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Section: Original Research

Article Title: Measurement Considerations of Peak Stepping Cadence Measures Using NHANES 2005-2006

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ABSTRACT

Background: This study examined the optimal measurement conditions to obtain reliable peak cadence measures using the accelerometer-determined step data from the NHANES 2005-2006. **Methods:** A total of 1,282 adults (>17 years) who provided valid accelerometer data for 7 consecutive days were included. The peak 1- and 30-minute cadences were extracted. The sources of variance in peak stepping cadences were estimated using Generalizability theory analysis. A simulation analysis was conducted to examine the effect of the inclusion of weekend days. The optimal number of monitoring days to achieve 80% reliability for peak stepping cadences were estimated. **Results:** Intra-individual variability was the largest variance component of peak cadences for young and middle-aged adults aged <60 years (50.55%-59.24%) compared to older adults aged ≥60 years (31.62%-41.72%). In general, the minimum of 7 and 5 days of monitoring were required for peak 1- and 30-minute cadences among young and middle-aged adults, while 3 days of monitoring was sufficient for older adults to achieve the desired reliability (.80). The inclusion of weekend days in the monitoring frame may not be practically important. **Conclusions:** The findings could be applied in future research as the reference measurement conditions for peak cadences.

Keywords: Generalizability theory, step counts, cadence, measurement, variability

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Introduction

Physical activity is a well-known lifestyle behavior that is significantly associated with various health outcomes.[1,2] Of the several distinct types of physical activity walking is one of the most commonly observed descriptors of ambulatory physical activity that comprises almost every form of natural locomotor movement in daily life.[3] Over the last few decades, there has been a large body of literature focusing on volume of walking (i.e., steps/day) to quantify the level of physical activity in a free-living environment;[4-6] however, one of the critical limitations of using steps/day as a measure of physical activity is that it provides no information on the intensity of accumulated step counts.[3,7]

Recent advances in technology have led to a significant improvement in objective measures of physical activity including accelerometer-based monitoring devices that provide time-stamped outputs in free-living environments. A review article has introduced the potential for using this advanced technology to represent step accumulation patterns and stepping rates (i.e., cadence),[3] in which the latter parameter can be seen as an intensity indicator of ambulatory activity that is associated with walking speed in a free-living environment.[8] Using 2005-2006 National Health and Nutrition Examination Survey (NHANES) accelerometer data, Tudor-Locke, et al. [9] described naturally occurring cadence patterns in free-living activities among US adults ≥ 20 years and also proposed the concept of 'peak stepping cadence' as an indicator of the highest intensity execution of ambulatory activities. Specifically, the authors demonstrated significantly decreasing trends in the peak 30-minute (defined as the mean steps/min for the 30 highest, not necessarily consecutive minutes in a day) and 1-minute (defined as the highest steps/min for a single minute in a day) cadences by increased level of BMI in this population and have suggested the potential of using peak stepping cadence as a physical activity parameter that is related to health outcomes.[9]

Despite the promising features of using peak stepping cadence as a feasible metric for monitoring the intensity levels of ambulatory activity in association with health outcomes,[10] there are fundamental methodological issues that have not yet been clearly addressed. Such issues may include the question of "How many monitoring days are required?" which is important to understand and better describe the peak stepping cadence measured in a free-living environment. Specifically, considering the suggested importance of peak stepping cadence as an indicator of health status, it is important to understand the inter- and intra-individual sources of variability in peak stepping cadence measures.

Numerous studies have examined the optimal measurement conditions (e.g., the number of monitoring days) for objectively measured physical activity across different physical activity parameters and monitoring devices;[11-15] however, to the best of our knowledge, there has been no study for the accelerometer-determined peak stepping cadence measures. Physical activity is a complex and multidimensional behavior that is difficult to measure due to known high inter- and intra-individual variability.[16,17] This may imply that the results from previous studies focusing on different physical activity parameters measured by varying types of monitoring devices may have limited generalizability to this newly proposed indicator of physical activity. Furthermore, because peak cadence indices are based on short-term measures rather than on whole-day data, it is reasonable to assume that patterns of variability may be different than has been found previously for whole-day indices such as total daily steps, requiring more efforts to understand the variability of peak stepping cadences in a free-living environment.

