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1 Abstract

Background: In light of evidence linking sedentary behaviors to health outcomes, there have
been calls for the measurement of sedentary behavior in surveillance studies. This study
examined the convergent validity of two self-report measures of sitting time and accelerometerdetermined sedentary time (minutes/day of <100 counts/minute).

6 **Methods:** 44 adults wore an ActiGraph accelerometer for seven days, during which they also 7 recorded daily sitting time in a diary, in response to a single-item question. After seven-days 8 participants completed a new domain-specific questionnaire to assess usual weekday and 9 weekend-day sitting time. Total sitting times recorded from the self-report measures were 10 compared with accelerometer-determined sedentary time.

Results: Total sitting time calculated from the domain-specific questionnaire did not differ significantly from accelerometer-determined sedentary time on weekdays (mean difference [±SE] =-14±28 mins/day) and weekend-days (-4±45 mins/day, both p>0.05). Sitting time was significantly underestimated using the single-item specific-day question on weekdays (-173±18 mins/day) and weekend-days (-219±23 mins/day, both p<0.001).</p>

Conclusions: When assessed via self-report, the estimation of total sitting time is improved by summing sitting times reported across different domains. The continued improvement of selfreport measures of sitting time will be important if we are to further our understanding of the links between sedentary behavior and health.

20

1 Introduction

Recent evidence suggests that time spent in sedentary behaviors (usually defined as time spent sitting) is an independent risk factor for a number of adverse health outcomes.^{1,2} In light of this evidence, there have been recent calls for the explicit measurement of sedentary behavior, in addition to the measurement of physical activity, in population surveillance studies.^{3,4} Indeed, there is a growing consensus that sedentary behaviors represent a unique aspect of human behavior and that they should not be viewed as simply the absence of physical activity, or as the extreme lower end of the physical activity continuum.²⁻⁵

9

Sedentary behavior research is considered to be a public health priority.⁶ vet to date there have 10 11 been problems with the measurement of sedentary behavior, including an over reliance on using television (TV) viewing as a single measure of sitting time.⁷ Many common forms of 12 sedentary behavior, such as the use of motorized transport,⁸ working at a desk in the 13 workplace,⁹ using a computer at home,⁷ socialising (for example dining out, reading, going to 14 the cinema)¹⁰ and watching TV or movies,⁷ all involve sitting; hence the assessment of TV 15 viewing time alone may vastly underestimate, or misrepresent, overall sedentary time. It is 16 17 important to measure all types of sedentary behavior, across a range of contexts (such as the 18 workplace, at home, whilst commuting, in social settings) if we are to truly understand patterns 19 and determinants of sedentary behavior in adults.

20

Whilst accelerometers have recently been used to objectively assess sedentary behaviour^{11,12} (with a lower cut-off of <100 counts/minute (cpm) commonly used to denote sedentary time¹³), accurate and reliable self-report measures of sedentary behavior are essential for large scale epidemiological studies in which the use of objective measures may be impractical due to their relative cost.⁸ Furthermore, although accelerometers have been used in some population-based studies to estimate sedentary behavior,^{6,14,15} they do not provide information about the context in

which these behaviors occur. As in physical activity research, it has been suggested that it will
likely be a combination of both objective and subjective monitoring of sedentary behaviors that
will yield the most reliable measurements and understanding of these behaviors.⁷

4

5 While accelerometers have been used to provide a measure of the total volume of sedentary 6 behaviour in surveillance studies,^{6,11,12,14,15} accelerometers mounted on the hip measure periods 7 of inactivity and are not capable of distinguishing between postures such as sitting and lying, or 8 standing still. Hence periods of standing still may be misclassified as sedentary time. With the 9 absence of a 'gold standard' measure of sedentary behaviour in free-living adults, despite this 10 limitation, accelerometer-determined sedentary time (<100 cpm) has recently been used as a 11 comparison measure in a number of studies validating self-report measures of sitting time.^{4,8,16}

