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Defining a valid day of accelerometer monitoring in adults with mental illness

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A B S T R A C T

Introduction: A valid day of accelerometry is commonly defined as an absolute duration of wear time. Data processing inconsistencies can arise when using *absolute* valid-day criteria for adults with varied waking hours. The aim was to compare the use of absolute and *relative* valid-day criteria in a sample of adults with mental illness.

Methods: Data were from 99 non-institutionalised adults with mental illness. Participants were asked to wear an ActiGraph GT3X+ accelerometer continuously for seven days, and to note sleep and non-wear times. Absolute valid-day criteria were defined as a set number of hours/day, and relative criteria as a proportion of waking hours. The mean waking duration, non-wear time, and time spent in physical activity (PA) and sedentary behaviour (SB), were derived from accelerometer data, and compared for a range of absolute and relative criteria. The potential inaccuracy of PA and SB estimates were also estimated.

Results: Use of absolute criteria systematically biased the sample toward those with longer waking hours, and resulted in a median of 86% (IQR = 47%–198%) more non-wear time than relative criteria. The potential inaccuracy of SB was from −2.5% to 0% with relative criteria, and from −2.2% to 10.6% for absolute criteria.

Conclusions: For participant samples with varied waking hours, such as adults with mental illness, a valid-day criterion should be based on the proportion of waking hours, rather than the absolute time. The specific valid-day criterion should be chosen for each study independently, and be accompanied with a measure of the non-wear time.

1. Introduction

Adults with mental illness have shorter life expectancy than the general population (Lawrence, Kisely, & Pais, 2010), increased risk of diabetes, heart conditions, and obesity (Parks, Svendsen, Singer, Foti, & Mauer, 2006), and reduced psychosocial functioning (Ustün, 1999). Physical activity (PA) decreases mortality risk (Lee & Skerrett, 2001), protects against chronic disease (Lee et al., 2012), reduces depression and anxiety (Rethorst, Wipfli, & Landers, 2009; Wipfli, Rethorst, & Landers, 2008), and can improve quality of life in adults with mental illness (Alexandratos, Barnett, & Thomas, 2012). High levels of sedentary behaviour (SB) are associated with increased risk of morbidity and all-cause mortality (Thorp, Owen, Neuhaus, & Dunstan, 2011). There is therefore a need for accurate monitoring of PA and SB in adults with mental illness, to determine prevalence and public health impact, and to evaluate interventions aimed at increasing PA and reducing SB (Troiano, 2005).

Objective methods, such as accelerometers, allow for direct measurement of PA and SB, and are widely used in epidemiological studies (Lee & Shiroma, 2014). Despite their wide use, inconsistencies in data reduction procedures have been identified that may reduce comparability between studies (Herrmann, Barreira, Kang, & Ainsworth, 2014; Keadle, Shiroma, Freedson, & Lee, 2014; Masse et al., 2005; Watson, Carlson, Carroll, & Fulton, 2014), and compromise the validity of accelerometer estimates (Baranowski, Masse, Ragan, & Welk, 2008; Colley, Gorber, & Tremblay, 2010; Herrmann, Barreira, Kang, & Ainsworth, 2013; Lee, 2014; Pedišić & Bauman, 2014; Phillips, 2013). It is important to identify and minimise sources of error and bias in data reduction procedures.

Accelerometer data reduction involves defining a valid period of monitoring considered adequate for estimating habitual behaviour (e.g. valid day and week). Valid-day criteria are commonly

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operationalised in *absolute* terms, as a pre-defined duration of wear time. A large range of such criteria has been used, ranging from 1 h/day to 16.7 h/day (Masse et al., 2005); most commonly ≥10 h/day (Trost, McIver, & Pate, 2005). Difficulties can arise, however, when using an *absolute* valid-day criterion, as it does not account for the intra- and inter-individual variability in waking hours (Matthews, Ainsworth, Thompson, & Bassett, 2002). For example, with the ≥10 h/day validity criterion, someone with a 14-h waking day could have up to 4 h of non-wear time (29% of their waking hours), whereas someone with a 12-h waking day could have only 2 h of non-wear time (17% of waking hours). Methods for imputing non-wear time have been developed (Catellier et al., 2005; Kang, Rowe, Barreira, Robinson, & Mahar, 2009; Lee, 2013); however, most studies simply remove missing data, which biases estimates of PA and SB levels (Paul et al., 2008), and can alter cross-sectional or longitudinal associations (Baranowski et al., 2008; Lee, 2014; Phillips, 2013). To reduce this potential source of error, recent suggestions have been to increase the valid-day criterion to 13 h/day (Herrmann et al., 2013, 2014). This may not be appropriate for population groups that commonly exhibit long sleep durations, such as people with depression or low socioeconomic status (Patel, Malhotra, Gottlieb, White, & Hu, 2006), due to the exclusion of participants with short waking hours.

