Accelerometer-Determined Lifestyle Activities in U.S. Adults

Sarah M. Camhi, Susan B. Sisson, William D. Johnson, Peter T. Katzmarzyk, and Catrine Tudor-Locke

Background: Objective physical activity data analyses focus on moderate-to-vigorous physical activity (MVPA) without considering lower intensity lifestyle-type activities (LA). We describe 1) quantity of LA (minutes and steps per day) across demographic groups, 2) proportion of LA to total physical activity, and 3) relationships between LA and MVPA using NHANES 2005–2006 accelerometer adult data (n = 3744). Methods: LA was defined as 760 to 2019 counts per minute (cpm) and MVPA as ≥2020 cpm. LA was compared within gender, ethnicity, age, and BMI groups. Regression analyses examined independent effects. Correlations were evaluated between LA and MVPA. All analyses incorporated sampling weights to represent national estimates. Results: Adults spent 110.4 ± 1.6 minutes and took 3476 ± 54 steps per day in LA. Similar to MVPA, LA was highest in men, Mexican Americans, and lowest in adults ≥60 years or obese. When LA was held constant, ethnic differences no longer predicted MVPA minutes, and age no longer predicted MVPA steps. LA and MVPA minutes \( (r = .84) \) and steps per day \( (r = .72) \) were significantly correlated, but attenuated with MVPA modified bouts \( (\geq 10 \text{ minutes sustained activity}) \). Conclusions: LA accumulation differs between demographic subgroups and is related to MVPA: adults who spend more minutes and steps in MVPA also spend them in LA.

Keywords: measurement, pedometry, physical activity assessment

Moderate-to-vigorous physical activity (MVPA) has been the focus of public health recommendations. Less is known about activities at lower intensities, such as lifestyle activities (LA) (eg, household chores or gardening), and how they may contribute to an individual’s overall activity levels. Furthermore, there is conflicting evidence on whether physical activities at this intensity may be beneficial for health.

The introduction of accelerometry into the National Health and Nutrition Examination Survey (NHANES) has allowed for the examination of population physical activity and sedentary behaviors. Waist-mounted accelerometers detect movement (ie, steps) and its vertical acceleration, and in turn such data can be transformed into estimates of time in various intensities of activity using accepted cutpoints. For example, the NHANES has adopted a cutpoint of 2020 activity counts per minute (cpm) to designate the threshold for time spent in MVPA. However, Matthews has suggested a MVPA cutpoint of 760 cpm to include common lifestyle type activities (LA; such as sweeping, vacuuming, and raking). LA, such as household chores and gardening, are commonly reported physical activities within the U.S. population, yet these types of activities produce lower accelerometer-determined cpm but may elicit increased energy expenditure due to upper body movements and/or complex lower body movements. Despite accelerometers providing objective measures of activity, they are limited in their ability to assess activities that involve mostly upper body movements, such as LA.

Rather than choosing one MVPA cutpoint as superior to the other, it may be useful to view them as being mutually exclusive to more closely examine these distinct types of activities: greater than or equal to 2020 cpm to represent MVPA and 760 to 2019 cpm to represent LA. Both cpm and steps per day were released with the 2005–2006 NHANES, permitting consideration of both types of instrument outputs. Thus, the purpose of this analysis of the NHANES adult (ie, >20 years of age) accelerometer dataset is 3-fold: 1) to describe demographic characteristics of minutes per day and steps per day spent in LA, 2) to determine what proportion of overall physical activity LA accounts for, and 3) examine relationships between LA and MVPA utilizing both minutes per day and steps per day.

Methods

NHANES

NHANES is the United States’ primary source of objective health and nutrition surveillance data. This survey
is designed to track the national prevalence of major diseases as well as to assess factors related to prevention and health promotion. To assess demographic, socioeconomic, dietary and health related questions NHANES includes a home interview, an examination in a mobile examination center (MEC), and a laboratory exam. Each year, approximately 5000 nationally representative civilian, noninstitutionalized participants are interviewed. Details of the complex sampling design can be found online at http://www.cdc.gov/nchs/tutorials/Nhanes/SurveyDesign/SampleDesign/intro.htm.

