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Original research

Validation and calibration of the *activ*PAL™ for estimating METs and physical activity in 4–6 year olds

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ABSTRACT

Objectives: Examine the predictive validity of the *activ*PAL™ metabolic equivalents equation, develop an *activ*PAL™ threshold value to define moderate-to vigorous-intensity physical activities, and examine the classification accuracy of the developed moderate-to vigorous-intensity physical activities threshold value in 4- to 6-year-old children.
Design: A sample of forty 4- to 6-year-old children from the Illawarra region in New South Wales, Australia were included in data analysis.
Methods: Participants completed a ~150-min room calorimeter protocol involving age-appropriate sedentary behaviors, light-intensity physical activities and moderate-to vigorous-intensity physical activities. *activ*PAL™ accelerometer counts were collected over 15 s epochs. Energy expenditure measured by room calorimetry and direct observation were used as the criterion measure. Predicted metabolic equivalents were calculated using the *activ*PAL™ metabolic equivalents equation (*activ*PAL™ software version 5.8.0). Predictive validity was evaluated using dependent-samples *t*-tests. Participants were randomly allocated into two groups to develop and cross-validate an intensity threshold for moderate-to vigorous-intensity physical activities. Receiver operating characteristic curve analysis was used to determine moderate-to vigorous-intensity physical activities threshold. The classification accuracy of the developed threshold was cross-validated using sensitivity, specificity, and area under the receiver operating characteristic-curve.
Results: The *activ*PAL™ metabolic equivalents equation significantly overestimated metabolic equivalents during sedentary behaviors and significantly underestimated metabolic equivalents for light-intensity physical activities, moderate-to vigorous-intensity physical activities and total metabolic equivalents compared to measured metabolic equivalents (all $P < 0.001$). The developed threshold of ≥1418 counts per 15 s resulted in good classification accuracy for moderate-to vigorous-intensity physical activities.
Conclusion: The current *activ*PAL™ metabolic equivalents equation requires further development before it can be used to accurately estimate metabolic equivalents in preschoolers. The developed threshold exhibited acceptable classification accuracy for moderate-to vigorous-intensity physical activities; however studies cross-validating this moderate-to vigorous-intensity physical activities threshold in free-living preschool-aged children are recommended.
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1. Introduction

Accelerometry has become the method of choice for measuring free-living physical activity (PA) behaviors in children.[1,2] However, sedentary behavior (SB), defined as any waking behavior characterized by an energy expenditure ≤1.5 metabolic equivalents (METs) while in a sitting or reclining posture,[3] has been shown to be adversely associated to cardiometabolic outcomes in adulthood, independent of moderate-to-vigorous physical activity (MVPA).[4] In addition, some evidence suggests that SB and MVPA might have independent associations with health outcomes in children and adolescents.[5] As such, there is an increasing need for an accurate

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objective measure of both SB and PA, ideally using a single device to minimize participant burden.

Currently, hip-mounted accelerometers are the most common objective monitoring tool used to measure PA and SB in children. However, the placement of accelerometers on the hip and the use of threshold values makes it difficult to distinguish sitting from standing still,[6] which in turn may increase measurement error when assessing SB and light intensity physical activity (LPA). Newer accelerometer-based devices use sensors which are sensitive to both static and dynamic accelerations and therefore make it possible to differentiate between postures.[6]

One of the devices using this new technology is the *activ*PAL™ (PAL Technologies Ltd., Glasgow, UK). The *activ*PAL™ is a uni-axial accelerometer which is positioned on the anterior upper thigh. The positioning on the thigh enhances the ability to classify periods of time in different postures, categorized as lying/sitting, standing or walking. In addition, the *activ*PAL™ output reports accelerometer counts and estimates of METs based on step rate using an equation embedded in the *activ*PAL™ software.[7] The *activ*PAL™ has shown promising results for measurement of SB among children aged 3–12 years.[8–10] However, only one study has examined the predictive validity of the METs equation provided in the *activ*PAL™ software against a criterion measure in 15–25 year old females.[11] Moreover, only one study has developed a MVPA threshold for the *activ*PAL™, and that study examined only adolescent girls.[12] No studies have examined the validity of the *activ*PAL™ for predicting METs among preschool-aged children, nor developed a threshold to classify MVPA from *activ*PAL™ count output in preschoolers. As compliance with objective monitoring is often lower than desirable among children, and might decrease further if participants are required to wear multiple monitors, it is preferable to use one monitor when assessing children's habitual SB and PA levels. Therefore, the aim of this study was to examine the predictive validity of the *activ*PAL™ METs equation in 4–6 year old children. If the *activ*PAL™ METs equation was found to provide biased estimates of energy expenditure, our secondary aims were to develop and validate an *activ*PAL™ intensity threshold for classifying MVPA in 4–6 year old children.