When assessing daily PA or SB, a valid day of monitoring could instead be defined *relatively,* as a proportion of the waking hours of each day. While the "gold standard" is wearing the monitor for 100% of waking hours (zero non-wear time), regardless of the absolute duration, compliance with this criterion is likely to be low, and may also introduce selection bias. When deciding on an appropriate valid-day criterion, it is therefore necessary to find a balance between compliance and allowable non-wear time. Few studies have investigated the use of relative valid-day criteria (Masse et al., 2005), and no studies have specifically compared the use of relative and absolute valid-day criteria.

The aim of this study was to compare potential sources of error (e.g. sample bias) resulting from the use of absolute and relative valid-day criteria matched on compliance in a group of adults with mental illness, in order to recommend a method of choosing an appropriate valid-day criterion.

2. Method

Accelerometer data from the Mind & Body study (n = 99) (J. J. Chapman, Fraser, Brown & Burton, 2015) were used to investigate different valid-day criteria. Participants were non-institutionalised men and women who self-identified as recovering from mental illness, were ambulatory, and over 18 years of age. Participants were asked to wear an ActiGraph GT3X+ accelerometer on the right hip 24 h/day for seven consecutive days. During the monitoring period, participants recorded time to bed at night, time out of bed, and times the accelerometer was not worn, in an accompanying diary. Participants provided written informed consent before data collection, and received an AUD$40 gratuity for completing the accelerometry.

Ethical approval was obtained from The University of Queensland Behavioural and Social Sciences Ethical Review Committee (2012000908), and the Royal Brisbane & Women's Hospital Human Ethical Review Committee (HREC/12/QRBW/286). Data were collected between October 2012 and December 2013.

2.1. Data management

Raw acceleration data were sampled at 30 Hz and filtered at a bandwidth of 0.25–2.5 Hz, corresponding with normal human movement (John & Freedson, 2012). Raw data were converted to counts per minute (cpm), and the vertical axis was used to estimate the intensity of activity for each 60-s epoch. Participants' self-reported time out of bed, and time to bed, were used to define their *waking hours*; only accelerometer data recorded during waking hours were analysed. Three participants lost their activity diary; the waking hours of these participants were imputed by visual inspection of the data (McVeigh et al., 2015).

2.2. Analysis

Compliance was defined as the proportion of participants meeting the criteria for a valid day and week. *Absolute* valid-day criteria were operationalised as a duration of wear time (hours/day); *relative* valid-day criteria were operationalised as a proportion of waking hours (%/day). Because the aim of this study was to investigate different *valid-day* criteria, standard criteria were used to define time spent in PA and SB, accelerometer non-wear, and a valid week of monitoring. Sedentary behaviour (SB), light activity, and moderate-to-vigorous activity (MVPA), were defined as ≤100 cpm, 101–2019 cpm, and >2019 cpm, respectively (Troiano et al., 2008). Non-wear time was identified from diaries, and from consecutive zero counts for 60 min or longer, and removed from the data. A valid week was defined as at least four valid days of monitoring, including at least one weekend day (Trost et al., 2005).

Some participants had "short" days, in which their total time spent awake was similar in duration to commonly used absolute valid-day criteria. The use of absolute valid-day criteria could result in those days being excluded even if the monitor was worn for a high proportion of waking hours. Therefore, *potentially valid short days* were defined as days that participants wore the monitor for at least 80% of waking hours, but that did not meet the absolute valid-day criterion because of short waking hours (waking hours ≤ 1.05*valid-day criterion). *Potentially valid cases* were defined as participants who would have met the valid-week criterion, had the potentially valid short days been included. The number of potentially valid short days and cases were identified for each of five absolute valid-day criteria (6, 8, 10, 12, and 14 h/day).

Compliance was calculated for a range of both *relative* and *absolute* valid-day criteria: from 80%/day to 100%/day in 1% increments, and from 6 to 16 h/day (360–960 min/day) in 1-min increments. Average waking hours, non-wear durations, proportion of waking hours identified as non-wear time, and time/day spent in SB, light activity, and MVPA, were compared for relative and absolute valid-day criteria matched on compliance.

Given that removal of non-wear time may bias estimates of time spent in PA and SB downward, this underestimation was approximated for a range of valid-day criteria as: (proportion of waking hours identified as non-wear)*(proportion of wear-time spent in PA or SB)*100. Because time spent in PA and SB may be *overestimated* when the sample is biased toward those with longer waking hours, this potential overestimation was estimated for the absolute criteria only, as: [(mean waking hours for absolute criteria)/(mean waking hours for relative criteria) − 1]*(proportion of wear-time spent in PA or SB). Potential underestimations were subtracted from potential overestimations to approximate the overall inaccuracy. Data reduction and analyses were performed with MATLAB (2011b), The MathWorks, Inc., Natick, Massachusetts, United States.

3. Results

3.1. Exclusion of data

Participant demographics are presented in Table 1. The characteristics of *potentially valid short days*, and proportion of *potentially valid cases*, are presented in Table 2. All potentially valid short days