Measurement of Adults' Sedentary Time in Population-Based Studies

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Abstract

Sedentary time (too much sitting) is increasingly being recognized as a distinct health risk behavior. This paper reviews the reliability and validity of self-report and device-based sedentary time measures and provides recommendations for their use in population-based studies. The focus is on instruments that have been used in free-living, population-based research in adults. Data from the 2003-06 National Health and Nutrition Examination Survey are utilized to compare the descriptive epidemiology of sedentary time that arises from the use of different sedentary time measures. A key recommendation from this review is that, wherever possible, population-based monitoring of sedentary time should incorporate both self-report measures (to capture important domain- and behavior-specific sedentary time information) and device-based measures (to measure both total sedentary time and patterns of sedentary time accumulation).

Introduction

Sedentary behaviors are those pursuits undertaken while awake that involve sitting or reclining and that result in little or no physical activity energy expenditure – typically 1 to 1.5 times the resting metabolic rate.[1,2] Common sedentary behaviors include sitting or lying down while watching television, using a computer, or driving. Sedentary time can be measured in three ways: (1) in terms of these specific behaviors (e.g. television viewing time); (2) the amount of sedentary time occurring in a specific domain (e.g. work, leisure, domestic, transport); and, (3) the overall sedentary time across the day. As the term "sedentary" encompasses both sitting and reclining, the broader term sedentary is used in this article, except when sitting is specifically measured.

This paper provides an overview of current methods used to measure sedentary time in free-living, population-based research in adults. The first section provides information on the reliability and validity of self-report measures, and extends from previous reviews[3] to encompass multiple domains of sedentary time. The second section describes device-based measures, with a particular focus on the interpretation and validity of data from the Actigraph activity monitor. The final section uses data from the U.S. National Health and Nutrition Examination Survey (NHANES) to provide an example of how the descriptive epidemiology of sedentary time may differ depending on how it is measured.

Section 1: Self-report Measurement of Sedentary Time

Overall sedentary time can be assessed with either a single item (sometimes asked separately for weekend and weekdays), or by summing responses for the various behaviors or domains (composite measure). Key self-report methods used are questionnaires (self-administered or interviewer-administered), behavioral logs, and short-term recalls. Questionnaires are a popular method[3] because they can be implemented on a large scale, are relatively inexpensive, and do not alter the behavior under investigation.[4] However, as with physical activity assessment,[4, 5] questionnaires that seek to assess habitual levels of sedentary behavior are susceptible to random and systematic reporting errors.

Short-term recalls (e.g. 24-hour recall) and behavioral logs[4] can reduce some of these reporting errors, such as long-term averaging. Traditionally, the disadvantages of behavioral logs (participant burden, systematic reporting errors and administration costs) have limited their use in population-based research. However, new approaches and technologies can reduce costs. For example, the National Cancer Institute has developed, and is currently testing, an internet-based instrument for population surveillance of both active and sedentary behaviors.[6]

Reliability and Validity of Self-Report Measures of Sedentary Time

The usefulness of a self-report measure is dictated to a large extent by the properties of test-retest reliability and criterion validity.[7] A summary of test-retest reliability[8-33] and criterion validity[8, 9, 11, 15, 17-22, 28, 29, 34-40] findings for self-report measures of overall and domain-specific sedentary time is provided in Tables 1 and 2. Depending on the available information, the intra-class correlation (ICC), Spearman's rho (ρ) or Pearson's correlation coefficient (r) are reported. Systematic differences between self-report and criterion measures, when reported,[8, 19-22, 34-37] are summarized in the text.

Reliability studies

Reliability studies have varied in terms of recall period (from three days[9, 10, 23, 25] to 3 months[24]), administration method (telephone or interview), and target population, making it difficult to compare their findings. Accordingly, the strength of association between test and retest measures varied widely across studies (Table 1). The majority of self-reported sedentary time measures showed moderate-to-high correlations, a magnitude comparable to results reported for physical activity measures,[11] indicating acceptable to good test-retest reliability. Stronger reliability was generally observed for sedentary behaviors that tend to be done on a regular basis and for prolonged periods of time, such as sitting at work and TV viewing time, than for less regularly performed behaviors, such as travel or other sitting.

