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Effect of Varying Accelerometry Criteria on Physical Activity: The Look AHEAD Study

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Abstract

The importance of physical activity in weight management is widely documented. Although accelerometers offer an objective measure of activity that provide a valuable tool for intervention research, considerations for processing these data need further development. This study tests the effects of using different criteria for accelerometry data reduction. Data were obtained from 2,240 overweight and obese individuals with type 2 diabetes mellitus (T2DM) from the Look AHEAD study, with 2,177 baseline accelerometer files used for analysis. Number, duration, and intensity of moderate (≥3 METS) and vigorous (≥6 METS) activity bouts were compared using various data reduction criteria. Daily wear time was identified as 1,440 minutes per day minus non-wear time. Comparisons of physical activity patterns for non-wear time (using either 20, 30 or 60 minutes of continuous zeros), minimal daily wear time (8, 10, and 12 hours), number of days with available data (4, 5, and 6 days), weekdays versus weekends, and one- or two-minute time interruptions in an activity bout were performed. In this mostly obese population with T2DM (BMI = 36.4 kg/m^2; mean age = 59.0 y), there were minimal differences in physical activity patterns using the different methods of data reduction. Altering criteria led to differences in the number of available data (sample size) meeting specific criteria. Although our results are likely directly applicable only to obese individuals with T2DM, an understudied population with regards to physical activity, the systematic analysis for data reduction employed can be more generalizable and provide guidance in this area in the absence of standard procedures.

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Keywords

Physical Activity Patterns; Bouts of Physical Activity; Obesity; Diabetes

INTRODUCTION

Being more physically active is associated with a reduced risk of morbidity and all-cause mortality (1, 2), and research shows that increased physical activity is a critical component of successful obesity treatment(3, 4). Several large randomized controlled trials (RCTs) in overweight and obese persons with type 2 diabetes (T2DM), including the Diabetes Prevention Program (DPP)(5, 6) and Look AHEAD(7) demonstrate sustained weight loss with the inclusion of physical activity as part of the intervention. Data from observational and RCTs also indicate that physical activity is important in reducing cardiovascular events associated with T2DM(8–11). Total volume of activity, including duration and frequency are prominent in the recommendations for physical activity in the management of diabetes(12).

A challenge in developing and evaluating physical activity training interventions is obtaining an objective measure of physical activity, particularly those that can assess patterns of physical activity. Historically, large-scale clinical studies have relied on self-report questionnaires for physical activity assessment. These subjective instruments are limited by recall bias and difficulty in developing and obtaining an appropriate population specific instrument. Assessment of physical activity using an accelerometer is advantageous in that it is an objective measure that circumvents recall bias. Numerous studies have demonstrated these devices provide valid and relatively reliable estimates of physical activity patterns and activity energy expenditure in a wide variety of populations(13–16). However, as suggested by Masse(17), there is a clear lack of standards in accelerometer data reduction; clarification of methodological issues is required for appropriate data interpretation. Some of these issues include: 1) identifying registered time as an indicator of wear period in a day; 2) identifying minimal wear requirement for a useable day, a.k.a. wear time; 3) aggregating days of data; and 4) defining intensity and duration of bouts for physical activity patterns. To date, one of the largest uses of accelerometers to assess physical activity behavior has been from the 2003–2006 National Health and Nutritional Examination Survey (NHANES), which obtained at least 4 days of accelerometer data from nearly 4,900 participants.(18–20) Although NHANES publications described criteria used for determining wear time and times the device is worn, there is minimal justification provided for their approach(18, 21) and a lack of data on the implications of using alternate criteria.

The Look AHEAD study, which is a randomized controlled clinical trial investigating the impact of weight loss on the primary and secondary prevention of cardiovascular disease in obese adults with T2DM, included accelerometry to provide an objective assessment of physical activity as a sub-study in over 2,200 participants. These accelerometer data provide a unique opportunity to study the impact that different data reduction criteria have on the interpretation of physical activity behavior. We investigated time worn per day, minimal

wear time per day, number of days of available data, and use of a short break in an activity bout on physical activity patterns. The aim of this investigation was to examine the methodology for examining accelerometer data reduction for large cohort studies, and not to provide descriptive physical activity data in this cohort. These cross-sectional analyses are presented elsewhere.(22) Based on the role of physical activity in obesity management, the current analysis adds to our understanding for implementing and interpreting data from accelerometers.

Methods

Look AHEAD Trial Description

Look AHEAD is a multi-center clinical trial with its primary objective to examine, in overweight and obese volunteers with T2DM, the long-term effects of an intensive lifestyle intervention program designed to achieve and maintain weight loss by decreased caloric intake and increased physical activity compared to a control condition involving a program of diabetes support and education on cardiovascular morbidity and mortality. Specific details related to design and procedures for this trial have previously been described(23). A total of 5,145 participants were recruited across 16 clinical sites in the United States. A total of 8 sites were selected to be a part of the accelerometer sub-study, which were used for the present analysis, and each site included these data collection procedures in their protocol. The number and location of sites chosen from the Look AHEAD study was determined by the executive committee for Look AHEAD. Because of the cost of these data, it was prohibitive to include participants across all clinic sites in the study.

In total, baseline data from 2,240 participants were examined, with 2,177 files being useable in the analysis procedures. Participants provided written consent approved by the local Institutional Review Boards prior to participation.

Accelerometry Methodology

The RT3 triaxial accelerometer (StayHealthy®, Monrovia, CA, USA) was selected for use in the Look AHEAD Trial. The RT3 unit is the size of a pager and is worn on the waist. Participants were instructed to wear the device at the approximate location on the anterior superior iliac spine during the waking hours for a period of 7 consecutive days. Participants were oriented to procedures for wearing the accelerometer and provided a handout that included information on the proper placement of the accelerometer on the body, dates (days) that the accelerometer should be worn, procedures to follow should there be trouble with the operation of the accelerometer, and procedures for returning the accelerometer. If desired, participants could request and were provided with a belt for attaching the unit when wearing certain clothing that did not allow a traditional belt to be worn or did not have a waistband (i.e., certain dress styles).

