Peak Stepping Cadence in Free-Living Adults: 2005–2006 NHANES

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Background: Analysis of the 2005–2006 National Health and Nutrition Examination Survey (NHANES) accelerometer data provides the descriptive epidemiology of peak 30-minute cadence (defined as the average steps/min recorded for the 30 highest, but not necessarily consecutive, minutes in a day) and peak 1-minute cadence (defined as the steps/min recorded for the highest single minute in a day) by sex, age, and body mass index (BMI). Methods: Minute-by-minute step data were rank ordered each day to identify the peak 30-minute and 1-minute cadences for 3522 adults (20+ years of age) with complete sex, age, and BMI data and at least 1 valid day (ie, 10/24 hours of accelerometer wear) of accelerometer data. Peak values were averaged across days within participants by sex, age, and BMI-defined categories. Results: U.S. adults average a peak 30-minute cadence of 71.1 (men: 73.7, women: 69.6, \( P < .0001 \)) steps/min and a peak 1-minute cadence of 100.7 (men: 100.9, women: 100.5, \( P = .54 \)) steps/min. Both peak cadence indicators displayed significant and consistent declines with age and increasing levels of obesity. Conclusions: Peak cadence indicators capture the highest intensity execution of naturally occurring ambulatory activity. Future examination of their relationship with health parameters using cross-sectional, longitudinal, and intervention designs is warranted.

Keywords: accelerometer, pedometer, surveillance, epidemiology, physical activity

The U.S. National Health and Nutrition Examination Survey (NHANES) used the ActiGraph model 7164 accelerometer in its 2005–2006 cycle of data collection to capture minute-by-minute physical activity data, including steps, on free-living civilian, noninstitutionalized Americans. Step data have not been released from the 2003–2004 cycle. These data have been previously analyzed and presented as steps/day, an indicator of total volume of physical activity, and specifically ambulatory activity. Since few people engage in activities that require considerable amounts of nonambulatory movement, ambulatory activity (most apparently walking, but also including any other bipedal locomotion such as skipping, running, dancing, etc.) is logically the single most important behavior to describe and track in free-living populations. However, a continued criticism of steps/day as a sole indicator of physical activity volume is that it fails to convey intensity of ambulatory activity, a central tenet of public health guidelines.

Recently, we demonstrated that minute-by-minute accelerometer-determined step data could be used to evaluate cadence (ie, steps/min) as it is naturally expressed in free-living, indicative of a full range of step accumulation patterns and stepping rates. A review of controlled studies of ambulatory activity using treadmills, tracks, and/or hallways concluded that the correlation between cadence and intensity (expressed as metabolic equivalents or METs) was \( r = .94 \). Previously, Tudor-Locke et al demonstrated that a cadence (ie, stepping rate) of 100 steps/min was associated with moderate intensity (absolutely defined as 3 METs) walking. Since that time, 4 other studies have also shown that, despite individual variation, 100 steps/min is a reasonable heuristic threshold indicative of absolutely-defined moderate intensity ambulatory activity. The relevance of this laboratory-determined cadence to real-world behavior is unknown; what is the highest cadence commonly observed in free-living? Inspired by alternative summary cadence variables published by researchers using the StepWatch Activity Monitor in small, select samples, the purpose of this analysis was to provide the descriptive epidemiology of peak 30-minute cadence (defined as the average steps/min recorded for the 30 highest, but not necessarily consecutive minutes in a day) and peak 1-minute cadence (defined as the steps/min recorded for the highest single minute in a day) by sex, age, and body mass index (BMI) 2005–2006 NHANES.

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Methods

NHANES 2005–2006

NHANES is an on-going health surveillance system for the U.S. Sampling strategies and data collection procedures are documented at http://www.cdc.gov/nchs/nhanes.htm. Directly relevant to this analysis, a detailed description of the anthropometry and accelerometer protocol is described at http://www.cdc.gov/nchs/data/nhanes/nhanes_05_06/BM.pdf. Briefly, during the physical examination, participants 6+ years of age and not limited in their ability to walk were invited to wear an accelerometer for 7 consecutive days. They were instructed only to remove the instrument at bedtime and for any type of water-based activity, including bathing and showering. The 2005–2006 cycle is the first release of accelerometer-determined minute-by-minute step data in addition to the more familiar activity count outputs (not a focus of this brief report). The National Center for Health Statistics (NCHS) Ethics Review Board approved the original protocol, and informed consent was obtained for all NHANES participants. The Pennington Biomedical Research Center’s Institutional Review Board approved this analysis.

