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Comparison of self-reported measure of sitting time (IPAQ) with objective measurement (activPAL)

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Running Head:

IPAQ sitting time compared to ActivPAL

ABSTRACT

Purpose: To compare sitting time measured by a questionnaire (International Physical Activity Questionnaire; IPAQ) with concurrently measured objective sitting time from an accelerometer-based measure of thigh inclination (ActivPAL).

Methods: Adults (n=69), wore an activPAL for a week, and then completed the long-form 7-day recall IPAQ questionnaire. IPAQ reported sitting time (including and excluding transportation sitting) for the week, weekdays and weekend days were compared to activPAL (criterion measure) sitting time using intraclass correlation coefficients and Bland Altman plots.

Results: Confidence intervals between the IPAQ and the activPAL were wide, while correlations between the two measures were low and non-significant (0.112-0.275). Compared to a direct measure of postural sitting (ActivPAL), the IPAQ underestimated sitting time across the group for the whole week, both when including (mean 2.2 hours/day) and excluding (mean 3.4 hours/day) transportation sitting. Sitting was less accurately reported on weekend days than weekdays, and at lower levels of sitting on weekdays.

Conclusions: Agreement between the IPAQ and the activPAL, a direct measure of sitting, in this study was poor. The direction of group agreement was different to comparisons using a measure of low accelerometer counts (Actigraph) as the criterion measure in previous research. Future studies should use a direct measure of sitting as a criterion measure to validate subjective measurement tools.

Key Words: sedentary behaviour, accelerometry, validity, actigraph, inclinometer

Subject classification

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Introduction

Too much time spent sitting has been identified as a public health risk (Owen *et al* 2010), independent of a lack of physical activity. Evidence suggests that time spent sitting is associated with higher levels of obesity, metabolic risk factors, increased risk of diabetes, cardiovascular disease and premature mortality (Edwardson *et al* 2012)(Healy *et al* 2011b)(VanderPloeg *et al* 2012). Consequently, policies concerning sitting time have started to appear with several countries (e.g. Canada and the UK (Department of Health 2011)) issuing recommendations to limit sitting time.

It is crucial to accurately measure time spent sitting across a wide range of research outputs and for population surveillance. While objective measures of sitting time are becoming more widely used, self-report measures, despite their known limitations, are still the most pragmatic and frequently used solution for large scale population research and surveillance (Healy *et al* 2011a). The simplest recall instrument to capture sitting time is to directly ask the respondent how long they spent sitting on an average day over a fixed recall period. This type of question has been adopted in several national health surveys and questionnaires with different recall periods ranging from 7 days to a whole year (Healy *et al* 2011a). Usually separate questions are asked for weekend and week days and some questionnaires include domain specific sitting items such as sitting during work, leisure or transportation. Multiple studies have tried to ascertain the accuracy and validity of these self-report instruments against sensor based criterion measures (Healy *et al* 2011a) and report widely different results mostly showing weak correlations. A major flaw common to these studies is that none have used an objective measure of sitting as reference criterion measure but instead have used an indirect estimation of sitting time through lack of movement (i.e. low activity counts) recorded by accelerometer. For example, a number of studies have used the Actigraph as the criterion measure with a cut-off point of 100 counts/minute, which may categorise time spent standing as sitting. The face validity of these types of sensors as the reference criterion and their ability to capture sitting time accurately is questionable (Kozey-Keadle *et al* 2011). New body worn sensors measuring the inclination of the thigh offer a direct detection of periods spent sitting (Chastin and Granat 2010)(Ryan *et al* 21011) and can accurately assess sitting time (Kozey-Keadle *et al* 2011).

The aim of this study is to assess the validity, accuracy and precision of self-reported sitting time instruments against a direct and valid objective reference measure of sitting time. The study focuses on the IPAQ, as an archetypal self-reported sitting time assessment tool as it has been widely validated (Healy *et al* 2011a) and used to estimate the epidemiology of sitting (Bauman *et al* 2011).

