PEDIATRIC EXERCISE SCIENCE
Official Journal of NASPEM and the
European Group of PWP
www.PES-Journal.com
ORIGINAL RESEARCH

Pediatric Exercise Science, 2014, 26, 103-109
http://dx.doi.org/10.1123/pes.2013-0021

Assessing Preschool Children's Physical Activity: How Many Days of Accelerometry Measurement

Cheryl L. Addy, Jennifer L. Trilk, and Marsha Dowda
University of South Carolina

Won Byun
North Dakota State University

Russell R. Pate
University of South Carolina

The purpose of this study was to determine the minimum number of days of accelerometry required to estimate accurately MVPA and total PA in 3- to 5-year-old children. The study examined these metrics for all days, weekdays, and in-school activities. Study participants were 204 children attending 22 preschools who wore accelerometers for at least 6 hr per day for up to 12 days during most waking hours. The primary analysis considered the intraclass correlation coefficient (ICC) for each metric to estimate the number of days required to attain a specified reliability. The ICC estimates are 0.81 for MVPA-all days, 0.78 for total PA-all days, 0.83 for MVPA weekdays, 0.80 for total PA-weekdays, 0.81 for in-school MVPA, and 0.84 for in-school total PA. We recommend a full seven days of measurement whenever possible, but researchers can achieve acceptable reliability with fewer days, as indicated by the Spearman-Brown prophecy: 3–4 days for any weekday measure and 5–6 days for the all-days measures.

Keywords: reliability, Actigraph, objective measurement, reliability, young children

Obesity and associated comorbidities in American children have increased dramatically in recent decades, and this alarming trend has been documented in children as young as preschool age (25). Researchers studying the pediatric obesity epidemic have examined the contributions of low levels of physical activity and high levels of physical inactivity to increased body fatness in young children (25,31) and to early onset of diseases such as atherosclerosis, reduced vascular function (38) and Type II diabetes (8,20). Although many people believe that preschool-age children are highly physically active, available data suggest that today's young children are not nearly as active as parents believe or as experts recommend (4,19,28,37). Indeed, available studies using self-report and objective measurement systems have consistently found that most preschool-age children do not meet the various national guidelines (e.g., ≥2 to 3 hr physical activity per day [10,24]) deemed necessary for health benefits (1,4,15,32,37). Because more than 4 million American children attend formal preschools or child care centers, studies in this setting may identify strategies to increase physical activity in 3-to 5-year-old children.

Researchers recommend using objective measures of physical activity in young children because of their intermittent activity patterns and limited ability to recall physical activity reliably (4,27). However, objective measurement of physical activity in this population is challenging, especially for unstructured activity. While direct observational systems (3) provide valuable contextual information about physical activity, these systems are labor intensive and therefore not practical for larger samples. Pedometers can be used as a surrogate indicator of physical activity, but they measure only a limited range of movement and do not account for the intensity of the activity. Accelerometers, therefore, are the objective instrument of choice for measuring young children's

Addy is with the Dept. of Epidemiology and Biostatistics, Arnold School of Public Health, University of South Carolina, Columbia, SC. Trilk is with the Dept. of Biomedical Sciences, University of South Carolina School of Medicine, Greenville, SC. Dowda and Pate are with the Dept. of Exercise Science, Arnold School of Public Health, University of South Carolina, Columbia, SC. Byun was with the School of Physical Education, Sport and Exercise Science, Ball State University, Muncie, IN at the time of this research and is now with North Dakota State University.

physical activity (12,26,31,35). Various investigators have evaluated measurement protocols for using accelerometers in adult populations (6,14,17,21,22) and in populations of elementary-aged children (11,40). Penpraze et al. (29) studied the number of days needed for acceptable reliability by examining accelerometry counts per minute in 5-year-olds. However, to the best of our knowledge, no studies to date have investigated how many days of wear time are needed for accurate measurement of moderate-to-vigorous and total physical activity (MVPA and total PA) over the total day and while in preschool in 3- to 5-year-old children.

The purpose of this study was to determine the minimum number of days of accelerometry monitoring required to estimate accurately MVPA and total PA in 3- to 5-year-old children. The study examined these metrics for in-school activity, weekday activity, and all-days activity.