Data Treatment and Analyses

This analysis was limited to adults (20+ years of age) with complete sex, age, and BMI data and at least 1 valid day of accelerometer data (defined as at least 10/24 hours of accelerometer wear). The mean number of valid days for this specific sample has been previously reported (5.3 SEM 0.05). A SAS macro supplied by the National Cancer Institute (NCI; http://riskfactor.cancer.gov/tools/nhanes_pam/) was used to identify nonwear time (defined as ≥ 60 consecutive minutes of zeros indicating no recorded movement). The use of at least a single day has been justified previously and used frequently in previous analyses of these same NHANES data.13–15 Since BMI was a focus of this analysis, we also excluded 269 self-reported pregnant women and a single individual with a BMI > 100 kg/m². The final analysis subsample of 3522 represents 81% of 4372 adult participants included in the original public use data set.

Minute-by-minute step data were rank ordered for each day to identify the peak 30-minute and 1-minute cadences, and then these were averaged across days within participants, and presented as mean and 95% CI for the total sample and by sex, age (20–29, 30–39, 40–49, 50–59, 60–69, and 70+ years), BMI categories [defined as underweight (BMI < 18.5 kg/m²), normal weight (18.5–24.9 kg/m²), overweight (25–29.9 kg/m²), obesity Class I (30–34.9 kg/m²), obesity Class II (35–39.9 kg/m²), and obesity Class III obesity (≥40 kg/m²)], and steps/day-defined physical activity categories (< 2500 steps/day = basal activity, 2500–4999 steps/day = limited activity, 5000–7499 steps/day = low active, 7500–9999 steps/day = somewhat active, ≥ 10,000–12,499 steps/day = active, and ≥ 12,500 steps/day = highly active). Statistical tests were conducted to evaluate significance of differences by sex and trends across age, BMI and step-defined physical activity categories. Correlations (Spearman) were also computed to further evaluate the relationship between BMI and the 2 peak cadence indicators. All analyses were conducted using SAS 9.1 (SAS Institute, Cary, NC, 2004) sample survey procedures to account for the complex NHANES sampling design. To assure national representativeness of results, sample weights were employed to account for oversampling and nonresponse.

Results

Peak 30-minute cadence for the total sample and by sex, age group, and BMI and steps/day-defined physical activity category is presented in Table 1. There were statistically significant differences between sexes (men > women, P = .0007) and age groups such that peak 30-minute cadence was highest in the youngest age group and thereafter became lower with each older age group (P for trend < 0.0001). Peak 30-minute cadence also differed significantly by BMI category: cadence was relatively lower for underweight individuals, was highest for normal weight individuals, and then became lower again with higher BMI categories (P for trend < 0.0001). Peak-30 minute cadence was lowest in those taking < 2500 steps/day and became progressively higher with each higher steps/day-defined physical activity category (P for trend < 0.0001). With the exception of no significant difference between sexes, similar patterns were obtained with peak 1-minute cadence values, also presented in Table 1. The correlation between BMI and peak 30-minute cadence was −0.18 and between BMI and peak 1-minute cadence was −0.19 (both P < .0001).

Discussion

The purpose of this analysis was to provide the descriptive epidemiology of peak 30-minute and 1-minute cadence in a large free-living sample representative of civilian, noninstitutionalized U.S. adults. With the exception of no apparent sex differences in peak 1-minute cadence, both variables displayed significant, consistent, and expected patterns by sex, age, BMI-defined weight status, and steps/day-defined physical activity categories. Overall, U.S. adults averaged a peak 30-minute cadence of 71.6 steps/min and a peak 1-minute cadence of 100.7 steps/min.

The seemingly low values, especially for peak 30-minute cadence, should not be surprising. Using the American Time Use Survey (based on a 24 hour recall of activities), we have previously shown that, on any given day, only ~46% of Americans engaged in any type of walking behavior (including walking for transportation or exercise, dog walking, shopping, or other type of walking) for an accumulated duration of ~45 minutes. We
have also shown, based on these NHANES accelerometer data that accelerometer-determined activity counts/day, steps/day, and time in moderate and vigorous intensity activity differed significantly across BMI-defined weight status categories for both men and women$^{19}$ ($P < .0001$). In addition, mean cadence (based on time worn) was significantly different across categories: 12.3 steps/min (normal weight), 11.8 steps/min (overweight), and 10.6 steps/min (obese)$^{19}$ ($P < .0001$).