The RT3 accelerometer was programmed to collect data at one-minute intervals. Prior to the participant wearing the accelerometer, the device was initialized by clinic staff. During the seven day period of data collection, participants were instructed not to alter their typical pattern of physical activity. A diary was provided for the participant to record when they

wore the accelerometer. The diary was used as a tool by the clinics to validate and record the use of the accelerometer. Upon return of the accelerometer, an initial visual inspection of the diary was performed to confirm that the accelerometer was worn at least five days within the seven day period. If the diary showed that participants reported wearing the unit for fewer than five days, participants were asked to wear the accelerometer for an additional seven day period. Recent work with activity counts from RT3's show that they have good intra-unit reliability(24) with a coefficient of variation of <1.81%. They have also been shown to have a coefficient of variation between units ranging from 9.5–34.7%(24) with a intraclass correlation between accelerometers of 0.75 with 95% confidence interval of 0.46–0.95)(25). For the Look AHEAD study, clinics did not perform routine calibration. However, units were serviced regularly by the manufacturer throughout the study.

Training and Certification of Staff Across Sites—Staff from each of the 8 clinics participated in centralized training involving the operation of the accelerometer, participant instructions, and data transfer to the Coordinating Center. In addition, staff completed a certification process prior to data collection for this study, with recertification occurring annually throughout the study.

Central Quality Control—Accelerometry data files were uploaded to the Look AHEAD data coordinating center (Wake Forest University) via the study website, with a tiered approach for data quality control implemented. For a qualitative and validity review, a graph of the minute-by-minute activity was generated at the coordinating center. Partial days at the beginning and the end of the 7-day wearing period were excluded from subsequent analyses. Each individual graph was visually inspected and was reviewed and graded as being "valid", "invalid", or "contains no data". The following criteria were used to determine if the data file was "valid":

1. Presence of activity energy expenditure, as depicted by vertical lines, over the course of the wear period;
2. Presence of episodes of activity interspersed with sustained periods of zero activity, indicating the unit was removed for sleeping;
3. Weekly activity energy expenditure was within limits for a varied population (between 200 and 15,000 kcals).

Data files not meeting these criteria were considered "invalid" and were not used in subsequent summaries. Assignment of the "contains no data" grade usually occurred as a result of a malfunction with the unit, problem with the interface procedure between the RT3 unit and computer, or inability to generate a graph from the data file. For files graded as "invalid" or "contains no data" clinics attempted to recollect data on the participant according to standard procedures and resubmit for review again. These criteria provided an overview of the data as well as identifying extreme outliers. These were meant to be inclusive for data processing. This initial qualitative review of all files was performed by one investigator throughout the entire study duration (G.D. Miller).

Defining Criteria for Accelerometer Data Reduction

Computing Daily Wear Time—Registered time as an indicator of daily wear time, which is the length of time that an accelerometer is worn daily, was determined by subtracting "non-wear time" from total minutes possible in a day (1440 minutes). Within the literature different criteria have been used to determine periods of non-wear time throughout the day, with 20, 30, and 60 consecutive minutes without activity ("zero" counts on the accelerometer) used to identify these periods(26, 27). The sum of periods of non-wear time was the total daily non-wear time. Daily wear time was then computed by subtracting the total daily non-wear time from 1440 minutes.

Defining Valid Days Based on Wear Time—Based on the published literature, different criteria were applied to the data to define a valid day based on wear time of the accelerometer. These include the following:

- ≥10 hours per day of wear-time of the accelerometer(17)
- 80% of a standard day, with a standard day often defined as the length of time in which 70% of the study participants wore the monitor(17). Based on data for this study, a standard day was 13.18 hours, with 80% being 10.55 hours. Because this was similar to the ≥10 hour criteria defined above, approximately two hours below and above this value (8 and 12 hours) were established as 2 other criteria that could be used to define a valid day for evaluation in this study.

The analysis for computing daily wear time and defining valid days based on wear time was performed in a step-wise manner. The first criterion was to determine length of periods of non-wear time (20, 30, or 60 minutes). Once that value was determined, the number of hours required for a valid day was analyzed.

Defining Physical Activity Bouts—Physical activity intensity level was expressed in metabolic equivalents (METS) by dividing the estimated energy expenditure per minute by estimated resting energy expenditure per minute as computed using the proprietary software provided by StayHealthy®. Periods of moderate-to-vigorous intensity physical activity were defined as ≥3 METS and vigorous activity was defined as ≥6 METS. The criteria for adults for moderate-to-vigorous activity were recently established by the American College of Sports Medicine and the American Heart Association.(28) Activity bouts to describe physical activity patterns were defined as: ≥3 METS for ≥1 minute, ≥3 METS for ≥10 minutes, and ≥6 METS for ≥10 minutes. Additionally, based on the published cutoffs for activity counts by Rowland et al.,(29) in healthy adults, analysis was performed on the activity counts that were reported to coincide with the 3 METs and 6 METs criteria (984.0 and 2340.8, respectively).

It has been suggested that consideration be made for whether or not a short interruption is allowed during an exercise session(17). This real-life scenario is present when activity intensity goes below a defined criterion for a short period, and then returns to the previously defined level. Thus, an exercise bout may be achieved that otherwise would have been missed. For instance, an individual walks for 8 minutes at 3 METS; they come to a stoplight and wait 1 minute to cross the road. They continue walking for 12 additional minutes. This

could count as a single bout of moderate activity of 12 minutes or if the 1 minute interruption is allowed, it would count for a 21 minute bout of moderate activity. Similarly, others have examined allowing up to 2 minutes of interruption and to continue with the bout duration(20). Thus, bouts of activity were defined in three ways; that is, not allowing and allowing for a 1-minute and a 2-minute break in a bout of moderate or vigorous activity lasting at least 10 minutes.

Spurious data were defined as any one minute that exceeded 100% of the maximal exercise intensity as determined by the maximal graded exercise test (GXT) that was performed for each Look AHEAD participant(23, 30). For cases when the 100% was exceeded, data for that minute were capped at 100% of the maximal MET value and the adjusted value was used in the analyses.

Statistical Analysis

All analyses were performed using SAS version 9.1 (SAS Institute, Cary, NC). Three variables were chosen to characterize activity bouts and to compare various methods of data reduction: number of bouts per day meeting the moderate and vigorous intensity levels, duration of bout (in minutes), and intensity of bout (in METS). The variable – 'number of bouts per day' was computed as the average daily number of bouts and it was set to be 0 if a participant did not have any activity bouts that met the specific definition. Variables 'duration of bout' and 'intensity of bout' were defined only when a participant had at least one activity bout of interest and were set to be missing if the participant did not have the type of activity bout.