12

Using this approach, Marshall et al.⁸ have recently described the validity of a newly developed 13 self-report measure of total and domain-specific sitting time, assessed in a sample of middle-14 15 aged (aged 53-59 years) Australian women. This measure requires participants to retrospectively report domain-specific sitting time (i.e. time spent sitting whilst travelling to and 16 17 from places, at work, watching TV, using a computer at home, and during leisure time), on a usual weekday and weekend day.⁸ Whilst this measure overcomes the limitations associated 18 19 with previous self-report measures of sedentary time by assessing sitting time across a range of 20 contexts, it relies on the individual's recall of their sitting time on a 'usual' weekday and weekend 21 day, and as yet has only been validated in a homogenous sample of mid-age Australian women. 22 In this sample, this questionnaire was deemed to have acceptable measurement properties in terms of test-retest reliability and validity for the assessment of weekday sitting times across 23 24 different domains. The assessment of weekend day sitting time was found to be less reliably 25 and validly reported however. As weekend day sitting behaviors appear to be more variable than weekday sitting,⁸ surveys enquiring about a 'specific' rather than a 'usual' weekend day 26

1 may increase the validity of self-reported sitting times at weekends. The aim of the current study therefore was to 1) extend the initial study⁸ by assessing the validity of the domain-specific 2 'usual day' questionnaire in a mixed-gender sample of adults living in the UK, against 3 4 accelerometer-determined sedentary time (<100 cpm); and 2) to compare the validity of 'usual' 5 total sitting time measured using the domain-specific questionnaire with the validity of a newly developed single-item sitting time measure that assesses total sitting time on a specific day. 6 7 Given the differences in classifying sedentary behaviour between the self-report measures described above (which specifically ask about time spent in a sitting posture), and 8 9 accelerometer-determined sedentary time which is derived from movement counts (or lack of), this study examines the convergent validity of the two self-report measures of sitting time. 10

11

12 Methods

13 Participants

A convenience sample of 56 adult volunteers, recruited via word of mouth and through advertisements posted on staff notice boards at Loughborough University, completed the study. A health screen completed prior to enrolment into the study confirmed that participants were all in good general health and none had any physical illnesses or disabilities that might affect their normal daily routine. The study received ethical approval from the Loughborough University Ethical Advisory Committee, and participants provided written informed consent.

20

21 Measurement of sedentary behavior

Participants wore an ActiGraph GT1M accelerometer (ActiGraph, Pensacola, FL) throughout waking hours for seven consecutive days, whilst continuing with their normal daily routine. Periods during which the accelerometer was removed were documented in a daily diary. The accelerometer was set to record movement counts at 1-minute epochs. Accelerometer data were considered valid if there were more than 600 minutes of monitoring per day (excluding strings of zeros for 20 minutes or longer) recorded over the entire seven day monitoring period.¹⁷ Data from participants who did not provide at least 600 minutes/day of accelerometer data for seven days were not included in the analyses, since Matthews et al.¹⁷ have recommended that at least seven days of monitoring, using an accelerometer, are required to obtain reliable estimates of time spent 'inactive'. Accelerometer counts <100 counts/minute were used to estimate daily sedentary time.¹³

7

During each day of the monitoring period, participants recorded their daily sitting time by 8 9 responding to the question "how long have you been sitting for today?" which was included in 10 their accelerometer diary. Participants were requested to complete this 'specific day' question 11 on a daily basis upon going to bed each night. After seven days, participants visited the 12 laboratory to return their accelerometers and diaries to an investigator. During this visit 13 participants were asked to report domain-specific sitting times on a usual weekday and weekend day using the newly developed self-administered domain-specific sitting time 14 auestionnaire.⁸ Here, participants responded to the question "Please estimate how many hours 15 16 and minutes you spend sitting each day in the following situations on a week day and weekend 17 day: whilst travelling to and from places, while at work, while watching TV, while using a 18 computer at home, and in your leisure time, not including TV (e.g. visiting friends, movies, dining 19 out etc.)". This questionnaire was completed in the presence of one of the investigators and participants were not permitted to look at their daily diary whist completing it. 20

21

22 Statistical analyses

23 Statistical analyses were conducted using SPSS version 17 (SPSS Inc., Chicago, IL). 24 Accelerometer-determined sedentary time (<100 cpm) recorded on each valid weekday and 25 weekend day was summed and divided by the number of valid days to provide separate 26 estimates for time spent sedentary on weekdays and weekend days. Similarly, participants'