Methods

Participants and Settings

Study participants were children enrolled in the Children's Activity and Movement in Preschools Study (CHAMPS) study. The overall goal of CHAMPS was to describe physical activity behavior in preschool children to inform the development of policies and practices related to children's physical activity in preschools. The sampling frame for CHAMPS involved community-based programs in the metropolitan area of Columbia, South Carolina. Twenty-two preschools with enrollment of at least 45 children aged 3–5 years were recruited. Eligible preschools were categorized into one of three program types: (a) commercial childcare centers, (b) faith-based preschools, and (c) Head Start programs. Then, a stratified random sample of schools was selected based on a representative number of preschools from each of the three program types. We invited preschool directors to participate and, if a director declined, invited the director from the next randomly-selected program. Once the preschools were recruited, we invited all parents of 3-, 4-, and 5-year-old children enrolled in the preschools to participate in CHAMPS. Written informed consent was obtained from each child's parent or guardian before collection of data. The study was approved by the University of South Carolina Institutional Review Board. The final sample for the analyses presented here included children from 22 preschools.

We collected study information between August 2003 and January 2006, with two independent waves of data collection in each preschool separated by 13–19 months. The number of participants per preschool ranged from 14 to 33 children. From the original pool of 297 study participants who had complete accelerometer data for at least 1 in-school day, we constructed three analytic samples: the all-days sample included 150 children with at least 6 total days (at least 4 weekdays and at least 1 weekend day) of valid accelerometry data, the weekdays sample included 204 children with at least 4 total weekdays of valid accelerometry data, and the in-school sample included 199 children with at least 4 in-school days of valid accelerometry data. Accelerometry data were used if at least 6 hr of data were available for total-day activity, or at least 4.9 hr of data for in-school activity; these criteria were based on the empirical distributions of wear time. Reasons for exclusion included noncompliance with wearing instructions and occasional equipment failure.

Physical Activity Measurement

Children wore ActiGraph accelerometers (model 7164; ActiGraph, Pensacola, FL) over a 2-week period to measure physical activity and sedentary behavior. The ActiGraph is a uniaxial accelerometer that measures acceleration in the vertical plane. The instrument is small ($2.0 \times 1.6 \times 0.6$ inches), light (1.5 oz), and unobtrusive. For the current study, the monitors were initialized to save data in 15-s intervals to detect the short bursts of activity that are characteristic of 3- to 5-year-old children (5,9,41). Participants wore the accelerometers on an elastic belt on the right hip (anterior to the iliac crest) for up to 12 consecutive days, including one weekend. Parents were instructed to remove the accelerometer only during water activities (e.g., bathing or swimming) and when the child went to bed at night. Accelerometers were replaced before the weekend and again on the following Monday. Data were linked according to child. Sixty minutes of consecutive zero values were considered as nonwear time and deleted before analysis. For analyses, data were reduced according to previously-published methods (39).

Trained data collectors recorded preschool arrival and departure times for each child, using sign-in and sign-out sheets that had been completed by the parent or guardian. Days on which a child was absent from preschool were not included for either the in-school or total-day activity. Occasional missing entry and exit times were imputed based on the child's other data (usual times entered on the consent form, entry and exit times on other days, and school average entry and exit times), using a SAS (SAS Institute, Cary, NC) algorithm developed by the researchers that weighted the child-specific data more heavily than the school-level data. Subjects for whom we were unable to identify accurately the time arriving at or departing the preschool were deleted for the in-school analysis.

Accelerometer data were reduced using cut points developed specifically for 3- to 5-year-old children (27,30) to identify intervals of MVPA (≥420 counts per 15-s interval) and total PA (≥200 counts per 15-s interval). Activity measured over the total day and for in-school day was then calculated by using each child's wear time for total day and in-school day, respectively, as the divisor. For the current study, the following were analyzed: 1) in-school MVPA (minutes MVPA per hour while in school), 2) MVPA-weekdays (minutes MVPA per hour anytime on weekday), 3) MVPA-all days (minutes MVPA per hour

anytime), 4) in-school total PA (minutes total PA per hour while in school), 5) total PA-weekdays (minutes total PA per hour anytime on weekdays), and 6) total PA-all days (minutes total PA per hour anytime).