Therefore, the purpose of this study was to examine the sources of variance in accelerometer-determined peak stepping cadences (peak 1- and 30-minute cadences), and to determine the optimal monitoring days required for reliable measurement of peak stepping cadence among adults using NHANES data. A secondary aim of this study included determining whether estimates of average peak stepping cadences vary depending on the type of monitoring days (i.e., week, weekend, or combination of both) across different measurement conditions. The results from this study will be a useful methodological resource for researchers and practitioners dealing with accelerometer-determined peak stepping cadences in a free-living environment.

METHODS

Survey data and study sample

Data from the NHANES conducted by the National Center for Health Statistics (NCHS) during a period between 2005 and 2006 were analyzed for this study. The NHANES 2005-2006 included cross-sectional data for a broad range of health-related outcomes among a representative sample of the US civilian non-institutionalized population selected under a complex, multistage probability design. All ambulatory participants aged greater than or equal to 6 years old who visited a mobile examination center (MEC) were invited for accelerometry measures. An ActiGraph accelerometer (model 7164; ActiGraph, LLC, Ft. Walton Beach, FL) was attached on an elasticized belt and the invited participants were asked to wear the accelerometer over the right hip during waking hours for 7 consecutive days with the exceptions of showering/bathing or other water-based activities. Details of the measurement protocol for accelerometry data have been reported previously.[18,19]

The eligible sample for this study included adults who were over 17 years old at the time of measurement and who participated in an accelerometry measure in the NHANES protocol (n

= 4,471). Specifically, because the nature of this study was to focus on average daily peak stepping cadences in a week that include week and weekend days, the participants who provided valid accelerometry data (≥10 hours of wear-time) for 7 consecutive days were included in the final analysis. The final analytic sample consisted of 1,282 (646 male) that represent 28.67% of initial sample of 4,471 adults who completed the accelerometry measures in NHANES 2005-2006.

Accelerometry data treatment

In NHANES 2005-2006, the Actigraph 7164 was initialized to record both activity counts and step data in 1-minute intervals. A customized SAS macro provided by the National Cancer Institute (NCI:http://riskfactor.cancer.gov/tools.nhanes_pam/) was used to identify non-wear time, defined as 60 consecutive minutes of zero activity counts (i.e., no movements) with an allowance of up to 1 or 2 minutes of interruptions (activity counts < 100).

Adhering to procedures described in Tudor-Locke, et al.,[9] 1-minute interval step-count data were rank ordered for each day for each participant to determine the peak 1- and 30-minute stepping cadences. Peak 1- and 30-minute stepping cadences have previously been defined as the highest steps/min in a single minute and an average of the 30 highest steps/min from nonconsecutive minutes in a day, respectively.[9]

Data analysis

The normality of distributions for peak 1-minute and 30-minute stepping cadences was examined and confirmed by skewness and kurtosis (i.e., all ≤ $|1.5|$ across each measurement day). Mean and coefficient of variation (CV) for peak 1-minute and 30-minute stepping cadences as well as total step counts were calculated across week days (Mon-Fri), weekend days (Sat and Sun), and days from the entire week (Mon-Sun). A set of paired and independent t-tests were conducted to examine the mean differences in step-count measures between week and weekend days, and between age groups (i.e., <60 and ≥ 60 years old), respectively.

A single-facet crossed design [person (p) x day (d)] of Generalizability theory (G-theory) with a random effects model was employed to estimate variance components of peak stepping cadences attributed to inter- and intra-individual variability. G-theory consists of two parts, a Generalizability study (G-study) and a Decision study (D-study). In a G-study, the observed variance of peak stepping cadences is decomposed into three variance components [$\sigma^2_{(\text{observed})} = \sigma^2_{(\text{person})} + \sigma^2_{(\text{day})} + \sigma^2_{(\text{person x day})}$]. Person effects ($\sigma^2_{(\text{person})}$), which represent variations of observed peak stepping cadences by inter-individual differences, is an object of measurement in this design and thus is theoretically considered true variance after accounting for measurement errors. Day effect ($\sigma^2_{(\text{day})}$) is considered a source of systematic measurement error associated with variations from day-to-day, and the interaction effect between person and day ($\sigma^2_{(\text{person x day})}$) is a component of random error that reflects variations by intra-individual differences across days. The relative contributions (%) of each variance component to total observed variance of peak stepping cadences were calculated.

