Published in final edited form as:

Med Sci Sports Exerc. 2018 June ; 50(6): 1333–1340. doi:10.1249/MSS.0000000000001568.

Comparison of Two Generations of ActiGraph Accelerometers: The CARDIA Study

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Abstract

Purpose—To examine the comparability of the ActiGraph 7164 and wGT3X-BT wear time, count-based estimates, and average time/day in physical activity of different intensities.

Methods—We studied 87 Coronary Artery Risk Development in Young Adults (CARDIA) participants, aged 48–60 years, who simultaneously wore the 7164 and wGT3X-BT accelerometers at the waist in 2015–16, with wear time 4 of 7 days, 10 hours/day for both monitors. Freedson cutpoints (counts/min) were used to define sedentary (<100), light (100–1951), moderate (1952–5724), and vigorous activity (>5725). Agreement was evaluated using paired difference tests, intraclass correlation coefficients and Bland-Altman plots. Given systematic differences in count-based estimates between monitors, a calibration formula applied to the wGT3X-BT values was obtained by linear regression.

Results—Total detected wear time min/day was nearly identical between the 7164 and wGT3X-BT (881.5±70.9 vs. 880.3±78.1, $p=0.72$). The wGT3X-BT values were calibrated to the 7164 values by dividing counts by 1.088. After calibration, no differences were observed between the 7164 and wGT3X-BT in total counts/day (310,184±129,189 vs. 307,085±135,362, $p=0.48$), average counts/min/day (349.5±139.5 vs. 346.5±147.2, $p=0.54$), sedentary (513.2±93.6 vs. 509.6±98.6, $p=0.23$), light (335.3±81.5 vs. 338.7±81.1, $p=0.22$), moderate (31.0±21.9 vs. 30.3±23.4, $p=0.31$), or moderate to vigorous min/day (33.1±24.6 vs. 32.0±26.0, $p=0.13$). A significant difference was observed for vigorous min/day (0.2±1.0 vs. 0.0±0.3, $p<0.01$); however,

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Conflict of Interest:

The authors report no conflicts of interest. The results of the study are presented clearly, honestly, and without fabrication, falsification, or inappropriate data manipulation. The results of the present study do not constitute endorsement by ACSM.

the absolute difference was marginal. Intraclass correlation coefficients showed excellent agreement for all measures (ICC=0.95–0.99).

Conclusion—After applying a calibration formula, the 7164 and wGT3X-BT were comparable for total wear time, count-based estimates, and average min/day in sedentary, light, moderate, and moderate to vigorous activity. Findings illustrate a novel methodological approach to facilitate accelerometer data harmonization.

Keywords

ActiGraph 7164; ActiGraph wGT3X-BT; Measurement; Coronary Risk Development in Young Adults

Introduction

Accurate assessment of physical activity is critical when examining the associations between physical activity and chronic diseases and disabilities. Accelerometer-based monitors have emerged as valid tools to directly quantify movement that results from physical activity and sedentary behaviors (1, 2). However, this rapidly evolving technology has led to a need for population-based studies to constantly keep pace with the latest accelerometer models and best-practices, particularly related to data reduction and processing techniques. ActiGraph LLC (Pensacola, FL) is one of the leading manufacturers of research-grade accelerometers. Since the company's inception, multiple models have been released for use in studies, including the AM 7164 (uniaxial), GT1M (uniaxial), and GT3X series (triaxial), which includes the GT3X+ (extra battery storage) and wGT3X-BT (extra battery storage plus wireless Bluetooth capabilities).

Prior population-based studies have used the ActiGraph 7164 to assess physical activity and sedentary behaviors (3, 4); however, the older generation models are no longer commercially available, and have since been replaced with newer generation devices. Little is known about the comparability of the old and new generation ActiGraphs. This gap in knowledge must be addressed in order to make accurate comparisons within studies, which are examining change in activity patterns over time when using two different types of instruments, as well as between studies. Some evidence suggests the ActiGraph 7164 and GT3X+ models are comparable (when using the low frequency extension for the GT3X+) for time spent sedentary and in light-, moderate-, and vigorous-intensity physical activity (5); however, findings are not consistent (6, 7).

