Agreement of objectively measured physical activity and sedentary time in preschool children

Eivind Aadland *, Kjersti Johannessen
Faculty of Teacher Education and Sport, Sogn og Fjordane University College, Box 133, 6851 Sogndal, Norway

ARTICLE INFO
Available online 21 July 2015

Keywords:
Accelerometry
Measurement
Bland–Altman plot
Test–retest
Agreement of objectively measured physical activity (PA) and sedentary behavior (SED) over two subsequent weeks in preschool children.

Method. Ninety-one children aged 3 to 5 years (49% boys) from three preschools in Sogn og Fjordane, Norway, provided 14 consecutive days of accelerometer data (Actigraph GT3X+) during the autumn of 2014. Week-by-week reliability was assessed using intraclass correlation (ICC), Bland–Altman plots and 95% limits of agreement for different wear time criteria (≥6, 8 and 10 h/day and ≥3 and 5 days/week).

Results. The week-by-week ICC was ≥0.75 for all variables across all wear criteria applied, except for absolute sedentary time (ICC 0.61–0.81). Using a ≥8 h/day and ≥3 days/week criterion (n = 78), limits of agreement were ±209.5 cpm for overall PA, ±68.6 min/day for SED, ±43.8 min/day for light PA, ±20.2 min/day for moderate-to-vigorous PA, and ±55.9 min/day for light-to-vigorous PA, equating 1.0–1.6 standard deviation units.

Conclusion. Considerable week-by-week variability was found for all variables. Researchers need to be aware of substantial intra-individual variability in accelerometer-measurements and take necessary actions according to the hypothesis under study, as noise in any measurement will preclude researchers’ ability to arrive at valid conclusions in epidemiology.

© 2015 The Authors. Published by Elsevier Inc. This is an open access article under the CC BY license (http://creativecommons.org/licenses/by/4.0/).

Introduction

Objective assessment of movement is the cornerstone of most ongoing epidemiological studies investigating health benefits of physical activity (PA) and sedentary behavior (SED). Yet, measurement error may preclude researchers from arriving at valid conclusions and possibly misinform the society regarding targets for public health initiatives (Hutcheon et al., 2010). Given the inherent variation in behavior over time, an important aspect of accelerometer measurements is how many days of measurement that are needed to obtain reliable estimates of habitual activity level.

Although findings vary somewhat between studies in both adults (Coleman and Epstein, 1998; Gretebeck and Montoye, 1992; Hart et al., 2011; Jerome et al., 2009; Matthews et al., 2002; Trost et al., 2005) and children (Addy et al., 2014; Basterfield et al., 2011; Hinkley et al., 2012; Hislop et al., 2014; Janz et al., 1995; Kang et al., 2009; Murray et al., 2004; Ojiambo et al., 2011; Penpraze et al., 2006; Rich et al., 2013; Treuth et al., 2003; Trost et al., 2000), most evidence suggest that a reliability (i.e., intraclass correlation (ICC)) of ~0.70–0.80 are achieved with 3–7 days of monitoring by estimation of the reliability and the number of days needed based on the Spearman Brown prophecy formula when measurements are conducted over a single 7-day period. However, such study designs have been criticized for possibly leading to optimistic results and should be interpreted with caution (Baranowski et al., 2008; Matthews et al., 2012; Wickel and Welk, 2010). First, the results are in principle only generalizable to the included days, as inclusion of additional days, weeks or seasons will add variability. Some few studies have determined the reliability for several periods of measurement over the course of a year, of which all have shown considerable intra-individual variation (Levin et al., 1999; Mattocks et al., 2007; Wickel and Welk, 2010), leaving reliability estimates for ~0.50 for one week monitoring in children. Second, the assumption of compound symmetry (i.e., similar variances and co-variances across days of measurement) might not be fulfilled. Additionally, ICC is the variance partitioning of subjects to the total variance, thus ICC is a relative and context-specific estimate that depends on the heterogeneity of the sample (Bland and Altman, 1986; Hopkins, 2000; Weir, 2005).