Results were presented as means ± standard deviations (SD) for continuous variables, while median and inter-quartile range (IQR) were presented for skewed data. For the definition of a valid day, we have examined nine different criteria: 8, 10, and 12 hour daily wear time using 20, 30, and 60 minutes non-wear time. The resulting sets of summary variables (one for each criterion) for every participant were treated as correlated measurements and were analyzed using mixed effects models (SAS/STAT® 9.1 User's Guide). Similarly, mixed effects models were used to examine differences in results using data for the first 4, 5, and 6 full days that met the minimal daily wear time, weekend days (Saturday and Sunday) versus weekdays, and bouts defined allowing no break versus allowing for a one-minute break in bouts.

Results

Approximately 85.3% (2,240 out of 2,627) of randomized participants at the clinics participating in this sub-study had accelerometer data files uploaded to the coordinating center at baseline. The most common reasons for missing files (n=387) were equipment failure (31.8%, n=123), participant refusal (22.5%, n=87), time/scheduling (7.0%, n=27), and other (38.8%, n=150). Not all clinics provided every participant the opportunity to participate in the study; this explanation fell within the "other" category. All uploaded files (n=2,240) were reviewed according to procedures developed for the initial review in data quality control procedures. Of this number, only 95 files (4.2%) were deemed to be invalid.

Participant characteristics were assessed between those with valid files vs. invalid files, and although age and gender were similar between the two, race did differ.

Baseline characteristics of participants with valid accelerometer files (n=2,177) are shown in Table 1. Mean age was 59.0 (SD=6.8) years, and most were female (57.3%) and white (73.0%). Mean BMI was 36.4 (SD=6.0) kg/m^2 with a maximal MET value of 7.1 (SD=1.9) as determined by a graded exercise stress test. Over 94% had metabolic syndrome and 86% were hypertensive.

Daily Wear Time

Identification of daily wear time was performed, and using these values, comparisons were made for physical activity patterns between 8, 10, and 12 hours of wear-time per day, with non-wear time computed using either 20, 30, or 60 minutes of continuous zero counts (Table 2). There were no statistically significant differences between the different methods used to define a day's minimal wear time for number, intensity or duration for a bout of activity ≥10 minute in duration for moderate (≥3 METs) or vigorous activity (≥6 METs) (Table 2). For our systematic approach, all subsequent analyses for data summary were performed on a single definition of daily wear time. Since our analysis for this cohort showed no differences in the bout criteria identified, we selected 10 hours with 30 minutes of continuous zero counts as the criteria for a useable day.

The number of minutes per day that exceeded at least 3 METs is presented in the bout criteria of ≥3 METs for ≥1 minute. This ranged from 26.5 to 28.1 minutes and signifies that the total time spent above 3 METs was less than 30 minutes a day, irrespective of the duration of the bout. This was the only significant effect of the different methods for wear period. In that these analyses were focused primarily on activity bouts of at least 10 minutes, this result did not factor into our decision of which method of daily wear to use.

As the wear time criteria changed across the 9 conditions (Table 2), the number of data files meeting the criteria differed for the moderate intensity ≥10 minute exercise bout from 1346 to 1433. Similar changes were seen for number of eligible data files for the vigorous exercise bout (398 to 449). In both cases, this amounted to ~5–10% drop in number of eligible files as the criteria became more stringent (greater number of hours per day required).

Number of Wear Days

Data were analyzed to determine whether there were differences in physical activity patterns assessing the first 4, 5, or 6 days that met the criteria of ≥10 hours of wear time as defined above. Results showed no significant differences between bouts per day, bout duration, or bout intensity when using the first 4, 5, or 6 days of data that met the ≥10 hours of wear-time criterion (Table 3); data for activity counts are also shown. For an activity bout meeting ≥984 counts (equivalent to ≥3 METs based on cutoffs by Rowlands et al(29) for the RT3 accelerometer) for ≥10 minutes, the average intensity was ~1550 counts for assessing the first 4, 5, or 6 days of data collection. For the high intensity activity bout of ≥2340 counts (≥6 METs), the values were ~3100 counts for all three conditions.

Changes in eligible data files across the different criteria for day number were apparent for moderate intensity activity with a sample size of 1099 for using the first 6 full days compared to 1204 for using the first 4 full days, an ~10% reduction. Number of data files meeting the vigorous activity criterion ranged from 383 to 353, an ~8% decrease.

Weekend vs. Weekdays

Comparison of data from weekend days versus weekdays is presented in Table 4. The bout duration for ≥3 METs for ≥10 minutes was higher on weekends vs. week days by about 1 minute. There was a significant difference for average bout intensity for vigorous activity with a bout of vigorous activity during the weekend occurring at a higher MET level (7.65 vs. 7.44 for weekends vs. week days). However, for each of these significant differences observed, the effect size was small (0.04 for bout duration of moderate intensity exercise and 0.04 for bout intensity for a vigorous exercise bout). Using activity counts, the difference in number of counts per bout was higher for week days vs. weekend days achieved statistical significance at p=0.048. No difference was observed for the more vigorous activity bout.

There were large differences in the number of files that had eligible days during the weekend compared to week days. For moderate activity, the sample size was 1192 for week days vs. 797 for weekend days, a 33% difference. Similarly, for vigorous activity, sample size was 625 for week days and 361 for weekend days, a 42% discrepancy.

Further analysis was performed to determine the differences in activity patterns using no weekend days, 1 weekend day, and 2 weekend days for the first 4 full days and the first 5 full days of data. Analyses performed incorporating either 1 or 2 weekend days did not change activity patterns compared to having no weekend days in data collected for either the first 4 or 5 full days (data not shown).

No time interruption (no breaks) versus 1 and 2 minute time interruption (breaks)

The number of bouts for ≥10-minutes and ≥3 METS was greater when a 1 or 2 minute interruption was allowed (0.5, 0.6, and 0.6 for no breaks and 1 and 2 minute breaks, respectively) (Table 5). For activity bouts defined as ≥3 METs for ≥10 minutes, the intensity per bout differed for the 3 criteria with bouts allowing no breaks having the highest intensity. This effect was also similar for vigorous activity.

Inclusion of the 1 or 2 minute interruption provided a larger sample size for both the moderate and vigorous intensity activity bouts. For moderate intensity, there was nearly a 15% drop in eligible files (1630 for 2 minute interruption vs. 1402 for no interruption). For vigorous intensity, the decrease in sample size was 16% (525 for 2 minute interruption vs. 441 for no interruption).