Methods

Sample

A convenience sample of adults (aged 18-65 years) was recruited via e-mail to staff of Glasgow Caledonian University, and data was collected between October 2007 and October 2009. All participants were capable of continuously wearing the monitor over a seven day period and could read, speak and understand English. Individuals who self-reported that they were unable to mobilise independently were excluded from the study. The study was approved by the Glasgow Caledonian University School of Health and Social care ethics committee and all participants signed an informed consent form.

Procedure

On day 1, participants met a researcher and self-reported demographic information (age, sex, height and weight) was collected. Participants were provided with an activPAL monitor, and instructed on its use. Each participant was asked to wear the monitor for the following seven consecutive days (days 2-8), including overnight, although not during water-based activities. On day 9, participants met with the researcher a second time, returned the activPAL and completed the IPAQ questionnaire.

Criterion measure

The activPAL physical activity monitor is a valid and reliable accelerometer based device that is mounted to the thigh. The activPAL measures thigh inclination directly, providing robust identification and quantification of the number and the length of sitting periods of activity throughout the day (Grant *et al* 2006)(Kozey-Keadle *et al* 2011). The activPAL monitor does not distinguish between a sitting and a lying posture. In addition the activPAL identifies periods of standing and of stepping activity (Ryan *et al* 2006).

Recall measure

The self-administered long-form, last 7-day IPAQ contains 27 questions, asking about physical activity in four domains: leisure time, work-related, transportation and housework/gardening (Craig *et al* 2003). Within the questionnaire there are three specific sitting items. Two questions ask respondents to estimate the total number of hours and minutes per day spent sitting at work, at home, and during leisure time for a weekday and a weekend day. The time spent sitting during motorised transportation is assessed in a separate question.

Data treatment

To be included in the analysis a subject would have to have worn the activPAL continuously for at least 3 week days and 1 weekend day. The activPAL data were processed using the activPAL software to identify daily sequences of seated, standing and stepping events throughout the seven days recording period. Total sitting time was estimated by summing the duration all sitting events in a daily pattern during waking hours. Waking time was defined from the first standing event after a long continuous period (> 2hours) of non-upright posture between the hours of midnight and 9 AM, to the last standing event before a long continuous period (> 3hours) in non upright posture during night hours 10:30PM. Sitting time for the total week, weekdays and weekends were obtained by averaging over the daily values.

The IPAQ items were tabulated directly from the questionnaire as sitting time during week days and during weekends. Sitting time for the total week was computed as a linear combination of these two items. In addition we also added the time spent seated in the motorised transportation item to obtain an estimate of the total sitting time in all four domains (home, work, leisure and transportation).

Statistical analysis

All statistical analyses were performed using the statistical package for the social sciences, version 19.0 (SPSS Inc., Illinois, USA). Two-way mixed model (single measure) intraclass correlation coefficient (ICC) and Pearson correlations were used to examine the absolute (ICC) and relative (Pearson) agreement between the criterion method (activPAL) and the IPAQ sitting items for average total week (including and excluding transportation time), weekdays and weekend sitting time. We considered correlation <0.5 to be low, 0.5-0.75 to be moderate, and >0.75 to be high (Portney and Watkins 1993). We computed the accuracy of IPAQ items as the mean difference between activPAL and IPAQ scores across the sample. Bland-Altman analysis was utilised to provide an indication of the heteroscedasticity of the data and the limits of agreement between the IPAQ sitting items and the activPAL device in accurately reporting average total week, weekdays and weekend sitting time (Bland and Altman 1999).

Results

Characteristics of study sample

Of the 101 participants who were recruited, 28 participants did not complete the IPAQ. In addition 4 participants were excluded from analysis because they did not wear the activPAL for the minimum required period (3 weekdays and 1 weekend days). Participants included in analysis (n=69) were mostly female (n=46). The mean age for this sample was 41.1 +/- 9.0 years, and BMI (mean 25.0 $kg \cdot m^{-2}$) ranged from underweight (17.7 $kg \cdot m^{-2}$) to obese (38.4 $kg \cdot m^{-2}$).