The household interview obtained self-reported sociodemographic information. Race was categorized into non-Hispanic white, non-Hispanic black, Mexican American, and other (mixed and Hispanic). Direct assessments of height and weight were taken at the MEC by trained technicians. Details of the procedures can be found in the online manual. Participants over the age of 6 years, without any impairments preventing them from walking or wearing the accelerometer, were instructed on proper use of the ActiGraph (ActiGraph AM-7164, ActiGraph, Ft. Walton Beach, FL) accelerometer during the MEC visit. The device was worn over the right hip and attached to an elastic belt. Participants were instructed to wear the accelerometer for 7 consecutive days and only remove it for sleeping and any activities involving water (bathing, swimming, etc.). Participants returned the accelerometers by prepaid envelopes in exchange for a $40 remuneration. The 2005–2006 NHANES accelerometer dataset is publically available at http://www.cdc.gov/nchs/about/major/nhanes/nhanes2005-2006/exam05_06.htm.

Procedures for data collection were approved by the National Center for Health Statistics’ Institutional Review Board, and all participants gave written informed consent. All secondary data analyses were approved by the Pennington Biomedical Research Center Institutional Review Board.

Data Treatment

Raw accelerometer data from 4372 adults were reviewed by the National Center for Health Statistics (NCHS) and the National Cancer Institute (NCI) before public release, and outliers and unreasonable values based on the published literature were flagged (n = 356). Flagged data included records containing >10 minutes with 1) 0 steps and >250 activity counts/minute, 2) steps/minute >200, and 3) 32,767 (maximum value possible) activity counts/minute, or data collected from instruments that were not in calibration upon return. Our analysis excluded all of these flagged data.

Body mass index (BMI) was calculated as the weight in kilograms divided by the height in meters squared (kg/m²). BMI categories were defined by the National Heart, Lung and Blood Institute (NHLBI) cutpoints: normal weight (<25 kg/m²), overweight (25–29.9 kg/m²), and obese (≥30 kg/m²). Underweight (BMI < 18.5 kg/m²) only accounted for 54 (5%) individuals with accelerometer data, thus they were combined with the normal weight category. Anyone with accelerometer data who was missing height and/or weight data (n = 15), or women who were pregnant based on self-report or urine analysis (n = 221), were eliminated only for the BMI comparison analysis (details below).

Total monitoring time was calculated as the mean number of hours each participant wore the accelerometer, computed using a SAS macro provided by the National Cancer Institute (NCI) (http://riskfactor.cancer.gov/tools/nhanes_pam). Nonwear minutes were calculated for each participant as the difference between 1440 minutes (total number of minutes in a single day) and actual accelerometer monitoring time. For specifics on how nonwear time was calculated from accelerometer counts, please see http://riskfactor.cancer.gov/tools/nhanes_pam/create.pam_perday.sas. We limited our analysis to “valid days,” defined as ≥ 10 hours of wear, on a minimum of 1 day. Participants who did not have at least 1 valid day were excluded (n = 272).

Minutes and Steps Per Day

Accelerometer data were originally recorded in 1-minute epochs (ie, time sampling intervals), 24-hours a day, for up to 7 days. Each minute was linked with a cpm value, which was then used to infer a specific intensity using cutpoints from previously published literature as stated above: MVPA was represented by cpm ≥2020, and Matthew’s alternative cutpoint for MVPA was adapted as an interval to exclusively represent LA (760–2019 cpm). Minutes per day and steps per day were respectively summed within LA or MVPA intensity, over the course of time monitored, to separately represent total daily minutes and steps spent in LA or MVPA. Total daily minutes and total daily steps were then averaged for each participant, across the total number of valid days, resulting in mean minutes per day (minutes per day) and mean steps per day (steps per day) spent in either LA or MVPA.