Most questions about leisure-time[3] and workplace sitting[12, 13] asked about typical patterns of behavior. In comparison, the overall sitting measures asked either about typical behavior[11, 14-17] or about sitting in the last seven days.[9, 11, 18, 23, 25-27] No difference between these two methods was found in a review of measures of non-occupational sitting time[3] and in a comparison of two versions of the International Physical Activity Questionnaire (IPAQ; 'typical' or 'last 7 days').[11]

Validity studies

As detailed in Table 2, the validity of most questionnaire measures of sedentary time has been assessed against behavioral logs or accelerometers. However, these are not 'gold standard' measures of sedentary time, having their own errors and biases. To date, the most robust criterion employed has been combined hip-mounted accelerometer and behavioral log data.[8, 37]

The validity of the IPAQ single-item question used to assess overall sitting time has been extensively examined in a number of countries with participants of varying age (18-65 years).[9, 11] This measure has mostly had low-to-moderate correlations with a criterion of accelerometer-derived sedentary time,[9, 11, 17, 18] comparable in magnitude to those reported for interviewer-administered physical activity measures (Figure 1).[41] While composite measures of sedentary time have also only shown low-to-moderate correlations with accelerometer-derived sedentary time (Figure 1),[15, 21, 22, 28] total sitting time tends to be lower when assessed by a single-item (4.35-7.92 hrs/day)[9, 42, 43] than those by composite measures (7.25-9.80 hrs/day).[12, 19, 21] While direct comparison is hampered by the use of varying criterion measures, mode of administration, and target populations, correlations tended to be higher for domain-specific measures than for overall sedentary measures (Table 2) – particularly for screen time,[8] computer use,[19, 29] work,[19] and TV viewing time.[19, 36] Collectively, results suggest it may be more difficult to recall the time spent sitting during the entire day than the time spent sedentary for specific behaviors or in different domains.

Findings from the relatively few studies that have reported on absolute agreement are mixed, with reports of both overestimation[20, 34, 35, 37] and underestimation[19, 21, 22] of sitting time compared with criterion measures. The sitting time reported for TV viewing, screen time and eating were typically underestimated compared to device-based measures of these same behaviors.[8, 36] For example, on average, people report half an hour less TV viewing time than is recorded by the criterion measure,[36] and the wide limits of agreement showed large discrepancies between self-report and the criterion at the individual level.

Summary and Recommendations for Future Research with Self-Report Measures

The reliability and validity of available self-report measures of sedentary time are highly variable but often at a level comparable to physical activity measures. The available evidence suggests many sedentary time measures have acceptable measurement properties (i.e. adequate test-retest and relative agreement with criterion measures) for establishing cross-sectional associations with health outcomes, but not necessarily for assessing changes over time in cohort and intervention studies. The evidence on absolute agreement is sparse, and shows only limited agreement against criterion measures that are less than ideal.[8, 19-22, 34-37] In the only study to examine responsiveness to change, questionnaire-assessed sitting performed as well as accelerometer-assessed sedentary time.[22]

More work is also required to assess: nuances associated with mode of questionnaire administration (e.g., interviewer vs. self-administration); different response formats (e.g., continuous or categorical); the time-frame of assessment (e.g., short-term, such as past day or last 7 days, versus habitual patterns such as typical day, usual week, or past year); and, to ascertain how these factors impact sedentary time estimates. Importantly, several achievable improvements to study design could improve understanding of the measurement properties. Much research to date has been conducted (either wholly or in part) with university samples[26, 29, 30, 44] or with particular population sub-groups, including overweight adults,[36] middle-aged women,[19] and young men.[18] Research also needs to focus on general populations and sub-populations for whom reliability and validity might be affected by issues of literacy, cognition, language and less 'regular' patterns of some sedentary behaviors (e.g. parents with young children or shift workers). Furthermore, improved criterion measures (see Section 2) are now available that could be used, with concomitant collection of behavioral log data where behavior- or domain-specific measures are required. Device-based measures specific to particular behaviors, such as the electronic TV monitor (which monitors user-specific TV viewing time),[36] may also be useful.