Discussion

Look AHEAD has the largest accelerometry data set available from a randomized controlled clinical trial of overweight and obese adults with T2DM and will provide ample opportunities to study the unique role that physical activity plays in weight management and

subsequent clinical outcomes. Whereas our previous work with the Look AHEAD cohort described the baseline physical activity patterns(22), the aim of the current study was to conduct a systematic analysis for establishing criteria for data reduction and how these outcomes can be interpreted. These results on the specific outcomes are not intended to be generalizable across sub-samples of the population, but instead this study highlights the various criteria to be considered when examining accelerometer data. The actual criteria utilized and the results obtained for this population is not likely ideal or the "gold standard" across all populations. The authors acknowledge that the effects or lack of effects of varying data reduction procedures employed in this analysis may only apply to those individuals who have similar characteristics and activity patterns as observed in our sample. For example, the relatively sedentary behaviors of our population shown in the small number of activity bouts at the different intensities may be influencing the findings on how to best analyze the data.

The current data provide an important and innovative contribution to Look AHEAD and to the field of obesity research in general. As the cost of accelerometers has decreased, and their use in large epidemiological studies has risen, it has become necessary to bring attention to issues related to the processing of these data. While the use of an objective measure of physical activity has advantages over self-report, it is still fraught with challenges and concerns(31). Since most accelerometer protocols request the user to wear it only during waking hours, determining the length of time during the day the unit is actually being worn can be a challenge, especially for a large and diverse population. If the activity for any time period is zero, then it is not known if the unit was not being worn or if there was no activity. Studies have used sustained periods of zero counts (20, 30, 60 minutes) to try to assess this. Thus, obtaining the wear time for each individual to assess if they achieved a daily minimal wear time in order for it to be considered an acceptable day for data analysis is an area of debate(31). Part of this challenge may stem from the difficulty in determining if the zero counts on the accelerometer reflect non-wear time, i.e. the individual removed the unit, or it was due simply due to physical inactivity. However, multi-sensor activity tracking devices, such as SenseWear Armband®, are able to measure skin and/or body temperature along with physical activity(32). This can be used to ease the burden in determining actual wear time. Masse and colleagues computed non-wear time using different criteria (20 to 60 minutes of consecutive zero counts), and used these data to compute wear time of the accelerometer(17). Their analysis of data showed that when non-wear time was computed using a greater duration of consecutive zeros (60 minutes vs. 20 minutes), the duration of activity bouts computed from wear-time was shorter. In contrast, we found no difference in duration of activity bouts, number of activity bouts per day, or intensity of the activity bouts when non-wear time was computed using either 20, 30 or 60 consecutive minutes of zero counts on the accelerometer (see Table 2). This suggests study cohorts and their activity levels may influence the criteria to choose for data reduction. The cohort in the current work was older and more diseased, as well as less active than that used by Masse and colleagues(17). Considering current findings and previous research in this area, data reduction criteria used in accelerometry assessment warrants continued attention.

Previous reports in the literature have also shown a range in wear time of 1 to 16 hours per day for data to be used for analysis of physical activity(27, 33, 34). Furthermore, a method

that has been proposed is that minimal wear time should be defined as 80% of a standard day, with a standard day being the length of time in which 70% of the study participants wore the monitor, also known as the 80/70 rule(17). Young et al., found in a cohort of over 1,600 obese and overweight adults that 82% of the participants wore their accelerometers for at least 10 hours per day(35). For the current study, the 80/70 rule reflects approximately 10 hours per day, which is consistent with the criteria commonly reported in the adult literature(17). Our study showed no difference in activity patterns when a usable day was defined as 8, 10, or 12 hours of wear-time (see Table 2). Moreover, there were negligible differences in the number of subjects defined as meeting these criteria, with only about 30 individuals being dropped as the criteria became more stringent (2119 vs. 2150). This suggests that when our participants were instructed to wear the accelerometer for all waking hours, defining usable days as any days that the accelerometer is worn for ≥8, 10, or 12 hours appears to provide reliable results with regard to physical activity patterns. However, this result may be due in part to the low level of physical activity in this cohort. One technique that has been used to account for wearing the unit for different durations in a day has been to normalize activity patterns for a set duration, commonly a 12-hour day(35). This allows for comparisons of activity for the same time interval; however, it also assumes that each time frame of the day has similar activity patterns. That is, the time the unit is not worn is identical in activity to the time when the unit is worn.

The RT3 is to be worn at the waist attached to a belt or waistband of clothes. However, some devices are gaining popularity because they can be worn on the wrist similar to a watch or bracelet and do not require special clothing. These have been validated and shown to provide estimates of physical activity patterns and energy expenditure(36). Some accelerometers are also waterproof and can be worn 24 hours a day without needing to be removed and transferred to other clothes. Taken together, technology has advanced to ease their wearing, lessen burden and improve activity measurements in water activities, thus facilitating long-term recordings.

Allowing a 1 or 2 minute interruption within a bout of physical activity increased the number and the average intensity of moderate intensity bouts lasting at least 10 minutes. This supports findings by Masse et al. who showed a significant decrease in the number of moderate to vigorous bouts of physical activity with no interruption compared to a 1 or 2 minute break(17). It is reasonable to consider allowing this interruption since a drop in activity ensues when stopping to take a drink or waiting for a traffic light to change. Since standard accelerometer software is not programmed to make such adjustments, with a large sample size or a high number of days being monitored, data processing programs need to be developed to make it practical and manageable to process accelerometer data files to account for these breaks.

Operationally defining minimal wear time for a day and minimum number of days the unit needs to be worn has important implications for compliance and overall study costs. The burden to the participant must also be considered as wearing the unit longer each day and for more days is demanding and cumbersome. Previous work in healthy adults (age = 45 years) showed that at least 3–4 days of wearing are needed to determine activity patterns(37). Others had observed that reliable results for adults were apparent in as few as 3 days(37);

however, up to 12 days of wear time was needed to achieve high reliability in other studies(38). A wider range for number of days has been demonstrated for children, varying from 4 to 9 days(39). Our current findings indicate that increasing the minimum number of wear days from 4, to 5, to 6 did not result in significantly different physical activity patterns in our population (see Table 3).