Follow up D-study was conducted to determine the minimum number of monitoring days required in order to obtain reliable measures of peak stepping cadences. Using the estimated variance components from G-study, the reliability coefficients (g-coefficient) were calculated for different measurement conditions (1 through 7 monitoring days) using the relative decision method:

$$\text{g-coefficient} = \frac{\sigma^2_{(person)}}{\sigma^2_{(person)}+\sigma^2_{(\delta)}}\text{, where } \sigma^2_{(\delta)} = \frac{\sigma^2_{(person \times day)}}{n'_{day}} \qquad (1)$$

in which the g-coefficient is the proportion of true variance ($\sigma^2_{(\text{person})}$) over the expected observed variance that includes the relative error variance ($\sigma^2_{(\delta)}$) in addition to the true variance. The relative error variance is associated with the variance component of random error that is subject to the number of required monitoring days (n'_{day}). We examined the changes in g-coefficients across one through seven days of monitoring frame and a threshold of g-coefficient $\geq .80$ is used to determine the optimal measurement condition for monitoring days.[20]

Finally, a simulation design was employed to examine the changes in accuracy of peak stepping cadences by different number of monitoring days required along with the inclusion of weekend days. Three different simulation datasets relative to weekend day condition (No-weekend, 1-weekend, and 2-weekend days) were created for each monitoring frame; hence, a total of 18 simulated datasets [three weekend day conditions across 1 through 6 monitoring days frame] were generated. An absolute location of day (e.g., Monday, Tuesday, Wednesday, etc.) within week and weekend days was not a focus of this study; alternatively, we took all possible combinations of week and weekend days for each individual for each simulated dataset into consideration. Using the example of 1 weekend day for a 3-days monitoring frame (see Table 1), 20 data lines [i.e., (${}_5C_2$) x (${}_2C_1$)] were created for each individual that include all possible combinations of any of 2 week days and 1 weekend day. Hence, a total of 18 simulated datasets [three weekend day conditions (No-weekend, 1-weekend, and 2-weekend days) across one through 6 monitoring days frame] were generated.

Using the averages of 7-day peak stepping cadences for each individual in the original data as a criterion, the absolute percentage errors (%) of average peak stepping cadences at each simulated data line for each individual were calculated. A mean absolute percentage error (MAPE, %) for each simulated dataset was obtained using a random intercept regression model to take repeated measures of APE within each individual into account. The GENOVA software was used for G-theory analysis and all other data manipulations including the simulation dataset generation and statistical analyses were conducted using SAS v9.3.

RESULTS

The descriptive statistics for step-count measures stratified by gender and age group are presented in Table 2. Overall, peak 1- and 30-minute cadences as well as total step counts were significantly lower during the weekend days than week days across gender and age groups (p's <.001). Older adults (≥ 60 years) showed significantly lower scores for all step-count measures compared to those of <60 years across gender (p's <.001). The amount of variation in step-count measures presented as CVs was consistently smaller for peak 1-minute cadence compared to peak 30-minute cadence and the largest CVs were observed for total step counts across gender and age groups. Pertaining to gender, relatively larger CVs on total step counts were found in males compared to females across age groups. Meanwhile, opposite results were observed in peak cadence measures for females, in whom relatively larger CVs were consistently detected compared to males in both age groups. In addition, the older adults aged ≥60 years showed consistently larger variations for all step-count measures compared to younger adults across both genders.

The results of the G-study are presented in Table 3. Overall, the relative proportions attributed to the inter-individual variability ($\sigma^2_{(\text{person})}$) after accounting for measurement errors associated with systematic day-to-day variation ($\sigma^2_{(\text{day})}$) and intra-individual variability ($\sigma^2_{(\text{person x day})}$) were relatively large (38.58%-67.31%) across gender and age groups. The larger inter-individual variations and smaller day-to-day variations were found in older adults aged ≥ 60 years compared to younger adults for both peak 1- and 30-minute cadences. Meanwhile, the older adults aged ≥ 60 years showed consistently lower intra-individual variability (31.62%-41.72%) compared to those aged <60 years old (50.55%-59.24%).