1 daily self-reported sitting time, from the specific-day single-item question, was summed for weekdays and weekend days and then divided by the number of corresponding days to obtain 2 mean self-reported sitting time for weekdays and weekend days. Total weekday and weekend 3 4 day sitting time was calculated from the domain-specific guestionnaire by summing the time 5 reported sitting in each domain. The mean data derived for weekday and weekend day sedentary time, from the objective (accelerometer-determined sedentary behaviour, <100 cpm) 6 7 and self-report measures were tested for normality using the one sample Kolmogorov-Smirnov test, which confirmed that all measures were normally distributed. Total sitting times reported for 8 9 (1) the single-item question, and (2) the domain-specific questions, were compared with mean 10 accelerometer-determined sedentary time for weekdays and weekend days using paired sample 11 t-tests (with significance set at p<0.05) and 95% confidence intervals. Pearson correlation coefficients (r) and intra-class correlation coefficients (ICC) were calculated for accelerometer-12 13 determined sedentary time and sitting time measured using the two self-report measures, on weekdays and weekend days, to determine the strength and consistency of the association 14 15 between accelerometer-determined sedentary time and the self-report measures. The limits of agreement between the two self-report measures and accelerometer-determined sedentary time 16 were calculated for weekday and weekend day sedentary time using Bland-Altman plots.¹⁸ 17

18

19 Results

Of the 56 participants enrolled in the study, 44 (79%) (30% male, age = 41.5±12.8 years, range: 23-65 years, BMI = 24.8±4.7 kg/m², range: 18.4-38.7 kg/m²) provided valid accelerometer data and satisfactorily completed the specific-day single-item sitting time question in the daily accelerometer diary, and the domain-specific sitting time questionnaire on completion of the study. 39 (88.6%) participants were in either full-time or part-time paid employment, while two (4.5%) did duties around the home, and three (6.9%) were enrolled in postgraduate education. Of the participants in full- or part-time work, 14 (35.8%) were employed in manual occupations whilst the remainder were employed in office-based work. 36% of the sample had a high school
education, 34% had a degree and 30% had a postgraduate qualification. All 44 participants
included in the analyses reported making no changes to their normal daily routine throughout
the seven day monitoring period, and all reported experiencing a typical week during their
participation in the study. Mean (±SD) accelerometer wear time was 914.7±108.5 minutes/day.
Based on the data collected from the domain-specific sitting time questionnaire, total sitting
times and time spent sitting in each domain are shown in Figure 1.

- 8
- 9

Insert Figure 1 about here

10

11 Mean minutes reported sitting using the two self-report measures, along with mean 12 accelerometer-determined sedentary time on weekdays and weekend days are shown in Table 13 1, and Bland-Altman plots showing the level of agreement between these measures are shown in Figure 2. There was good overall agreement between total sitting time calculated from the 14 15 domain-specific questionnaire and accelerometer-determined sedentary time on weekdays and 16 weekend days (Table 1, t-test: p>0.05 for both), but the ICC was higher for weekdays (0.64) 17 than for weekend days (0.20). Despite a stronger association between accelerometer-18 determined sedentary time and mean sitting times reported from the single-item measure (Table 19 1), mean sitting time reported from the single-item question was significantly lower on weekdays 20 and weekend days than accelerometer-determined sedentary time (Table 1, both p<0.001).

- 21
- 22

Insert Table 1 and Figure 2 about here

23

24 Discussion

This study was the first of its kind to examine the convergent validity of two different self-report measures of sitting time against accelerometer-determined sedentary time (<100 cpm). The domain-specific sitting time questionnaire is a relatively new measure of self-reported sitting
time, and has only been validated to date in a sample of middle-aged (range 53-59 years)
Australian women.⁸ The present study extends the Australian one⁸ by assessing the convergent
validity of this new measure in a mixed-gender sample of UK adults (age range: 23-65 years).

5

The mean differences, relative to accelerometer-determined sedentary time (<100 cpm), in total 6 7 sitting time reported on weekdays and weekend days using the domain-specific questionnaire, were smaller than the differences reported between these measures in the Australian study.⁸ 8 9 For example, in the current study, participants underestimated their total daily sitting time using 10 this measure by 13.7 minutes (95% CI = -69.2 to 41.8) and 4.2 minutes (95% CI = -91.7 to 83.4) 11 on weekdays and weekend days respectively. In the Australian study participants underestimated their sitting time by 63.6 minutes (95% CI = -115.1 to -12.1) on weekdays and 12 10.8 minutes (95% CI = -52.6 to 74.2) on weekend days.⁸ Despite the smaller mean differences 13 reported in the present study, the Bland-Altman limits of agreement between the domain-14 specific questionnaire and accelerometer-determined sedentary time were larger for weekday 15 and weekend day sitting times (weekday = -382.0 to 354.6 minutes; weekend day = -578.5 to 16 17 570.2 minutes) when compared with the Australian study (weekday = -395.6 to 268.4 minutes: weekend day = -398.0 to 419.7 minutes).⁸ A possible explanation for the greater variability 18 19 observed in the current study could be due to the wider range of participants used, in terms of 20 their age and gender.