It is not uncommon to observe differences between weekend and week days with regard to physical activity patterns(35, 37). Since individuals typically have different work and leisure routines between weekend and week days, it would be reasonable for patterns and energy expenditure from physical activity to differ among the days. This current study showed longer bout durations (about 1 minute longer for each intensity level) for weekend days versus weekdays for bouts of ≥3 METs for ≥10 minutes or ≥6 METs for ≥10 minutes (see Table 4). Furthermore, Matthews et al. reported that physical inactivity, as determined by total daily counts from accelerometer wear, was lower on weekend days compared to weekdays(37), with a difference of about 30–45 minutes per day between weekend and weekdays on time spent in physical inactivity.

Altering the criteria for the various parameters involved in data reduction of accelerometer files may not only influence results for physical activity patterns, but the number of eligible files analyzed, i.e. sample size, can differ. Whereas some differences were minimal (~5%), other criteria showed a more dramatic effect (> 15%). Depending on the study aims, this could influence statistical power, or require additional resources for increasing the number of participants to be studied.

In light of our findings and earlier work by others, we recommend that future studies systematically make considerations for data reduction prior to their analysis. Based on each study's specific aims, deliberations should include defining wear time, minimal daily wear time, number of days required, use of weekend and week days, and whether to allow 1 or 2 minute interruptions for determining bouts of exercise. Furthermore, the age, health status, activity level, and other factors may influence the data reduction criteria being used. Processing of physical activity data should specify the characteristics of activity bouts, including the length and intensity (ex. ≥ 10 minutes; ≥ 3 METS) for describing physical activity and their patterns. Acceptance for the specific criteria used in data reduction (ex. minimum of 4 vs. 5 vs. 6 days of data) should consider the change in sample size and data available for analysis, impact and interpretation of these values, feasibility of achieving the criteria, and participant burden. Stringent requirements may be desired, such as requiring the wear time to be 16 hours per day; however, these may present undue burden to the participant with little to no impact on the results. Whereas it is recognized that not all studies that use accelerometers have the resources to systematically evaluate the data as suggested, researchers should be aware of the data limitations, and these need to be addressed in the publication.

It is recognized that the current participants could be considered homogenous in that they are all overweight or obese, are sedentary, and have type 2 diabetes. Their low physical activity suggests there is less variability as they have few bouts of moderate and vigorous activity, the intensity of the bouts is low, and the length of their exercise bouts is short as

compared to a non-obese group. Although the lower variability may have impacted the results, this does not diminish from the purpose of the paper being to establish a systematic procedure for data reduction with accelerometry data. The findings from the analysis may also be influenced by not having standardized calibration for the units among the various clinic sites. In two previous studies(24, 25) that examined the intra- and inter-unit variability of the RT3s, they found good intra-unit reliability for activity counts, but there was concern regarding inter-unit reliability. Krasnoff et al. observed an inter-unit coefficient of variability range of 9.5–37.4%(24), whereas Reneman et al. reported an intraclass correlation of 0.75 with a 95% confidence interval of 0.46–0.95(25). Currently, no studies have examined reliability with these devices using energy expenditure or METS outcomes. Although the lack of calibration is a critical issue in the data, it is likely that is not as significant for this work as the purpose of the current analysis was to create a systematic approach for data reduction,

The purpose of this study was to demonstrate a systematic analysis for establishing criteria for data reduction and how these outcomes can be interpreted. This was performed by comparing the effect of using various criteria to define periods of physical activity from accelerometry data in a large sample of obese and overweight subjects with T2DM at baseline prior to randomization into a clinical trial. Reviews of previous work, along with the results from our study demonstrate that interpreting findings can be influenced by how criteria for defining key issues in data reduction of accelerometer data are made. The specific criteria utilized may be dependent on characteristics of the population, including age, gender, and activity level, among others. Given the lack of standards accelerometry data reduction(17), these analyses demonstrate how different analysis criteria can be employed to test the best methods for analyzing and interpreting accelerometer data. In the absence of standardized procedures, data analysis for each study needs to tailored for the group being studied, as well as the specific purpose of the study. Moreover, this may provide an opportunity to standardize the criteria used for accelerometry data to define physical activity across studies and study populations.

These findings are critical to the literature in that they were evolved from a large cohort of overweight men and women in the United States with T2DM, a much understudied population with regards to physical activity behaviors. As the number of researchers studying physical activity in obese populations with T2DM continues to grow, our results will be valuable for their decision making when it comes to including accelerometry in large-scale clinical trials and the processing of these accelerometer data. Finally, the results of this paper will provide guidance and be used as a major reference source for publications of many subsequent investigations from Look AHEAD that involve the accelerometry data.

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Table 1

Baseline Characteristics of Accelerometry Participants With Valid Baseline Files (n=2,177).

Variable	Means ± S.D. or n (%)
Age* (years)	59.0 ± 6.8
Body mass index* (kg/m2)	36.4 ± 6.0
Weight* (kg)	102.9 ± 19.2
Waist Circumference* (cm)	115.4 ± 14.5
Cardiorespiratory Fitness* (Maximal METs)	7.1 ± 1.9
Duration of diabetes* (years)	6.9 ± 6.5
Sex+ (Female)	1228 (57.3%)
Race Ethnicity+	
African American / Black (not Hispanic)	401 (18.7%)
American Indian / Native American / Alaskan Native	12 (0.6%)
Asian/Pacific Islander	13 (0.6%)
White	1563 (73.0%)
Hispanic	107 (5.0%)
Other/Mixed	45 (2.1%)
Body mass index+	
25.0 – < 30.0 kg/m^2	280 (13.1%)
≥ 30.0 – < 35.0 kg/m^2	719 (33.6%)
≥ 35.0 – < 40.0 kg/m^2	619 (28.4%)
≥ 40.0 kg/m^2	525 (24.5%)
History of CVD+	329 (15.3%)
Hypertension+	1853 (86.4%)

* Data presented are mean ± S.D.

+ Data presented are sample size n and percent.

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Table 2

Methods comparison of registered time as an indicator of wear period.