Section 2: Device-Based measures of Sedentary Time

Given the errors associated with self-report, the ideal measure of sedentary time would:

- be accurate and reliable across different population groups;
- distinguish between sleep, reclining, sitting and standing;

- distinguish between different domains and specific behaviors;
- be low cost, have low participant burden, and be able to be worn continuously for extended periods of time;
- produce data that are easily analysed and interpreted and can be provided in real-time.

No such instrument currently exists. To date, the main instrument used to derive sedentary time in population-based studies is the hip-mounted uniaxial Actigraph accelerometer (model 7164), using one-minute data collection epochs.[45, 46] In this paper, unless otherwise specified, the term "Actigraph activity monitor" refers to this particular model (7164), placement (hip), and epoch length (one minute). This device has been shown to provide reliable, valid, and stable measurements of physical activity when compared with other measures of functional capacity.[47] It can also provide information about total sedentary time and the manner in which sedentary time is accumulated, both of which have shown associations with health outcomes.[48, 49] The primary aim of this section was to describe the collection, analysis and interpretation of data from the Actigraph activity monitor. We also have reported its validity when compared with two other device-based measures of sedentary time: the Intelligent Device for Energy Expenditure and Activity (IDEEA) monitor,[50] and the activPAL activity monitor.[51] Both instruments have been reported to have high accuracy for determining body position as compared to direct observation,[50, 51] though neither have yet been used in population monitoring of sedentary time.

Collection, Analysis, and Interpretation of Actigraph Activity Monitor Data

Collection

Accelerometers measure time-varying changes in force.[52] Activity levels are typically recorded as counts, which are then summed over a user-specified time frame, or epoch. There are several considerations when using accelerometers in field-based research that have been reported in detail, [53-55] including accelerometer type, days of wear, and epoch length. Population-based studies utilising accelerometers have typically used Actigraph activity monitors, had a 7-day wear protocol, and used a one-minute epoch.[45, 46, 56, 57]

Analysis and interpretation

Once data are collected there are several analytic decisions, including cut-points, wear time, and data cleaning, to ensure that data can be meaningfully interpreted. Although the most accurate cut-point is yet to be established, counts per minute (cpm) of <100 are typically classified as sedentary time.[11, 57-59]

Wear time is a particularly important consideration. Participants are typically instructed to wear the monitor during "waking hours", and to remove it for any water-based activity. As suggested by physical activity research, a minimum time of wear is generally required (for example, 10 hours per day[59] and four days of wear including a weekend day[60]). Even so, individual wear time is highly variable and 'missing data' are usually indistinguishable from sleeping time, which should be excluded from sedentary time calculations. This introduces measurement error. In population-based studies, wear time for Actigraph activity monitors is usually estimated by automated programs, designed to detect long periods of low (mostly zero) counts.[59] However, this can misclassify sedentary time as non-wear, and vice-versa.[61] Methods of correcting for wear time include reporting sedentary time as a percentage of wear time, statistical adjustment in regression models, and using the residuals method.[62]

Sedentary time data derived from the Actigraph activity monitor are typically reported either as average hours per day or as a percentage of total wear time. The manner of sedentary time accumulation provides important additional information, such as the length and intensity of each sedentary bout or the number of interruptions (breaks) in sedentary time.[48, 49]

Furthermore, as data are date and time stamped, there is potential for more detailed examination of both sedentary time and patterns during specific time periods, such as during work hours.