The results of the follow-up D-study in conjunction with the results from a set of simulation analyses are presented in Table 4 and 5 for peak 1- and 30-minute cadences, respectively. Pertaining to peak 1-minute cadence measure, the D-study revealed that the entire 7 days of monitoring in a week is required to obtain a reliable cadence measure (G-coefficient ≥.80) for younger adults across males and females. Meanwhile, fewer numbers of monitoring days are required for older adults in that 3 days of monitoring are shown to be enough to achieve the desired reliability coefficient of ≥.80. The MAPE that represents the accuracy of peak cadence measures for each monitoring frame along with the inclusion of weekend days were relatively large (>10%) in a 1-day monitoring frame across gender and age groups. Specifically, the largest MAPEs were detected in the 1- day and 1-weekend day monitoring frames (>10%). Systematic trends were observed in males for both age groups such that, for instance, including 1 weekend day for 2- to 3-day monitoring frames resulted in the smallest MAPEs compared to no-weekend and 2-weekend day conditions while the inclusion of 2 weekend days showed the smallest MAPEs in the 5- to 6-day monitoring frames.

Pertaining to peak 30-minute cadence measures in Table 5, a minimum of a 5-day monitoring period is required to obtain a reliable measure for younger adults aged <60 years across gender (g-coefficients = .81 and .82 for male and female, respectively), while a smaller number of monitoring days is required for older adults (2 days with a g-coefficient of .81 for males; 3 days with a g-coefficient of .85 for females). Overall, the MAPEs for peak 30-minute cadence for different measurement conditions were larger than the MAPEs for peak 1-minute cadence. However, systematic trends were detected for all gender and age groups with an exception of younger females that, for instance, inclusion of 1 weekend day in a monitoring period resulted in the smallest MAPEs compared to no-weekend and 2-weekend days for 2- to 4-day monitoring frames, while inclusion of 2 weekend days in a monitoring period showed the smallest MAPEs for 5- to 6-day monitoring frames.

DISCUSSION

The present study primarily aimed to examine the sources of variance in naturally occurring peak 1-minute and 30-minute cadences and to estimate the optimal number of monitoring days required to obtain reliable peak cadence measures among US adults using the NHANES accelerometer data. The results of this study identified that true variation by inter-individual differences ($\sigma^2_{\text{(person)}}$) and random variability by intra-individual differences across days ($\sigma^2_{\text{(person x day)}}$) accounted for relatively large proportions of total variance observed in both peak stepping cadence measures across gender and age groups (38.58%-67.31% for inter-individual variability; and 31.62%-59.24% for intra-individual variability).

Our findings are generally aligned with previous studies that confirmed large inter- and intra-individual variability in physical activity measures. Sheers, et al.[21] examined the sources of variability in physical activity measures including steps/day among 394 Flemish adults using a SenseWear™ Armband (BodyMedia, Pittsburgh, PA) accelerometer and demonstrated large inter-individual variability of observed variance in steps/day across gender (54.4% and 44.4% for male and female). A study conducted by Matthews, et al.[20] that examined the variance components of accelerometer outputs among 92 healthy adults using an Actigraph model 7164 (CSA) accelerometer indicated that inter-individual variability was the largest variance component in total variance observed (53%-62%), followed by intra-individual variability (29%-46%).

The current study, however, also found different rank orders of inter- and intra-individual variability after taking age groups into account. Specifically, adults aged <60 years showed relatively larger intra-individual variability (50.55%-59.24%) compared to older adults aged ≥60 years (31.62%-41.72%) across gender for both peak 1- and 30-minute cadence measures. Furthermore, systematic variation due to the difference in peak stepping cadences from day to day accounted for relatively larger proportions for adults aged <60 years (1.74%-2.77%) compared to older adults aged ≥60 years (0.26%-1.07%) across gender. Our findings regarding lower intra-individual variability in older adults are generally similar to previously published findings among older adults. Nicolai, et al.[22] examined the data from older retired adults (mean age = 80.75±4.05 years) who wore a Physilog device (BioAGM, CH) for 7 consecutive days. The results indicated that average intra-individual variability of walking time among 44 participants was 31.9% (±10.79%). One possible explanation regarding low intra-individual and day-to-day variability in peak stepping cadence measures in older adults could be related to their retirement status in that daily physical activity in this population may not be significantly varied across days including week and weekend days;[22,23] however, we could not clearly address as to how the retirement status in the current sample influenced lower intra-individual and day-to-day variability compared to young and middle-aged adults. Considering that the intra-individual variability is a component of random error that influences reliability of peak stepping cadence measures in the current analytical design, more effort is required to examine the unidentified factors that may further explain the intra-individual variability as well as the discrepancies in the variability of peak stepping cadence measures across age groups.