Table1. Comparison of IPAQ sitting items with activPAL objective measure of sitting time.

Sitting time [hours/day]	Inter Class Correlation	Pearson's correlation	Mean ± sd IPAQ	Mean ± sd AP	Mean [95% CI] (AP-IPAQ)
Total Week	0.112	0.114 (*P* =0.351)	6.6 ± 2.6	9.9 ± 1.9	3.40 [-2.15 8.93]
Total Week(inc transportation)	0.149	0.159 (*P* =0.193)	8.1 ± 2.6	9.9 ± 1.9	2.15 [-3.71 7.22]
Total Weekdays	0.159	0.174 (*P* =0.154)	7.4 ± 2.7	10.6 ± 1.6	3.43 [-2.08 8.94]
Total Weekends	0.275	0.010 (*P* =0.936)	5.4 ± 2.6	10.9 ± 1.7	4.64 [-2.01 11.30]

AP: activPAL; IPAQ: International Physical Activity Questionnaire [long version]; sd: standard deviation; 95% CI: 95% confidence interval

Criterion Validity

Interclass correlation coefficients between IPAQ sitting items and activPAL data displayed low agreement for sitting time for the total week, weekdays or weekends (table 1). Pearson's correlation coefficients were also low and were not statistically significant indicating that there was no linear relationship between the two measures (table 1).

Accuracy and agreement

IPAQ items tended to underestimate sitting time (table1), with the mean difference between IPAQ items and activPAL ranging from 2.2 h/day for the total week including transportation time and 4.6 h/day during weekends. The confidence intervals showed that for some individuals IPAQ overestimated true sitting time and that the precision of IPAQ items to capture sitting time was poor.

The level of agreement between the two measurement methods was evaluated using Bland-Altman analysis, in which differences between the measurement methods are plotted against their average.

There was a consistent underestimation by the IPAQ sitting items of time spent sitting for the total week and weekend days across all levels of sitting time (figures 1 & 2). The Bland-Altman plot for average total weekdays (figure 3) presented a negative correlation (r=-0.250 p = 0.002 Kendall Tau correlation) between the IPAQ sitting item and activPAL. This indicated that the absolute error in estimating sitting time using the IPAQ week day item decreased at higher levels of sitting time. This trend also appeared in the Bland-Altman plot of total week sitting time corrected to include the IPAQ transportation item (figure 4), but the trend was not statistically significant (r=-0.156 p = 0.057 Kendall Tau correlation).