The Coronary Artery Risk Development in Young Adults (CARDIA) study included accelerometer based measures of physical activity and sedentary time in 2005–2006 (year 20), and again in 2015–2016 (year 30), using the ActiGraph 7164 and wGT3X-BT models, respectively. The primary objective of assessing physical activity at two separate exams was to evaluate the 10-year changes in physical activity and sedentary behaviors from early to late midlife in relation to cardiovascular disease risk. However, in order to do so, it is first necessary to examine the comparability of these two monitors. For this purpose, a subset of participants who had worn the ActiGraph 7164 at the year 20 exam were asked to

simultaneously wear the ActiGraph 7164 and the wGT3X-BT for seven consecutive days at the year 30 exam.

The primary objective of the present study was to examine the comparability, including agreement between the ActiGraph 7164 and wGT3X-BT (using the low frequency extension) in wear time, count-based estimates (vertical axis), and average time spent per day in sedentary, light-intensity physical activity (LPA), moderate-intensity physical activity (MPA), vigorous-intensity physical activity (VPA), and moderate-to-vigorous physical activity (MVPA), assessed during the year 30 CARDIA exam. If differences were observed, our secondary objective was to develop and test a calibration formula to enhance comparability of the two monitors. Together, these steps outline a methodological approach that could be applied to other research scenarios where accelerometer data harmonization is necessary. In exploratory analyses we also examined differences in comparability by race/sex group, as well as body mass index (BMI) category.

Methods

Study participants

CARDIA is an ongoing prospective cohort study of 5,115 black and white men and women recruited for an in-person clinical examination in 1985–1986 (year 0) at the ages of 18–30 years from four centers: Birmingham, Alabama; Minneapolis, Minnesota; Chicago, Illinois; and Oakland, California. Participants completed additional in-person clinic examinations in 1987–1988 (year 2), 1990–1991 (year 5), 1992–1993 (year 7), 1995–1996 (year 10), 2000–2001 (year 15), 2005–2006 (year 20), 2010–2011 (year 25), and 2015–2016 (year 30). Details on eligibility criteria, methods of participant selection and follow-up have been previously reported (8).

As part of the CARDIA Activity Study, an ancillary study conducted in conjunction with the year 30 CARDIA examination, 100 ambulatory participants (25 from each of the four race-sex groups: black men, black women, white men, white women) from the Oakland, CA site were asked to simultaneously wear the 7164 and wGT3X-BT accelerometers for seven days. The wGT3X-BT was included as part of the general CARDIA Activity Study protocol that was conducted at each of the four CARDIA sites. A total of 91 participants conformed to wear-rules. Four devices malfunctioned (all 7164, which had been purchased in 2004); therefore, data from 87 participants were available for analyses. The institutional review board at each center approved all study protocols for the core CARDIA exam, as well as the CARDIA Activity study. Written informed consent was obtained at each exam, separately for the core and ancillary study.

Data handling and processing

Both the 7164 and wGT3X-BT were initialized to start collecting data at 12:00am on Day 1 of data collection (day following the in-person exam) using the participant's unique study ID number. The monitors were worn at the waist on the same elastic belt, approximately 10 centimeters apart. The 7164 model was initialized to collect data in 60 second epochs and for the wGT3X-BT devices, raw tri-axial data were sampled at 40 Hz. When the

accelerometer and wear-time log were returned to the Oakland site, data from both devices were downloaded and prepared for processing and analysis. Raw data from the wGT3X-BT were reintegrated to 60-second epochs with the low frequency extension applied using ActiLife software to maximize compatibility with the 7164 data. Files from both devices were screened for wear time using the Troiano algorithm via modified SAS programs developed for processing NHANES 2003–04 accelerometer data (4, 9). The low frequency extension was applied to the data based on previous work indicating that this option has great sensitivity at lower intensity activities and resulted in more comparable results with older accelerometer models (5, 6). Weekly summary physical activity and sedentary behavior estimates were averaged (across days) for all participants with at least four valid days of 10 or more hours of wear time based on criteria established for NHANES 2003–04 and 2005–06 cycles (4). Total and average accelerometer counts per day were calculated using summed counts detected over wear periods and time (i.e., minutes) spent in different intensity levels using standardized cut point threshold values (4, 10, 11). For this analysis, estimates that apply Freedson cut point threshold values were applied. Sedentary time in counts/min was defined as <100, LPA as 100–1951, MPA as 1952–5724, and VPA as 5725 (11).