Validity of the Actigraph Activity Monitor to Measure Sedentary Time

Following is a description of two studies led by co-author Charles Matthews that examined the validity of sedentary time derived from the Actigraph activity monitor (<100 cpm) against the criterion of the IDEEA monitor and the activPAL activity monitor.

Accelerometer vs. IDEEA monitor

Participants (n=19, mean age 40.1 years) concurrently wore the Actigraph activity monitor and IDEEA monitor for two days[59] for the same amount of time on average (both 13.2 hours/day, SD 2.15). Sedentary time was similar for the accelerometer (8.63 hours/day, SD 1.90) and the IDEEA (8.53 hours/day, SD 1.86), and the two measures were highly correlated (ρ=0.59).[59] This initial field study supported the use of the <100 cpm threshold for estimating sedentary time.[11, 63]

Accelerometer vs. activPAL

In a second study, 86 participants (87% women; mean age 52.7, SD 8.6 yrs) simultaneously wore an Actigraph activity monitor and activPAL for seven consecutive days. For this analysis, only valid days that had similar estimated wear times for both devices (± 30 minutes) were considered. Sedentary time derived from the Actigraph activity monitor (<100 cpm) was compared with that from the activPAL (sitting and lying down) over an average of 4.5 observed days per person, and an average wear time of 14.3 hours per day (SD=1.5) for each device.

On average, recorded sedentary time was lower for the Actigraph activity monitor (8.7 [SD=1.6] hrs/d, or 60.9%) than for the activPAL (9.0 [SD=1.8] hrs/d, or 63.4%; both p=0.01), but the correlation between the measures was relatively high ($\rho=0.76$, $p < 0.01$). Interestingly, Bland-Altman analysis[64] (Figure 2) showed a small mean difference (-0.34 hrs) and wide 95% limits of agreement (2.11 to -2.79 hrs). This indicates that the Actigraph activity monitor has minimal bias overall, but can both substantially over and underestimate sedentary time compared with the activPAL.

These two validity studies imply that Actigraph activity monitors provide useful estimates of sedentary time in the population and that they are sufficiently accurate to rank individuals by their level of sedentary time. The width of the limits of agreement observed warrants further study and suggests some caution is required when using indirect measures of sedentary time derived from only body motion. Instruments that measure body position more directly may be preferable in studies that require precise and accurate measures of sedentary time.

Recommendations for Future Research with Device-Based Measures

The incorporation of Actigraph activity monitor measures into the 2003/04 and 2005/06 NHANES was an important development in the field of physical activity and sedentary time research. With data from over 14,000 participants, it demonstrated the feasibility and utility of using these devices on a large scale. The inclusion of device-based measures in current[65, 66] and future national health surveys will enable cross-country comparisons of levels of physical activity and sedentary time, as well as the ability to monitor population trends in these behaviors.

More sophisticated systems for measuring time spent in different postures (e.g. sitting vs. standing/upright) using more direct measures of body position have recently been developed.[50, 51, 67-69] In addition, new approaches for translating more densely sampled data from hip-mounted accelerometers (e.g., 1 or 10 second epochs; raw data) to classify different types of behavior are also on the horizon.[70-72] These new instruments and analytic approaches appear to provide more accurate and precise estimates of time spent in sedentary behaviors than were reported with the Actigraph 7164 activity monitor. There is also now the potential for the integration of multiple information sources, such as accelerometry, inclinometers, physiological monitors, global position system (GPS) technology, and behavioral logs.

In summary, key directions for future research in device-based measures of time spent sedentary are:

- studies to inform "best practice" for collection, analyses, reporting of device-based sedentary-time data including monitor placement (s) and wear time (both daily and number of days);
- developing analytical and modelling techniques to appropriately summarize the data for different population groups (for example children; older adults);
- examining how measurement errors in the instruments vary according to the type of instrument employed and how results from surveillance and association studies may, or may not, be affected;
- developing products that are more affordable, have relatively low participant burden, can integrate multiple information sources, and provide contextual information.

