How many days are enough for measuring weekly activity behaviours with the ActivPAL in adults?

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How many days are enough for measuring weekly activity behaviours with the ActivPAL in adults?

Short title: Days needed for measuring activity behaviours in adults

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ABSTRACT

Objectives: The purpose of this study was to determine the number of monitoring days needed to reliably measure **weekly** activity behaviours with the ActivPAL (AP) monitor in adults.

Design: Cross-sectional study.

Methods: Participants (90 adults (51.1% men); age=39.1±12.43 years) wore an AP for 7 consecutive days. Mean time spent sitting/lying, standing and **stepping** per day, and mean number of transitions from sitting to standing per day were calculated for each participant using 7 days of monitoring (reference). Estimates for these activities were also derived from a combination of randomly selected days (from 1 to 6 days), and randomly selected weekdays and weekend days, and compared with the reference using ANOVA, correlation coefficients and Bland-Altman methods. Spearman-Brown Prophecy Formula, based on Intraclass correlation of 0.8, was used to predict the minimum number of days needed to represent activity behaviours as measured with the AP.

Results: At least five days of monitoring were necessary to achieve a reliability of 0.8 for all postures and transitions. Correlation coefficients between estimates derived from any combination of 5 days and the reference were high (rho=0.96-0.98). When using a combination of weekdays and weekend days, mean biases were comparable with those shown by any combination of days, but 95% limits of agreement were narrower.

Conclusions: When using the AP for a week, data from a combination of any 5 days provided reliable estimates of all activities and transitions per day, but more precise estimates were achieved if at least 1 weekend day was included.

Keywords: physical activity; sedentary behaviour; sitting; reliability; measurement

INTRODUCTION

Promotion of physical activity and reduction of sedentary behaviour are key actors in promoting better health across the lifespan.[1] However, the way these activity behaviours are accrued in everyday life is highly variable, both within and between individuals.[2] Objective measurement tools such as accelerometers have some advantages when compared against self-report methods as they capture the variable nature of activity across days or seasons,[3] and show stronger relationships between physical behaviours and health outcomes.[4].

The ActivPAL 3™µ (AP; Pal Technologies, UK) is a very accurate accelerometer for measuring activity behaviours, including postures and transitions from sitting to standing and stepping.[5] It has been used in large studies and in different populations, including, for example, healthy people and cancer patients.[6, 7] Although researchers have provided technical recommendations for data collection,[8] extraction[9, 10] and reporting,[8, 10] little is known about the minimum number of days of monitoring required for providing reliable estimates of different activity behaviours when using the AP in adults.[8] In order to better capture 'usual' behaviour, most researchers have asked participants to wear the AP for seven consecutive days.[8] However, as participants do not always wear devices according to instructions, due to forgetfulness, discomfort, or loss of the monitor, it is important to assess whether fewer days of monitoring can provide accurate estimates of the time spent in activity, sitting/lying and standing behaviours.

The purpose of this study was to determine the number of monitoring days needed to achieve reliable estimates of **weekly** sitting/lying, standing, **stepping**, and transitions, with the AP monitor in working adults.

METHODS

A cross-sectional study was conducted with a sample of working adults. Participants were recruited through posters, emails and calls to different worksites in Temuco, Chile. Participants aged 18 and over were included in the study and the only exclusion criterion was being a wheelchair user. The sample was part of a validation study that tested the concurrent validity of a questionnaire and the AP. **A target** sample size of 100 participants was **used** to ensure stability of the variance-covariance matrix based on the recommendations for this type of study.[11, 12] The sample included participants from different sectors: public transport, schools, childcare, healthcare, higher education, sales and administration, among others. All participants signed a consent form approved by the ethics committee of the **XXXXXX**.