Analysis

The magnitude of the intraclass correlation coefficient (ICC) is a key determinant of how many days of measurement are needed to provide a reliable measure of physical activity. Therefore, ICC was calculated using variance components from repeated measures analysis of variance (ANOVA) as ICC = (MS-MSE)/MS (MS = mean square for subject, MSE= mean square error), for the six respective analyses of MVPA and total PA. In addition, these components of variance were used to estimate 1-day and 4-day ICC values (34) and to apply the Spearman-Brown prophecy formula (36) for days required to attain a specified reliability. Finally, the reliabilities were explored using 2- or 3-day combinations of available data.

Results

Approximately half of the children were male and 48% were black (Table 1). Mean age and BMI were 4.1 years and 16.3 kg/m^2, respectively, with 26% of the children classified as overweight/obese (above age and sex-specific 85th percentile of CDC growth curves, http://www.cdc.gov/growthcharts). Children wore the accelerometer on average 8.2 hr per day while in preschool (child's mean wear time 4.9–10.8 hr) and 12.2 hr per day total (child's mean wear time 6.3–17.5 hr).

Table 2 displays results of the mean minutes per hour of daily MVPA and total PA used to construct the MVPA-all days, MVPA-weekdays, in-school MVPA, total PA-all days, total PA-weekdays and in-school total PA metrics. Analyses were repeated including only subsamples of children who contributed the full seven measurements for the all-days metrics (83 of 150 children) and those who had 5 days for weekday (154 of 204) and in-school (124 of 199 children) activity metrics. However, results for the subsamples were very similar across all six metrics and therefore are not presented. The means and variability were similar across samples for each day, although variability for weekend activity was slightly greater than for weekday activity, and in-school activity was more variable than total-day activity, especially on Monday and Friday. No time by sex interactions were significant in any of the samples; therefore, sex was pooled. Within the all-days sample, children exhibited more MVPA on weekend days than on weekdays. The average MVPA on Saturday differed significantly from every weekday; total MVPA between Wednesday and Thursday and between Sunday and Thursday also differed in the all-days sample. Activity levels for weekday and in-school MVPA did not vary significantly by day of the week; none of the total PA metrics varied by day of week.

Table 1 Characteristics of Preschool Children

	Total Day		School Day
Characteristic	Weekday Sample (*n* = 204)	All-Days Sample (*n* = 150)	In-School Sample (*n* = 199)
Age, years	4.2 (0.7)	4.1 (0.6)	4.2 (0.6)
BMI (kg/m^2)	16.3 (1.8)	16.3 (1.9)	16.3 (1.8)
Overweight/obese[a]	26.5%	26.0%	26.1%
Sex, percent males	48.0%	48.7%	49.8%
3 years	42.6%	45.3%	42.2%
4 years	46.6%	43.3%	46.7%
5 years	10.8%	11.3%	11.1%
Black	47.1%	48.0%	47.7%
Other[b]	11.3%	12.7%	11.6%
White	41.7%	39.3%	40.7%
Monitor wear (hr)	12.2 (2.7)	12.1 (2.7)	8.2 (1.4)

Note. Weekday sample = 4–5 weekdays of data, all-days sample = 6–7 days of data, in-school sample = 4–5 days of data. Mean (*SD*) or percent

[a]Overweight/obese defined as above age and sex-specific 85%ile of CDC growth curves (http://www.cdc.gov/growthcharts/)

[b]Other race includes Hispanic, Asian, two or more races, and unknown.

Table 2 Descriptive Statistics for MVPA and Total PA (Min/Hr) by Day

	MVPA						Total PA					
	All days[a]		Weekdays		In-school		All days		Weekdays		In-school	
	N	Mean (*SD*)	*N*	Mean (*SD*)	*N*	Mean (*SD*)	*N*	Mean (*SD*)	*N*	Mean (*SD*)	*N*	Mean (*SD*)
Monday	134	7.5 (2.8)	172	7.5 (2.7)	172	7.3 (3.6)	134	14.1 (3.9)	172	14.2 (3.9)	172	13.0 (5.7)
Tuesday	146	7.3 (2.7)	200	7.4 (2.8)	195	7.3 (3.5)	146	13.9 (3.9)	200	14.0 (4.0)	195	13.0 (5.2)
Wednesday	148	7.6 (2.6)	197	7.5 (2.5)	194	7.6 (3.1)	148	14.2 (3.5)	197	14.2 (3.5)	194	13.4 (4.7)
Thursday	148	7.0 (2.7)	194	7.2 (2.7)	188	7.3 (3.5)	148	13.5 (3.8)	194	13.7 (3.8)	188	12.9 (5.3)
Friday	135	7.6 (2.9)	177	7.7 (2.9)	171	7.9 (4.1)	135	14.2 (3.9)	177	14.4 (4.0)	171	13.8 (5.7)
Saturday	133	8.4 (3.5)					133	16.0 (5.0)				
Sunday	139	7.9 (3.4)					139	15.0 (4.9)				
Mean	150	7.6 (2.1)	204	7.5 (2.1)	199	7.5 (2.7)	150	14.4 (2.8)	204	14.1 (2.9)	199	13.2 (4.3)