Descriptive Variables

Descriptive variables include self-reported race, sex, and age. Body mass index was calculated using measured height and weight (kg/m^2). Smoking behaviors were self-reported via a tobacco use questionnaire (previously validated by a study using serum cotinine levels) (12).

Statistical Analysis

Minute by minute within-person Pearson correlations of counts/min/day were examined. Next, paired t-tests or Wilcoxon signed ranks tests (VPA only) compared the values for the 7164 and wGT3X-BT in estimates from the vertical axis, including: wear time, count-based estimates, and average min/day in sedentary, LPA, MPA, VPA, and MVPA. Count-based estimates systematically differed between the two accelerometers; therefore, a calibration formula was applied to the wGT3X-BT values. We chose to calibrate the wGT3X-BT values, rather than the 7164 values, because the Freedson cut points for physical activity intensities were originally developed using the 7164 accelerometer (11). Linear regression of the wGT3X-BT on the 7164 counts/min/day passed very close to the origin; therefore the slope of the 7164 counts/min/day (1.088) was the calibration proportionality. The wGT3X-BT count-based estimates and average min/day in sedentary, LPA, MPA, VPA, and MVPA were calibrated by dividing the count in each 60 second epoch by 1.088. Then, paired t-tests or Wilcoxon signed ranks test were repeated to compare values for count-based estimates, sedentary, LPA, MPA, VPA, and MVPA between the 7164 and calibrated wGT3X-BT (see Figure, Supplemental Digital Content 1, conceptual schematic of the calibration method).

Agreement between the models, using both the original and calibrated wGT3X-BT values, was further evaluated by calculating intraclass correlation coefficients (ICC), with values of <0.5, 0.5–0.75, 0.75–0.9, and >0.9 indicative of poor, moderate, good, and excellent reliability (13). Bland-Altman plots were created in Microsoft Excel using both the original

and calibrated wGT3X-BT values to assess the limits of agreement, which were set at ± 2 SD of the difference scores. The difference between the 7164 and calibrated wGT3X values by race/sex group and BMI category were evaluated using Kruskal Wallis tests. Statistical analyses were conducted using SAS 9.4, (SAS Institute, Inc., Cary, North Carolina) and SPSS 24 (IBM Corp., Chicago, IL). All tests were 2-sided, with statistical significance set at $P < 0.05$.

Results

As seen in Table 1, participants averaged 55.4 ± 3.4 years (range 48.0–61.0). Average body mass index (kg/m^2) was 28.3 ± 5.3 for black men, 28.0 ± 3.9 for white men, 30.6 ± 7.6 for black women, and 25.4 ± 8.6 for white women. Participants wore the two accelerometers for an average of 6.7 days ± 1.1 (range 4.0–9.0), 14.7 hours/day ± 1.3 (range 11.9–19.0). Prior to calibration, the minute by minute within-person correlations of counts/min/day identified four dysfunctional 7164 devices (average correlation = 0.03). After exclusion of these devices, the minute by minute correlations of counts/min/day in the final sample ($N=87$) averaged 0.74 ($r=0.34$ – 0.49 , $n=12$; $r=0.50$ – 0.74 , $n=31$; $r=0.75$, $n=44$). While not statistically significant, in comparison to those with high minute by minute correlations ($r=0.75$), individuals with lower correlations ($r<0.75$) wore the accelerometers for fewer days (6.9 ± 0.7 vs. 6.5 ± 1.3 , $p=0.08$) and for fewer hours/day (14.9 ± 1.3 vs. 14.4 ± 1.3 , $p=0.06$).

Comparisons between 7164 and original wGT3X-BT values

There were no significant differences between the 7164 and original wGT3X-BT values for total wear time (mean difference = 1.3 ± 33.5 min/day, $p=0.72$) (see Table 2). The 7164 reported significantly lower values for total accelerometer counts/day ($-23,924.6$, $p<0.001$), average counts/min/day (-27.5 , $p<0.001$), LPA (-6.8 , $p=0.02$), MPA (-3.8 , $p<0.001$), and MVPA (-4.1 , $p<0.001$), and significantly higher values for sedentary min/day (12.1 , $p<0.001$) as compared to the wGT3X-BT. No differences were observed for VPA min/day (0.0 , $p=0.22$). The overall difference between monitors in total counts/day was approximately 7% (mean counts/day difference between monitors using original wGT3X-BT data divided by mean counts/day for the 7164).