Participants were visited twice in their workplaces. The first visit included measurement of sociodemographic and physical characteristics. Weight and height were measured with a scale (Seca 803, Germany) and stadiometer (Seca 213, Germany), respectively, to calculate body mass index (BMI; weight/height^2). Each participant was provided with an AP to be worn for the next 7 consecutive days. Participants received instructions on how to wear the device and were requested to maintain their normal activities during the monitoring week. The volunteers were asked to complete a log-book to include **sleeping (time of going to bed**

and going to sleep) and awake hours (time of waking up and time of getting up) for each day of monitoring.

The AP was sealed with a nitrile cot and attached to the mid-anterior area of the right thigh with a hypoallergenic and transparent tape (Tegaderm™ Roll, 3M™) to provide waterproof protection. This allowed participants to wear the AP continuously without removal for showering or sleeping. Each participant was provided with a set of adhesive tapes and cots to replace them when needed. The AP, a light (10 gr) and small device (23.5 x 43 x 5 mm), is an accelerometer and inclinometer for detecting postures, especially sitting and lying.[5] This instrument has shown minimal differences with direct observation for detecting sitting time (0-3%)[5, 13] and is more sensitive to change than other objective measurement tools such as the ActiGraph GT3X.[13]

A second visit was agreed with each participant on the eighth day of monitoring to recover the AP, and for completion of a questionnaire about compliance and wearing issues.

The APs were initialized and downloaded with ActivPAL™ Professional Software, v7.2.32 Research Edition (Pal Technologies Ltd., 2013). Accelerometer data were extracted from the event files that include a chronological list of all continuum intervals (bouts), with the time each interval began and duration of sitting/lying, standing and **stepping** during the monitoring frame. A semi-automated filter was created to exclude sleeping time, based on information from log-books and recorded AP activity. Waking times were based on the first standing bout followed by **stepping**, within a ±30-minute range of the time reported in the log-book. When the first standing bout was out of that window (i.e. awake, but stayed in bed while reading a book or watching TV), the reported time in the log-book was used as waking time. A similar procedure was used to detect going to sleep time, using the last sitting/lying bout within a ±30-minute window of the reported time in the log-book. After sleeping hours were removed, total wear time per day was calculated. Based on previous large studies conducted in adults, data from participants with at least 10 hours of AP data per day on 7 days were considered for the following analyses.[8, 14]

For each participant, total **duration** of sitting/lying, standing and **stepping** behaviours, and total number of transitions, were calculated. The average weekly **duration**, based on 7 days for each of these variables, was used as reference. For comparison purposes, averages for each activity behaviour, and transitions, were calculated for different combinations (1 to 6 days) of randomly selected days using Stata's random-number generator command (StataCorp. College Station, TX, USA). Combinations of randomly selected weekdays and weekend days were also created. These averages included a combination of any weekday (1 to 5 days) and one weekend day, and any weekday (1 to 4 days) and two weekend days. For these estimates, averages for both weekdays and weekend days were calculated independently to derive the total weekly time spent in different behaviours and number of transitions, using the following equation: (5* mean weekday + 2* mean weekend day)/7.

To describe the study sample, means and standard deviations were presented for continuous variables, and percentages for categorical variables. The different combinations of estimates for activity behaviours and transitions were compared with the reference using one-way ANOVA with post-hoc Tukey tests, correlation coefficients (Spearman or Pearson depending on distribution) and Bland-Altman methods, to examine mean biases (accuracy) and limits of agreement (precision).[15, 16] The Spearman-Brown Prophecy Formula, based on an Intraclass correlation (ICC) of 0.8, was used to predict the minimum number of days needed to represent mean total sitting/lying, standing and **stepping** times, and transitions per day. The use of an ICC of 0.8 is not an absolute criterion, but it decreases correlations between estimates by 10%.[17, 18] The Formula was as follows: n= [ICCd (1ICCd)]*[(1-ICCe)/ICCe], where n = number of days needed, ICCd = desired level of reliability (0.80) and ICCe = estimated level of reliability.[2, 19] The calculation was conducted with the sbrowni command in Stata. Mean inter-individual variability was calculated for each activity behaviour for all days, weekdays, and weekend days, as the ratio of the root mean squared error (RMSE) to the mean of each activity behaviour (dependent variable).[20] All data cleaning and statistical analyses were completed using Stata version 13 (StataCorp. College Station, TX, USA). The level of significance was set at p<0.05. The funding organization had no role in the analysis, interpretation, reviewing or writing of the manuscript.