[a]Based on repeated-measures ANOVA, MVPA-all days varies by day of week ($p < .001$). None of other metrics vary significantly by day of week.

ICCs and the number of days of monitoring to achieve certain levels of reliability are presented in Table 3. For MVPA-all days, the ICC was 0.81 using the 150 children with six or seven days of data (average 6.55 days). The calculated 1-day ICC was 0.39, while the 4-day ICC was 0.72 for MVPA-all days. The Spearman-Brown prophecy suggested that 4.7 days of monitoring are needed for a reliability of 0.75 to estimate MVPA-all days. For MVPA-weekdays, the ICC was 0.83 using the 204 children with at least 4 days of weekday physical activity data (average 4.75 days). The 1-day ICC was 0.51, while the 4-day ICC was 0.81. The Spearman-Brown prophecy suggested that 2.9 days of monitoring are needed for a reliability of 0.75.

Similarly, for total PA-all days, the ICC was 0.78 using the 150 children with 6 or 7 days of data. The calculated 1-day ICC was 0.36, while the 4-day ICC was 0.69 for total PA-all days. The Spearman-Brown prophecy suggested that 5.5 days of monitoring are needed for a reliability of 0.75 to estimate total PA-all days. For total PA-weekdays, the ICC was 0.80 using the 204 children with at least 4 days of weekday physical activity data. The 1-day ICC was 0.46, while the 4-day ICC was 0.78. The Spearman-Brown prophecy suggested that 3.5 days of monitoring are needed for a reliability of 0.75.

For in-school MVPA, the ICC was 0.81 using 199 children with 4 or 5 days of data (average 4.62 days). The calculated 1-day ICC was 0.48, while the 4-day ICC improved to 0.79. Based on the Spearman-Brown prophecy, 3.3 days of monitoring are needed to attain a reliability of 0.75. For in-school total PA, the ICC was 0.84 using the same 199 children. The calculated 1-day ICC was 0.53, while the 4-day ICC improved to 0.82. Based on the Spearman-Brown prophecy, 2.6 days of monitoring are needed to attain a reliability of 0.75. To achieve a reliability of 0.90, at least eight days of data collection would be needed for any of the six metrics.

While collecting a full week of data is clearly preferable for measuring any of the total-day or in-school PA metrics, there are circumstances for which this is

Table 3 Reliability Outcomes for Days of Monitoring, and the Number of Days Needed to Achieve Acceptable Reliability

			ICCs for 1 and 4 days		Number of days[a] to achieve ICCs		
Physical Activity Metric	*n*	ICC	1 Day	4 Day	0.7	0.75	0.8
MVPA-all days	150	0.81	0.39	0.72	3.62	4.65	6.21
MVPA-weekdays	204	0.83	0.51	0.81	2.28	2.93	3.90
In-school MVPA	199	0.81	0.48	0.79	2.54	3.26	4.35
Total PA-all days	150	0.78	0.36	0.69	4.24	5.45	7.26
Total PA-weekdays	204	0.80	0.46	0.78	2.68	3.45	4.60
In-school total PA	199	0.84	0.53	0.82	2.04	2.62	3.50

[a]Spearman-Brown prophecy calculation.

not practical. We therefore explored the reliability of measuring any 2 or 3 days for the metrics. When limited to any combination with 1 weekday and 1 weekend day, the ICC estimates based on 2 days of monitoring were unacceptably low for both MVPA and total PA. Using the sample of 204 children with at least four weekdays of data, the highest ICCs for 2-day monitoring used to estimate MVPA-weekdays were Monday–Tuesday (ICC = 0.75), Tuesday through Wednesday (ICC = 0.70) and Wednesday through Thursday (ICC = 0.75); ICCs for other combinations of 2 weekdays ranged from 0.54 to 0.69. The Monday–Tuesday combination had the highest ICC for in-school MVPA (0.72), with other pairs of days having ICCs from 0.51 to 0.69.