No studies have determined the intra-individual week-by-week agreement of accelerometer outcomes using absolute measures of reliability, i.e., standard error of the measurement (SEM) or limits of agreement (LoA). Such measures provide researchers a direct quantification of how much outcomes should be expected to vary over time and is independent of the variability of observations (Bland and Altman, 1986; Hopkins, 2000; Weir, 2005).
Consistent with studies in other age groups, it is estimated that 3 – 7 days of accelerometer monitoring are needed to reliably determine PA in preschool children (Addy et al., 2014; Hinkley et al., 2012; Hislop et al., 2014; Penpraze et al., 2006). As preschool children is an understudied population in PA epidemiology (Pate et al., 2013), the quantification of measurement error for determination of PA and SED in this age-group is important for methodological considerations concerning the measurement of habitual activity level, which is fundamental to promote high-quality research and significantly advance knowledge in this field.

The aim of the present study was to determine the intra-individual agreement of PA and SED for two subsequent weeks of measurement in preschool children. Based on previous studies, we hypothesized great variability across weeks for all accelerometer outcomes.

Methods

Subjects

Ninety-four children aged 3 to 5 years from three different preschools in the county of Sogn og Fjordane, Norway were recruited for a two-week objective measurement of PA level during the autumn 2014. Written informed consent was obtained from the children’s parents/guardians prior to the data collection. The study was approved by the Norwegian Social Science Data Services.

Procedures

Physical activity was measured using the Actigraph GT3X+ accelerometer (firmware 2.2.1) (Pensacola, FL, USA) (John and Freedson, 2012). Children were instructed to wear the accelerometer at all times over two consecutive weeks, except during water activities (swimming, showering) or while sleeping. Parents/guardians and preschool personnel were encouraged to be vigilant concerning the use of the accelerometers every day for the 14 day period. Units were initialized at a sampling rate of 30 Hz. Files were analyzed at 10 second epochs using Kinesoft® v. 3.3.75 software (Kinesoft), using different criteria for valid wear time (≥6; ≥8; ≥10 h/day). In all analyses, consecutive periods of ≥20 min of zero counts were defined as non-wear time (Cain et al., 2013; Esliger et al., 2005). Results are reported for overall PA level (cpm), as well as SED (≤100 cpm), light PA (LPA) (100–2295 cpm), moderate-to-vigorous PA (MVPA) (≥2296 cpm) and light-to-vigorous PA (LVPA) (non-SED PA) (≥100 cpm) obtained from the vertical axis (axis 1) (Evenson et al., 2008; Janssen et al., 2013; Trost et al., 2011). Intensity-specific PA and SED were reported as min/day and as percentage values of valid wear time.

Statistical analyses

Subject characteristics were reported as frequencies, means and standard deviations (SD).

The single-day reliability and number of days needed to obtain the desired reliability were determined for wear times of ≥6, ≥8 and ≥10 h/day. Reliability for single days of measurement was assessed using variance partitioning obtained through a one-way random effect model (between subject variance / (between subject variance + residual variance)) (McGraw and Wong, 1996). Number of days needed to obtain a reliability of 0.80 was estimated using the Spearman Brown prophecy formula (ICCs) and the number of days (N) needed to achieve a reliability of 0.80, as estimated by the Spearman Brown prophecy formula. Reliability increased with a stricter wear time criteria: More than 7 days of measurement (ICC ≥ 0.80) was achieved for 55 and 100% of the children, according to the aim of achieving ≥60 min/day of MVPA and ≥180 min/day of LVPA, respectively.

| Overall PA (cpm) | ≥6 h ICC N | ≥8 h ICC N | ≥10 h ICC N |
|------------------|------------|------------|------------|
| Overall PA (cpm) | 0.37 7.0   | 0.38 6.6   | 0.38 6.4   |
| SED (min/day)    | 0.30 9.5   | 0.32 8.6   | 0.37 6.7   |
| SED (%)          | 0.38 6.5   | 0.39 6.1   | 0.42 5.6   |
| LPA (min/day)    | 0.30 9.1   | 0.33 8.2   | 0.36 7.1   |
| LPA (%)          | 0.42 5.5   | 0.43 5.3   | 0.46 4.8   |
| MVPA (min/day)   | 0.45 4.8   | 0.48 4.3   | 0.51 3.9   |
| MVPA (%)         | 0.48 4.3   | 0.49 4.2   | 0.51 3.9   |
| LVPA (min/day)   | 0.31 8.9   | 0.34 7.6   | 0.37 6.9   |
| LVPA (%)         | 0.38 6.5   | 0.39 6.1   | 0.42 5.6   |