Numbers in each cell: Mean ± S.D. (Sample Size) Median (Interquartile Range)	**8 Hour, 20 Min. without Activity**	**8 Hour, 30 Min. without Activity**	**8 Hour, 60 Min. without Activity**	**10 Hour, 20 Min. without Activity**	**10 Hour, 30 Min. without Activity**	**10 Hour, 60 Min. without Activity**	**12 Hour, 20 Min. without Activity**	**12 Hour, 30 Min. without Activity**	**12 Hour, 60 Min. without Activity**	**P-value**
≥3 METS for ≥1 minute										
Number of Bouts per Day	27.0 ± 13.8 (N=2148) 24.8 (17.2 – 34.8)	26.8 ± 13.8 (N=2149) 24.6 (17.0 – 34.5)	26.5 ± 13.6 (N=2150) 24.2 (16.6 – 34.0)	27.4 ± 14.2 (N=2145) 25.1 (17.4 – 35.2)	27.2 ± 14.0 (N=2145) 25.0 (17.3 – 35.0)	26.8 ± 13.9 (N=2149) 24.5 (17.0 – 34.5)	28.1 ± 14.7 (N=2119) 25.8 (17.7 – 35.8)	27.9 ± 14.6 (N=2130) 25.5 (17.5 – 35.6)	27.4 ± 14.3 (N=2140) 25.0 (17.3 – 35.2)	0.0010
Bout Duration (minutes)	2.0 ± 0.8 (N=2146) 1.8 (1.6 – 2.2)	2.0 ± 0.8 (N=2147) 1.8 (1.6 – 2.2)	2.0 ± 0.8 (N=2148) 1.8 (1.6 – 2.2)	2.0 ± 0.8 (N=2143) 1.8 (1.5 – 2.2)	2.0 ± 0.8 (N=2143) 1.8 (1.5 – 2.2)	2.0 ± 0.8 (N=2147) 1.8 (1.5 – 2.2)	2.0 ± 0.8 (N=2116) 1.8 (1.5 – 2.2)	2.0 ± 0.9 (N=2126) 1.8 (1.5 – 2.2)	2.0 ± 0.9 (N=2137) 1.8 (1.5 – 2.2)	0.9994
Bout Intensity (METS)	3.9 ± 0.3 (N=2146) 3.8 (3.7 – 4.0)	3.9 ± 0.3 (N=2147) 3.8 (3.7 – 4.0)	3.9 ± 0.3 (N=2148) 3.8 (3.7 – 4.0)	3.9 ± 0.3 (N=2143) 3.8 (3.7 – 4.0)	3.9 ± 0.3 (N=2143) 3.8 (3.7 – 4.0)	3.9 ± 0.3 (N=2147) 3.8 (3.7 – 4.0)	3.9 ± 0.3 (N=2116) 3.8 (3.7 – 4.0)	3.9 ± 0.3 (N=2126) 3.8 (3.7 – 4.0)	3.9 ± 0.3 (N=2137) 3.8 (3.7 – 4.0)	1.0000
≥3 METS for ≥ 10 minutes										
Number of Bouts per Day	0.5 ± 0.8 (N=2148) 0.3 (0.0 – 0.7)	0.5 ± 0.8 (N=2149) 0.3 (0.0 – 0.7)	0.5 ± 0.8 (N=2150) 0.3 (0.0 – 0.7)	0.5 ± 0.8 (N=2145) 0.3 (0.0 – 0.7)	0.5 ± 0.8 (N=2145) 0.3 (0.0 – 0.7)	0.5 ± 0.8 (N=2149) 0.3 (0.0 – 0.7)	0.5 ± 0.8 (N=2119) 0.3 (0.0 – 0.8)	0.5 ± 0.8 (N=2130) 0.3 (0.0 – 0.8)	0.5 ± 0.8 (N=2140) 0.3 (0.0 – 0.8)	0.9990
Bout Duration (minutes)	19.7 ± 9.6 (N=1418) 16.6 (13.0 – 23.4)	19.6 ± 9.6 (N=1425) 16.6 (13.0 – 23.3)	19.6 ± 9.6 (N=1433) 16.6 (13.0 – 23.2)	19.7 ± 9.6 (N=1394) 16.6 (13.0 – 23.4)	19.7 ± 9.6 (N=1402) 16.7 (13.0 – 23.4)	19.7 ± 9.6 (N=1417) 16.6 (13.0 – 23.3)	19.8 ± 9.9 (N=1325) 16.5 (13.0 – 23.6)	19.8 ± 9.9 (N=1348) 16.5 (13.0 – 23.7)	19.8 ± 9.8 (N=1381) 16.5 (13.0 – 23.4)	0.9999
Bout Intensity (METS)	5.2 ± 0.9 (N=1418) 5.1 (4.5 – 5.7)	5.2 ± 0.9 (N=1425) 5.1 (4.5 – 5.7)	5.2 ± 0.9 (N=1433) 5.1 (4.5 – 5.7)	5.2 ± 0.9 (N=1394) 5.1 (4.5 – 5.7)	5.2 ± 0.9 (N=1402) 5.1 (4.5 – 5.7)	5.2 ± 0.9 (N=1417) 5.1 (4.5 – 5.7)	5.2 ± 1.0 (N=1325) 5.1 (4.5 – 5.7)	5.2 ± 0.9 (N=1348) 5.1 (4.5 – 5.7)	5.2 ± 0.9 (N=1381) 5.1 (4.5 – 5.7)	1.0000
≥6 METS for ≥10 minutes										
Number of Bouts per Day	0.1 ± 0.3 (N=2148) 0.0 (0.0 – 0.0)	0.1 ± 0.3 (N=2149) 0.0 (0.0 – 0.0)	0.1 ± 0.3 (N=2150) 0.0 (0.0 – 0.0)	0.1 ± 0.3 (N=2145) 0.0 (0.0 – 0.0)	0.1 ± 0.3 (N=2145) 0.0 (0.0 – 0.0)	0.1 ± 0.3 (N=2149) 0.0 (0.0 – 0.0)	0.1 ± 0.3 (N=2119) 0.0 (0.0 – 0.0)	0.1 ± 0.3 (N=2130) 0.0 (0.0 – 0.0)	0.1 ± 0.3 (N=2140) 0.0 (0.0 – 0.0)	1.0000
Bout Duration (minutes)	18.6 ± 8.7 (N=444) 16.0 (12.6 – 21.7)	18.6 ± 8.7 (N=445) 16.0 (12.7 – 21.7)	18.6 ± 8.6 (N=449) 16.0 (12.5 – 21.5)	18.5 ± 8.6 (N=437) 16.0 (12.7 – 21.3)	18.5 ± 8.6 (N=441) 16.0 (12.5 – 21.2)	18.5 ± 8.6 (N=445) 16.0 (12.5 – 21.3)	18.8 ± 8.8 (N=398) 16.0 (12.7 – 21.7)	18.7 ± 9.0 (N=413) 16.0 (12.5 – 21.3)	18.6 ± 9.0 (N=428) 16.0 (12.3 – 21.6)	1.0000
Bout Intensity (METS)	7.5 ± 1.0 (N=444) 7.2 (6.7 – 8.1)	7.5 ± 1.0 (N=445) 7.2 (6.7 – 8.1)	7.5 ± 1.0 (N=449) 7.2 (6.7 – 8.0)	7.5 ± 1.0 (N=437) 7.2 (6.7 – 8.0)	7.5 ± 1.0 (N=441) 7.2 (6.7 – 8.0)	7.5 ± 1.0 (N=445) 7.2 (6.7 – 8.0)	7.5 ± 1.0 (N=398) 7.2 (6.7 – 8.0)	7.4 ± 1.0 (N=413) 7.2 (6.7 – 8.0)	7.4 ± 1.0 (N=428) 7.2 (6.7 – 8.0)	0.9999