RESULTS

In total 101 volunteers participated in the study, and 90 (51.1% men; age= 39.1±12.43 years) provided accelerometer data on 7 valid days (lost:1, forgot: 9, skin irritation: 1). There were no sociodemographic differences, between those who did and did not provide 7 days of valid data. Mean total time spent in different activities was 554.9±130.15 min/day for sitting/lying, 297.8±85.43 min/day for standing, and 126.1±42.99 min/day for **stepping**. Overall, men tended to **sit/lie** more than women (584.2 min/day vs 524.3 min/day, p=0.03). Women spent more time standing than men (318.9 min/day vs 277.6 min/day, p=0.02). On weekend days, men had longer waking times than women (957.0 min/day vs 905.7 min/day, p=0.03), but they accumulated more sitting/lying time than women (596.5 min/day vs 513.5 min/day, p=0.01). More details about the demographic characteristics of the sample and times spent in different behaviours are shown in Table 1.

Table 1 near here.

Based on the Spearman-Brown Prophecy Formula, five or more days of monitoring with the AP were necessary to achieve a reliability of 0.8 for all activity behaviours in these working adults. Sitting/lying, standing and **stepping** time required at least 5 days of monitoring, while transitions to standing required at least 3 days. **No differences were observed on the**

number of days when running separate analyses for men and women. Also, no statistical differences were observed between any combinations of days for the mean estimates of standing, **stepping** and transitions, but for sitting/lying, inclusion of only 1 random day underestimated this behaviour by 30.9 min/day (p=0.028). When comparing estimates of activity behaviours and transitions derived from different combinations of days with the reference (Table 2), higher correlation coefficients were observed for estimates that included more days. Mean biases across different combinations and the reference for each activity behaviour and transitions were similar. However, precision increased (i.e. narrower limits of agreement) as the number of combined days increased.

Table 2 near here

When using a combination of any 5 days for estimating time spent in different activity behaviours and transitions, correlation coefficients ranged from 0.96 to 0.97 (Table 2). Overall, accuracy was similar for each behaviour. Estimates for **stepping** time were more precise than those for sitting/lying time in absolute terms (±20 min/day vs ±70 min/day, respectively), but comparable in relative terms (approximately ±15%). When deriving transitions to standing from any 5 days, the mean bias (compared with the reference) was only -0.4 transitions/day (95% Limits of agreement (LoA): -10.1 to 9.2).

Similar correlation coefficients, accuracy and precision were observed for each estimate, when results derived from combinations of 5 days that included either one or two weekend days were compared. However, the LoAs for standing time derived from combinations that included two weekend days, were wider than those estimated from only one weekend day (±50 min/day vs ±35 min/day, respectively). Intra-individual variability for activity behaviours on all days was lowest for sitting/lying 4.9%, and highest for **stepping** (9.4%) (Table 3). Variation was slightly less on weekend days than on weekdays for all behaviours.

Table 3 near here

DISCUSSION

In this sample of working adults, a minimum of any 5 days of AP monitoring was required to reliably estimate activity behaviours. Accuracy was comparable across different combinations of days, but precision increased as the number of monitoring days increased. Intra-individual variability for activity behaviours ranged from 4.9% to 9.3% on all days, but variation was slightly less on weekend days than on weekdays.

