins vs. 9.4 mins), 7-8 am (15.4 mins vs. 13.3 mins), 8-9 am (18.5 mins vs. 17.2 mins), 9-10 am (18.8 mins vs. 17.5 mins) and in more MVPA than girls between 6-7 am (3.3
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mins vs. 2.2 mins), 7-8 am (3.8 mins vs. 2.9 mins), and 8-9 am (4.5 mins vs. 3.8 mins) respectively.

**Paragraph Number 17** Figure 3 shows the time spent in LPA and MVPA by maternal employment status. Significantly higher LPA was demonstrated by children with a mother who works full or part time during 8-9 am (18.8 mins vs. 16.2 mins), 9-10 am (18.9 mins vs. 16.8 mins), 10-11 am (19.3 mins vs. 17.9 mins), 3-4 pm (19.3 mins vs. 17.6 mins) and 4-5 pm (20.8 mins vs. 19.4 mins) while the opposite occurred during 6-7 pm (18.1 mins vs. 16.8 mins) and 7-8 pm (18.0 mins and 15.2 mins). Significantly higher MVPA was found in children with a mother who was employed during 9-10 am (4.6 mins vs. 4.0 mins) and 10-11 am (4.9 mins vs. 4.1 mins) and in children with a mother at home during 7-8 pm (5.5 mins vs. 4.4 mins).

**Paragraph Number 18** Wear time between 8:00 am and 6:00 pm varied very little (53.7 minutes/hour to 57.7 minutes/hour), with the exception of the first two periods of the day (6:00 am to 8:00 am), during which a mean wear time of 45.8 minutes/hour and 49.4 minutes/hour were observed.

**Discussion**

**Paragraph Number 19** To the best of our knowledge, this study was the first to examine the physical activity levels and patterns of toddlers using objective measures and to determine compliance with age-appropriate physical activity recommendations. Most children met the current physical activity recommendations, though this was mainly achieved through light-intensity physical activity. This finding suggests that previous studies reporting parental perceptions that young children are highly active (12, 14) is likely a perception of the time
spent in LPA, rather than MVPA, given that children only spent, on average, 47 minutes in MVPA per day.

**Paragraph Number 20** While there were no significant differences in total daily LPA or MVPA between boys and girls in this study, boys’ MVPA tended to be higher than girls’ \((p<0.06)\). Previous reviews have shown that boys are more active than girls in the preschool (13) and primary school (27) years, and it appears this phenomenon is emerging as early as 19 months of age. Furthermore, when comparing the number of minutes spent in MVPA per day in this study to Bornstein and colleagues’ (3) meta-analysis examining physical activity levels in preschool children, it appears that daily MVPA increases by about 5 minutes for boys between the ages of 19 months and 3-5 years, but remains the same for girls. While it is difficult to determine whether this phenomenon is biological, sociological, or both, this finding has important implications for future intervention strategies, as MVPA may need to be targeted in girls from a very early age. Future studies warrant investigation into potential reasons why approximately 10% of children did not meet the current physical activity recommendations.

**Paragraph Number 21** When looking at patterns of LPA and MVPA throughout the day, boys’ and girls’ activity displayed a remarkably similar pattern characterized by increasing activity in the morning which drops down around midday, and then increases in the afternoon until about 4 pm. Compared to other studies, this pattern of activity is quite unique as it typically occurs in reverse in primary school populations (at least on weekends when they are not limited by the school day), where activity levels increase up until midday and then decrease thereafter (23). One consistent finding when compared to previous physical activity pattern studies in primary school children (22, 23) was that boys were significantly more active than girls in the morning hours. It is difficult to determine whether the periods of high activity for toddlers are those in which children tend to be most active naturally, if these are
the periods that children have the most opportunity to be active, or both. However, this pattern analysis does highlight times of the day when physical activity levels could potentially be increased, particularly for MVPA, since a maximum of only 5.5 mins was spent in MVPA in any given hour. Future research should investigate whether it is most advantageous to encourage physical activity during the periods when children are already the most active and may be more responsive to physical activity promotion efforts or during those times when decreased physical activity levels occur.

**Paragraph Number 22** This study also examined the daily physical activity patterns of children based on maternal employment status, as this would largely dictate whether children spend the majority of their day in childcare or at home. Children with mothers who were currently employed outside the home exhibited significantly higher LPA and MVPA levels mid-morning and mid-afternoon, while children whose mothers did not work outside the home exhibited the highest physical activity in the early evening. Thus, although different patterns of physical activity engagement were observed across the day, children engaged in similar levels of daily physical activity regardless of maternal employment status. This suggests that physical activity patterns may differ according to environmental opportunities and that while different periods of the day do not contribute equally to daily physical activity engagement, similar levels are observed when considering daily physical activity. One possible explanation for this finding is that children have an innate set point for physical activity (termed the ‘activitystat’) suggesting that if physical activity engagement during one part of the day is low, physical activity engagement is increased in other parts of the day to maintain the innate set point (25). The present data suggest that compensation of physical activity across the day may be occurring, however to date, this hypothesis has not been investigated in children of such a young age and it has not been consistently supported when
examined in research with older children (2, 11, 30). Longitudinal or experimental research is needed to examine this hypothesis further.