Section 3: Descriptive Epidemiology of Sedentary Time in the United States as Measured by Self-Report and by Accelerometry

In 2003/04 and 2005/06, the large, population-representative NHANES included both self-report (global sitting time, TV viewing time, computer time) and device-based (accelerometer) measures of sedentary time. These data provide the unique opportunity to examine, within one sample, the descriptive epidemiology of sedentary time in the U.S. using a variety of measures. Rather than reporting the relationship between the various sedentary measures (which has been described previously[73]), the aim of this section is to examine similarities and differences between the measures in the *patterning* of sedentary time by gender, race/ethnicity and age.

Methods

The relevant NHANES methods are described in at http://www.cdc.gov/nchs/nhanes.htm.[45] The National Centre for Health Statistics Ethics Review Board approved the protocols and written informed consent was obtained. For this study, 2003-2006 data from adult participants (≥20 years) were used. The study did not vary in protocol and had high response rates across this period.[45]

Self-report sedentary time measures

In the household interviews, participants were asked to report the time they spent watching TV or videos (TV time) and using a computer or playing computer games (computer use) on an average day over the last 30 days. The categorical responses were collapsed into three dichotomous sedentary markers: TV time, computer use, and screen time (combined TV time and computer use). Cut-points were ≥2 hours per day for TV, ≥1 hour per day for computer use, and ≥3 hours for screen time. These were based on the availability of sufficient responses in all sub-populations, low rates of computer use in older age groups, and values used in previous research.[74] Participants were also asked to best describe their usual daily activities (i.e. work, domestic activities, or general activities throughout the day). The response options were collapsed into a dichotomous variable *sitting*, which was *yes* if the respondent answered yes to the first option ("sitting during the day and not walking about very much") or *no* if the respondent answered yes to any of the remaining options.

Accelerometer-derived sedentary time

An accelerometer (Actigraph model 7164; Actigraph, LLC, Fort Walton Beach, Florida) was worn on the right hip during waking hours (except for water-based activities) for seven days. Data cleaning and automated wear time estimation was undertaken as previously described.[60] Daily sedentary time (<100 cpm) were calculated and standardized for wear time using the residuals method.[62] Data are reported as averages for valid days (≥10 hours wear, counts <20,000, monitor returned in calibration), limited to participants who provided at least four valid days of observation.[75]

Statistical analysis

Data were analysed in STATA version 11.0 (College Station, TX, Stata Corporation), with statistical significance set at $p<0.05$. Data were pooled from 2003-2006 to obtain sufficient numbers for stratified analyses. No significant changes (2003/04 to 2005/06) were observed. Self-report TV time and computer use data were available for 10,012 adults, self-report sitting data were available for 10,009, and ≥4 days of valid accelerometer data were available for 6,235.

Mean accelerometer-derived sedentary time (hours per day) and the prevalence of sitting, ≥2 hours per day TV time, ≥1 hour per day computer use, and ≥3 hours per day screen time were compared across gender, race/ethnicity categories (self-reported non-Hispanic white, Mexican American, and non-Hispanic black), and 10-year age bands using marginal means from linear (accelerometer) or population marginal probabilities from logistic (self-report) regression models. In view of the complex survey design, and to ensure population representativeness, all models used linearized variance estimation and, except when testing interactions, were weighted for selection probabilities and non-response. The weights provided by NHANES were further reweighted to correct for the large amount of missing/invalid accelerometer data.[75] The data are population representative.

Results

Gender differences

After adjusting for age and race/ethnicity, there were statistically significant gender differences in all measures of sedentary time, with the direction and magnitude of the difference depending on the measure. For the domain-specific measures, prevalence was lower in women than men for high TV time (64.9 [95% CI 63.0, 66.8]% vs. 69.2 [67.6, 70.7]%, p<0.001), computer use (27.1 [25.1, 29.1]% vs. 31.3 [27.9, 32.8]%, p=0.034), and screen time (48.3 [46.2, 50.3]% vs. 52.0 [49.7, 54.4]%, p=0.012). However, more women than men reported sitting for most of the day (26.2 [24.4, 28.0]% vs. 21.5 [20.1, 22.9]%, p<0.001). This was consistent with the accelerometer findings (mean 8.50 [8.41, 8.59] hrs/day in women versus 8.35 [8.25, 8.45] hrs/day in men, p=0.006), though the magnitude of this difference was relatively small.