Comparisons between 7164 and calibrated wGT3X-BT values

Calibrated wGT3X-BT values were obtained by dividing counts/min/day by 1.088 based on regression of the wGT3X-BT on the 7164. The value 1.088 was similar to the value obtained (1.081) when only examining the 44 people with minute by minute count correlations 0.75 . When comparing the 7164 and calibrated wGT3X-BT values, there were no significant differences between the two devices in total accelerometer counts/day ($3,098.9$, $p=0.48$), average counts/min/day (3.0 , $p=0.54$), sedentary (3.6 , $p=0.23$), LPA (-3.5 , $p=0.22$), MPA (0.7 , $p=0.31$), or MVPA min/day (1.2 , $p=0.13$). However, there was a significant difference between the two monitors in VPA, with the 7164 reporting more min/day as compared to the wGT3X-BT (0.1 , $p<0.01$). However, the absolute difference between monitors was marginal. There were 52 participants who reached the threshold for VPA with the 7164 accelerometer, compared to 31 for the wGT3X-BT (using calibrated data). Significant differences in VPA min/day remained when including only those who reached the threshold

for VPA on both monitors (N=28, 0.4, $p=0.01$, data not shown). Using the calibrated wGT3X-BT data, the overall difference between monitors in total counts/day was less than 1%. There were no significant differences by race/sex group (see Table, Supplemental Digital Content 2, activity comparisons by race/sex group) or BMI category (see Table, Supplemental Digital Content 3, activity comparisons by BMI category) when examining the difference in accelerometer values between monitors.

Agreement between the 7164 and original wGT3X-BT values for estimating total wear time, count-based estimates, and average time spent in physical activity of varying intensities was excellent (ICC range 0.948–0.975, see Table 3). All ICC values increased when examining agreement between the 7164 and calibrated wGT3X-BT values (ICC range 0.973–0.986). When examining only those with high minute by minute correlations ($r = 0.75$, $n=44$), there were additional improvements in ICC, using both the original (ICC range 0.957–0.979) and calibrated wGT3X-BT values (ICC range 0.979–0.990; data not shown).

In Figure 1, the Bland-Altman plots show the agreement between the 7164 and wGT3X-BT, using the original or calibrated values, for total wear time, count-based estimates, and average time spent in sedentary, LPA, MPA, VPA, and MVPA. The plots indicate that the differences between monitors, whether using original or calibrated values for the wGT3X-BT, were generally within 2 SD, with no clear pattern of disagreement observed across the x-axis, with few exceptions. For example, the limits of agreement for MVPA ranged from –21.9 to 13.8 min/day using the original wGT3X-BT data, and from –12.8 to 15.1 min/day for the calibrated wGT3X-BT data. The mean difference in MVPA using original data was –4.1 min/day, compared to 1.2 min/day for the calibrated values, indicating that bias was reduced after calibration.

Discussion

In this comparison of two different Actigraph accelerometer models worn simultaneously by 87 CARDIA participants at the Year 30 exam, significant differences between the older generation 7164 and newer generation wGT3X-BT existed for count-based estimates and physical activity of different intensities, with the 7164 reporting lower values for counts/day, counts/min/day, LPA, MPA, and MVPA, and higher values for sedentary min/day. No significant differences were observed for VPA. However, after applying a calibration formula to the wGT3X-BT, there were no significant differences in count-based estimates or time spent in sedentary, LPA, MPA, and MVPA between the two accelerometers. There was a difference between the two monitors in VPA after calibration, with the 7164 reporting on average, an additional 0.1 min/day than the wGT3X-BT. Agreement as assessed by ICC between the two accelerometers, using either original or calibrated wGT3X-BT values was excellent. Bland-Altman plots also showed reasonable agreement across measures. While agreement between the 7164 and original wGT3X-BT was high, significant differences in the output prior to calibration indicate that the two monitors should be compared after calibration.