2. Methods

Forty healthy 4–6 year old children were recruited from childcare centers in the Illawarra region of New South Wales, Australia. The study was approved by the University of Wollongong Human Research Ethics Committee. Parents of participants provided informed written consent, and their children provided their verbal assent to participate in the study.

Children followed a 150-min activity protocol including age-appropriate SB, LPA and MVPA such as, watching a movie on TV, playing with toys and shooting hoops, within the room calorimeter. Children ate a light standardized breakfast 1.5 h before entering the room calorimeter, which had a minimal impact on their energy expenditure.[13] Children performed all activities in an identical order over a pre-determined duration under the guidance of a trained research assistant (Online supplement 1).

Supplementary material related to this article can be found, in the online version, at http://dx.doi.org/10.1016/j.jsams.2013.10.252.

The *activ*PAL™ (PAL Technologies Ltd., Glasgow, UK) is a uni-axial accelerometer which classifies periods of time in different postures, categorized as lying/sitting, standing or walking. In addition, the *activ*PAL™ output reports accelerometer counts and estimates of METs based on step rate using an equation embedded in the *activ*PAL™ software (version 5.8.0).[7] Before each experiment the *activ*PAL™ was initialized and time synchronized with the video camera—used for direct observation purposes—and the room calorimeter. Children were fitted with an *activ*PAL™ which was worn on the front of the right thigh using a double sided hydrogel adhesive pad and an elastic bandage to provide additional security.

To assess the validity of the *activ*PAL™ for predicting METs, EE measured by the room calorimeter was used as the criterion measure. Oxygen consumption and carbon dioxide production were measured continuously (paramagnetic O_2 and infrared CO_2 analysers, Sable System Inc., Las Vegas, USA) and corrected to standard temperature, pressure and humidity in the room calorimeter (3 m × 2.1 m × 2.1 m). Technical procedures related to the room calorimeter are described in more detail elsewhere.[13] Chamber air was sampled every two min and rates of oxygen consumption and carbon dioxide production were then averaged over 10-min blocks to produce stable measures of EE.[14]

During their time in the room calorimeter participants were digitally recorded, and activity start and end times and breaks between activities were recorded. To define a MVPA intensity threshold for the *activ*PAL™ and examine the validity of the *activ*PAL™ METs equation, children's movement was coded using the Children's Activity Rating Scale (CARS).[15] CARS is based on a 1–5 coding scheme, identifying five levels defining the following intensities: level 1 and 2 = SB, Level 3 = LPA and Level 4 and 5 = MVPA. It has been shown to be a reliable and valid tool to assess PA levels in young children[16] and has been used in accelerometer validation studies in these age groups.[17,18] Video footage was coded with the help of Vitessa 0.1 (Version 0.1, University of Leuven, Belgium) which generated a time stamp every time a change in intensity was coded by the observer. Data were coded by one observer who undertook two days of specific CARS training. During training, data from pilot trials were used. After coding, weighted average CARS scores were calculated for each 15 s epoch corresponding to the *activ*PAL™ output. In this study averaged 15-s epochs were classified into intensity as follows: SB ≤ level 2; LPA > level 2.0 and ≤3.0; MVPA > level 3.0.[15]

EE for every 10-min block was calculated using the Weir equation.[19] MET values were calculated by dividing measured EE by estimated basal metabolic rate (BMR) using the Schofield equation for children aged 4–10 years.[20] The 10-min blocks of EE were classified based on their equivalent MET values, into PA intensities as follows; SB ≤ 1.5 METs, LPA > 1.5 and <3.0 METs and MVPA ≥ 3.0 METs.

To examine the predictive validity of the *activPAL*™ METs equation the *Activ*PAL™ MET values were collected in 15-s epochs and then averaged over 10-min blocks that aligned with 10-min MET values defined using EE measured by the room calorimeter. Participants' MET values were averaged per intensity and over the duration of the protocol. Predicted MET values were then compared to measured MET values by the room calorimeter.

For the development of the *activ*PAL™ MVPA intensity threshold participants were stratified by sex and randomly allocated into either the development or validation group to ensure the groups were relatively similar. To define an MVPA intensity threshold, data from the development group was used. *activ*PAL™ 15-s epoch acceleration counts were used as provided by the *activ*PAL™ software (version 5.8.0) and aligned with direct observation data.

Data from participants allocated to the validation group were used to cross-validate the developed intensity threshold against direct observation. *Activ*PAL™ data were classified as MVPA using the developed *activ*PAL™ MVPA intensity threshold intensity threshold. *Activ*PAL™ data were then compared to direct observation data.

Classification accuracy of the *activ*PAL™ MVPA intensity threshold was also examined using both direct observation and EE as criterion measures. The required EE for a given activity varies between individual children.[21] Because direct observation systems such as CARS rely on subjective classification and use general

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