21

From the domain-specific questionnaire, the greatest contributor to daily sitting time was sitting at work on weekdays and watching TV on weekends. This is in line with the findings of the Australian study,⁸ and emphasises the need to assess sitting time across a variety of domains rather than solely relying on TV viewing time. The small differences in usual weekday and weekend day total sitting times observed between the domain-specific questionnaire and

1 accelerometer-determined sedentary time in the current study suggest that this measure may be suitable for use in population surveillance studies, where overall estimates of sedentary time 2 3 are required. However, the wide limits of agreement associated with this measure suggest that it 4 may not be sensitive enough to detect subtle changes in sedentary time observed in 5 intervention studies. In contrast, whilst the single-item 'specific day' sitting time question significantly underestimated sitting time on both weekdays and weekend days relative to 6 7 accelerometer-determined sedentary time, the limits of agreement between these measures were smaller (weekday = -401.6 to 55.6 minutes; weekend day = -509.6 to 72.4 minutes) than 8 9 those observed between the domain-specific questionnaire and accelerometer-determined 10 sedentary time. This finding, along with the stronger correlation coefficients (Table 1) between 11 self-reported sitting time using the single-item measure and accelerometer-determined 12 sedentary time, suggests that whilst the single-item measure underestimated sitting time, it did 13 this with a certain degree of consistency. Given the smaller limits of agreement observed for the single-item specific day question, this measure may be more sensitive than the domain-14 15 specific questionnaire at detecting changes in sitting time.

16

17 Despite the small differences between mean total sitting time measured using the domain-18 specific questionnaire and accelerometer-determined sedentary time on weekends (-4.2 19 minutes), the limits of agreement (Figure 2) between these two measures were large, and no 20 associations were observed between these measures for weekend day sitting times. As reported previously,⁸ the present study found that participants appear to be able to report sitting 21 22 time more accurately for weekdays than for weekend days, presumably because activities that occur during the working week may be more structured and may follow a set routine. The 23 24 domain-specific questionnaire does not enquire about concurrent sitting in more than one 25 domain, for example, while watching TV and using a computer simultaneously. The inability of 26 the domain-specific questionnaire to capture sitting concurrently in different domains may have

1 contributed to the wide limits of agreement observed for this measure, particularly for the weekend data when individuals may be more likely to report sitting in a combination of domains. 2 3 It would be interesting in further research to determine whether the questionnaire could be 4 modified to enable participants to report time spent sitting in multiple domains, and whether this 5 would improve its validity, particularly for weekend sitting. As weekend day sitting behaviors appear to be more variable than weekday sitting, asking about a 'specific' (e.g. Saturday or 6 7 Sunday) rather than a 'usual' weekend day may also improve the validity of this question. However, when asked about total sitting time on a specific weekend day using the single-item 8 9 question, on average, participants failed to report more than 200 minutes of time recorded on the accelerometer as sedentary. Further research is required to improve reporting of sitting time 10 11 on weekend days.

12

13 One limitation of this study was the possibility that participants' completion of the daily diary, in which they reported their specific-day total sitting times over a period of seven days, may have 14 15 aided their recall when completing the domain-specific questionnaire following this monitoring 16 period. However, any potential influence of the specific-day sitting time question on the validity 17 of the domain-specific questionnaire is debatable, given the inaccuracies observed in the self-18 reported total sitting times using this specific-day single-item measure. Furthermore, as the 19 single-item measure did not enquire about domain-specific sitting times, it is unlikely that this 20 measure would have primed participants in terms of their time spent sitting in different domains/contexts. In support of this suggestion. Timperio et al.¹⁹ observed no influence of the 21 completion of a daily physical activity log book on the validity of four different 7-day recall 22 physical activity questionnaires. As in the Australian study,⁸ a second limitation of this study was 23 24 the fact that the sample consisted of a relatively well educated group of volunteers. However, in 25 the current study we included men and women with ages ranging from 23 to 65 years, and more than one third of these were employed in manual occupations. 26

