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Original research

ActiGraph GT3X+ cut-points for identifying sedentary behaviour in older adults in free-living environments

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ABSTRACT

Objectives: To determine the ActiGraph GT3X+ cut-points with the highest accuracy for estimating time spent in sedentary behaviour in older adults in free-living environments. ActivPAL^{3TM} was used as the reference standard.
Design: Cross-sectional study.
Methods: 37 participants (13 males and 24 females, 73.5 ± 7.3 years old) wore an ActiGraph GT3X+ and an ActivPAL^{3TM} for 7 consecutive days. For ActivPAL^{3TM}, variables were created based on posture. For ActiGraph GT3X+, sedentary behaviour was defined as (1) vector magnitude and (2) vertical axis counts for 1-s, 15-s and 1-min epochs, with cut-points for 1-s epochs of <1 to <10 counts, for 15-s epochs of <1 to <100 counts and for 1-min epochs of <1 to <400 counts. For each of the ActiGraph GT3X+ cut-points, area under the receiver operating characteristic curve (area under the curve), sensitivity, specificity, and percentage correctly classified were calculated. Bias and 95% limits of agreement were calculated using the Bland-Altman method.
Results: The highest areas under the curve were obtained for the vector magnitude cut-points: <1 count/s, <70 counts/15-s, and <200 counts/min; and for the vertical axis cut-points: <1 count/s, <10 counts/15-s and <25 counts/min. Mean biases ranged from −4.29 to 124.28 min/day. The 95% limits of agreement for these cut-points were ±2 h suggesting great inter-individual variation.
Conclusions: The results suggest that cut-points are dependent on unit of analyses (i.e. epoch length and axes); cut-points for a given epoch length and axis cannot simply be extrapolated to other epoch lengths. Limitations regarding inter-individual variability and misclassification of standing activity as sitting/lying must be considered.

1. Introduction

In addition to the well documented benefits of physical activity (PA) for health,[1] there is growing evidence that sedentary behaviour (SB), defined as energy expenditure between 1 and 1.5 METs while sitting or lying,[2] is related to increased risk of cardiovascular disease, diabetes, mental health problems and some cancers, as well as premature all-cause, cancer and cardiovascular disease mortality.[3,4]

Accelerometry has been shown to be a reliable method for assessing both PA and SB, with various cut-points used for analysing the data.[3,5] These cut-points may, however vary depending on the manufacturer, type of accelerometer, and wearing location.[6] In addition, there is evidence that the optimal cut-points and prediction equations may vary for different age groups, due to dissimilar activity patterns, mechanical efficiency and the contrasting nature of movements at different life stages.[7–9] Although recommendations for data cleaning and handling have recently been published and new methods are in development,[5] evidence on specific methods for measuring SB in older adults is limited.

Most evidence relating to cut-points has been based on the ActiGraph GT1M (ActiGraph LLC, Fort Walton Beach, FL) which is a biaxial accelerometer, usually used to measure acceleration in the vertical axis (VT). However, in recent years the manufacturer has developed a triaxial version, the ActiGraph GT3X+ (ActiGraph LLC, Fort Walton Beach, FL), which provides measures of acceleration in three axes, with a composite measure called vector magnitude ($VM = \sqrt{(x^2 + y^2 + z^2)}$). Recent evidence suggests that different generations of ActiGraphs (GT1M, GT3X, GT3X+) are comparable when using VT as the measure for defining cut-points.[10,11] However, VM and VT cut-points are not comparable, either between or within devices, as they measure different things (acceleration in 3 axes and acceleration in the vertical axis, respectively).[12]

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Because of its high level of accuracy in differentiating between sitting/lying, standing and walking activity,[13] the ActivPAL3TM (Pal Technologies Ltd., Glasgow, UK) is commonly used as a reference standard for measuring sedentary activities.[14] It has been shown to be more precise, and more sensitive to measuring reductions in sitting time, than the ActiGraph GT3X+.[15,16] At present many researchers use the AP and the AG concurrently to provide accurate measures of both PA and SB. It would however be less burdensome, and more time and cost efficient for participants and researchers if a single instrument could be used.[17]

The purpose of this study was therefore to determine the ActiGraph GT3X+ cut-points with the highest accuracy for estimating time spent in SB in older adults in free-living environments. Cut-points per 1-s, 15-s and 1-min epochs were examined for both the vertical axis and vector magnitude. Sitting/lying activity as measured with ActivPAL3TM was used as the reference standard.

2. Methods

Participants were community-dwelling adults (aged ≥65 years) living in Brisbane, Australia. They were recruited using a range of strategies including flyers displayed at senior centres and exercise centres, and emails to university staff. Eligibility criteria included being 65 years or older, able to walk (with or without assistive devices but not requiring assistance from another person), lack of severe memory problems, and living in the greater Brisbane area, Australia. Data from 41 participants were collected between July 2011 and April 2012. All participants provided written informed consent. The study protocol was approved by the Behavioural & Social Sciences Ethical Review Committee of the University of Queensland, Australia.