* The *P*-values were obtained from the type III test for the fixed effect of criteria being used.

Use of “Wear Time” in column headings is used for brevity to indicate “registered time as an indicator of wear period”.

Sample size changes for bout duration and intensity for the 2 categories as compared to number of bouts since all participants' data are included in the number of bouts, but only those that met the specific criteria (ex. ≥6 METS for ≥ 10 minutes) are included in the bout duration and intensity. For each specific bout definition, sample size is the same for bout duration and intensity, which signifies the number of participants that met that criterion.

Table 3

Comparison of 4, 5, and 6 full Days for Physical Activity Patterns.

Numbers in each cell: Mean ± S.D. (Sample Size) Median (Interquartile range)	**First 4 Full Days**	**First 5 Full Days**	**First 6 Full Days**	**P-value***
Criteria to Define an Activity Bout				
≥3 METS for ≥1 minute				
Number of Bouts per Day	27.6 ± 14.5 (N=2066) 25.0 (17.3 – 35.5)	27.4 ± 14.2 (N=1962) 25.1 (17.0 – 35.0)	27.4 ± 13.9 (N=1635) 25.2 (17.2 – 35.0)	0.8520
Bout Duration (minutes)	2.0 ± 0.8 (N=2064) 1.8 (1.5 – 2.2)	2.0 ± 0.8 (N=1961) 1.8 (1.5 – 2.3)	2.0 ± 0.8 (N=1634) 1.8 (1.6 – 2.3)	0.7446
Bout Intensity (METS)	3.9 ± 0.3 (N=2064) 3.8 (3.7 – 4.0)	3.9 ± 0.3 (N=1961) 3.8 (3.7 – 4.0)	3.9 ± 0.3 (N=1634) 3.8 (3.7 – 4.0)	0.9509
≥3 METS (≥984.0 counts) for ≥10 minutes				
Number of Bouts per Day	0.5 ± 0.8 (N=2066) 0.3 (0.0 – 0.8)	0.5 ± 0.8 (N=1962) 0.2 (0.0 – 0.8)	0.5 ± 0.8 (N=1635) 0.3 (0.0 – 0.8)	0.8739
Bout Duration (minutes)	20.3 ± 10.9 (N=1204) 16.9 (13.0 – 24.0)	19.9 ± 10.2 (N=1232) 16.6 (13.0 – 23.5)	19.8 ± 9.5 (N=1099) 16.7 (13.0 – 23.6)	0.5360
Bout Intensity (METS)	5.2 ± 1.0 (N=1204) 5.1 (4.5 – 5.8)	5.2 ± 1.0 (N=1232) 5.1 (4.5 – 5.7)	5.2 ± 0.9 (N=1099) 5.1 (4.5 – 5.7)	0.8264
Bout Intensity (counts)	1546.6 ± 362.6 (N=2097) 1455.0 (1317.1, 1662.5)	1552.4 ± 356.9 (N=2103) 1464.9 (1322.3, 1669.8)	1554.6 ± 343.7 (N=2109) 1466.0 (1326.9, 1676.4)	0.7489
≥6 METS (≥2340.8 counts) for ≥10 minutes				
Number of Bouts per Day	0.1 ± 0.3 (N=2066) 0.0 (0.0 – 0.0)	0.1 ± 0.3 (N=1962) 0.0 (0.0 – 0.0)	0.1 ± 0.3 (N=1635) 0.0 (0.0 – 0.0)	0.8481
Bout Duration (minutes)	19.1 ± 10.0 (N=357) 16.0 (12.0 – 22.5)	18.9 ± 9.0 (N=383) 16.0 (12.7 – 22.8)	18.7 ± 8.8 (N=353) 16.0 (13.0 – 21.7)	0.8637
Bout Intensity (METS)	7.5 ± 1.0 (N=357) 7.3 (6.8 – 8.2)	7.5 ± 1.0 (N=383) 7.3 (6.8 – 8.2)	7.5 ± 1.0 (N=353) 7.3 (6.8 – 8.1)	0.9491
Bout Intensity (counts)	3127.0 ± 821.7 (N=1645) 2978.3 (2687.4, 3370.8)	3143.3 ± 802.0 (N=1714) 3004.1 (2724.1, 3385.7)	3149.5 ± 799.8 (N=1771) 3013.1 (2734.4, 3392.8)	0.7053

* The *P*-values were obtained from the type III test for the fixed effect of number of full days.

Sample size changes for bout duration and intensity for the 3 categories of bout criteria as compared to number of bouts since all participants' data are included in the number of bouts, but only those that met the specific criteria (ex. ≥6 METS for ≥10 minutes) are included in the bout duration and intensity. For each specific bout definition, sample size is the same for bout duration and intensity, which signifies the number of participants that met that criterion.

Table 4

Comparison of Weekends vs. Week Days for Physical Activity Patterns.