A question related to the optimal measurement condition for physical activity monitoring in a free-living environment has long been asked in the literature. Specifically, much attention has been paid in the field of physical activity monitoring to the perennial problem of what is the optimum number of days to obtain reliable data, while minimizing participant burden.[11] Matthews, et al.[20] indicated that at least 3 to 4 days of monitoring are required to achieve the desired reliability of .80 in the activity measures including activity counts and minutes in moderate and moderate-to-vigorous activity in healthy adults. Kang, et al.[13] reported that at least 5 continuous monitoring days are necessary to achieve an intra-class correlation of .80 using a 1-year average of pedometer step-count data in adults. Meanwhile several studies have concluded that fewer numbers of monitoring days are required for older adults. Hart, et al. [24] recommended that 2 to 3 days of monitoring are needed to reliably predict 21 days of light- and moderate-to-vigorous intensity physical activity behaviors for older adults. Rowe, et al. [23] confirmed that 2 days of monitoring would result in a reliability of ≥.80 for accelerometer- and pedometer-based step-count data in this population.

Our findings add to the literature by examining the minimum number of monitoring periods for a newly proposed intensity indicator of physical activity, peak stepping cadence. A follow up D-study indicated that a relatively larger number of monitoring days are required for adults aged <60 years compared to older adults aged ≥60 years across both peak 1- and 30-minute cadence measures. A minimum of 7 and 5 days of monitoring are required for adults aged <60 years for peak 1- and 30-minute cadence measures, respectively, whereas 3 days of monitoring generally yields greater reliability coefficients than desired for older adults. The greater number of monitoring days required for adults aged <60 years than for older adults is due to larger intra-individual variability across days in this population as indicated in the variance components estimated from the G-study. Peak stepping cadence represents the best natural effort of ambulatory activities in a free-living environment and is generally expected to be related to activities with high intensity levels. [9] However, the contexts of ambulatory activity that produce the peak stepping cadence may be difficult to identify in a free-living environment. Identifying context may help us to better explain the causes of intra-individual variability in this variable. Future studies are therefore warranted to identify the factors associated with variability of peak stepping cadences in a free-living environment.

A secondary aim of this study was to examine differences in accuracy of peak stepping cadence measures based on the type of day. The simulation analysis was conducted by examining the differences in peak stepping cadence measures between simulated datasets (no weekend days, 1 weekend day, and 2 weekend days) within the 1- through 7-day monitoring frames and 7-day complete datasets. Our findings indicated that peak stepping cadences were significantly different between week and weekend days (Table 2); however, in general, inclusion of weekend days in the monitoring frame did not substantially improve the accuracy of peak stepping cadence measures within each monitoring frame compared to the 7-day peak stepping cadence measures while the number of overall monitoring days may be more important to obtain accurate estimates of 7-day peak stepping cadence measures. Specifically, having a 1-day monitoring period generally resulted in the largest errors with ≥10% of MAPEs for peak 1- and 30-minute cadences, while 2 or more days of monitoring demonstrated acceptable accuracy with <10% MAPEs. In agreement with the current study, there have been several studies that confirmed significant differences in physical activity levels between week and weekend days in that adults tend to be less active during weekend days (more specifically on Sunday) compared to week days [11,12,23,25] but this is not of practical importance when determining the monitoring periods for physical activity measures.[11] Our simulation analysis focused on the absolute differences in peak stepping cadence measures using different simulated conditions compared to 7-day complete datasets in the current analytical sample. Although we took all possible combinations of week and weekend days within each monitoring frame into account, caution is warranted when interpreting the results. The implications are solely limited to the information on accuracy, which is not the same as the stability of the estimates obtained from the G-theory analyses.