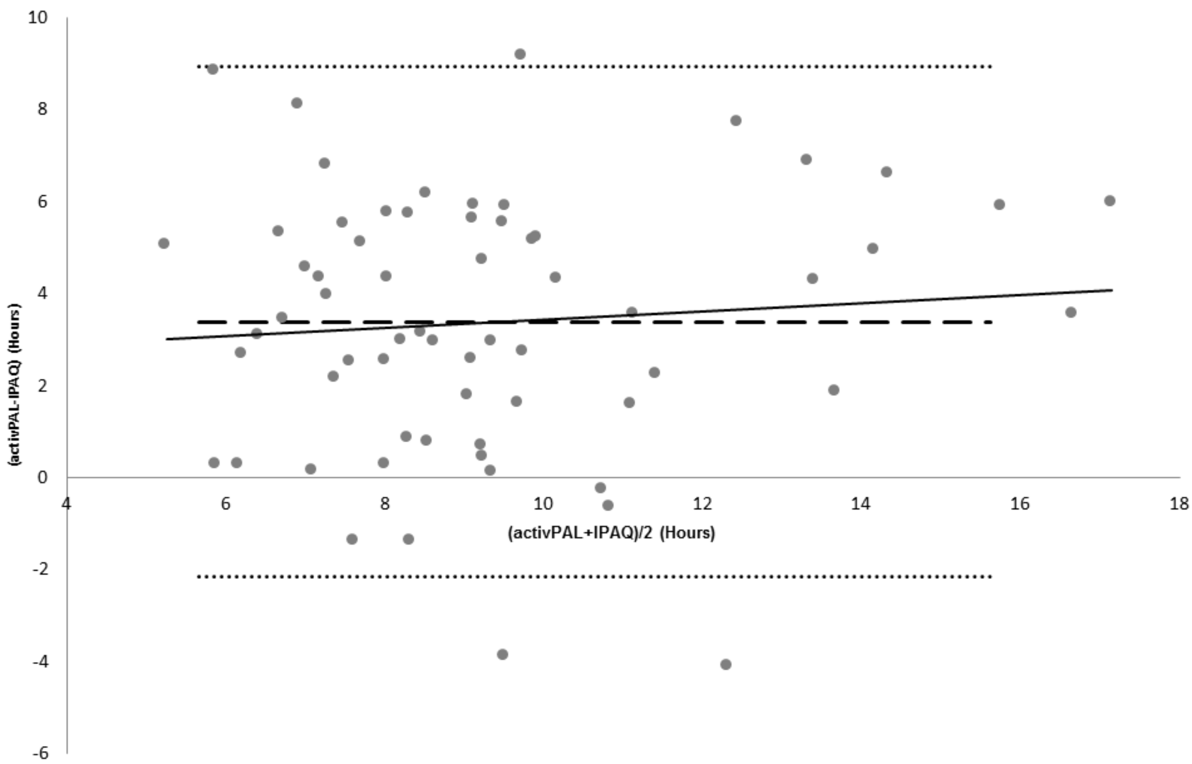

Figure 1 – Bland-Altman plot for the average total hours of the week spent in sitting measured by activPAL and IPAQ. Dashed line shows the mean difference, dotted lines the limit of agreement at the 95% level and solid line the heteroscedasticity trend.