The highest ICCs for 2-day monitoring used to estimate total PA-weekdays were Monday–Tuesday (ICC = 0.70) and Wednesday through Thursday (ICC = 0.72), with ICCs from 0.53 to 0.66 for other combinations. Similarly, for in-school total PA, the best combination was Monday–Tuesday (ICC = 0.76) with other combinations ranging from 0.56 to 0.74.

The 3-day ICCs for MVPA-weekdays ranged from 0.71 to 0.79, with the 3 consecutive weekday combinations not including Friday each having an ICC of 0.79. The combinations of weekdays that included Friday had ICCs between 0.71 and 0.74. As with the 2-day ICCs, the 3-day ICCs for in-school MVPA were consistently lower than for the corresponding MVPA-weekdays, ranging from 0.64 to 0.76, because of the greater variability in in-school MVPA than total-day activity. For total PA-weekdays, the 3-day combinations not including Friday had ICCs between 0.75 and 0.77; those combinations with Friday had ICCs between 0.67 and 0.71. ICCs for in-school total PA were slightly higher, between 0.78 and 0.80 for 3-day combinations not including Friday and between 0.70 and 0.76 for combinations including Friday. Across all six metrics and both 2- and 3-day combinations, those combinations with consecutive days excluding Friday tended to have slightly higher reliabilities than combinations of nonconsecutive days.

Discussion

This study was among the first to determine the number of days of measurement required to accurately estimate MVPA and total PA using accelerometry in 3- to 5-year-old preschool children. Based on the analyses, we recommend that accelerometry data be collected for a full 7 days in 3- to 5-year-old children to maximize the likelihood of acquiring sufficient data for any metric. However, for practical applications, a key finding is that researchers can achieve acceptable reliability (ICC $\geq$ 0.75) with a minimum of 5 days of monitoring for MVPA-all days, 6 days of monitoring for total PA-all days, 3 days of monitoring for MVPA-weekdays or in-school total PA, and 4 days of monitoring for in-school MVPA or total PA-weekdays. This information will aid researchers in determining the best methods for objectively measuring physical activity in 3- to 5-year-old preschool children and assist public health officials in developing intervention strategies to increase physical activity in the preschool setting.

Several previous studies have determined the number of days of accelerometry needed to measure MVPA reliably ranges from 4 to 5 days to 8 to 10 days for children and adolescents respectively (11,16,23,29,39,40). A study by Trost et al. (40) showed less day-to-day variability in MVPA measured by accelerometry among younger children (1st–6th grades) than older children (7th-12th grades), which resulted in a lower number of days of required to achieve the same level of reliability in young children compared with older children (4–5 days vs. 8–9 days). A study by Penpraze et al. (29) found that 4 days of monitoring were necessary to achieve a reliable measure of accelerometry counts/minute (ICC = 0.84) in young children (mean age of 5.6 years). Our finding that 5 days and 3 days of monitoring can be used to measure total day and total weekday MVPA reliably in preschool children is consistent with these previous findings and with the more recent recommendation from Hinkley et al. (15) of 2.7–3.4 days, depending on hours measured per day, for preschool children in Australia.

Our study is the first to examine physical activity for the in-school period and for total day separately. We observed more variability in in-school activity than in weekday activity, indicating that more days of monitoring may be required to measure in-school than total weekday activity. This information could have important implications for public health officials since children spend a significant amount of time in the school setting, making it an ideal environment to test the effects of physical activity interventions. Researchers can apply this information confidently when determining the best methods for objectively measuring physical activity in 3- to 5-year-old preschool children, or during intervention strategies to increase physical activity in the preschool setting. Future research is needed to validate the number of days necessary to reliably measure in-school activity across different populations. Gidlow et al. (13) compared in-school versus out-of-school physical activity for a sample ages 3–16 and reported that accelerometer counts were higher for out-of-school activity, suggesting the importance of promoting physical activity during the school day. However, preschool children comprised only a small portion of their total sample, and the difference between in-school and out-of-school physical activity was much smaller in that age group.