Modified MVPA Bout

Since current physical activity recommendations encourage MVPA be undertaken in bouts of at least 10 minutes, a modified MVPA bout was defined as engaging in MVPA for at least 10 consecutive minutes, with an allowance for a 1 to 2 minute interruption below the cpm cutpoint using the same SAS macro used in previous analyses and publically available at http://riskfactor.cancer.gov/tools/nhanes_pam/create.html. Since we were interested in understanding relationships between minutes accumulated in LA and modified MVPA bouts, and between steps accumulated in LA and modified MVPA bouts, we only calculated the sum of minutes and steps per day accumulated within modified MVPA bouts in individuals who engaged in at least 1 MVPA modified bout on at least 1 day.
Data Analysis

Analyses were performed using SAS version 9.1 with procedures specific to complex sampling designs. Descriptive data are presented as means ± standard error or frequencies, as appropriate. To provide nationally representative means, sampling weights were used. Values were calculated with 95% confidence intervals for LA and MVPA in both minutes per day and steps per day. Nonoverlapping confidence intervals for intensity-defined minutes per day and steps per day were reviewed to illuminate significant differences within gender, ethnicity, age group (20–39, 40–59, ≥60 years), and BMI categories.

Linear regression models were used to test the significance of gender, ethnicity, age group, and BMI as predictors of 1) minutes per day and 2) steps per day, separately for MVPA and LA. A regression analysis was also performed with LA added as an additional predictor of MVPA (minutes or steps) to hold constant LA (minutes or steps) while examining the independent predictive value of gender, ethnicity, age group, and BMI.

Correlation analyses were performed to explore the relationship between MVPA and LA with respect to 1) minutes per day and 2) steps per day. As stated above, public health recommendations indicate that MVPA should be accumulated in bouts of at least 10 minutes in duration to improve health. In contrast, LA do not carry such a bout requirement and there is no logic to support analyzing these data in a similar manner. Therefore, we also examined the relationship between only those minutes or steps accumulated during modified MVPA bouts and any minutes or steps of LA. At all times, due to the skewed distributions of minutes per day and steps per day in both LA and MVPA, correlations were performed on rescaled (to account for 0 values), natural-log-transformed data.

Results

The final analyses were based on 3744 adults (86%) from the original sample with a single exception: analyses for BMI-defined weight categories were based on only 3508 adults (80% of the original sample) due to missing values for height or weight and/or exclusion of women who were pregnant. Estimates for demographic characteristics are weighted to represent national means and are presented in Table 1. Overall, the sample was 47% men and 72% non-Hispanic white. Mean age was 47.1 ± 0.7 years and BMI was 28.6 ± 0.2 kg/m².

Minutes Per Day Accumulated During LA and MVPA

Mean accelerometer monitoring time was 14.0 ± 0.06 hours per day (840 minutes) representing 58% of the 24 hour day (ie, 1440 minutes). Minutes per day spent in LA and MVPA in the total sample and across demographic subgroups are presented in Table 2. Overall minutes spent in LA totaled 110.4 ± 1.6 minutes per day (13% of monitored time; 8% of total day), and MVPA totaled 22.8 ± 0.7 minutes per day (3% of monitored time; 2% of total day).

Men had significantly higher minutes per day accumulated during both LA and MVPA intensities than

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Characteristics of Adults ≥ 20 Years With Valid Accelerometer Data; Values Are Expressed as Mean ± SE and n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total sample</td>
</tr>
<tr>
<td>n (%)</td>
<td>3744 (100)</td>
</tr>
<tr>
<td>Age (yrs)</td>
<td>47.1 ± 0.7</td>
</tr>
<tr>
<td>20–39</td>
<td>1366 (36)</td>
</tr>
<tr>
<td>40–59</td>
<td>1182 (40)</td>
</tr>
<tr>
<td>≥60</td>
<td>1196 (24)</td>
</tr>
<tr>
<td>Race n (%)</td>
<td></td>
</tr>
<tr>
<td>Non-Hispanic White</td>
<td>1865 (72)</td>
</tr>
<tr>
<td>Non-Hispanic Black</td>
<td>851 (11)</td>
</tr>
<tr>
<td>Mexican American</td>
<td>765 (8)</td>
</tr>
<tr>
<td>Other</td>
<td>263 (9)</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>28.6 ± 0.2</td>
</tr>
<tr>
<td>Normal weight</td>
<td>1070 (33)</td>
</tr>
<tr>
<td>Overweight</td>
<td>1195 (32)</td>
</tr>
<tr>
<td>Obese</td>
<td>1243 (36)</td>
</tr>
</tbody>
</table>

Note. Mean ± SE and frequencies are weighted to represent national population estimates. BMI analyses exclude those who are pregnant, or are missing height and/or weight (total excluded n = 236 (6%); men n = 8; women n = 228).
Women. Mexican Americans had significantly higher minutes per day spent in both LA and MVPA than non-Hispanic white, non-Hispanic black and other. Individuals ≥60 years of age had lower accumulated minutes in LA than their younger counterparts (20–39 years and 40–59 years). Normal-weight and overweight individuals had significantly higher minutes per day in both LA and MVPA than obese adults.