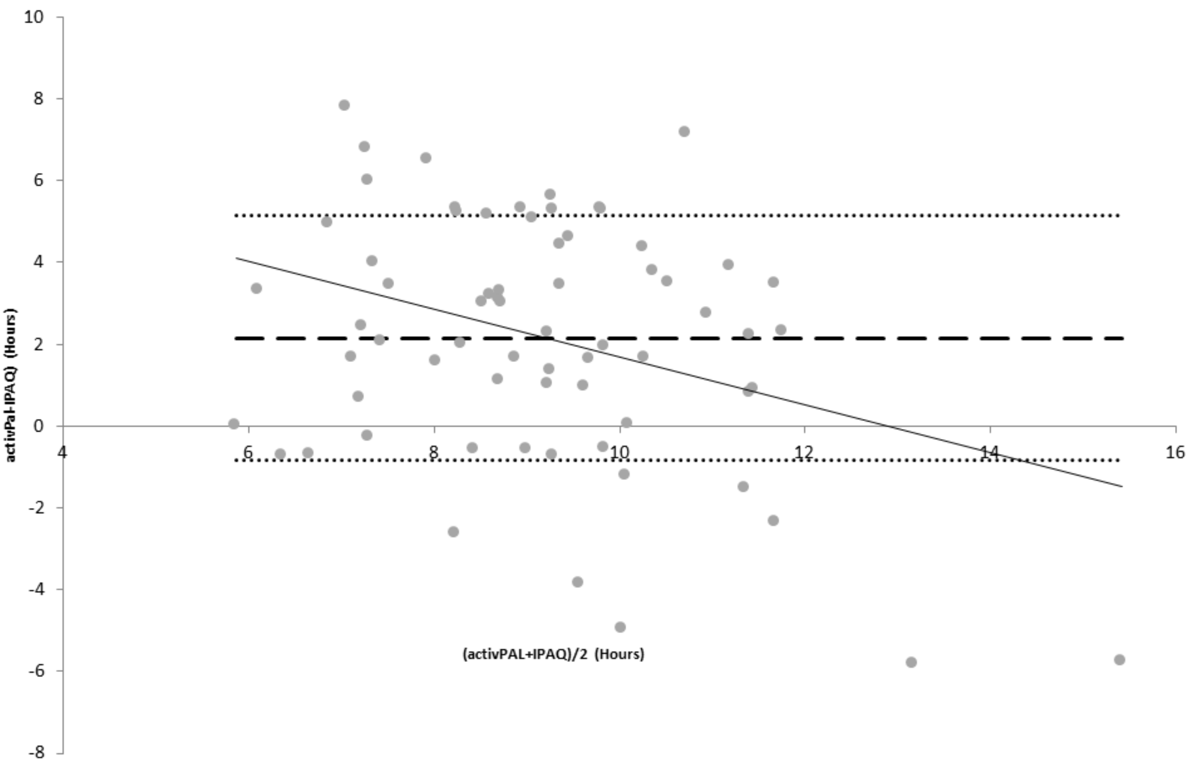

Figure 2 - Bland-Altman plot for the average total hours of the weekends spent in sitting measured by activPAL and IPAQ. Dashed line shows the mean difference, dotted lines the limit of agreement at the 95% level and solid line the heteroscedasticity trend.

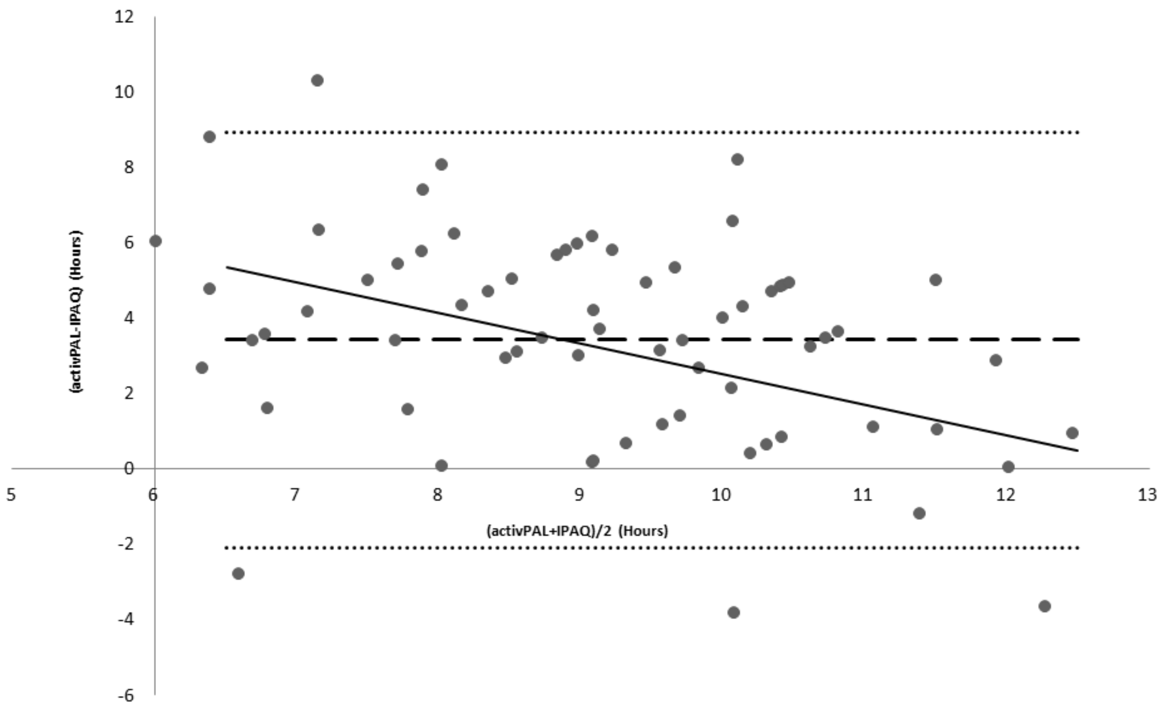

Figure 3 - Bland-Altman plot for the average total hours of the weekdays spent in sitting measured by activPAL and IPAQ. Dashed line shows the mean difference, dotted lines the limit of agreement at the 95% level and solid line the heteroscedasticity trend.