When deciding which number of days is best for monitoring purposes, researchers must balance a high reliability with the practicality of obtaining the measure. Although all combinations of days could be used, the better strategy for balancing reliability with practicality is to use consecutive days (e.g., Tuesday, Wednesday, Thursday) when measuring physical activity via accelerometry in 3- to 5-year-old preschool children. It is impractical to place accelerometers on children (or any population) on nonadjacent days and expect to obtain complete measures for total day activity. Any combination that included a Friday decreased the reliability of the measure. This is

likely due to either greater variability in the preschool setting on Fridays compared with other school days, or that excluding Fridays may slightly underestimate physical activity obtained both in school and over the total day, if Friday is typically the most physically active weekday in this population. Because the number of children in our sample with valid data for Friday was lower, we cannot determine if the Friday activity is typical or an artifact of lower attendance/participation.

In addition, estimating MVPA-all days requires capturing data for both Saturday and Sunday, since each of these days may be distinct in terms of physical activity behavior. The 2- and 3-day combinations resulting in the highest ICC estimates were those with weekdays only, and thus should be thought of as appropriate for measurement of MVPA-weekdays, not MVPA-all days. Our results are consistent with Hinkley et al. (15), who found greater activity for preschool children on weekend days compared with weekdays, but contradict one study that identified greater MVPA on weekdays than weekend days in a very small group of preschool children (2). In a large sample of Canadian children and youth (ages 5–19), Craig et al. reported more pedometer steps on weekdays than weekend days, but the differences were virtually nonexistent among the youngest subjects (7). Finally, advantages to capturing a full week of measurement include the potential differences in Monday (first day back from the weekend) and Friday (day before the weekend; less formal curriculum and more physical activity). This is especially critical for in-school activity and to capture weekend behaviors that may start before the weekend actually begins.

A major strength of this study is the large sample size; with the exception of Hinkley et al. (15), most studies involving young children included 60 or fewer subjects. Other researchers have documented no differences in measurement properties across several Actigraph models (18,33), so our results are relevant to a broad range of accelerometry research in this population. Compliance is a challenge with accelerometry measurement for all ages, but perhaps more so for preschool children. A parent may remove the equipment for several reasons, after which s/he must remember to reposition the accelerometer on the child for subsequent measurement. A limitation of our study design was the challenge of collecting accurate time-in/time-out data to delimit in-school activity in some of the preschool settings.

Future studies should strive to duplicate and refine these results in other preschool populations. Our group has developed a comprehensive method of direct observation (3), but further work is needed to integrate accelerometry measurement with direct observation.