CPM = counts per minute; SED = sedentary time; LPA = light physical activity; MVPA = moderate-to-vigorous physical activity; LVPA = light-to-vigorous physical activity; ICC = intraclass correlation for a single day of measurement; N = number of days needed to achieve a ICC = 0.80. The study was conducted in Sogn og Fjordane, Norway, 2014.
Reliability for two consecutive weeks of measurement

We found slight improvements in week-by-week reliability when data was accumulated over longer days (≥6 to ≥10 h) and more days (≥3 to ≥5 d) (Table 2), however, the pattern was not fully consistent and the differences were minor. All criteria provided ICC estimates ≥0.75 for all outcome variables, except for SED reported as an absolute value (min/day), for which ICC varied from 0.61 to 0.81. The estimated ICC for applying two weeks of measurement were 0.87 for overall PA, 0.81 (min/day)/0.88 (%) for SED, 0.88 (min/day)/0.89 (%) for LPA, 0.93 (min/day)/0.92 (%) for MVPA, and 0.89 (min/day)/0.88 (%) for LVPA. The ICC and LoA for wear time varied from 0.53 to 0.73 and from 45 to 105 min/day across the criteria, respectively, with LoAs clearly decreasing as stricter criteria were applied.

Fig. 1 shows Bland Altman plots for overall PA, SED, MVPA, and LVPA using a ≥8 h & ≥3 days wear time criterion (week 1: wear time = mean (SD) 675 (42) min/day, wear days = 3, 4, 14, 25 and 35 children with 3, 4, 5, 6 and 7 valid days, respectively; week 2: wear time = 682 (45) min/day, wear days = 1, 7, 12, 24 and 34 children with 3, 4, 5, 6 and 7 valid days). Although all variables except SED (ICC = 0.69) reached an ICC equal to or above ~0.80, the absolute measures of reliability clearly showed that a substantial degree of individual variability must be expected across subsequent weeks. Across variables, the 95% LoAs were ±1.0 to 1.6 SD units.

The present study is the first to investigate agreement of week-by-week measurements of SED and PA, as obtained by accelerometry in preschool children. Our findings indicate that the activity level of a given child should be expected to vary by up to ±1.0 to 1.6 SD units from one week to another. Thus measurement error was substantial for all outcome variables.

By application of standard data reduction wear criteria (≥6–10 h/day and ≥3 and 5 days/week), we found reliability estimates ≥0.75 for all outcome variables, except for SED (min/day). Thus, in terms of ICC, our results were consistent with previous studies that have estimated reliability over one week of measurement in preschool- (Addy et al., 2014; Hinkley et al., 2012; Hislop et al., 2014; Penpraze et al., 2006) and older children (Basterfield et al., 2011; Chinapaw et al., 2014; Janz et al., 1995; Kang et al., 2009; Murray et al., 2004; Ojiambo et al., 2011; Rich et al., 2013; Treuth et al., 2003; Trost et al., 2000), which indicates generalizability to preschool children in general. A limitation of the present study as well as previous studies, we believe that the reported results are generalizable to preschool children in general. A limitation of the present study is that we only report reliability for the Evenson et al. (2008) cut points as obtained by accelerometry. As our findings, in terms of ICC, as well as overall PA level (Bornstein et al., 2011), were consistent with previous studies, we believe that the reported results are generalizable to preschool children in general. A limitation of the present study is that we only report reliability for the Evenson et al. (2008) cut points for SED, LPA, MVPA and LVPA. Which accelerometer cut points to apply in different populations is heavily debated, and the use of many different thresholds to determine the time spent in different intensities causes a certain degree of confusion across studies (Cain et al., 2013). The Evenson et al. (2008) cut points have been found to perform well.
in external validation studies in youth (5–15 years of age) (Trost et al., 2011) and preschool (4–6 years of age) (Janssen et al., 2013) samples. Janssen et al. (2013) also found the Pate et al. (2006) MVPA cut point (≥1680 cpm) developed in preschool children to perform well, however, applying this cut point to our data did not change any findings in terms of reliability.

Future studies should seek to verify the current findings and explore agreement for longer intermittent periods of accelerometer measurement across populations.