Some adults did register 0 for the mean daily minutes in LA and/or MVPA. One non-Hispanic white, obese female, 41 years of age, had 0 minutes in LA; all of her monitored minutes were below the LA threshold. Thirty-four adults (less than 1% of total sample) had 0 minutes in MVPA. General demographics of this specific subsample were 76% women, 75% ≥60 years, 76% non-Hispanic white, and 50% normal weight.

Steps Per Day Accumulated During LA and MVPA

The mean number of steps per day taken in the overall group was 9676 ± 102; with 3476 ± 54 steps taken in LA (36% of total steps per day), and 1718 ± 64 steps taken in MVPA (18% of total steps per day). Steps accumulated during LA and MVPA are presented in Figure 1, and follow the same general patterns across demographic subgroups as minutes per day. Men took significantly more steps per day during both LA and MVPA than women. Mexican Americans also took significantly more steps per day during LA than non-Hispanic whites and non-Hispanic blacks. Individuals ≥60 years of age took significantly fewer steps per day in both LA and MVPA than their younger counterparts. Obese individuals also took significantly fewer steps per day during both LA and MVPA than normal-weight and overweight adults.

Regression Analyses for LA and MVPA

Minutes per Day. Differences in minutes observed between gender, ethnicity, age, and BMI categories persisted even when these variables were combined into multivariable regression models. Gender, ethnicity, age, and BMI were all significant independent predictors of MVPA minutes (all variables: \( P < .0001 \)) and LA minutes (all variables: \( P < .0001 \)). When LA minutes per day were held constant, only gender, age, and BMI categories remained significant predictors for MVPA. Thus, once MVPA minutes were adjusted for minutes in LA, Mexican Americans no longer had higher MVPA minutes than any other ethnic group.

Steps per Day. Gender, ethnicity, age, and BMI were also all independent predictors for both MVPA steps (all variables: \( P < .03 \)) and LA steps (all variables: \( P < .005 \)). When LA steps were held constant, only gender, ethnicity, and BMI remained significant predictors for MVPA. Therefore, adults ≥60 years of age no longer had significantly lower MVPA steps per day compared with other age groups.

Correlation Between LA and MVPA

Minutes per Day. The correlation between LA and MVPA minutes per day for the total group (n = 3744) was \( r = .84 (P > .0001) \). Within demographic subgroups for minutes per day, correlations ranged from \( r = .78 \) to .85. The correlation between any minutes per day accumulated in LA and minutes per day accumulated in MVPA modified bouts was \( r = .17 (P < .0001) \).

Steps per Day. The correlation between LA and MVPA steps per day was \( r = .72 (P > .0001) \). Within subgroups for steps per day, correlations ranged from \( r = .57 \) to .75.
The correlation between steps per day accumulated in LA and steps per day accumulated in MVPA modified bouts was $r = .20$ ($P < .0001$).

**Discussion**

Adopting two physical activity thresholds as mutually exclusive intensities reveals that the patterns for minutes per day (when bouts are not required and any minutes are considered) and steps per day accumulated across demographic subgroups are similar for LA and MVPA. Men accumulate more minutes and steps per day in MVPA and LA than women, Mexican Americans accumulate more minutes and steps in MVPA and LA than other ethnic groups, adults ≥ 60 years of age accumulate less total minutes and steps in both MVPA and LA than other age groups, and obese adults accumulate less minutes and steps in MVPA and LA. However, if models for MVPA are adjusted for gender, ethnicity, age, BMI, and LA together, ethnic differences are no longer significant for MVPA minutes, and age group differences are no longer significant for MVPA steps. The overall minutes per day spent in LA explains approximately 70% of the variance in MVPA minutes per day and LA steps per day explains approximately 52% of the variance in MVPA steps per day. However, little variance for modified MVPA bouts is explained by LA utilizing either minutes (3%) or steps per day (4%).