This study has some limitations. The study sample was limited to adults who provided valid daily accelerometer data (defined as ≥10 hours/day) across seven entire consecutive days (i.e., non-missing days). The missing data imputation methods [i.e., EM algorithm, multiple imputation (MI), or individual information-centered (IIC) approach] for objectively measured physical activity using accelerometer has been documented elsewhere. [26,27] However, the effectiveness of such statistical techniques (EM or MI) could be expected when at least 70% of the study population has complete accelerometer data for each measurement day along with an assumption of missing completely at random (MCAR) or missing at random (MAR), [26] and IIC approach has not yet been validated in peak stepping cadence measures. In the current analytical sample, only approximately 30% of participants provided valid accelerometer data for each measurement day and it was hard to know whether the missing data followed the assumption of MCAR or MAR in reality, which collectively precluded us from implementing the imputation methods to maximize the final sample size for current study. Our findings did not take the complex sampling design of the NHANES into account due to the analytical complexity of variance component estimation in G-theory analyses. We are aware of a few studies that demonstrated methods of incorporating survey weights into the framework of G-theory;[28] however, to the best of our knowledge, no statistical software is currently available to accomplish such a goal. The G-theory framework assumes simple random sampling and therefore, our findings could likely be biased due to the disproportional sampling techniques employed in the NHANES protocol. Despite the above mentioned limitations, this is the first study that has examined the sources of variance in peak stepping cadence measures in accelerometer data using a relatively large sample. Our findings regarding the optimal measurement conditions can be of benefit for researchers or practitioners interested in measuring peak stepping cadences in a free-living environment.

CONCLUSION

In conclusion, we identified that intra-individual variability in peak stepping cadence measures accounts for larger portions of the total variance observed in young and middle-aged adults aged <60 years, compared to older adults aged ≥60 years. A minimum of 7 and 5 days of monitoring is necessary in order to obtain reliable peak 1- and 30-minute cadence measures in adults aged <60 years, respectively. For older adults aged ≥60 years, a minimum of 2 to 3 days of monitoring is sufficient to achieve the desired reliability level of .80 for accelerometer-determined peak cadence measures. It appears that the inclusion of weekend days in the monitoring frame may improve the accuracy of the peak stepping cadences but may not be of practical importance.

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Table 1. An Example of Simulation Data Generation for 3-days of Monitoring Frame with 2-week Days and 1-weekend Day

ID	Combination	2-Week days	1-Weekend day
1	1	Monday, Tuesday	Saturday
1	2	Monday, Tuesday	Sunday
1	3	Monday, Wednesday	Saturday
1	4	Monday, Wednesday	Sunday
1	5	Monday, Thursday	Saturday
1	6	Monday, Thursday	Sunday
1	7	Monday, Friday	Saturday
1	8	Monday, Friday	Sunday
1	9	Tuesday, Wednesday	Saturday
1	10	Tuesday, Wednesday	Sunday
1	11	Tuesday, Thursday	Saturday
1	12	Tuesday, Thursday	Sunday
1	13	Tuesday, Friday	Saturday
1	14	Tuesday, Friday	Sunday
1	15	Wednesday, Thursday	Saturday
1	16	Wednesday, Thursday	Sunday
1	17	Wednesday, Friday	Saturday
1	18	Wednesday, Friday	Sunday
1	19	Thursday, Friday	Saturday
1	20	Thursday, Friday	Sunday

Note. 20 data lines that include all possible combination of 2-week days and 1 weekend day [$({}_5C_2)$ x $({}_2C_1)$] were created for each individual. The absolute percentage error (APE, %) was calculated for each data line by comparing the average of peak stepping cadences across the selected days with the criteria measures (average of 7-day complete data).

Table 2. Descriptive Statistics of Step-Count Measures for the Total Sample by Gender and Age Group

	n (%)	Peak 1-minute cadence			Peak 30-minute cadence			Total step counts		
		Week	Weekend	Total	Week	Weekend	Total	Week	Weekend	Total
Male										
< 60 yrs	375	107.31	101.60*	105.68	81.21	74.05*	79.17	12211.64	10416.75*	11698.81
	(58.05)	(12.85)	(15.18)	(12.18)	(20.55)	(23.79)	(19.56)	(36.38)	(38.96)	(33.36)
≥ 60 yrs	271	92.84	89.74*	91.96	65.01	60.69*	63.78	8555.71	7303.82*	8198.02
	(41.95)	(19.83)	(21.27)	(19.00)	(33.81)	(33.35)	(32.37)	(49.76)	(48.71)	(47.04)
p-value[a]		<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001
Sub Total	646	101.24	96.62*	99.92	74.42	68.45*	72.71	10677.96	9110.86	10230.22
	(50.39)	(17.20)	(18.65)	(16.44)	(27.79)	(29.04)	(26.64)	(44.21)	(45.54)	(41.53)
Female										
< 60 yrs	374	109.43	104.31*	107.97	78.49	71.52*	76.50	10301.63	9473.29*	10064.96
	(58.81)	(14.58)	(17.69)	(13.84)	(24.93)	(27.08)	(23.26)	(33.96)	(36.96)	(31.88)
≥ 60 yrs	262	90.24	88.01*	89.60	61.03	57.73*	60.09	7696.24	7090.65*	7523.21
	(41.19)	(26.98)	(26.98)	(25.59)	(38.69)	(38.85)	(37.24)	(45.10)	(44.90)	(43.82)
p-value[a]		<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001
Sub Total	636	101.52	97.60*	100.40	71.29	65.84*	69.74	9228.34	8491.76*	9017.89
	(49.61)	(21.64)	(22.82)	(20.63)	(32.23)	(33.04)	(30.66)	(40.24)	(42.04)	(38.54)
Grand Total	1,282	101.38	97.11	100.16	72.87	67.15*	71.24	9958.80	8803.72*	9628.78
		(19.53)	(20.84)	(18.64)	(30.05)	(31.07)	(28.69)	(43.29)	(44.11)	(40.81)