To our knowledge, this is the first study to examine the minimum number of days needed for providing reliable estimates, not only for sedentary behaviour (sitting and lying down), but also for standing, **stepping** and transitions, using the AP in adults. A previous study conducted only with women reported that four days were necessary to provide reliable measures of time spent in sedentary behaviour and moderate-to-vigorous PA with the AP.[21] Studies conducted in adults with the ActiGraph have reported similar results to ours in a sample of Danish office workers,[2] but a study of Norwegian students and academics found at least seven days were required to achieve a reliability of 0.80 when wearing an ActiGraph accelerometer for 21 days as reference.[22] Studies of other age groups have shown different results, reflecting the variability of sitting and **stepping** patterns across the lifespan.[23, 24] For example, a study conducted with the AP in adolescent girls found more days were required to achieve a reliability of ≥0.8 for estimating time spent in different behaviours (≥15 days) or counting daily steps (≥21 days).[24] These differences may be partially explained by the higher intra-individual variability in daily patterns of activity in adolescents than in working adults.[2, 24] In the present study, intra-individual variability was smaller than in other studies of adults.[2,

[21] The findings support the need for age-specific protocols for data extraction and analysis with the AP, as similarly shown by previous research for other devices.[23, 25]

Correlation values were very high for combinations of days and the reference for the different estimates (>0.8 for combinations of 2 or more days). This is partially explained by the low intra-individual variability observed in this sample (<10%), which would increase exchangeability or comparability between days without greatly affecting relationships. Furthermore, estimates derived from combinations of any 5 days that included at least one weekend day, showed higher accuracy for each physical behaviour and transitions to standing (about 1% difference with the total estimate) than those with fewer days. This 1% bias may be an acceptable trade off when deciding whether to include data from participants who completed only 5 instead of 7 days in a protocol. However, precision should be always considered, especially when using these methods for assessing change or dose-response relationships in association or in intervention studies, as dispersion is larger when using fewer days.

Our findings suggest that for overall weekly estimations, a combination of any 4 weekdays with at least one weekend day may be preferred, as this combination had narrower LoAs, especially for standing, when compared with other combinations. In the current study, if we had used the 'any' 5-day inclusion criterion, we would have increased wearing compliance by 5% (i.e. reduced invalid data from 11 to 6 out of 101 participants) while providing accurate determinations, which may be relevant in larger studies.

Although recruitment was not probabilistic, the sample was diverse in terms of age, occupations and activity behaviours. Also, demographic characteristics such as nutritional status and educational level were comparable with national data for working populations.[26] This is important, as most validation studies have been conducted in office or university settings, in participants with similar activity patterns,[2, 5, 27] which limits extrapolation of the results to other populations. Although we used a 24/7 protocol for the AP, wear compliance among participants was high.

The study has some limitations. Recruitment was not weighted to account for seasonal variance in PA patterns, but data collection covered most of the year, except for part of January and February (summer holidays). Following recommended protocols for the AP, participants were monitored only for 7 consecutive days.[8] We acknowledge that this reference period may not reflect habitual activity behaviours,[22, 28, 29] but only reflect movement patterns during the week of measurement.[30] For pragmatic reasons, a one week measurement period is commonly used in intervention studies.

Also, our recommendation (to use a minimum of 5 days monitoring) only applies when data from complete days or at least 10 hours/day are available, as variability may change if only a portion of each day is monitored. If estimates of 'usual' behaviour over a period longer than one week are required, 5 days of monitoring may be insufficient to capture the true variability. We recommend that future studies designed to assess intra-individual variability should monitor participants in different periods of the year, so that seasonal variance can be assessed.

CONCLUSION

When using the AP in adults, a combination of any 5 days was needed to reliably estimate weekly time spent in sedentary, standing and **stepping** behaviours, and transitions to standing. However, more precise estimates may be obtained if data from at least one weekend day are included.

PRACTICAL IMPLICATIONS

- Data from at least 5 days of monitoring are needed to obtain reliable estimates of sitting/lying, standing, and **stepping** times and transitions to standing, when using the AP in adults for a week.
- More precise estimates can be obtained if data from at least one weekend day and four weekdays are included.
- Sitting/lying behaviour was less variable day-to-day than standing, **stepping** and transitions to standing.
- Intra-individual variability in activity behaviours tended to be smaller on weekend days than on weekdays.