Our findings that the 7164 and wGT3X-BT values (prior to calibration) were significantly different across measures, with the 7164 reporting lower values for total physical activity

(−23,925 counts/day), average physical activity (−27.5 counts/min/day), LPA (−6.8 min/day), MPA (−3.8 min/day), and MVPA (−4.1 min/day), and higher values for sedentary time (12.1 min/day), are not consistent with the existing literature. Sandroff and colleagues also reported significant differences in counts/day between the 7164 and GT3X among 41 participants with multiple sclerosis and 41 matched controls; however, in their study the 7164 reported higher, rather than lower values as compared to the GT3X (12,487 counts/day) (7). It is worth noting that Sandroff used the GT3X and not the GT3X+, therefore they did not have the ability to use the low frequency extension option, which has shown to enhance comparability between the older and newer generation monitors (5, 6).

Prior studies to examine the comparability of the 7164 and GT3X+ using the low frequency extension option, as done in the present study, are limited and findings are mixed. Cain et al. reported non-significant differences between the 7164 and GT3X+, using the Freedson accelerometer cut points, for sedentary time (3.5 min/day), LPA (4.3 min/day), MPA (0.3 min/day) and VPA (0.4 min/day) among 25 adults who wore the monitors consecutively for three days (5). Reid-Larsen et al. examined the comparability of the two monitors among 20 adults over 24 hours, reporting non-significant differences between the two monitors for mean physical activity (3 counts/min/day), sedentary time (2.5 min/day), and LPA (2.2 min/day). However, significant differences were observed for MPA (−3.0 min/day), and VPA (1.3 min/day). A consistent finding between our study and Reid-Larsen's was the significant difference between monitors in MPA, with the 7164 reporting lower values in both studies. Overall both Cain and Reid-Larsen reported more comparable outputs between the two monitors than observed in the present study, particularly for lower intensity activities. These discrepancies in findings between our study and others using the low frequency extension option may be due in part to differences in total observation period (one to three days as compared to at least four of seven days in the present study), smaller sample sizes (N=20 and N=25 as compared to N=87), and differences in average ages of the cohorts. The samples in the Cain and Reid-Larsen studies were younger than in our study, which may potentially reflect different movement patterns. Differences in methods for processing and scoring the accelerometer data may also explain discrepancies in findings. For example, Reid-Larsen and colleagues initialized data with a 10-second epoch (compared to a 60-second epoch as done in the present study and in the study by Cain et al.), and they used different accelerometer cut points for sedentary time and LPA, although Freedson cut points were used for MPA and VPA. Furthermore, the processing software differed across the three studies (ActiLife vs. MeterPlus vs. Propero). The age of the 7164 device may have played a role in the discrepancy in counts/min/day from the wGT3X-BT, given that the minute by minute count correlations were close to 0 for four devices. However, the calibration formula was almost identical when derived only from those devices that had high minute by minute count correlations compared to deriving it from all 87 functioning 7164 devices.

Interestingly, there was no difference between the monitors for VPA prior to calibration; however, after calibration this difference became statistically significant. Overall levels of VPA were very low, with a median of 0.2 min/day with the 7164 and 0.0 min/day with the wGT3X-BT (original and calibrated data). The median difference between monitors was also small, at 0.0 min/day using the original wGT3X-BT data and 0.1 min/day (or 6 seconds per day) using the calibrated data. Therefore, it is difficult to draw meaningful conclusions

about the comparability of the monitors for VPA given the low levels observed in this sample and small observed differences between monitors, which may not be physiologically relevant. Further, it is unlikely that this difference between monitors and how they detect VPA would lead to different observed measures of association with health outcomes or change the overall interpretations of these associations.

Due to observed differences in count-based estimates between monitors, we developed and applied a calibration factor to the wGT3X-BT data. Prior to calibration the net difference between devices for total physical activity (counts/day) was 7%, after calibration this difference decreased to 1%. Our findings indicate that the 7164 and wGT3X-BT are not interchangeable in their original state, and researchers should be aware of these differences. However, it is possible to make valid comparisons between the monitors after calibration. It is important to note that the overall agreement between monitors as assessed by ICC's was excellent before calibration, with small improvements after calibration. Therefore, if researchers are interested in overall agreement, and do not plan to compare activity intensity categories, then calibration may not be necessary.