*p <.001 for the comparison of step count measures between Week and Weekend days; [a]p-value for the comparison of step count measures between age groups; All values are presented as mean (coefficient of variation); Week = Monday through Friday; Weekend = Saturday and Sunday

Table 3. The Estimated Variance Components in G-Study

	Peak 1-minute cadence	Peak 30-minute cadence
	Estimated variance components (%)	Estimated variance components (%)
Male		
Ages < 60 yrs		
$\sigma^2_{(person)}$	135.94 (38.58%)	204.85 (44.34%)
$\sigma^2_{(day)}$	7.7 (2.19%)	12.8 (2.77%)
$\sigma^2_{(person\ x\ day)}$	208.72 (59.23%)	244.37 (52.89%)
Ages ≥ 60 yrs		
$\sigma^2_{(person)}$	276.65 (57.55%)	399.51 (67.31%)
$\sigma^2_{(day)}$	3.5 (0.73%)	6.34 (1.07%)
$\sigma^2_{(person\ x\ day)}$	200.53 (41.72%)	187.64 (31.62%)
Female		
Ages < 60 yrs		
$\sigma^2_{(person)}$	183.59 (39.02%)	274.36 (47.05%)
$\sigma^2_{(day)}$	8.2 (1.74%)	12.22 (2.09%)
$\sigma^2_{(person\ x\ day)}$	278.67 (59.24%)	296.5 (50.55%)
Ages ≥ 60 yrs		
$\sigma^2_{(person)}$	483.26 (61.67%)	464.71 (64.56%)
$\sigma^2_{(day)}$	2.06 (0.26%)	3.79 (0.53%)
$\sigma^2_{(person\ x\ day)}$	298.32 (38.07%)	251.36 (34.91%)

$\sigma^2_{(person)}$ = inter-individual variability; $\sigma^2_{(day)}$ = systematic day-to-day variability; $\sigma^2_{(person\ x\ day)}$ = intra-individual variability

Table 4. Reliability and MAPE by Days of Monitoring Frame for a Peak 1-minute Cadence

Number of day	Male				Female			
	Ages < 60 yrs		Ages ≥ 60 yrs		Ages < 60 yrs		Ages ≥ 60 yrs	
	MAPE (SE)	G-coefficient	MAPE (SE)	G-coefficient	MAPE (SE)	G-coefficient	MAPE (SE)	G-coefficient
1-day		.394		.580		.397		.618
No-weekend	10.14 (.006)		8.39 (.004)		14.81 (.008)		10.28 (.005)	
1-weekend	13.28 (.007)		11.12 (.005)		15.76 (.009)		13.26 (.006)	
2-weekend	-		-		-		-	
2-day		.566		.734		.568		.764
No-weekend	7.50 (.004)		6.07 (.002)		9.75 (.005)		**7.06 (.003)**	
1-weekend	**6.71 (.004)**		**5.88 (.003)**		**9.39 (.005)**		7.13 (.003)	
2-weekend	8.53 (.005)		7.64 (.004)		11.44 (.006)		8.99 (.004)	
3-day		.661		.805*		.664		.829*
No-weekend	5.58 (.003)		4.71 (.002)		7.38 (.004)		**5.49 (.002)**	
1-weekend	**5.20 (.003)**		**4.52 (.002)**		**6.78 (.004)**		5.57 (.002)	
2-weekend	5.55 (.003)		4.93 (.002)		7.28 (.004)		5.69 (.003)	
4-day		.723		.847		.724		.866
No-weekend	4.36 (.003)		3.69 (.002)		5.86 (.003)		4.55 (.002)	
1-weekend	**3.89 (.002)**		**3.38 (.002)**		5.57 (.003)		4.19 (.002)	
2-weekend	4.25 (.002)		3.74 (.002)		**5.31 (.003)**		**4.16 (.001)**	
5-day		.765		.873		.767		.890
No-weekend	3.41 (.002)		3.56 (.001)		4.57 (.002)		3.59 (.002)	
1-weekend	2.90 (.002)		2.51 (.001)		3.98 (.002)		3.26 (.001)	
2-weekend	**2.89 (.002)**		**2.48 (.001)**		**3.95 (.002)**		**2.85 (.001)**	
6-day		.796		.892		.798		.907
No-weekend	-		-		-		-	
1-weekend	2.21 (.001)		1.85 (.001)		2.63 (.002)		2.21 (.001)	
2-weekend	**1.78 (.001)**		**1.40 (.001)**		**2.35 (.001)**		**1.79 (.001)**	
7-day		.820*		.906		.822*		.919
No-weekend	-		-		-		-	
1-weekend	-		-		-		-	
2-weekend	-		-		-		-	