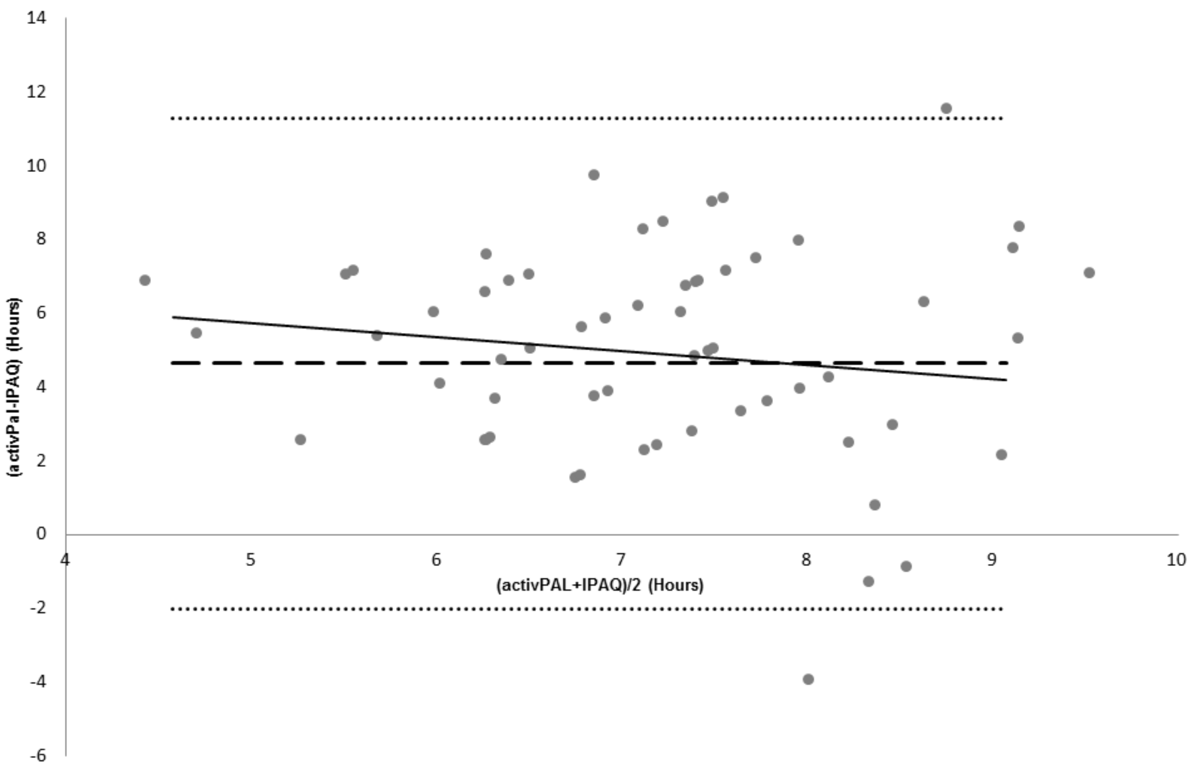

Figure 4- Bland-Altman plot for the average total hours of the week spent in sitting measured by activPAL and IPAQ including transportation time. Dashed line shows the mean difference, dotted lines the limit of agreement at the 95% level and solid line the heteroscedasticity trend.

Discussion

In this study we found the IPAQ sitting items underestimated sitting time by large amounts (up to 4.6 h/day). The accuracy improved a little if estimates of sitting time were obtained by combining all sitting items including seated transportation time, but this still left an average underestimation of the order 2 hours per day (representing an error of 20% in sitting duration across the week).