This methodological approach could apply to a variety of real-world scenarios. For example, there is a need for longitudinal studies assessing accelerometer-measured physical activity to change the types of monitors used in their study to stay current with evolving technology. In less than 20 years, accelerometers have evolved from a uniaxial piezoelectric system to a triaxial capacitive microelectro-mechanical system (14). These rapid changes in technology greatly deter efforts to evaluate patterns of physical activity change across important life-course transitions, such as midlife in CARDIA. Our calibration approach can be used to more accurately assess physical activity change within studies using different devices over time. The importance of calibration in this scenario can be illustrated by examining the Bland-Altman plots, using MVPA as an example. We found greater bias when using the original wGT3X-BT data as compared to the calibrated data (mean MPVA difference = -4.1 min/day vs. 1.2 min/day, respectively). Therefore, if we were to assess change in activity, first using the 7164 and later using the wGT3X-BT, then change in MVPA over time would be exaggerated without calibration, possibly leading to biased associations with health outcomes.

An additional scenario where this methodological approach could be implemented is in community based studies with limited resources, where physical activity is measured using multiple types of monitors based on monitor availability. A third potential use for this approach is in harmonizing accelerometer data across studies using different devices. For example, calibration provides researchers the ability to harmonize and pool data from various cohort studies using different types of monitors. Using this methodological approach in the three scenarios described above would require a small sub-study where participants wear both types of monitors to determine the appropriate calibration coefficient, rather than using the calibration coefficient reported in this study due to concerns about generalizability. It would also be necessary for the different devices to provide the same type of output (e.g. counts/min/day or min/day) in order to calculate the calibration proportionality, and to have the same activity categories (e.g. sedentary, LPA, MPA, VPA) to directly compare the monitors. It would be feasible, for example, to calibrate the ActiGraph and Actical using the

approach described, as both devices provide information on min/day in sedentary, LPA, MPA, and VPA. However, the ActivPAL classifies time spent sitting, standing, and walking, and therefore would not be directly comparable to an ActiGraph (or Actical) using this methodological approach.

Strengths of this study include the larger sample size and longer duration of wear time as compared to the existing literature. Furthermore, a unique aspect of our study was the ability to examine differences between monitors by race/sex group and BMI category. We found no differences across groups, indicating that the accelerometers, after calibration, are comparable regardless of body dimensions. This paper makes an important contribution by calculating and applying a calibration formula which allows for greater comparability between the older and newer generation accelerometers, and can be applied to multiple real-world scenarios.

Limitations of the study include the 10-year age and previous use of the 7164 accelerometers. Earlier work has shown the 7164 output alters over time when used repeatedly (15). Therefore the differences observed between the 7164 and original wGT3X-BT values may be due to changes in the mechanical properties of the older generation accelerometer. Additionally, VPA in our sample was very low; therefore it is difficult to draw conclusions about the non-significant difference observed prior to calibration, or the significant difference observed after calibration. Finally, while our ability to examine differences between monitors by race/sex group and BMI category is a strength of our study, the findings should be interpreted with caution due to the small sample sizes across groups.

In conclusion, we found that the ActiGraph 7164 and wGT3X-BT accelerometers had high levels of agreement but significantly different outputs for count-based estimates and physical activity of different intensities. However, after applying a calibration factor to the wGT3X-BT, the differences in monitors was attenuated across all measures, with the exception of VPA. Comparison of values between the older generation 7164 and newer generation wGT3X-BT accelerometers should only be done after calibration.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

The Coronary Artery Risk Development in Young Adults Study (CARDIA) is supported by contracts HHSN268201300025C, HHSN268201300026C, HHSN268201300027C, HHSN268201300028C, HHSN268201300029C, and HHSN268200900041C from the National Heart, Lung, and Blood Institute (NHLBI), the Intramural Research Program of the National Institute on Aging (NIA), and an intra-agency agreement between NIA and NHLBI (AG0005). Accelerometer data collection was supported by grants R01 HL078972 and R56 HL125423 from the NHLBI. KMW was supported by T32 HL007779 from the NHLBI. The authors thank the investigators, the staff, and the participants of the CARDIA study for their valuable contributions.