Conclusion

We conclude that one out of two consecutive weeks of accelerometer monitoring in preschool children using standard wear criteria left modest agreement, despite the relative reliability being apparently good (ICC equal to or above ~0.80). Thus, considerable week-by-week variability was found. Because noise in any measurement will preclude researchers’ ability to arrive at valid conclusions in epidemiology, researchers need to be aware of intra-individual variability in accelerometer-measurements and take appropriate actions according to the hypothesis under study. We encourage researchers to consider more than 7 days of accelerometer measurement in future studies involving preschool children to increase the reliability of the accelerometer measurements and increase the validity of the study conclusions.

Conflict of interest statement

The authors declare that they have no competing interests.

Acknowledgment

We thank all participants that made the study possible, and Einar Ylvisåker for participating in the data collection.

References

Addy, C.L., Trilk, J.L., Dowda, M., Byun, W., Pate, R.R., 2014. Assessing preschool children’s physical activity: how many days of accelerometry measurement. Pediatr. Exerc. Sci. 26, 103–109.

Baranowski, T., Masse, L.C., Ragan, B., Welk, G., 2008. How many days was that? We’re still not sure, but we’re asking the question better! Med. Sci. Sports Exerc. 40, S544–S549.

Basterfield, L., Adamson, A.J., Pearce, M.S., Reilly, J.J., 2011. Stability of habitual physical activity and sedentary behavior monitoring by accelerometry in 6-to 8-year-olds. J. Phys. Act. Health 8, 543–547.

Bland, J.M., Altman, D.G., 1986. Statistical methods for assessing agreement between two methods of clinical measurement. Lancet 1, 307–310.

Bornstein, D.B., Beets, M.W., Byun, W., McIver, K., 2011. Accelerometer-derived physical activity levels of preschoolers: a meta-analysis. J. Sci. Med. Sport 14, 504–511.

Cain, K.L., Sallis, J.F., Conway, T.L., Van Dyck, D., Calhoon, L., 2013. Using accelerometers in youth physical activity studies: a review of methods. J. Phys. Act. Health 10, 437–450.

Chinapaw, M.J.M., de Niet, M., Verloigne, M., De Bourdeaudhuij, I., Brug, J., Altenburg, T.M., 2014. From sedentary time to sedentary patterns: accelerometer data reduction decisions in youth. PLoS One 9 (11) (e111205).
Coleman, K.J., Epstein, L.H., 1998. Application of generalizability theory to measurement of activity in males who are not regularly active: a preliminary report. Res. Q. Exerc. Sport 69, 58–63.

Colley, R., Connor Gorber, S., Tremblay, M.S., 2010. Quality control and data reduction procedures for accelerometer-derived measures of physical activity. Health Rep. 21, 83–89.

Esliger, DW., Copeland, JL., Barnes, JD., Tremblay, MS., 2005. Standardizing and optimizing the use of accelerometer data for free-living physical activity monitoring. J. Phys. Act. Health 2, 366.

Everson, K.R., Catellier, DJ., Gill, K., Ondrak, KS., McMurray, RG., 2008. Calibration of two objective measures of physical activity for children. J. Sports Sci. 26, 1557–1565.

Gretebeck, RJ., Montoye, HJ., 1992. Variability of some objective measures of physical activity. Med. Sci. Sports Exerc. 24, 1167–1172.

Hart, TL., Swartz, AM., Cashin, SE., Strath, SJ., 2011. How many days of monitoring predict physical activity and sedentary behaviour in older adults? Int. J. Behav. Nutr. Phys. Act. 8 (1), 62.

Herrmann, SD., Barreira, TV., Kang, M., Ainsworth, B.E., 2014. Impact of accelerometer wear time on physical activity data: a NHANES semisimulation data approach. Br. J. Sports Med. 48, 278–282.

Hinley, T., O’Connell, E., Ollely, A.D., Crawford, D., Hesketh, K., Salmon, J., 2012. Assessing volume of accelerometry data for reliability in preschool children. Med. Sci. Sports Exerc. 44, 2436–2441.

Hislop, J., Law, J., Rush, R., et al., 2014. An investigation into the minimum accelerometer wear time for reliable estimates of habitual physical activity and definition of a standard measurement day in pre-school children. Physiol. Meas. 35, 2213–2228.

Hopkins, WG., 2000. Measures of reliability in sports medicine and science. Sports Med. 30, 1–15.

Butcheron, JA., Chirollera, A., Hanley, JA., 2010. Random measurement error and regression dilution bias. BMJ 340.

