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Utility of accelerometer thresholds for classifying sitting in office workers

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ABSTRACT

Objective. To investigate the utility of a variety of Actical accelerometer count thresholds for determining sitting time in a sample of office workers.

Methods. Data were collected from 21 participants in Auckland, New Zealand, between December 2009 and January 2010. Participants wore a hip-mounted Actical accelerometer and thigh-mounted activPAL inclinometer (criterion) for a 48-h period. Raw inclinometer and accelerometer data for each 15 s epoch of wear time were matched by date and time. Candidate accelerometer count thresholds for sitting classification were compared with the criterion measure using receiver operating characteristic analyses. Agreement in sitting time classification was determined using Bland–Altman methodology.

Results. Significant differences in area under the curve (AUC) values by threshold criteria were found ($p<0.001$). A threshold of 0 counts provided the highest combined sensitivity and specificity (AUC 0.759, 95%CI 0.756, 0.761). The 95% limits of agreement for time spent sitting were wide, at 328 min (range −30.8, 297.5).

Conclusion. A threshold of 0 counts/15 s epoch with Actical accelerometers is likely to yield the most accurate quantification of sitting in office-based workers, however the wide limits of agreement found indicate limited utility of this threshold to accurately distinguish sitting time in office-based workers.

Introduction

There is growing interest in public health on the independent effects of sedentary behaviour (e.g., sitting) on health (Hamilton et al., 2007). Sedentary lifestyles have been associated with increased body size, unhealthy blood lipid profiles, high blood pressure, elevated risk of type 2 diabetes, overall clustered metabolic risk, and increased risk of mortality in adults (Healy et al., 2008b; Hu et al., 2003; Warren et al., 2010).

Many adults employed in office-based duties sit for long periods (Mummery et al., 2005; Schofield et al., 2005), thereby increasing their exposure to time spent being sedentary. Self-reported sitting time has been negatively related to biomarkers of metabolic health (e.g., see Owen et al., 2009). Objectively assessed breaks in sedentary time have been beneficially associated with body size, triglycerides, and plasma glucose in adults, independent of overall time spent sedentary and in moderate-to-vigorous physical activity (Healy et al., 2008a). As such, accurately measuring sitting time and breaks in sedentary/sitting time may be especially important, however these variables are challenging to assess. In particular, self-report measures are not sensitive enough to detect small breaks (e.g., <5 min) in sedentary behaviours that may confer health benefits. The use of accelerometry to objectively assess sedentary time has thus become popular. Currently there is no best-practice evidence-based approach for classifying adult behaviour as "sedentary" on the basis of accelerometer counts per epoch. Generally, counts registering under a pragmatic yet somewhat arbitrary threshold (e.g., <100 counts/min) have been used to identify sedentary time (e.g., Hagströmer et al., 2010; Healy et al., 2008a; Matthews et al., 2008). One key limitation of using accelerometry to define sedentary behaviour is that it is not possible to discern sitting from standing time. This is an arguably important distinction to make if considering the increased energy expenditure and postural requirements (and thus potential for beneficial health outcomes) of standing compared with sitting.

There is also growing interest in describing activity intensity in epochs shorter than 1 min to minimize data smoothing and consequent misclassification of activity intensity (Edwardson & Gorely, 2010). To our knowledge, no investigation of these issues (i.e., defining sitting behaviour; classifying activity intensities in epochs shorter than 1 min) has occurred with relation to Actical accelerometer use with adults.

The aim of this research was thus to investigate the utility of a variety of Actical accelerometer count thresholds (per 15 s) for determining sitting time (conceptualised as being a key component of sedentary time) in a sample of office workers, using a femur-mounted inclinometer as a criterion measure.

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Methods

Participants

A convenience sample of university employees ($n=25$) in Auckland, New Zealand was recruited. Participants who reported spending a majority of their work day sitting were included in the study. No other inclusion criteria were employed. Ethical approval was provided by the host institution and written informed consent was obtained from all participants. Data were collected between December 2009 and January 2010 on weekdays only.

Procedures

Participants were provided with an Actical accelerometer (Mini-Mitter, Bend, OR) and an activPAL inclinometer (PAL Technologies Ltd, Glasgow). The highest resolution available with Actical accelerometers is 15 s, therefore both units were set to record activity in 15-s epochs to enable consistency in data treatment across monitors. Actical accelerometers have been validated for the assessment of energy expenditure in adults using indirect calorimetry (Heil, 2006). Activity intensity (including sedentary) can then be derived from the energy expenditure data, but currently not from the raw data, or for epochs shorter than 1 min. When positioned at the thigh, activPAL inclinometers provide date and time stamped information on time spent sitting, lying, standing, walking, and steps accumulated. These monitors are reliable and valid for measuring time spent being sitting and lying (Grant et al., 2006), and can accurately distinguish static and dynamic activities in prolonged free-living situations (~6 h) (Godfrey et al., 2007). Because the activPAL inclinometer provides a sensitive and accurate (to within 96%) measurement of sedentary behaviours (i.e., sitting, lying) (Grant et al., 2006), this monitor was considered a suitable and pragmatic criterion measure for the purposes of this study.