Race/ethnicity differences

After adjusting for age and gender, Mexican Americans were significantly less sedentary ($p<0.05$) than non-Hispanic whites and non-Hispanic blacks according to all sedentary time measures, with the exception of high TV time. Here, the prevalence was similar for Mexican Americans (69.0 [66.3, 71.5]%) and non-Hispanic whites (67.6 [65.8, 69.3]%, p=0.383), but significantly higher for non-Hispanic blacks (79.1 [75.7, 82.5]%, $p<0.01$). Compared with non-Hispanic whites, non-Hispanic blacks also had a higher prevalence of high screen time (51.1 [48.6, 53.7]% vs. 65.8 [61.8, 69.7]%, $p<0.001$), but these two racial/ethnic groups did not differ significantly for any other measure.

Age differences

Figure 3 shows (A) the mean and (B) the prevalence estimates of the sedentary time measures by age group (adjusted for gender and race/ethnicity). With the exception of computer use (where prevalence decreased with age), mean sedentary time and prevalence estimates tended to increase with age, but with a decrease between the 20-29 and 30-39 year age groups for all measures except sitting (which increased steadily with age).

Figure 4 expands on Figure 3 by showing the mean (A & B) and the prevalence (C-H) estimates of the sedentary time measures by racial/ethnic group across age categories separately for men and for women. Among men, age trends in sedentary time differed significantly across racial/ethnic groups according to accelerometer-derived sedentary time ($F(df: 10, 21)=3.24$, p=0.01), but not according to the self-report measures ($p\geq0.1$). Among women, the age trends differed significantly by race/ethnicity according to the self-report measures (sitting, screen time, TV time, and computer use; all $p<0.05$), but not the accelerometer-derived measure (p>0.1). Screen time results (omitted) were very similar to TV time. For a complete summary of results, please refer to Supplementary Tables 1 and 2.

Summary

In summary, the sedentary measures were consistent to some extent in identifying populations comparatively more or less sedentary, with older (60+) adults generally the most sedentary, and Mexican Americans generally the least sedentary. However, these subgroup differences are not apparent if only a single sedentary time measure is assessed. For example, if NHANES had measured only TV time, then the strong and largely consistent differences between Mexican Americans and non-Hispanic whites would not have been observed. If only accelerometer-derived sedentary time had been measured, then important differences in specific sedentary behaviors between men and women and across the lifespan would not have been seen. Thus, wherever possible, both domain-specific and overall measures of sedentary time (preferably device-based) should be assessed. Furthermore, the inclusion of time spent sedentary in other domains, such as work and travel, should also be considered.

Conclusions

This paper provides an overview of the reliability and validity of current self-report and device-based (primarily the Actigraph activity monitor) population-based measures of time spent sedentary. The 2003-2006 NHANES was utilized as an example of how various measures of sedentary time identify different population as ‘at-risk’.

Given that both self-report and device-based instruments capture important aspects of sedentary behavior, it is recommended that wherever possible, both measures should be used for population-monitoring of sedentary time. For self-report measures, monitoring should extend beyond measures of overall sitting to include the various domains. The battery of questions should be succinct, consistent in their terminology and administration (to allow comparison across time, and across different populations), and based on reliable and valid measures. Device-based measures should be affordable, distinguish between various postures, have relatively low participant burden, and where possible, integrate multiple sources of information that provide greater context for the behaviors observed. This paper identified key research directions for the development and refinement of such measures.