MAPE = mean absolute percentage error (%) obtained from the random intercept regression models for each simulated data; SE = standard error; Bolds indicate the lowest MAPEs at a given condition; *minimum number days of monitoring to achieve G-coefficient ≥.80

Table 5. Reliability and MAPE by Days of Monitoring Frame for a Peak 30-minute Cadence

Number of day	Male				Female			
	Ages < 60 yrs		Ages ≥ 60 yrs		Ages < 60 yrs		Ages ≥ 60 yrs	
	MAPE (SE)	G-coefficient	MAPE (SE)	G-coefficient	MAPE (SE)	G-coefficient	MAPE (SE)	G-coefficient
1-day		.456		.680		.480		.649
No-weekend	13.51 (.008)		12.26 (.006)		18.52 (.009)		15.15 (.007)	
1-weekend	17.69 (.009)		17.05 (.007)		18.75 (.009)		19.63 (.007)	
2-weekend	-		-		-		-	
2-day		.626		.809*		.649		.787
No-weekend	10.62 (.005)		8.99 (.004)		11.29 (.006)		10.42 (.004)	
1-weekend	**9.14 (.006)**		**8.41 (.004)**		**11.07 (.006)**		**9.88 (.005)**	
2-weekend	9.55 (.002)		8.65 (.001)		11.33 (.002)		10.18 (.001)	
3-day		.716		.864		.735		.847*
No-weekend	7.48 (.004)		6.85 (.003)		8.82 (.005)		8.01 (.003)	
1-weekend	**7.43 (.004)**		**6.67 (.003)**		**8.47 (.004)**		**7.65 (.003)**	
2-weekend	7.61 (.004)		7.28 (.003)		8.54 (.005)		8.43 (.003)	
4-day		.770		.894		.787		.881
No-weekend	5.82 (.003)		5.67 (.002)		6.84 (.004)		6.60 (.003)	
1-weekend	**5.57 (.003)**		**4.86 (.002)**		6.53 (.003)		**5.58 (.002)**	
2-weekend	5.58 (.003)		5.55 (.002)		**6.27 (.003)**		6.21 (.002)	
5-day		.807*		.914		.822*		.902
No-weekend	4.38 (.002)		4.70 (.002)		5.28 (.003)		5.35 (.002)	
1-weekend	4.10 (.002)		3.68 (.002)		4.69 (.003)		4.30 (.002)	
2-weekend	**3.84 (.002)**		**3.53 (.002)**		**4.64 (.002)**		**4.18 (.002)**	
6-day		.834		.927		.847		.917
No-weekend	-		-		-		-	
1-weekend	2.95 (.002)		2.84 (.001)		3.13 (.002)		3.27 (.001)	
2-weekend	**2.46 (.001)**		**2.10 (.001)**		**2.65 (.002)**		**2.49 (.001)**	
7-day		.854		.937		.866		.928
No-weekend	-		-		-		-	
1-weekend	-		-		-		-	
2-weekend	-		-		-		-	

MAPE = mean absolute percentage error (%) obtained from the random intercept regression models for each simulated data; SE = standard error; Bolds indicate the lowest MAPEs at a given condition; *minimum number days of monitoring to achieve G-coefficient ≥.80