Each participant was visited twice. The first visit comprised a brief interviewer-administered questionnaire, and explanation of the use of accelerometers and logbook. Each participant was fitted with both an ActivPAL3TM and ActiGraph GT3X+ and was given oral and written instructions on how to wear the accelerometers and keep the logbook for the following 7 days. On the eighth day after the first visit, a second home visit took place, during which the accelerometers and logbook were collected.

The ActiGraph GT3X+ (AG; ActiGraph, Pensacola, FL) is able to assess acceleration in the vertical, antero-posterior and mediolateral axes. It is a reliable instrument with high inter-instrument reliability (0.97 ICC; $p < 0.001$) and intra-instrument reliability within frequencies that are common in human activities.[18] This device has been widely used in research, with good validity for measuring PA levels.[12] The AG was attached to an elastic waist belt and placed in line with the axillary line of the right iliac crest. Participants were asked to wear the accelerometer from the moment they woke up until they went to bed at night, and requested to remove it only during water-based activities such as showering and swimming.

The ActivPAL3TM (AP; Pal Technologies Ltd., Glasgow, UK) monitor provides a reliable method for differentiating between static and dynamic activities, with an accuracy of 98%[13] and mean percentage bias of 0.19% for time spent in SB, compared with direct observation.[19] The AP was worn on the middle-anterior line of the right thigh. The device was sealed with a nitrile finger cot and attached to the skin with a transparent film (TegadermTM Roll, 3MTM) in order to provide a waterproof barrier. This allowed it to be worn continuously for 24 h a day for 7 days, without having to remove it for water-based activities or sleeping.

Participants were asked to record waking/sleeping hours and accelerometer wear time in a logbook. They were asked to record timings and reasons for every occasion the AG or AP were removed from the indicated position.

All equipment was initialized and downloaded on the same computer in order to ensure time and date matching. AGs were initialized using a sample rate of 30 Hz and then downloaded using the low filter extension option in Actilife5 Software v5.7.4 (ActiGraph, Pensacola, FL). For every AG, a compliance and control quality check was performed once data were downloaded. Non-wear-time was filtered from the raw data using a semi-automated algorithm, based on ≥90 min of consecutive vector-magnitude (VM) counts per minute equal to zero, without allowing for interruptions.[20] A filter on the AG's VT was applied in order to identify spurious data (counts over 15,000 per minute).[7] Log-book data were used to check the accuracy of the wear-time algorithm, to ensure inclusion of only waking hours, but manual corrections to the filtered wear time were not necessary in this data set.

Data were included in the analyses if participants had at least 10 h of wear time on any 5 days of the week.[21] Each epoch was classified as sedentary time if VM and VT counts (tested separately) were below the cut-point. Different cut-points were tested for 1-s (<1 to <10 in increments of 1 counts/s), 15-s (<1 to <100 in increments of 5 counts/15 s) and 1-min epochs (<1 to <400 in increments of 25 counts/min). The 1-s epoch was included because longer epochs (which may or may not overlap shorter bouts of activity), as suggested in other studies, are more likely to misclassify activity, particularly in free-living environments when activities are highly variable.[5,9] Data were collapsed into 15-s and 1-min intervals to allow comparison with previous publications and data from older AG models.

The APs were initialized and data were downloaded using ActivPalTM Professional Software, v6.1.2 Research Edition (Pal Technologies Ltd., 2010). Because no non-wear time was observed for the AP, the AP recordings were matched with those of the filtered wear time AG data. Three dichotomous variables (yes/no) were created to indicate whether participants were sitting/lying, standing (i.e. upright but not walking), and sitting/lying or standing for each 1-s, 15-s and 1-min epochs.

Sample characteristics were derived from the questionnaire which included questions about date of birth, type of residence (house/flat, retirement village, hostel, nursing home, other), living situation (alone, with partner, with others), and self-rated health (poor, fair, good, very good, excellent). Height and weight were measured using a floor scale (Model 762, Seca GmbH & Co. KG., Germany) and a stadiometer (Model 217, Seca GmbH & Co. KG., Germany) and used to calculate body mass index ($BMI = kg/m^2$).

To describe the study sample, means and standard deviations were presented for near-normally distributed continuous variables, and percentages for categorical variables. To explore the accuracy of each cut-point for defining SB based on AG data, every epoch of AG data was compared against concurrent AP data. AP data were used to derive time spent (1) sitting/lying, (2) standing, and (3) sitting/lying/standing for each epoch. Sensitivity, specificity, accuracy expressed as the area under the receiver operating characteristic curve (AUC) and percentage correctly classified were calculated, using time spent sitting/lying from the AP as the reference. Also, bias and limits of agreement (LoA) for the AG compared with the AP (sitting/lying) were calculated using the Bland-Altman method.[22] A positive bias indicates overestimation of total time spent as measured by AG compared with AP, and a negative bias indicates underestimation. In case of equal AUC, the mean bias was considered for determining accuracy. Positive predictive value (PPV) was calculated to estimate the proportion of all sedentary epochs (according to AG) confirmed by AP as being sedentary. Negative predictive value (NPV) was calculated to estimate the proportion of all non-sedentary epochs (according to AG) confirmed by AP as being non-sedentary. To estimate misclassification of sedentary time as standing, sensitivity analyses were done for the cut-point with the highest accuracy, but with the reference