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Figure Legends

Figure 1: Correlations (r or ρ) of self-report sitting time assessed by a single-item (circles) or as a composite total (four items or more, triangles) with accelerometer-derived sedentary time. Reference lines indicate typical correlations of moderate and vigorous physical activity (interviewer-administered) with accelerometer measures.[41] *partial correlations, adjusted for age, marital status, white or non-white ethnicity, number of children, and highest level of education.

Figure 2: Bland Altman Plot of agreement between activPAL and accelerometer-derived (<100 counts per minute) sedentary time (hours).

Figure 3. Device-based (a) and self-reported (b) measures of sedentary time across age categories in US adults ≥20 years (NHANES 2003-2006). Data are reported as mean or prevalence (95% CI).

Figure 4. Prevalence (95% CI) of self-reported TV viewing ≥ 2 hours/day (a,b), computer use ≥1hour/day (c,d), sitting (e,f) and mean (95% CI) accelerometer-measured sedentary time (g,h) across age categories in US men (a,c,e,g) and women (b,d,f,h) ≥20 years by race/ethnicity (NHANES 2003-2006).

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Table 1: Reliability coefficients for questionnaire measures of waking time spent in sedentary behaviors

Type of Questionnaire	Name of Questionnaire (if available)	Range of correlation coefficients	Test-retest periods
OVERALL			
Single item measures	IPAQ, short form	ρ=0.18-0.95[9-11, 26, 27]	3 days - 3 weeks
		ICC=0.80-0.97[18, 23, 25]	
	WAIPAQ	ICC=0.79[14]	10 days
	St Louis Instrument	ICC=0.37[16]	7-21 days
	GPAQ	ρ=0.50-0.69[17]	2 weeks - 2 months
Composite measure of sitting (sum of multiple domains)	IPAQ, long form	ρ=0.28-0.93[9, 11]	3 – 10 days
		ICC=0.65-0.71 [31, 32]	
	AWAS	ICC=0.42[15]	7 days
	RPAQ*	ICC=0.76[20]	14 days
	AQuAA	ICC=0.60[21]	14 days
	SBQ	ICC=0.77-0.85[28]	2 weeks
	Other questionnaire	ICC=0.52[22]	7 days
DOMAIN-SPECIFIC			
Leisure-time			
TV Viewing	NHANES	ICC=0.32[33]	9-30 days
	EPAQ-2	r=0.75-0.78[24]	3 months
	SBQ	ICC=0.83-0.86[28]	2 weeks
	Other questionnaires	ICC=0.42-0.82[13, 19, 22, 29, 30]	1-11weeks
TV viewing and computer use	WAIPAQ	ICC=0.88[14]	10 days
	FPACQ	ICC=0.76-0.93[8]	2 weeks
	Other questionnaires	ICC=0.54[12]	1 week
Computer use	NHANES	ICC=0.69[33]	9-30 days
	SBQ	ICC=0.80-0.83[28]	2 weeks

	Other questionnaires	ICC=0.59-0.79[19, 22, 29]	1 week-11 days
Other sitting	SBQ	ICC=0.48-0.93[28]	2 weeks
	FPACQ	ICC=0.14-0.74[8]	2 weeks
	Other questionnaires	ICC=0.04-0.81[12, 13, 22, 29]	1 -11 weeks
		ρ=0.25-0.38[19]	
Work			
Workplace sitting	SBQ	ICC=0.64-0.77[28]	2 weeks
	Other questionnaires	ICC=0.76-0.86[12, 13, 19]	1 -11 weeks
Workplace computer use	WAIPAQ	ICC=0.93[14]	10 days
Travel			
All travel	SBQ	ICC=0.72-0.76[28]	2 weeks
	Other questionnaires	ICC= 0.40-0.54[13, 22]	11 days
		ρ=0.31-0.60[19]	
Travel for leisure	Other questionnaires	ICC=0.85[29]	1 week
Travel for work	St Louis Instrument	ICC=0.29[16]	7 to 21days
	Other questionnaires	ICC=0.54[12]	1 week

Other sitting includes listening to music, reading, meals, telephone, socialising, relaxing, and hobbies.