Objectively measured physical activity from NHANES 2003–2004 was recently published by Hawkins et al., who used separate accelerometer thresholds to represent light (260–1952 cpm) and MVPA (>1952 cpm). Despite different accelerometer cutpoints, similar demographic differences were reported: younger adults, Mexican Americans, and men had more LA minutes than their demographic counterparts. Our research utilizes a cutpoint to distinguish LA as separate and distinct from light and MVPA, and also updates findings with the most recent data for population estimates, includes steps per day as another measure of physical activity accumulation to confirm the findings, and extends demographic comparisons between BMI groups. In addition, we were able to examine the LA’s contribution to total physical activity and its relationship to MVPA.

Self-reported LA have been assessed in other epidemiological data, although they have been labeled as several different types of activities, such as nonleisure activities, domestic physical activity, and/or household chores. Limitations for assessing LA with self-report may only include specific activities and predefined intensities. For example, some studies only assess housework or household chores while others also include gardening. Several self-reported domestic activity assessments include only “heavy” or “vigorous” intensities, while others also include activities at a “light” intensity. Additional challenges with self-reported domestic activities include a possible gender bias. Phongsavan and colleagues found that the inclusion of domestic activities in estimating daily physical activity changed estimates particularly in women. Objective assessment for the differences in gender for the volume of LA has not been performed, however, our results suggest that men have
higher LA than women. Finally, as with any self-report assessment protocol, there is a possible bias toward over-reporting the specific behavior. While the current study does not attempt to specifically identify or distinguish between types of LA, we were able to objectively quantify the volume (minutes and steps per day) within a range of intensity whereby domestic activities and household chores may be classified. Furthermore, LA was quantified within a representative group of U.S. adults.

Minutes and steps per day accrued during LA are important to consider due to their likely contribution to overall energy expenditure. Self-reported time spent in intensities comparable to LA accounted for 82% of total activity assessed in women. Even objective measures show that the proportion of time spent in activities classified between light and moderate intensities, a similar magnitude to LA as classified herein, has a greater influence on overall energy expenditure than time spent in more vigorous physical activity. In the current study, minutes spent in LA averaged 13% of monitored time and 32% of the total steps per day, contributing more overall time and steps to their respective totals than MVPA (MVPA minutes per day: 3% of monitored time; 16% of total steps per day). Despite the appearance of a relatively low contribution to the total day, objectively measured LA minutes accounted for approximately 82% of minutes of combined time in LA and MVPA. It is important to note that we report U.S. adults taking approximately 9676 ± 102 steps per day. However, the accelerometer used in NHANES is known to be more sensitive to lower force accelerations, resulting in accumulation of more steps than a research quality pedometer. Our population estimates for steps within LA (>760 cpm) and MVPA (>2020) are both above the thresholds suggested for censoring (<500 cpm), thus our estimates at these intensities are not affected by the accelerometer sensitivity at lower thresholds. However, if the steps were censored to eliminate steps < 500 cpm, then steps per day for the total sample are 6540 ± 106. This lower overall number does not attempt to specifically identify or distinguish between types of LA, we were able to objectively quantify the volume (minutes and steps per day) within a range of intensity whereby domestic activities and household chores may be classified. Furthermore, LA was quantified within a representative group of U.S. adults.

The association between LA and MVPA displayed a smaller $r^2$ magnitude when examined as steps per day versus minutes per day. It is important to note that an increased walking intensity translates to a faster cadence, ultimately producing a greater accumulation of steps in a reduced period of time. Stated another way, steps in MVPA accumulate more quickly than steps in LA over the same amount of time. Therefore, the observed lower regression coefficient for steps per day in LA and MVPA appears to be due to the increasingly complex interaction of time and step counts as intensity increases.