Three Actical accelerometers and 3 activPAL inclinometers were used in this study. All monitors were calibrated on the same computer by MO. Accuracy of activPAL units was checked as per the manufacturer's specifications as follows: each unit was set to collect data, placed horizontally on a flat surface for 1 h then moved to a vertical position for 1 h. Data were then downloaded and checked for correct classification of posture and synchronicity with the computer's internal clock (to the nearest second). Accuracy and reliability of the Actical accelerometers was determined by setting the units to collect data, attaching the 3 units to one belt and leaving the belt on a desk for an hour, followed by 1 h of wear including sitting, walking, and standing with activity times recorded. Data were downloaded and examined for accurate classification of desk (i.e., static, registering 0 counts for the hour) versus wear (i.e., registering counts during active bouts) time. Synchrony with the computer time for each unit and concordance between the three units for accelerometer counts accumulated in each 15 s epoch was determined.

The accelerometer was attached to an elastic belt worn at the waist with the unit positioned above the right iliac crest. The activPAL was secured medially on the anterior of the right thigh with Physiomed TheraFIX Underwrap tape. Participants were instructed to wear the accelerometer belt and inclinometer for 48 consecutive hours, to remove the units for bathing or sleeping only, and to record monitor removal and reattachment on a compliance diary. Each participant was called once during the measurement period to confirm monitor wear.

Data extraction and treatment

Raw inclinometer and accelerometer data for each 15 s epoch were extracted and matched by date and time. Times where participants reported unit removal were removed from further analysis. Binary classifications (sitting/lying versus active) for each 15 s epoch of the activPAL data were determined as per the manufacturer's specifications (i.e., ≥ 10 s of sitting/lying data was required for a 15 s epoch to be classified as sitting/lying). Histograms of accelerometer count data were generated to inform the development of candidate count thresholds for investigation and binary classifications (sitting/lying versus active) made for each candidate threshold criterion used. Overall time spent sitting/lying, expressed in minutes, was derived for the activPAL data and the data for each candidate accelerometer threshold, calculated as: (n epochs classified as sitting/lying $\times$ 15) / 60.

Statistical analyses

Receiver Operating Characteristic (ROC) analyses were conducted for each individual and the combined group data. Sensitivity, specificity, and area under the ROC curve (AUC) values were compared for each threshold criterion employed. Sensitivity was defined as the accurate classification of sedentary time, calculated as the number of true positives/(number of true positives + false negatives). Specificity was defined as the accurate classification of active time, calculated as the number of true negatives / (number of true negatives + number of false positives). Agreement between time spent sitting as classified by the activPAL and candidate thresholds was determined using Bland–Altman methodology (Bland and Altman, 1999). Statistical analyses were undertaken using Stata SE version 9.2 (StataCorp, TX) and $\alpha=0.05$ was used to determine statistical significance.

Results

In total, 25 adults (24% male) aged 41.6 ± 11.8 years with BMI values of 26.1 ± 5.0 kg/m participated in this study. Unit failure resulted in data loss for 4 participants; valid data were collected for the remaining 21 participants. No significant differences were found in age or BMI status between participants with and without valid data ($p>0.05$). After removal of self-reported non-wear time data, participants wore the units for an average of 28.3 ± 3.2 h, yielding 142,662 15 s data points for the total sample. On average, 1170 ± 218 min were spent sitting or lying as classified by the activPAL, equivalent to an average of 68.9% of time the units were worn. Average time spent sitting as classified by the candidate thresholds ranged from 1303 ± 212 min (76.6% of wear time) for 0 counts/15 s epoch, to 1542 ± 212 min (90.6% of wear time) for 100 counts/15 s epoch.

Histogram analysis revealed that the most appropriate count thresholds to investigate ranged between 0-25 counts per 15 s epoch. Candidate thresholds thus ranged from 0 to ≤25 counts, in 5 count increments per 15 s epoch. In the interest of providing further comparative data, we also investigated thresholds of ≤50 counts and ≤100 counts per 15 s epoch to define sitting time.

Significant differences in AUC values ($p<0.001$) by differing threshold criteria were found at the group level, and for all individuals except one. At the group level, increased AUC values were found with decreasing count thresholds (predominantly due to increased specificity), with the 0 count threshold providing the greatest combined sensitivity and specificity (overall AUC = 0.759, 95% CI 0.756, 0.761) (Table 1). This pattern was also observed at the individual level, however considerable variance between individuals was found (e.g., individual AUC values for the 0 count threshold ranged from AUC = 0.512, 95% CI 0.502, 0.521 to AUC = 0.859, 95% CI 0.849, 0.869) (Fig. 1).

Table 2 shows the descriptive information for time classified as sitting using the candidate accelerometer count thresholds, as well as the mean differences and 95% limits of agreement between the activPAL sitting/lying time and candidate thresholds. In all instances,

Table 1
Results of Receiver Operating Characteristic analysis of differing accelerometer count threshold criteria during 15 s epochs compared with criterion sitting measure (activPAL) for combined group data.

AC count threshold per 15 s	Sensitivity (%)	Specificity (%)	AUC	95% CI
0 counts	92.8	58.9	0.759	0.756, 0.761
≤5	94.4	53.7	0.741	0.738, 0.743
≤10	94.9	51.1	0.730	0.728, 0.733
≤15	95.4	48.7	0.721	0.718, 0.723
≤20	95.9	45.9	0.709	0.707, 0.712
≤25	96.3	43.4	0.698	0.696, 0.701
≤50	97.4	34.9	0.661	0.659, 0.664
≤100	98.3	25.8	0.621	0.618, 0.623

Notes: AC = Actical accelerometer, AUC = Area under the curve; CI = Confidence Interval; s = second. Data collected in Auckland, New Zealand between December 2009 and January 2010 on weekdays only.