Numbers in each cell: **Mean ± S.D. (Sample Size)** **Median (Interquartile range)**	**Weekends (Saturday and Sunday)**	**Week Days (Monday – Friday)**	**P-value***
Criteria to Define an Activity Bout			
≥3 METS for ≥1 minute			
Number of Bouts per Day	25.45 ± 15.61 (N=2055) 22.50 (14.00 – 34.00)	27.99 ± 14.97 (N=2141) 25.40 (17.25 – 35.75)	<.0001
Bout Duration (minutes)	2.00 ± 1.03 (N=2046) 1.72 (1.42 – 2.22)	2.02 ± 0.88 (N=2139) 1.79 (1.52 – 2.25)	0.4446
Bout Intensity (METS)	3.86 ± 0.32 (N=2046) 3.80 (3.64 – 4.00)	3.89 ± 0.28 (N=2139) 3.84 (3.70 – 4.02)	0.0012
≥3 METS (≥984.0 counts) for ≥10 minutes			
Number of Bouts per Day	0.50 ± 0.94 (N=2055) 0.00 (0.00 – 0.50)	0.53 ± 0.88 (N=2141) 0.25 (0.00 – 0.75)	0.2573
Bout Duration (minutes)	21.03 ± 12.62 (N=800) 16.50 (13.00 – 24.71)	19.95 ± 10.21 (N=1241) 17.00 (12.80 – 23.78)	0.0343
Bout Intensity (METS)	5.27 ± 1.13 (N=800) 5.05 (4.45 – 5.88)	5.23 ± 0.98 (N=1241) 5.17 (4.49 – 5.78)	0.4694
Bout Intensity (counts)	1521.8 ± 477.9 (N=1992) 1401.7 (1265.0, 1638.1) 1521.8 (9.4)	1548.0 ± 350.8 (N=2104) 1462.7 (1319.9, 1670.6) 1548.0 (9.1)	0.0448
≥6 METS (≥2340.8 counts) for ≥10 minutes			
Number of Bouts per Day	0.09 ± 0.40 (N=2055) 0.00 (0.00 – 0.00)	0.10 ± 0.31 (N=2141) 0.00 (0.00 – 0.00)	0.6573
Bout Duration (minutes)	19.90 ± 10.29 (N=196) 17.00 (12.00 – 23.83)	18.76 ± 8.90 (N=380) 16.00 (12.42 – 21.33)	0.1691
Bout Intensity (METS)	7.65 ± 1.01 (N=196) 7.44 (6.94 – 8.27)	7.44 ± 0.98 (N=380) 7.21 (6.69 – 8.03)	0.0139
Bout Intensity (counts)	3137.7.4 ± 741.3 (N=1185) 2962.8 (2655.4, 3408.3) 3137.7 (23.2)	3133.3 ± 837.6 (N=1690) 2981.1 (2706.4, 3352.8) 3133.3 (19.4)	0.8865

* The *P*-values were obtained from the type III test for the fixed effect of the indicator for weekends.

Sample size changes for bout duration and intensity for the 3 categories as compared to number of bouts since all participants' data are included in the number of bouts, but only those that met the specific criteria (ex. ≥6 METS for ≥10 minutes) are included in the bout duration and intensity. For each specific bout definition, sample size is the same for bout duration and intensity, which signifies the number of participants that met that criterion.

Table 5

Comparison of One Minute Break, Two Minute Break, and No Breaks in Physical Activity Patterns

Numbers in each cell: Mean ± S.D. (Sample Size) Median (Interquartile range)	**Continuous Activity Bouts that Met the Activity Bout Criteria**	**Non-Continuous Activity Bouts Allowing a 1-minute Interruption to Meet the Activity Bout Criteria**	**Non-Continuous Activity Bouts Allowing a 2-minute Interruption to Meet the Activity Bout Criteria**	**P-value**
Criteria to Define an Activity Bout				
≥3 METS for ≥1 minute				
Number of Bouts per Day	27.2 ± 14.0 (N=2145) 25.0 (17.3 – 35.0)	25.1 ± 13.2 (N=2151) 23.0 (15.7 – 32.4)	20.0 ± 9.4 (N=2151) 18.7 (13.1 – 25.4)	<.0001
Bout Duration (minutes)	2.0 ± 0.8 (N=2143) 1.8 (1.5 – 2.2)	2.1 ± 0.9 (N=2148) 1.8 (1.6 – 2.3)	2.5 ± 1.1 (N=2148) 2.3 (1.9 – 2.9)	<.0001
Bout Intensity (METS)	3.9 ± 0.3 (N=2143) 3.8 (3.7 – 4.0)	3.9 ± 0.3 (N=2148) 3.8 (3.7 – 4.0)	3.8 ± 0.2 (N=2148) 3.7 (3.6 – 3.9)	<.0001
≥3 METS for ≥10 minutes				
Number of Bouts per Day	0.5 ± 0.8 (N=2145) 0.3 (0.0 – 0.7)	0.6 ± 0.8 (N=2151) 0.3 (0.0 – 0.8)	0.6 ± 0.9 (N=2151) 0.3 (0.1 – 0.9)	<.0001
Bout Duration (minutes)	19.7 ± 9.6 (N=1402) 16.7 (13.0 – 23.4)	19.5 ± 9.3 (N=1574) 16.7 (13.0 – 22.8)	19.3 ± 9.2 (N=1630) 16.5 (13.0 – 22.6)	0.5896
Bout Intensity (METS)	5.2 ± 0.9 (N=1402) 5.1 (4.5 – 5.7)	4.9 ± 0.9 (N=1574) 4.8 (4.2 – 5.4)	4.8 ± 0.9 (N=1630) 4.7 (4.1 – 5.3)	<.0001
≥6 METS for ≥10 minutes				
Number of Bouts per Day	0.1 ± 0.3 (N=2145) 0.0 (0.0 – 0.0)	0.1 ± 0.3 (N=2151) 0.0 (0.0 – 0.0)	0.1 ± 0.3 (N=2151) 0.0 (0.0 – 0.0)	0.3337
Bout Duration (minutes)	18.5 ± 8.6 (N=441) 16.0 (12.5 – 21.2)	19.2 ± 9.2 (N=508) 16.0 (13.0 – 23.0)	19.5 ± 9.5 (N=525) 16.0 (13.0 – 23.0)	0.2495
Bout Intensity (METS)	7.5 ± 1.0 (N=441) 7.2 (6.7 – 8.0)	7.3 ± 0.9 (N=508) 7.1 (6.6 – 7.8)	7.2 ± 0.9 (N=525) 7.1 (6.6 – 7.7)	0.0017

* The *P*-values were obtained from the type III test for the fixed effect of the indicator for defining continuous bouts without 1-minute break.

Sample size changes for bout duration and intensity as compared to number of bouts since all participants' data are included in the number of bouts, but only those that met the specific criteria (ex. ≥6 METS for ≥10 minutes) are included in the bout duration and intensity. For each specific criterion, sample size is the same for bout duration and intensity, which signifies the number of participants that met that criterion.