References

1. Chen KY, Bassett DR Jr. The technology of accelerometry-based activity monitors: current and future. *Med Sci Sports Exerc.* 2005; 37(11 Suppl):S490–500. [PubMed: 16294112]

2. Plasqui G, Bonomi AG, Westerterp KR. Daily physical activity assessment with accelerometers: new insights and validation studies. *Obes Rev.* 2013; 14(6):451–462. [PubMed: 23398786]
3. Cain KL, Sallis JF, Conway TL, et al. Using accelerometers in youth physical activity studies: a review of methods. *J Phys Act Health.* 2013; 10(3):437–450. [PubMed: 23620392]
4. Troiano RP, Berrigan D, Dodd KW, et al. Physical activity in the United States measured by accelerometer. *Med Sci Sports Exerc.* 2008; 40(1):181–188. [PubMed: 18091006]
5. Cain KL, Conway TL, Adams MA, et al. Comparison of older and newer generations of ActiGraph accelerometers with the normal filter and the low frequency extension. *Int J Behav Nutr Phys Act.* 2013; 10:51. [PubMed: 23618461]
6. Ried-Larsen M, Brond JC, Brage S, et al. Mechanical and free living comparisons of four generations of the Actigraph activity monitor. *Int J Behav Nutr Phys Act.* 2012; 9:113. [PubMed: 22971175]
7. Sandroff BM, Motl RW. Comparison of ActiGraph activity monitors in persons with multiple sclerosis and controls. *Disabil Rehabil.* 2013; 35(9):725–731. [PubMed: 23557239]
8. Friedman GD, Cutter GR, Donahue RP, et al. CARDIA: study design, recruitment, and some characteristics of the examined subjects. *Journal of clinical epidemiology.* 1988; 41(11):1105–1016. [PubMed: 3204420]
9. National Cancer Institute. SAS Programs for Analyzing NHANES 2003–2004 Accelerometer Data. 2016. [cited 2017 October 25]. Available from https://epi.grants.cancer.gov/nhanes_pam/
10. Matthews CE. Calibration of accelerometer output for adults. *Med Sci Sports Exerc.* 2005; 37(Supplement):S512–522. [PubMed: 16294114]
11. Freedson PS, Melanson E, Sirard J. Calibration of the Computer Science and Applications, Inc. accelerometer. *Med Sci Sports Exerc.* 1998; 30(5):777–781. [PubMed: 9588623]
12. Wagenknecht LE, Cutter GR, Haley NJ, et al. Racial differences in serum cotinine levels among smokers in the Coronary Artery Risk Development in (Young) Adults study. *Am J Public Health.* 1990; 80(9):1053–1056. [PubMed: 2382740]
13. Koo TK, Li MY. A Guideline of Selecting and Reporting Intraclass Correlation Coefficients for Reliability Research. *J Chiropr Med.* 2016; 15(2):155–163. [PubMed: 27330520]
14. John D, Freedson P. ActiGraph and Actical physical activity monitors: a peek under the hood. *Med Sci Sports Exerc.* 2012; 44(1 Suppl 1):S86–89. [PubMed: 22157779]
15. Moeller NC, Korsholm L, Kristensen PL, et al. Unit-specific calibration of Actigraph accelerometers in a mechanical setup - is it worth the effort? The effect on random output variation caused by technical inter-instrument variability in the laboratory and in the field. *BMC Med Res Methodol.* 2008; 8:19. [PubMed: 18405353]

Panel 1

Panel 2A

Panel 2B

Panel 3A

Panel 3B

Panel 4A

Panel 4B

Figure 1. Bland-Altman plots for total wear time, count based estimates, and physical activity of different intensities, using the original (Panels 1, 2A–8A) and calibrated (Panels 2B–8B) wGT3X-BT values, the CARDIA Study, 2015–2016 (N=87)

Panels 1, 2A–8A are the Bland-Altman plots for the 7164 and original wGT3X-BT values.

Panels 2B–8B are the Bland-Altman plots for the 7164 and calibrated wGT3X-BT values.

Table 1

Participant Characteristics by Race and Sex, the CARDIA Study, 2015–2016

Participant Characteristics	Total (N=87)	Black Men (N=18)	White Men (N=23)	Black Women (N=22)	White Women (N=24)
Age, years	55.4 (3.4)	55.1 (3.7)	55.2 (2.7)	55.3 (3.8)	56.0 (3.5)
Body mass index, kg/m ²	28.0 (6.9)	28.3 (5.3)	28.0 (3.9)	30.6 (7.6)	25.4 (8.6)
Current smoker, n(%)	10 (11.6)	3 (16.7)	1 (4.3)	5 (25.6)	1 (4.2)
Accelerometer measures					
Valid wear time, days	6.7 (1.1)	6.4 (1.4)	7.1 (0.8)	6.4 (1.1)	7.0 (0.7)
Valid wear time, hours/day	14.7 (1.3)	15.0 (1.5)	14.9 (1.4)	14.1 (1.1)	14.7 (1.1)

Data presented as mean (SD) unless otherwise specified.

