Journal of Science and Medicine in Sport 20 (2017) 273–277

Contents lists available at ScienceDirect

Journal of Science and Medicine in Sport

journal homepage: www.elsevier.com/locate/jsams

Original research

Validation of thigh-based accelerometer estimates of postural allocation in 5–12 year-olds

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ARTICLE INFO

Article history:
Received 18 February 2016
Received in revised form 15 July 2016
Accepted 5 August 2016
Available online 12 August 2016

Keywords:
Sedentary behaviour
Physical activity
Child
Accelerometry
activPAL
Breaks

ABSTRACT

Objectives: To validate activPAL3™ (AP3) for classifying postural allocation, estimating time spent in postures and examining the number of breaks in sedentary behaviour (SB) in 5–12 year-olds.
Design: Laboratory-based validation study.
Methods: Fifty-seven children completed 15 sedentary, light- and moderate-to-vigorous intensity activities. Direct observation (DO) was used as the criterion measure. The accuracy of AP3 was examined using a confusion matrix, equivalence testing, Bland–Altman procedures and a paired *t*-test for 5–8y and 9–12y.
Results: Sensitivity of AP3 was 86.8%, 82.5% and 85.3% for sitting/lying, standing, and stepping, respectively, in 5–8y and 95.3%, 81.5% and 85.1%, respectively, in 9–12y. Time estimates of AP3 were equivalent to DO for sitting/lying in 9–12y and stepping in all ages, but not for sitting/lying in 5–12y and standing in all ages. Underestimation of sitting/lying time was smaller in 9–12y (1.4%, limits of agreement [LoA]: −13.8 to 11.1%) compared to 5–8y (12.6%, LoA: −39.8 to 14.7%). Underestimation for stepping time was small (5–8y: 6.5%, LoA: −18.3 to 5.3%; 9–12y: 7.6%, LoA: −16.8 to 1.6%). Considerable overestimation was found for standing (5–8y: 36.8%, LoA: −16.3 to 89.8%; 9–12y: 19.3%, LoA: −1.6 to 36.9%). SB breaks were significantly overestimated (5–8y: 53.2%, 9–12y: 28.3%, $p < 0.001$).
Conclusions: AP3 showed acceptable accuracy for classifying postures, however estimates of time spent standing were consistently overestimated and individual error was considerable. Estimates of sitting/lying were more accurate for 9–12y. Stepping time was accurately estimated for all ages. SB breaks were significantly overestimated, although the absolute difference was larger in 5–8y. Surveillance applications of AP3 would be acceptable, however, individual level applications might be less accurate.

1. Introduction

High levels of sedentary behaviours (SB) and prolonged bouts of SB are negatively associated with health outcomes in adults,[1,2] independent of the amount of time engaged in moderate-to-vigorous intensity physical activity (MVPA).[3] Frequent interruptions in sedentary time could reduce this risk.[4,5] Although some studies among children and adolescents[6–8] suggest that the total volume or pattern of SB is associated with adverse health outcomes, overall, the evidence among young age groups is inconsistent.[9–11] The accurate measurement of SB in observational and experimental research in children is essential to better understand the potential influence of SB on health outcomes.

Assessing subtle differences between SB and light-intensity physical activity (LPA) using traditional hip-mounted accelerometers and cut-point methodologies seems to be difficult, because these methods categorise SB based on the lack of movement,[12] and some LPAs such as standing tend to be misclassified as SB.[13,14] Activity monitors or data reduction approaches that are sensitive to

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http://dx.doi.org/10.1016/j.jsams.2016.08.008

changes in posture offer potential for improved measurement of SB and LPA. An example is the activPAL3™ (AP3; PAL Technology Ltd., Glasgow, Scotland), an activity monitor worn on the thigh that uses triaxial acceleration data (20 Hz) to assess the position and movement of the limb. The AP3 software uses proprietary algorithms to classify periods spent sitting/lying, standing or stepping. Before being used in observational and experimental studies in children, it is important to determine if the device accurately detects postures and precisely estimates time spent sedentary and non-sedentary. Furthermore, it is important to evaluate the device's accuracy to detect breaks in SB in order to understand their influence on health outcomes.

The uni-axial activPAL™ (AP1) has been validated in young children (3–6y),[15–17] but to our knowledge only one study has evaluated AP1 in school-aged children.[18] Aminian et al.[18] included 25 participants aged 9–10y who performed 4 sedentary and 7 ambulatory activities, plus a selection of 3 activity patterns including sit-to-stand and stand-to-sit transitions to simulate real-world conditions. High correlations were found between direct observation (DO) and time spent in different postures and transitions between postures, as estimated by AP1. However, correlational approaches can only determine the relative strength of the relationship between measurement outcomes and do not provide information about potential systematic differences or the agreement between estimates.[19,20] Data on the measurement agreement or potential systematic bias of the monitor was only reported in 4–6y.[16] No studies have investigated whether potential measurement errors of the monitor lie within a clinically acceptable range. This study aimed to examine the classification accuracy and validity of AP3 for estimating sitting/lying, standing and stepping time and the number of SB breaks in 5–12 year-old children.