Our results suggest that a person who accumulates any minute or steps in LA is also accumulating minutes and steps in MVPA. However, the relationship between modified MVPA bouts and any minute of LA is more complex. Little variance for modified bouts of MVPA was explained by LA. It is important to emphasize that LA was not similarly restricted to bouts of 10 minutes or longer. Sustained bouts of MVPA are recommended to achieve physical activity recommendations, however, current studies estimate that <5% of the American population are achieving physical activity recommendations when bouts of at least 10 minutes are considered. Our regression analyses for modified MVPA bouts should be interpreted with caution, as over 60% of the sample could not be included due to the fact that only a subsample achieved at least 1 modified bout on at least 1 day. Although the regression coefficients representing the modified MVPA bouts analysis were statistically significant for both minutes per day and steps per day, they were very small in magnitude, and most of the variance in modified MPVA bouts remained unexplained. An explanation for the attenuation of the relationship between intensities when relating MVPA modified bouts may be due to different types of behavior. Modified MVPA bouts most likely represent structured and strategic activity. On the other hand, any minute or step in MVPA or LA may represent an entirely different pattern of accumulation characterized as spontaneous and sporadic movement.

Describing activities occurring within the acceleromter range of 760 to 2019 cpm was a challenge, as there is no accepted terminology within the existing literature. We felt it was important to use a term that was consistent with Matthews' suggestion that common household chores, gardening, and certain sports such as golf and softball, did fall into this range. Thus, our broad use of the term lifestyle type activities is an attempt to capture the varied nature of activities within this range. However, we also acknowledge that all activities captured by the accelerometer in this range may not be lifestyle type activities. The NHANES data set is a large representative cross-sectional data set, thus cause and effect cannot be determined. Accelerometers are objective measures of physical activity which can be used to ascertain time in intensity categories and steps, eliminating a number of biases commonly associated with self-report. However, even though we used specific cutpoints to identify LA and MVPA, not all physical activities can be accounted for using an accelerometer. MVPA activities such as swimming, cycling, and resistance training cannot be assessed due to limitations of wear in wet environments, inability to assess horizontal acceleration, and/or activities composed of mostly upper body movements. Thus, while the accelerometer does provide an assessment of physical activity, it still may not completely represent a person’s actual total minutes in a full range of physical activity. However, new objective monitors are advancing the ability to assess multiple planes of movement, as well as posture and position of limbs, which could more accurately represent an individual’s total physical activity level.

Future studies are needed to explore the relationship between the minutes and steps of objectively measured LA and chronic diseases such as cardiovascular disease, certain types of cancer and type 2 diabetes. Self-reported heavy housework was not related to being overweight, though accelerometer which assessed minutes (utilizing
a cutpoint equivalent to that used to classify the combination of LA and MVPA herein) showed a negative association between minutes accrued and both BMI and waist circumference. Increased participation in self-reported domestic physical activity was not associated with cardiovascular risk factors, but was associated with a reduced risk of mortality by 32% and 30% in men and women, respectively. Clarifying the role of LA and its relationship to health outcomes may inform future intensity physical activity recommendations. If minutes per day spent in LA are independent predictors of health-related outcomes, this intensity could also improve overall health and wellbeing.

In summary, utilizing mutually exclusive thresholds to identify LA and MVPA revealed that the accumulation of LA is positively related to MVPA. Adults who spend more time and steps in MVPA also spend more time and steps in LA. In addition, for equal minutes of LA (ie, when they were held constant in analyses), ethnic differences were no longer significant; for equal steps in LA, differences between age group were no longer significant. Thus, once the volume (minutes or steps) of LA is accounted for, ethnic and age group differences in MVPA may not exist, which has important clinical implications in targeting other special populations for physical activity interventions. For example, gender and BMI differences remain significant in predicting MVPA at the same level of LA, thus, promotion of LA in women and obese individuals should be a major focus for future interventions. Despite these relationships, volume of activity in LA (minutes or steps) explains little of the variation in the accumulation of minutes or steps if only modified MVPA bouts are considered. Future studies need to clarify whether LA is a surrogate indicator for MVPA (unrestricted by bout requirements), or an intensity independently associated with health outcomes.

Acknowledgments

We would like to thank Meghan McGlone at Pennington Biomedical Research Center, Baton Rouge, for her assistance in data analysis. P.T. Katzmarzyk is partially endowed by the Louisiana Public Facilities Authority Endowed Chair in Nutrition. No funding sources to report.

References