**Paragraph Number 23** Additionally, this study examined the reliability of physical activity data in a young age group. We found that toddlers needed four days of valid data to provide acceptable (>0.70) reliability for all physical activity levels, similar to what Penpraze and colleagues reported for a comparable wear time criteria in preschool children using CPM (21). Our study however examined reliability of LPA and MVPA and found that MVPA was less variable in this age group than LPA. This was likely influenced by the fact that little MVPA was undertaken each day compared to LPA, though it may also suggest that interventions aimed at increasing MVPA may carry over into daily activity patterns more consistently than light activity.

**Paragraph Number 24** Strengths of this study include a large sample size and an objective measure of physical activity in a population whose physical activity has not previously been investigated. Furthermore, despite the potential logistical challenges of using accelerometry to measure physical activity in young children, 70% of our sample had valid, reliable data to use. However, the number of children included in each period analysis differed, as not all children met the 50% wear time criteria for each period (largely due to variability in nap times). This was unavoidable however, since children of this age are still napping at different times during the day. Additionally, reduced mean wear time during the first two periods of the day may have influenced the lower physical activity levels observed from 6:00 am to 8:00 am.

**Conclusion**

**Paragraph Number 25** In summary, this study contributed to our understanding of physical activity levels and patterns in young children who are just beginning to establish physical
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activity behaviours. In this study, most children met the current Australian physical activity recommendations for toddlers; however 10% did not, which could be of some concern at this young age. Furthermore, the daily physical activity level and pattern of toddlers was consistent between boys and girls, though boys did accumulate more LPA and MVPA during the morning hours. As low levels of MVPA were observed in children across the day, interventions are warranted in this population. Based on the hourly data presented, interventions delivered at certain times of the day may hold more promise than others.

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Tables:

Table 1: Number of days of monitoring needed to reliably estimate light and moderate-to-vigorous physical activity in 19 month old children

<table>
<thead>
<tr>
<th></th>
<th>Single day ICC</th>
<th>0.70</th>
<th>0.80</th>
<th>0.90</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light physical activity</td>
<td>0.376</td>
<td>3.9</td>
<td>6.6</td>
<td>14.9</td>
</tr>
<tr>
<td>Moderate-to-vigorous physical activity</td>
<td>0.497</td>
<td>2.4</td>
<td>4.0</td>
<td>9.1</td>
</tr>
<tr>
<td>Counts per minute</td>
<td>0.440</td>
<td>3.0</td>
<td>5.1</td>
<td>11.5</td>
</tr>
</tbody>
</table>

Table 2: Participant demographic and physical activity characteristics (n=295)

<table>
<thead>
<tr>
<th>Participant Characteristic</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>53.6</td>
</tr>
<tr>
<td>Age (months): mean (SD)</td>
<td>19.1 (2.3)</td>
</tr>
<tr>
<td>Avg wear mins each 60 min period: mean (SD)</td>
<td>55.0 (6.1)</td>
</tr>
<tr>
<td>Avg wear mins total: mean (SD)</td>
<td>586.41 (65.1)</td>
</tr>
<tr>
<td>Avg wear days: mean (SD)</td>
<td>6.8 (1.5)</td>
</tr>
<tr>
<td>Maternal education</td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>16.3</td>
</tr>
<tr>
<td>Medium</td>
<td>24.4</td>
</tr>
<tr>
<td>High</td>
<td>59.3</td>
</tr>
<tr>
<td>Main carer employment status</td>
<td></td>
</tr>
<tr>
<td>Maternity/paternity leave</td>
<td>6.8</td>
</tr>
<tr>
<td>Full time</td>
<td>9.2</td>
</tr>
<tr>
<td>Part time</td>
<td>51.9</td>
</tr>
<tr>
<td>Unemployed</td>
<td>2.4</td>
</tr>
<tr>
<td>Student</td>
<td>1.4</td>
</tr>
<tr>
<td>Home duties</td>
<td>24.1</td>
</tr>
<tr>
<td>Other</td>
<td>0.7</td>
</tr>
<tr>
<td>Missing</td>
<td>3.7</td>
</tr>
</tbody>
</table>
Table 3: Time spent in light and moderate-to-vigorous physical activity (mins/day) and percentage meeting the physical activity recommendations (≥180 mins/day)

<table>
<thead>
<tr>
<th></th>
<th>Boys: mean (SD)</th>
<th>Girls: mean (SD)</th>
<th>Total: mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light</td>
<td>186.5 (31.6)</td>
<td>182.3 (29.7)</td>
<td>184.5 (30.7)</td>
</tr>
<tr>
<td>Moderate-to-vigorous</td>
<td>49.6 (16.3)</td>
<td>46.0 (16.0)</td>
<td>47.9 (16.2)</td>
</tr>
<tr>
<td>% meeting guidelines</td>
<td>91.1%</td>
<td>89.8%</td>
<td>90.5%</td>
</tr>
</tbody>
</table>

Figures:

Figure 1: Daily light and moderate-to-vigorous physical activity patterns in 19 month old children
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Figure 2: Boys’ and girls’ light and moderate-to-vigorous physical activity patterns

Figure 3: Physical activity pattern of children based on maternal employment status
References