Janssen, X., Cliff, D.P., Reilly, J.J., et al., 2013. Predictive validity and classification accuracy of ActiGraph energy expenditure equations and cut-points in young children. PLoS One 8 (11) (e79124).

Janz, K.F., Witt, J., Mahoney, L.T., 1995. The stability of children’s physical activity as measured by accelerometry and self-report. Med. Sci. Sports Exerc. 27, 1326–1332.

Jerk, G.J., Young, D.C., Laferriere, D., Chen, C.H., Vollmer, W.M., 2009. Reliability of RT3 accelerometers among overweight and obese adults. Med. Sci. Sports Exerc. 41, 110–114.

John, D., Freedson, P., 2012. ActiGraph and Actical physical activity monitors: a peek under the hood. Med. Sci. Sports Exerc. 44, S86–S89.

Kang, M., Bassett, D.R., Barreira, T.V., et al., 2009. How many days are enough? A study of 365 days of pedometer monitoring. Res. Q. Exerc. Sport 80, 445–453.

Kinesoft Software © d. Available from, http://kinesoft.org/ (accessed 28th of November 2014).

Levin, S., Jacobs, D.R., Ainsworth, B.E., Richardson, M.T., Leon, A.S., 1999. Intra-individual variation and estimates of usual physical activity. Ann. Epidemiol. 9, 481–488.

Matthews, C.E., Ainsworth, B.E., Thompson, R.W., Bassett, D.R., 2002. Sources of variance in daily physical activity levels as measured by an accelerometer. Med. Sci. Sports Exerc. 34, 1370–1381.

Matthews, C.E., Hagstromer, M., Pober, D.M., Bowles, H.R., 2012. Best practices for using physical activity monitors in population-based research. Med. Sci. Sports Exerc. 44, 558–576.

Matthews, C.E., Leary, S., Ness, A., et al., 2007. Intraindividual variation of objectively measured physical activity in children. Med. Sci. Sports Exerc. 39, 622–629.

McGraw, K.O., Wong, S.P., 1996. Forming inferences about some intraclass correlation coefficients. Psychol. Methods 1, 30–46.

Murray, D.M., Catellier, DJ., Hannon, PJ., et al., 2004. School-level intraclass correlation for physical activity in adolescent girls. Med. Sci. Sports Exerc. 36, 876–882.

Ojiambo, R., Cuthill, R., Budd, H., et al., 2011. Impact of methodological decisions on accelerometer outcome variables in young children. Int. J. Obes. 35, S98–S103.

Pate, R.R., Almeida, M.J., McIver, K.L., Pfeiffer, K.A., Dowda, M., 2006. Validation and calibration of an accelerometer in preschool children. Obesity 14 (11), 2000–2006.

Pate, R.R., O’Neill, J.R., Brown, W.H., McIver, K.L., Howie, E.K., Dowda, M., 2013. Top 10 research questions related to physical activity in preschool children. Res. Q. Exerc. Sport 84, 448–455.

Penpraze, V., Reilly, J.J., Maclean, C.M., et al., 2006. Monitoring of physical activity in young children: how much is enough? Pediatr. Exerc. Sci. 18, 483–491.

Rich, C., Geraci, M., Griffiths, L., Sera, F., Desateux, C., Cortina-Borja, M., 2013. Quality control methods in accelerometer data processing: defining minimum wear time. PLoS One 8 (6) (e67206).

Treuth, M.S., Sherwood, N.E., Butte, N.F., et al., 2003. Validity and reliability of activity measures in African–American girls for GEMS. Med. Sci. Sports Exerc. 35, 532–539.

Trost, S.G., Pate, R.R., Freedson, P.S., Sallis, J.F., Taylor, W.C., 2000. Using objective physical activity measures with youth: how many days of monitoring are needed? Med. Sci. Sports Exerc. 32, 426–431.

Trost, S.G., McIver, K.L., Pate, R.R., 2005. Conducting accelerometer-based activity assessments in field-based research. Med. Sci. Sports Exerc. 37, 5531–5543.

Weir, J.P., 2005. Quantifying test–retest reliability using the intraclass correlation coefficient and the SEM. J. Strength Cond. Res. 19, 231–240.

Wickel, E.E., Welk, G.J., 2010. Applying generalizability theory to estimate habitual activity levels. Med. Sci. Sports Exerc. 42, 1528–1534.