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CONFLICT OF INTEREST

The authors declare no conflict of interests

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Table 1. Socio-demographic and movement characteristics of the participants.

Variable	Total (n=90)	Men (n=46)	Women (n=44)	p
Age (mean, SD) years	39.1 (12.43)	39.4 (12.61)	38.8 (12.37)	0.82
Body Mass Index (%)				
Normal	31.1	13.0	50.0	0.001
Overweight	47.8	58.7	36.4	
Obese	21.1	28.3	13.6	
Marital status (% married/de facto)	40.0	52.2	27.3	0.02
Educational level (%)				
No formal education after school	18.9	30.4	6.8	0.02
University degree, certificate or diploma	50.0	43.5	56.8	
Postgraduate	31.1	26.1	36.4	
Occupation (%)				
Administration	11.1	17.4	4.6	0.01
Education	46.7	30.5	63.6	
Health	18.9	8.7	29.5	
Drivers	11.1	21.7	0.0	
Other	12.2	21.7	2.3	
Self-rated health (%)				
Fair	16.7	17.4	15.9	0.66
Good	54.4	50.0	59.1	
Very good/excellent	28.9	32.6	25.0	
Objectively measured activity behaviours				
Overall week				
Waking time (mean, SD) min/day	978.8 (75.46)	986.5 (73.25)	970.8 (77.73)	0.32
Sitting/lying time (mean, SD) min/day	554.9 (130.15)	584.2 (138.45)	524.3 (114.54)	0.03
Standing time (mean, SD) min/day	297.8 (85.43)	277.6 (86.12)	318.9 (80.31)	0.02
Stepping time (mean, SD) min/day	126.1 (42.99)	124.7 (51.15)	127 (32.92)	0.76
Transitions to standing (mean, SD)	74.9 (27.26)	71.2 (29.58)	78.9 (24.33)	0.18
Weekdays				
Waking time (mean, SD) min/day	997.6 (94.09)	998.3 (72.91)	996.8 (94.09)	0.93
Sitting/lying time (mean, SD) min/day	554.5 (137.95)	579.3 (144.39)	528.7 (127.39)	0.08
Standing time (mean, SD) min/day	311.7 (98.27)	289.5 (98.00)	334.9 (94.11)	0.03
Stepping time (mean, SD) min/day	131.3 (49.70)	129.6 (57.56)	133.2 (40.47)	0.73
Transitions to standing (mean, SD)	77.6 (30.45)	73.5 (36.10)	81.8 (22.77)	0.19
Weekend days				
Waking time (mean, SD) min/day	932.0 (113.03)	957.0 (114.79)	905.7 (113.03)	0.03

Sitting/lying time (mean, SD) min/day	555.9 (149.09)	596.5 (165.87)	513.5 (116.65)	0.01
Standing time (mean, SD) min/day	263.0 (85.62)	247.9 (84.20)	278.8 (85.16)	0.09
Stepping time (mean, SD) min/day	113.0 (47.87)	112.6 (52.58)	113.4 (43.00)	0.94
Transitions to standing (mean, SD)	68.4 (28.30)	65.5 (23.06)	71.5 (32.90)	0.32

Table 2. Correlation coefficients and mean biases for different combinations of days and 7 days (reference) of activity monitoring with the ActivPAL in working adults. (N=90)