This trend of underestimation may be a consequence of social desirability error. Individuals may report inaccurately on sensitive topics to present themselves in a positive light for self-esteem enhancement or to appear in keeping with perceived cultural norms (Irwin *et al* 2001)(Adams *et al* 2005). Social desirability bias has been shown to influence self-report physical activity recall questionnaires (Fisher and Katz 2000) and it is conceivable that a similar effect may occur when individuals self-report sitting time. Conversely, study participants may have underestimated the time spent in sedentary behaviours due to interpreting favourable anthropometric indicators as verification of adequate activity levels (Watkinson *et al* 2010). Most participants (59%) had a BMI in the normal range which, consequently, may have resulted in the underestimation of sedentary time observed. Results appear more accurate for weekdays then for weekend days. In a working population respondents might find it more socially acceptable and easy to recall sitting time during days with an imposed routine.

The bias in the IPAQ sitting time will affect estimates of sitting time in population surveys, and recent epidemiological reports using IPAQ or 7 day recall sitting questions are likely to have underestimated sitting time (Bauman *et al* 2011). If this bias was systematic across all levels of sitting time then it could potentially be corrected by a measurement error term. However, we found low but significant heteroscedasticity trends for week days (figure 3), and the bias appeared to be relative to the amount of sitting. There was increased inaccuracy bias at lower levels of sitting. This relative error might be inherent to human nature. It has been shown that human perception of time follows Weber–Fechner law (Takahashi *et al* 2008), therefore longer amount time spent sitting are likely to be more accurately recalled. Using this law it might be possible to obtain more accurate estimates of sitting time from subjective measure by introducing a relative error term of the form

$$(1) \qquad \Delta S = k\,S + \varepsilon$$

with S the real sitting time, ΔS the relative error, k a constant and ε the systematic error.

In addition, we also found that the precision of sitting time estimates obtained using IPAQ was very low, even after inclusion of the transportation items. This was also reflected in the apparent low level of criterion validity of single and combined items scores compared to activPAL. The wide confidence intervals reported here do not directly affect the accuracy of estimates of sitting time of a population, but they are a more critical issue in terms of surveillance or application in intervention trials, where the lack of precision would be likely to impact sensitivity to detect change. Population surveillance instruments or the outcome measures of intervention trials incorporating 7 day recall sitting questions are unlikely to be responsive to change. The combination of large and relative underestimation and low precision is also likely to also significantly reduce the ability to detect and identify dose–response relationship between a sitting time and health outcomes. This might explain some of the recent reports showing different associations with health markers between self-reported and objectively measured sitting time (Stamatakis *et al* 2012a)(Stamatakis *et al* 2012b)(Celis-Morales *et al* 2012).

Overall, we found that the IPAQ long form sitting items, and by extension 7 day recall sitting time questions, offered poor and imprecise estimates of sitting time with very limited criterion validity. Previous studies have also examined the validity of the IPAQ (long form) sitting items as tools to assess sitting time (Hagstromer *et al* 2010)(Craig *et al* 2003)(Hagströmer *et al* 2006)(Celis-Morales *et al* 2012)(Rosenberg *et al* 2008), using the Actigraph accelerometer as the criterion measure. The results of these studies and the way they have treated and combined the various sitting items vary widely. However, generally the studies agree upon a statistically significant tendency for IPAQ, when the sitting item and transportation item are combined, to overestimate sitting time compared to the time spent below 100 counts per minutes recorded by Actigraph. The overestimates reported range from 0.22 h/day (Hagströmer *et al* 2006) to 1.14 h/day (Celis-Morales *et al* 2012). When the transportation sitting time item is omitted from the estimates of total sitting time IPAQ has a tendency to underestimate by around 0.61 h/day. In terms of criterion validity, there is no clear agreement between these studies, which report low r=0.17 (Hagströmer *et al* 2006) to moderate r=0.65 (Celis-Morales *et al* 2012) correlations between IPAQ and Actigraph depending on populations. The larger scale studies (Hagstromer *et al* 2010)(Hagströmer *et al* 2006), however, tend towards low correlations (r <0.2), which some authors have deemed adequate (Rosenberg *et al* 2008). Some evidence of heteroscedasticity has also been reported (Hagstromer *et al* 2010).