Table 2

Activity comparisons between the ActiGraph 7164 and wGT3X-BT (original and calibrated), the CARDIA Study, 2015–2016 (N=87)

ActiGraph Measures	7164	Original wGT3X-BT	Calibrated wGT3X-BT ^b	7164 and Original wGT3X-BT Difference	p-value ^d	7164 and Calibrated wGT3X-BT Difference	p-value ^c
Total wear time, min/day	881.5 (70.9)	880.3 (78.1)	-	1.3 (33.5)	0.722	-	-
Total PA, counts/day	310,184.3 (129,188.9)	334,108.9 (147,273.8)	307,085.4 (135,362.0)	-23,924.6 (45,473.9)	<0.001	3,098.9 (40,473.6)	0.477
Average PA, counts/min/day	349.5 (139.5)	377.0 (160.1)	346.5 (147.2)	-27.5 (50.6)	<0.001	3.0 (44.9)	0.537
Sedentary, min/day	513.2 (93.6)	501.1 (98.6)	509.6 (98.6)	12.1 (27.9)	<0.001	3.6 (27.9)	0.233
LPA, min/day	335.3 (81.5)	342.0 (80.5)	338.7 (81.1)	-6.8 (26.5)	0.019	-3.5 (26.2)	0.221
MPA, min/day	31.0 (21.9)	34.9 (24.8)	30.3 (23.4)	-3.8 (9.1)	<0.001	0.7 (6.8)	0.314
VPA, min/day ^d	0.2 (1.0)	0.0 (0.9)	0.0 (0.3)	0.0 (10.1)	0.220	0.1 (2.4)	<0.001
MVPA, min/day	33.1 (24.6)	37.2 (28.0)	32.0 (26.0)	-4.1 (9.1)	<0.001	1.2 (7.1)	0.132

Abbreviations: PA = physical activity, LPA = light-intensity physical activity, MPA = moderate-intensity physical activity, VPA = vigorous-intensity physical activity, MVPA = moderate-to-vigorous intensity physical activity. Data presented as Mean (SD) unless otherwise specified.

^aP-value testing difference between the 7164 and original wGT3X-BT using paired t-tests or Wilcoxon signed ranks tests.

^bCalibration factor applied to wGT3X-BT for count based estimates and average min/day in sedentary, LPA, MPA, VPA, and MVPA

^cP-value testing difference between the 7164 and calibrated wGT3X-BT using paired t-tests or Wilcoxon signed ranks tests.

^dData presented as median, interquartile range due to non-normal distribution for 7164 and wGT3X-BT values. Difference values presented as median and variance.

Table 3

Agreement between the ActiGraph 7164 and wGT3X-BT (original and calibrated) for estimating total wear time, count-based estimates, and time spent in physical activity of different intensities using Intraclass Correlation Coefficients (ICC), the CARDIA Study, 2015–2016 (N=87)

Actigraph Measures	7164 and Original wGT3X-BT		7164 and Calibrated wGT3X-BT	
	ICC	95% CI	ICC	95% CI
Total wear time	0.948	0.920, 0.966	-	-
Total PA, counts/day	0.965	0.923, 0.982	0.976	0.964, 0.984
Average PA, counts/min/day	0.963	0.915, 0.981	0.975	0.962, 0.984
Sedentary, min/day	0.975	0.953, 0.986	0.978	0.967, 0.986
LPA, min/day	0.971	0.955, 0.981	0.973	0.959, 0.982
MPA, min/day	0.954	0.916, 0.973	0.977	0.965, 0.985
VPA, min/day	0.956	0.933, 0.971	0.986	0.977, 0.991
MVPA, min/day	0.964	0.931, 0.979	0.979	0.968, 0.987

Abbreviations: PA = physical activity, LPA = light-intensity physical activity, MPA = moderate-intensity physical activity, VPA = vigorous-intensity physical activity, MVPA = moderate-to-vigorous-intensity physical activity.