Gardner et al$^{12}$ used the StepWatch Activity Monitor in a study of 227 older adults with and without intermittent claudication. This instrument detects a full gait cycle (eg, right foot toe-off to right foot heel-strike) and outputs ambulatory activity as strides. Strides/min must be doubled to compare with cadence expressed as steps/min. The results reported in their study (converted herein) indicate that these older adults (mean age ~65 years of age) had a peak 30-minute cadence of 52 steps/min and a peak 1-minute cadence of 90 steps/min (if they had intermittent claudication) and 62 steps/min and 100 steps/min (if they did not have intermittent claudication). These latter values are not too different from what the NHANES data show, providing additional support for the veracity of these cadence values.

Using the same NHANES data as analyzed herein, we recently showed that Americans accumulate...
approximately 8.7 hours between 1–59 steps/min, 16 min/day at cadences of 60–79 steps/min, 8 minutes at 80–99 steps/min, 5 minutes at 100–119 steps/min, and only 2 minutes at 120+ steps/min. Overall, it appears that expressions of moderate+ intensity walking are rare in daily living. Orenduff et al20 conducted a detailed analysis of 10 nondisabled employed adults’ (mean age 36.3 years) habitual ambulatory activity to define the duration of natural walking bouts and the number of sequentially accumulated steps. They operationally defined a walking bout as a period of time in which steps occurred in subsequent 10-second intervals; a walking bout was considered to be concluded when no steps were detected in a 10-second window of time. The authors effectively demonstrated that, even in this apparently generally active sample (with reported involvement in walking for fitness, soccer, bicycling, sailing, and hiking), daily steps were typically accumulated in short-duration bouts of low numbers of steps; 40% of all recorded walking bouts (continuously accumulated steps) amounted to only 12 steps overall. Walking bouts that accumulated more than 100 steps in a row represented only approximately 6% of all walking bouts. And very long-duration walking (defined as 3000–10,000 steps in a row) was extremely rare, accounting for only 0.14% of all walking bouts. The authors observed that individual subjects typically only performed 1 to 2 relatively longer walking bouts each day, usually in the morning before work and again in the afternoon after work, and these occasions were believed to be associated with walking to and from motor vehicle transportation (ie, a parked car or a bus stop).

Cadence is just one of the spatiotemporal parameters of gait, the other being stride length. Laboratory gait tests have shown that stride length is related to height, and thus to cadence in performance of preferred self-selected walking speeds.9,10 Essentially, shorter people typically have a faster cadence during self-selected walking than taller people. For example, women have a higher normal pace cadence than men, and this has been attributed to height differences.10 However, in this examination of free-living self-selected cadence (which includes a range of speeds beyond that tested under laboratory conditions), peak 30-minute (73.7 vs. 69.6 steps/min) was significantly higher in men (who were on average taller also; 176.2 ± SEM 0.3 vs. 162.1 ± 0.2 cm) than women, suggesting these ambulatory activity intensity indicators are not distorted by height in the anticipated direction in this population-level analysis. It should be also noted the observed sex-based cadence differences also line up with the fact that men are more vigorously active on average than women.21

Laboratory tests of self-selected normal or preferred cadence assessed using short distance walks and conducted in relatively small, select samples have shown lower cadence with advancing age,22,23 but also no differences related to age.24 Cadence assessed in this manner reflects a performance measure (eg, during self-selected normal pace) and is not necessarily a reflection of habitual behavior undertaken during free-living contexts. In contrast, the peak cadence values considered in these NHANES data provide a very clear indication of the maximum speed/intensity of ambulatory activity undertaken for the top 30 minutes and 1 minute, respectively, as it occurs naturally in this free-living sample. The age-related free-living patterns reveal that peak cadences are progressively lower with each older age group beyond young adulthood and are the lowest in those aged 70+ years (perhaps, at least in part, to diminished opportunities for such behavior, both in terms of bout duration and cadence).

The limitations of these cross-sectional data have been previously cataloged1,21 and include the fact that causality, for example in terms of BMI-defined weight status, cannot be substantiated because cadence levels may decline after adults become obese. Another important caveat is that this was a population level analysis and the findings do not necessarily apply to all individuals; some people will have either higher or lower peak 30-minute and 1-minute cadence values than the summary indicators of central tendency presented herein. Regardless, these data can be tracked over time and also used as benchmark values to aid in comparative data interpretation. Previous research has demonstrated that steps/day is a simple indicator of free-living physical (ambulatory) activity volume that is related to a number of health parameters including BMI-defined weight status25,26 and cardiometabolic health.14,27 Peak cadence indicators capture the highest intensity execution of naturally occurring ambulatory activity. Since this analysis shows a relationship between these peak cadence indicators and BMI, it is important now to move beyond the descriptive epidemiology to examine their relationship with other health parameters using cross-sectional, longitudinal, and intervention study designs.

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References