Due to differences in classifying sedentary behaviour between the self-report measures 2 3 assessed herein and accelerometer-determined sedentary time, this study assessed the 4 convergent validity of the two self-report measures of sitting time. As accelerometers are not 5 capable of distinguishing between sitting and lying, or standing still, it is possible that some of the variability observed between the self-report measures and accelerometer-determined 6 7 sedentary time could be due to the misclassification of standing still as sedentary time by the Further work should examine the criterion validity of the two self-report 8 accelerometer. 9 measures included in the current study using an appropriate criterion measure. The activPAL inclinometer is capable of differentiating between postures and classifies an individual's 10 11 behaviour into sitting, standing and stepping. This device shows promise as an objective measure of sedentary behavior as it has been shown to be a valid tool for assessing sitting, 12 standing and stepping under laboratory conditions,²⁰ and could therefore become a suitable 13 criterion measure of sedentary behavior in free-living adults. 14

15

In conclusion, the current findings suggest that the estimation of total sitting time is improved by summing sitting times reported across different domains. Estimates of sitting time are more precise for weekdays than for weekend days. The continued improvement of self-report measures of sitting time, particularly for weekend days, will be important if we are to further our understanding of the links between the behavioral epidemiology of sedentary time and health outcomes.

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5

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- 8 using resources already available within the School of Sport, Exercise and Health Sciences.
- 9
- 10
- 11

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2 Table legend

Table 1. Mean (±SD) minutes reportedly spent sitting on a weekday and weekend day measured using the domain-specific questionnaire, and the single-item measure, along with mean time spent in accelerometer-determined sedentary behaviour (<100 cpm). The differences in reported sitting time between the two self-report measures and accelerometer-determined sedentary time are also shown, with the 95% confidence intervals of the differences, and the correlation coefficients between the self-report measures and accelerometer-determined sedentary time.

Table 1. Mean (±SD) minutes reportedly spent sitting on a weekday and weekend day measured using the domain-specific
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 cpm). The differences in reported sitting time between the two self-report measures and accelerometer-determined sedentary time
 are also shown, with the 95% confidence intervals of the differences, and the correlation coefficients between the self-report
 measures and accelerometer-determined sedentary time.

		Total sitting	Differences of	Pearson	ICC between		Differences of	Pearson	
	ActiGraph- determined sedentary time (mins)	time from domain- specific questionnaire (mins)	specific questionnaire from ActiGraph	between domain- specific questionnaire	domain- specific questionnaire and ActiGraph	Single-item self-reported sitting time (mins)	single-item question from ActiGraph (95% CI)	correlation (r) between single-item question and ActiGraph	ICC between single-item question and ActiGraph
			(95% CI)	and ActiGraph					
Weekday	639.7±133.9	626.0 ± 222.1	-13.7 (-69.2 - 41.8)	0.54 (p < 0.001)	0.64 (p < 0.001)	466.8±161.7	-173.0 (-207.5138.5)	0.70 (p < 0.001)	0.82 (p < 0.001)
Weekend day	612.4±132.7	615.6±280.0	-4.2 (-91.7 - 83.4)	0.13 (p = 0.41)	0.20 (p = 0.23)	391.4±171.3	-218.6 (-262.9174.2)	0.55 (p < 0.001)	0.69 (p < 0.001)

6 ICC: Intra-class correlation coefficient

1 Figure legends

Figure 1. Mean time (in minutes) reportedly spent sitting in each domain on a usual weekday and weekend day, calculated from participants' responses on the domain-specific sitting time questionnaire. Total sitting time calculated across domains was 626 minutes on a usual weekday and 616 minutes on a usual weekend day.

6

7 Figure 2. Modified Bland-Altman plots showing the limits of agreement in sitting time between 8 the domain-specific questionnaire and accelerometer-determined sedentary time (<100 cpm) for 9 weekdays (A) and weekend days (B), and between the single-item measure and accelerometer-10 determined sedentary time for weekdays (C) and weekend days (D). The solid lines represent 11 the mean difference in minutes between the self-report measures and the accelerometer and 12 the dashed lines represent the 95% confidence intervals of the agreement between the 13 measures. The x axis represents accelerometer-determined sedentary time, and the y axis is the difference in sitting time (in minutes) between the self-report measure and the 14 15 accelerometer (self-report - accelerometer-determined sedentary time).



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