	Sitting/lying time		Standing time		Moving time		Transitions to standing	
Combination of days	**Pearson's correlation coefficient**	**Mean bias (min/day, 95% LoA)**	**Spearman's correlation coefficient**	**Mean bias (min/day, 95% LoA)**	**Spearman's correlation coefficient**	**Mean bias (min/day, 95% LoA)**	**Spearman's correlation coefficient**	**Mean bias (transitions/ day, 95% LoA)**
Any 1 day	0.71	0.0 (-221.6; 221.6)	0.66	2.2 (-153.7; 158.0)	0.75	0.0 (-79.0; 79.0)	0.74	3.3 (-33.4; 40.0)
Any 2 days	0.83	-11.8 (-136.1; 112.6)	0.79	3.7 (-97.8; 105.2)	0.83	2.0 (-53.4; 57.4)	0.87	1.0 (-23.0; 25.0)
Any 3 days	0.92	-7.0 (-123.4; 109.3)	0.89	-2.4 (-78.7; 73.8)	0.89	0.4 (-41.4; 42.2)	0.91	0.9 (-18.1; 20.0)
Any 4 days	0.95	-4.8 (-100.1; 90.4)	0.91	0.2 (-58.1; 58.5)	0.93	1.7 (-27.3; 30.8)	0.92	-0.4 (-13.3; 13.0)
Any 5 days	0.97	-2.9 (-72.3; 66.5)	0.96	-3.0 (-49.5; 43.6)	0.97	0.8 (-22.4; 24.0)	0.96	-0.4 (-10.1; 9.2)
Any 6 days	0.99	-2.3 (-38.2; 33.6)	0.98	-0.5 (-26,0; 25.0)	0.99	-0.4 (13.6; 12.7)	0.99	-0.1 (-6.3; 6.1)
1 wd + 1 we	0.86	-4.0 (-163.8; 155.8)	0.79	6.2 (-87.4; 100.0)	0.86	-1.5 (-49.4; 46.5)	0.85	-0.3 (-23.4; 22.8)
2 wd + 1 we	0.92	-9.5 (-135.1; 116.1)	0.91	1.5 (-67.7; 70.8)	0.92	-0.1 (-32.4; 32.2)	0.91	0.1 (-16.5; 16.7)
3 wd + 1 we	0.96	-6.6 (-101.4; 88.2)	0.95	-0.8 (-55.6; 53.9)	0.96	2.1 (-26.0; 30.2)	0.95	0.5 (-10.9; 11.9)
4 wd + 1 we	0.98	-5.0 (-68.2; 58.2)	0.96	2.8 (-32.2; 37.8)	0.97	2.1 (-26.0; 30.2)	0.97	0.8 (-8.3; 9.8)
5 wd + 1 we	0.99	-4.4 (-52.0; 46.3)	0.98	4.1 (-20.6; 28.8)	0.99	3.3 (-12.1; 18.7)	0.99	1.2 (-5.4; 7.9)
1 wd + 2 we	0.90	0.3 (148.8; 149.4)	0.84	2.1 (-95.8; 100.0)	0.85	-1.2 (-50.0; 48.0)	0.90	1.8 (-20.7; 24.3)
2 wd + 2 we	0.94	-5.1 (-116.3; 106.0)	0.93	-2.6 (-69.1; 64.0)	0.92	-1.5 (-32.0; 29.0)	0.92	0.3 (-15.1; 15.6)
3 wd + 2 we	0.97	-2.3 (-76.8; 72.2)	0.96	-5.0 (-54.0; 43.7)	0.97	-0.17 (-24.0; 24.0)	0.97	0.0 (-9.9; 9.8)
4 wd + 2 we	0.99	-0.7 (-39.7; 38.3	0.98	-1.3 (-26.0; 23.2)	0.99	-0.4 (-14.4; 14.0)	0.98	-0.2 (-6.8; 6.4)

Abbreviations: LoA: Limits of agreement; wd: weekday; we: weekend day.

Table 3. Intra-individual variability* in activity behaviours as measured with the ActivPAL in working adults within a week. (N=90)

	Sitting/lying	Standing time	Moving time	Transitions to standing
Variation on all days (%)	4.9	9.2	9.4	9.3
Variation on weekdays (%)	4.9	9.3	9.4	9.8
Variation on weekend days (%)	4.4	7.2	8.6	7.4

*Variability was estimated as the ratio of the root mean squared error (RMSE) to the mean of each activity behaviour ((RMSE/mean estimate)*100).