Reference

1. Beets MW, Bornstein D, Dowda M, Pate RR. Compliance with national guidelines for physical activity in U.S. preschoolers: Measurement and interpretation. *Pediatrics.* 2011; 127(4):658–664. PubMed doi:10.1542/peds.2010-2021
2. Benham-Deal T. Preschool children's accumulated and sustained physical activity. *Percept Mot Skills.* 2005; 100(2):443–450. PubMed doi:10.2466/pms.100.2.443-450
3. Brown WH, Pfeiffer KA, McIver KL, Dowda M, Almeida MJCA, Pate RR. Assessing preschool children's physical activity: An Observational System for Recording Physical Activity in Children - Preschool Version (OSRAC-P). *Res Q Exerc Sport.* 2006; 77(2):167–176. PubMed
4. Cardon GM, De B. I. Are preschool children active enough? Objectively measured physical activity levels. *Res Q Exerc Sport.* 2008; 79(3):326–332. PubMed
5. Cliff DP, Reilly JJ, Okely AD. Methodological considerations in using accelerometers to assess habitual physical activity in children aged 0-5 years. *J Sci Med Sport.* 2009; 12(5):557–567. PubMed doi:10.1016/j.jsams.2008.10.008
6. Coleman KJ, Epstein LH. Application of generalizability theory to measurement of activity in males who are not regularly active: A preliminary report. *Res Q Exerc Sport.* 1998; 69(1):58–63. PubMed doi:10.1080/02701367.1998.10607667
7. Craig CL, Cameron C, Griffiths JM, Tudor-Locke C. Descriptive epidemiology of youth pedometer-determined physical activity: CANPLAY. *Med Sci Sports Exerc.* 2010; 42(9):1639–1643. PubMed doi:10.1249/MSS.0b013e3181d58a92
8. Dabelea D, Mayer-Davis E, Talton JW, Hamman RF, Bell RA, Dolan LM. Is prevalence of type 2 diabetes increasing in youth? The SEARCH for Diabetes in Youth Study. Diabetes 2012; 61((Suppl. 1)):A61.
9. de Vries SI, Bakker I, Hopman-Rock M, Hirasing RA. van MW. Clinimetric review of motion sensors in children and adolescents. *J Clin Epidemiol.* 2006; 59(7):670–680. PubMed doi:10.1016/j.jclinepi.2005.11.020
10. Department of Health and Ageing. National Physical Activity Guidelines for Australians. Physical Activity Recommendations for 0-5 Year Olds. 2010. Canberra, Commonwealth of Australia.
11. Fairclough SJ, Butcher ZH, Stratton G. Whole-day and segmented-day physical activity variability of northwest England school children. *Prev Med.* 2007; 44(5):421–425. PubMed doi:10.1016/j.ypmed.2007.01.002
12. Finn KJ, Specker B. Comparison of Actiwatch activity monitor and Children's Activity Rating Scale in children. *Med Sci Sports Exerc.* 2000; 32:1794–1797. PubMed doi:10.1097/00005768-200010000-00021
13. Gidlow CJ, Cochrane T, Davey R, Smith H. In-school and out-of-school physical activity in primary and secondary school children. *J Sports Sci.* 2008; 26(13):1411–1419. PubMed doi:10.1080/02640410802277445
14. Gretebeck RJ, Montoye HJ. Variability of some objective measures of physical activity. *Med Sci Sports Exerc.* 1992; 24(10):1167–1172. PubMed doi:10.1249/00005768-199210000-00016
15. Hinkley T, O'Connell E, Okely AD, Crawford D, Hesketh K, Salmon J. Assessing volume of accelerometry data for reliability in preschool children. *Med Sci Sports Exerc.* 2012; 44(12):2436–2441. PubMed doi:10.1249/MSS.0b013e3182661478
16. Janz KF, Witt J, Mahoney LT. The stability of children's physical activity as measured by accelerometry and self-