*Questionnaire includes sleep in sedentary time.

ICC: intra-class correlation; ρ: Spearman's rho. IPAQ : International Physical Activity Questionnaire, WAIPAQ: Western Australian Physical Activity Questionnaire, GPAQ: Global Physical Activity Questionnaire, AWAS : Australian Women's Activity Survey, RPAQ: Recent Physical Activity Questionnaire, AQuAA : Activity Questionnaire for Adults and Adolescents, SBQ: Sedentary Behavior Questionnaire, NHANES: National Health and Nutrition Examination Survey, EPAQ-2: EPIC (European Prospective Investigation into Cancer) Physical Activity Questionnaire, FPACQ: Flemish Physical Activity Computerised Questionnaire

Table 2: Validity coefficients for questionnaire measures of waking time spent in sedentary behaviors

Type of Questionnaire	Name of Questionnaire (if available)	Range of correlation coefficients	Criterion measure
OVERALL			
Single item measures	IPAQ, short form	ρ=0.07-0.61[9, 11] r=0.16[39]	accelerometer (Actigraph 7164), <100cpm
	IPAQ, short form	ρ=0.44[18]	combined position and activity monitor (ActiReg), METS 1-3
	IPAQ, short form	ρ=0.18[35]	combined accelerometer and heart-rate monitor (Actiheart), METS 1-1.8
	GPAQ	ρ=-0.02-0.40[17, 38]	accelerometer (Actigraph GT1M, MTI), <100cpm
Composite measure of sitting (sum of multiple domains)	IPAQ, long form	ρ = 0.14-0.49[9, 11, 34, 40]	accelerometer (MTI), <100cpm
	IPAQ, long form	ρ=0.75[40]	activity log
	AWAS	ρ=0.32[15]	accelerometer (Actigraph 7164), <100cpm
	RPAQ*	ρ=0.27[20]	combined heart rate and activity monitor (Actiheart), <2 METS
	AQuAA	ρ=0.15[21]	accelerometer (Actigraph 7164), <699cpm
	SBQ	r=-0.02-0.18[28], adjusted for socio-demographic characteristics	accelerometer (Actigraph 7164), <100cpm
	Other	ρ=0.30[22]	accelerometer (Actigraph GT1M),

	questionnaire		<100cpm
Leisure-time			
TV Viewing	Other questionnaires	ρ=0.30-0.61[19, 29]	activity log
		ρ=0.54[36]	electronic monitor which records time TV is on when personal code is entered
TV viewing and computer use	FPACQ	r=0.69-0.83[8]	triaxial accelerometer (RT3) combined with activity log
Computer Use		ρ=0.60-0.74[19, 29]	activity log
Other sitting	FPACQ (eating)	r=0.13-0.56 [8]	triaxial accelerometer (RT3) combined with activity log
		ρ =0.20-0.42[19, 29]	activity log
Work			
Workplace sitting	Other questionnaires	ρ =0.13-0.74[19]	activity log
		r=0.39[37]	accelerometer (Actigraph GT1M), <100cpm; combined with activity log
Travel			
All travel	Other questionnaires	ρ =0.15-0.64[19]	activity log
Travel for leisure		ρ =0.40[29]	activity log

Other sitting includes listening to music, reading, meals, telephone, socialising, relaxing, and hobbies.

*Questionnaire includes sleep in sedentary time.

ρ: Spearman's rho; r: Pearson's correlation coefficient. IPAQ : International Physical Activity Questionnaire, GPAQ: Global Physical Activity Questionnaire, AWAS : Australian Women's Activity Survey, RPAQ: Recent Physical Activity Questionnaire, AQuAA : Activity Questionnaire for Adults and Adolescents, SBQ: Sedentary Behavior Questionnaire, FPACQ: Flemish Physical Activity Computerised Questionnaire