While these results agree with ours in terms of the assessment of criterion validity, it is worth examining why there are notable disagreements in the direction and amount of the group difference between IPAQ and the objective criterion measures. We found that IPAQ underestimated by several hours per day compared to activPAL while the studies above report a smaller overestimation compared to the Actigraph. This disagreement is attributable to the difference in criterion measure. The Actigraph is not an adequate criterion measure for sitting time as it does not measure sitting directly. Cross validation of the Actigraph against activPAL and direct observation clearly showed that the Actigraph underestimated sitting time (Kozey-Keadle *et al* 2011). It is therefore not surprising to see that IPAQ appears to overestimate compared to the Actigraph. On the other hand measuring sitting time via thigh inclination with devices such as activPAL has been shown to be a valid and accurate measure (Kozey-Keadle *et al* 2011). Therefore the activPAL can be considered as an adequate criterion measure and our results more valid.

Using subjective recall instruments is still the only practical solution for large scale population surveillance and it is imperative that these measure are accurate and precise (Healy *et al* 2011a). A seven day recall question asking directly how much time the respondent spent sitting is possibly the simplest instrument, and this has been integrated in several national surveys and the IPAQ. The IPAQ was selected as the self-report measure of sedentary behaviour in this study because it is widely used. Recalling sedentary behaviour over a shorter period (e.g. the past day) with or without the assistance of a detailed interview to assist recall (Clark *et al* 2013)(Matthews *et al* 2013), may provide a better estimate of actual sitting time than using a week-long single item question.

There are several limitations to this study. The modest sample size could restrict generalisation of the results to the wider population. Subjects volunteered for inclusion in the study, which can lead to a selection bias within the participants. Equally the participant group could be limited by demographic constraints as it contained students and university-based employees who consequently sit for longer periods of time and may not be representative of the broader population. However the range of sitting time levels in this study appeared to be wide and seemed to adequately cover the range of sitting behaviour reported in large scale population studies. The main strength of this research is that it is the first to use a direct objective measure of sitting time (Chastin and Granat 2010)(Kozey-Keadle *et al* 2011) as criterion measure to assess the validity of subjective assessment of sitting time. The activPAL monitor does not distinguish between a sitting and a lying posture. Some of the data we report as sitting might in fact be lying, but whilst a person is awake both postures (sitting and lying) are classified as sedentary behaviour. Any sleeping during the day time, however, will have been incorrectly included as sedentary behaviour in our study. Culturally, working adults in Scotland are unlikely to take a nap during the day, so this discrepancy is likely to be small.

Although some studies have used the activPAL monitor in a moderate-large scale study (e.g. >13,000 individuals; Klenk *et al* 2012), the relatively high cost of objective measures of sitting via inclinometry limits its use in most large population surveillance surveys, however, current 7 day recall sitting questions do not seem to offer a valid and accurate alternative. There is a need to identify a valid, accurate and sensitive self-report measure of sitting time for use in large population studies and intervention trials. Other types of self-report instruments using shorter recall periods or using more detailed domains of sitting should be evaluated. However, in order to draw accurate conclusions, care should be taken to conduct evaluations using a direct measure of sitting rather than a proxy measure, even if that proxy measure is objective.

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FIGURE CAPTIONS

Figure 1 – Bland-Altman plot for the average total hours of the week spent in sitting measured by activPAL and IPAQ. Dashed line shows the mean difference, dotted lines the limit of agreement at the 95% level and solid line the heteroscedasticity trend.

Figure 2 - Bland-Altman plot for the average total hours of the weekends spent in sitting measured by activPAL and IPAQ. Dashed line shows the mean difference, dotted lines the limit of agreement at the 95% level and solid line the heteroscedasticity trend.

Figure 3 - Bland-Altman plot for the average total hours of the weekdays spent in sitting measured by activPAL and IPAQ. Dashed line shows the mean difference, dotted lines the limit of agreement at the 95% level and solid line the heteroscedasticity trend.

Figure 4- Bland-Altman plot for the average total hours of the week spent in sitting measured by activPAL and IPAQ including transportation time. Dashed line shows the mean difference, dotted lines the limit of agreement at the 95% level and solid line the heteroscedasticity trend.