report. *Med Sci Sports Exerc.* 1995; 27(9):1326–1332. PubMed doi:10.1249/00005768-199509000-00014
17. Jerome GJ, Young DR, Laferriere D, Chen C, Vollmer WM. Reliability of RT3 accelerometers among overweight and obese adults. *Med Sci Sports Exerc.* 2009; 41(1):110–114. PubMed doi:10.1249/MSS.0b013e3181846cd8
18. John D, Tyo B, Bassett DR. Comparison of four ActiGraph accelerometers during walking and running. *Med Sci Sports Exerc.* 2010; 42(2):368–374. PubMed doi:10.1249/MSS.0b013e3181b3af49
19. Kelly LA, Reilly JJ, Jackson DM, Montgomery C, Grant S, Paton JY. Tracking physical activity and sedentary behavior in young children. *Pediatr Exerc Sci.* 2007; 19:51–60. PubMed
20. Kriska A, Delahanty L, Edelstein S, et al. Sedentary behavior and physical activity in youth with recent onset of type 2 diabetes. *Pediatrics.* 2013; 131(3):e850–e856. PubMed doi:10.1542/peds.2012-0620
21. Levin S, Jacobs, Jr. DR, Ainsworth BE, Richardson MT, Leon AS. Intra-individual variation and estimates of usual physical activity. *Ann Epidemiol.* 1999; 9(8):481–488. PubMed doi:10.1016/S1047-2797(99)00022-8
22. Matthews CE, Ainsworth BE, Thompson RW, Bassett, Jr. DR. Sources of variance in daily physical activity levels as measured by an accelerometer. *Med Sci Sports Exerc.* 2002; 34(8):1376–1381. PubMed doi:10.1097/00005768-200208000-00021
23. Murray DM, Catellier DJ, Hannan PJ, et al. School-level intraclass correlation for physical activity in adolescent girls. *Med Sci Sports Exerc.* 2004; 36(5):876–882. PubMed doi:10.1249/01.MSS.0000126806.72453.1C
24. National Association for Sport and Physical Education. *Active Start: A Statement of Physical Activity Guidelines for Children from Birth to Age 5*. Washington, DC: AAHPERD, 2009.
25. Ogden CL, Carroll MD, Curtin LR, McDowell MA, Tabak CJ, Flegal KM. Prevalence of overweight and obesity in the United States, 1999-2004. *JAMA.* 2006; 295(13):1549–1555. PubMed doi:10.1001/jama.295.13.1549
26. Oliver M, Schofield GM, Kolt GS. Physical activity in preschoolers: Understanding prevalence and measurement issues. *Sports Med.* 2007; 37(12):1045–1070. PubMed doi:10.2165/00007256-200737120-00004
27. Pate RR, Almeida MJCA, McIver KL, Pfeiffer KA, Dowda M. Validation and calibration of an accelerometer in preschool children. *Obesity (Silver Spring).* 2006; 14(11):2000–2006. PubMed doi:10.1038/oby.2006.234
28. Pate RR, McIver K, Dowda M, Brown WH, Addy C. Directly observed physical activity levels in preschool children. *J Sch Health.* 2008; 78(8):438–444. PubMed doi:10.1111/j.1746-1561.2008.00327.x
29. Penpraze V, Reilly JJ, MacLean CM, et al. Monitoring of physical activity in young children: How much is enough? *Pediatr Exerc Sci.* 2006; 18(4):483–491.
30. Pfeiffer KA, Dowda M, McIver KL, Pate RR. Factors related to objectively measured physical activity in preschool children. *Pediatr Exerc Sci.* 2009; 21(2):196–208. PubMed
31. Reilly JJ, Coyle J, Kelly L, Burke G, Grant S, Paton JY. An objective method for measurement of sedentary behavior in 3- to 4-year olds. *Obes Res.* 2003; 11:1155–1158. PubMed doi:10.1038/oby.2003.158
32. Sallis JF, Patterson TL, McKenzie TL, Nader PR. Family variables and physical activity in preschool children. *J Dev Behav Pediatr.* 1988; 9(2):57–61. PubMed doi:10.1097/00004703-198804000-00001
33. Sasaki JE, John D, Freedson PS. Validation and comparison of ActiGraph activity monitors. *J Sci Med Sport.* 2011; 14(5):411–416. PubMed doi:10.1016/j.jsams.2011.04.003
34. Shrout PE, Fleiss JL. Intraclass correlations: Uses in assessing rater reliability. *Psychol Bull.* 1979; 86(2):420–428. PubMed doi:10.1037/0033-2909.86.2.420
35. Sirard JR, Pate RR. Physical activity assessment in children and adolescents. *Sports Med.* 2001; 31:439–454. PubMed doi:10.2165/00007256-200131060-00004
36. Spearman CE. Proof and measurement of association between two things. *Am J Psychiatry.* 1904; 5:72–101.
37. Taylor RW, Murdoch L, Carter P, Gerrard DF, Williams SM, Taylor BJ. Longitudinal study of physical activity and inactivity in preschoolers: The FLAME study. *Med Sci Sports Exerc.* 2009; 41(1):96–102. PubMed doi:10.1249/MSS.0b013e3181849d81
38. Timmons BW, LeBlanc AG, Carson V, et al. Systematic review of physical activity and health in the early years (aged 0-4 years). *Appl Physiol Nutr Metab.* 2012; 37(4):773–792. PubMed doi:10.1139/h2012-070
39. Treuth MS, Schmitz K, Catellier DJ, et al. Defining accelerometer thresholds for activity intensities in adolescent girls. *Med Sci Sports Exerc.* 2004; 36(7):1259–1266. PubMed
40. Trost SG, Pate RR, Freedson PS, Sallis JF, Taylor WC. Using objective physical activity measures with youth: How many days of monitoring are needed? *Med Sci Sports Exerc.* 2000; 32(2):426–431. PubMed doi:10.1097/00005768-200002000-00025
41. Ward DS, Evenson KR, Vaughn A, Rodgers AB, Troiano RP. Accelerometer use in physical activity: Best practices and research recommendations. *Med Sci Sports Exerc.* 2005; 37(11 Suppl):S582–S588. PubMed doi:10.1249/01.mss.0000185292.71933.91