2. Methods

Fifty-seven children (5–12y) who were without physical or health conditions that would affect participation in physical activity were recruited. The study was approved by the University of Wollongong Health and Medical Human Research Ethics Committee. Parental written consent and participant verbal assent were obtained prior to participation.

Participants were required to visit the laboratory on two occasions. Anthropometric measures were completed using standardised procedures after which BMI (kg/m^2) and weight status were calculated.[21] Children completed a protocol of 15 semi-structured activities (Supplementary Table 1) from sedentary (e.g. TV viewing, writing/colouring), light (e.g. slow walk, dancing), and moderate-to-vigorous (e.g. soccer, running) intensity. Activities were equally divided over 2 visits and completed in a structured order of increasing intensity for 5 min, except for lying down (10 min).

The single unit accelerometer AP3 (53 × 35 × 7 mm, 15.0 g) was placed mid-anteriorly on the right thigh and initialised with minimum sitting or upright period of 1 s. Event records created by the AP3 software were used to classify periods spent sitting/lying, standing or stepping and transitions from sit/lie to upright (breaks in SB).

DO was used as the criterion measure. Children were recorded on video completing the activities as well as during transitions between activities. A single observer coded all videos using Vitessa 0.1 (University of Leuven, Belgium) which generated a time stamp every time a change in posture was coded. Subsequently, a second-by-second classification system was generated using customised software, in order to synchronise DO data with AP3's 1s epochs. Every second following the time stamp inserted by the observer was classified the same as the posture occurring at the time stamp itself until the next time stamp was created, indicating that the child's posture had changed. Postures were coded as sitting/lying (gluteus muscles resting on ground, feet, legs or any other surface, or lying in prone position), standing (both feet touching the ground), "other standing" (e.g. squatting, standing on one foot, kneeling on one or two knees), stepping (moving one leg in front of the other, including stepping with a flight phase), "other active" (e.g. jumping, sliding/side gallop) and "off screen" for DO. Seconds coded as "other standing" were recoded as standing, because these postures required the engagement of large postural muscles and did not involve the gluteus muscles resting on any surface. Seconds coded as "other active" were recoded as stepping. In the event of two postures occurring within the same second in either DO or AP3 data, this second was duplicated at the corresponding time point for the AP3 or DO output, in order to evaluate classification accuracy. This method was in line with previous validation studies.[15,16] For estimated time spent in postures, codes of duplicated seconds for either DO (0.02% of total DO data) or AP3 (0.04% of total AP3 data) were assigned 0.5 sec to avoid artificially inflating the total time observed. The synchronised DO and AP3 epochs were excluded when DO was coded as "off screen", which occasionally occurred when moving between different locations during transitions. Videos of 5 randomly selected participants were analysed twice by the same observer and once by a criterion observer to test inter- and intra-observer reliability. Inter- and intra-observer reliability were examined using Cohen's Kappa and single measure intra-class correlation coefficients (ICC) from two-way mixed effect models (fixed-effects = observer; random effects = participants), using the consistency definition. Cohen's Kappa coefficient for inter-observer reliability was 0.941. Inter-observer ICC was 0.974 (0.974–0.974) and intra-observer ICC was 0.963 (0.962–0.963).

Prior to analyses, participants were divided into two age groups (5–8y and 9–12y) because younger and older children potentially engage in and move between sitting, standing and non-standard postures differently.[16,22] Normality of the data was confirmed and analyses were performed for each group. The accuracy of AP3 for classifying sitting/lying, standing and stepping was established using sensitivity (true positive rate) and specificity (true negative rate), and summarised using a confusion matrix.[23] The equivalence of time estimates between AP3 and DO for each posture was examined at the group level using the 95% equivalence test. The methods are equivalent if the 90% confidence interval (CI) of time estimated by AP3 entirely falls within the predefined equivalence region of ±10% of the average time coded by DO.[24,25] Measurement agreement and systematic bias for estimated time spent in postures were evaluated at the individual level using Bland–Altman procedures.[20] Pearson correlations were used to evaluate the ability of AP3 to estimate the relative number of SB breaks compared to DO. The difference between the absolute number of SB breaks was tested using a paired sample *t*-test. Analyses were performed using the statistical computing language R v.3.1.2 and SPSS v.19.0.

3. Results

Descriptive characteristics of participants are presented in Supplementary Table 2. All participants completed the protocol and had valid AP3 data. Videos from one of the visits were unavailable for 3 children (age 5, 9 and 10y). Out of the remaining 267,952 1s epochs of DO from 5 to 8y and 345,226 epochs from 9 to 12y, 27,493 epochs and 25,042 epochs were coded as "off screen" and excluded from analyses, respectively, leaving 240,459 (89.7%) valid epochs for 5–8y and 320,184 (92.7%) for 9–12y. Mean DO time for 5–8y was 167.0 ± 22.4 min, of which 77.8 ± 12.0 min was classified as sitting/lying, 26.9 ± 8.6 min as standing and 62.2 ± 9.3 min as