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Validation of Activity Trackers in a Daily Living Setting in Young Adults

Jodi B. Wimmer

A thesis submitted to the faculty of
Brigham Young University
in partial fulfillment of the requirements for the degree of

Master of Science

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ABSTRACT

Validation of Activity Trackers in a Daily Living Setting in Young Adults

Jodi B. Wimmer
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Master of Science

Sedentary behavior (SB) contributes to many negative health-related outcomes. Motivation to reduce SB and increase physical activity (PA) is necessary to reduce co-morbidities. Tracking SB and PA provides objective data to help promote wellness. The purposes of this quasi-experimental study were to 1) determine the accuracy of three commercially available activity trackers compared to research-grade accelerometers, and 2) explore whether using these activity trackers led to a change in activity level one week after gathering baseline data. Activity trackers used in this study were Apple Watch, Fitbit Surge, and Microsoft Band 2. A convenience sample of college-age students and community members wore the research-grade ActiGraph 3GTX+ accelerometer on the non-dominant wrist for one week. Participants returned and the activity tracker was added to the non-dominant wrist with the ActiGraph 3GTX+ for another week. Results of all activity trackers significantly differed from the ActiGraph accelerometers. Fitbit Surge had a significant regression equation that could adjust for this difference, but not Apple Watch or Microsoft Band 2. Participants had below average sedentary time, exhibiting 288.4 min/day (*SD* 100.7) of SB. They also surpassed United States PA standards, averaging 130.3 (*SD* 48.8) min/day of moderate-to-vigorous physical activity. Few significant changes in activity level transpired between week 1 and week 2. In a group that already has low SB and high PA, activity trackers do not seem to make an impact on activity levels. Further testing is required to determine if activity trackers are motivating to reduce SB and increase PA in groups with different activity profiles.

Keywords: activity tracker, sedentary behavior, accelerometer, Actigraph, physical activity

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Validation of Activity Trackers in a Daily Living Setting in Young Adults

The word sedentary comes from the Latin word *sedenatrius,* which means remaining in one place. Excessive sedentary behavior (SB) is an increasing problem today with one in four adults not active enough (World Health Organization, 2019). One definition of SB as proposed by the Sedentary Behavior Research Network is any waking behavior done while sitting or reclining and uses ≤ 1.5 metabolic equivalents (METs) (Tremblay et al., 2017). A MET is a ratio of your metabolic rate compared to rest. For comparison, sitting quietly at rest is 1.0 METs, typing on a computer is 1.3 METs, and leisurely walk is 2.0 METs (Ainsworth et al., 2011).

SB contributes to both acute and chronic conditions (de Rezende et al., 2014). Such conditions include diabetes, coronary artery and kidney disease, and chronic fatigue. SB leads to fewer calories burned with a slowed metabolism and can cause insulin resistance (Tremblay et al., 2017). SB can cause bones and muscles to atrophy, which increases the risk for injury and falls (Panahi & Tremblay, 2018). Additionally, inflammation, hormone imbalance, and poor circulation occur with SB. SB also effects the intensity of anxiety and depression (Hoare et al., 2016). SB effects all aspects of health (Panahi & Tremblay, 2018).

Lack of motivation to reduce SB and increase physical activity (PA) is a limiting factor for a healthy lifestyle. Using objective measurement and feedback may help encourage and promote healthy behaviors to become routine. While assessment from healthcare professionals is periodic, continuous feedback may be more helpful for individuals seeking to improve healthy behaviors. The use of activity trackers is one strategy that could provide constant feedback and healthy behavior reinforcement.

Activity trackers can be used to monitor SB and PA. In the past, pedometers have been found to be a non-invasive, cost-effective motivational tool for promoting PA across a wide range of population groups (Kang et al., 2009). Today, activity trackers can give even more information regarding activity including step count, active minutes, standing time, sedentary time, and estimated calories burned. In a 2019 Gallup survey of 1,015 people from all states, about one in three Americans reported at some point having worn a fitness tracker, such as a Fitbit or smartwatch or having tracked their health statistics on a phone or tablet app (Gallup Inc, 2019). About three in four current or former users of wearable fitness trackers reported they found them very or somewhat helpful (Gallup Inc, 2019). As activity trackers gain popularity and use, their potential to reduce SB may be an untapped resource for clinicians to promote PA.

Using commercially available activity trackers for ongoing feedback could encourage people to monitor daily activity levels and make changes. Guidance from activity trackers analyzing daily data could be more personalized than recommendations from healthcare providers using only periodic information that is less tailored. This personalized feedback may be especially effective in encouraging individuals to monitor and change their own behaviors (Sullivan & Lachman, 2017). Tracking personal changes in activity levels and exercise behaviors can motivate steady progress toward goals, while increasing self-efficacy (Sullivan & Lachman, 2017). Features of activity trackers aim to provide practical information to the user, such as prompts to stand, move, and track physical activity and goals.

The current gold standard for objective activity measurement is ActiGraph accelerometers (ActiGraph LLC, Pensacola, FL). These devices are used by the United States in the National Health and Nutrition Examination Survey (NHANES). This is a nationally representative sample. Although helpful for researchers, ActiGraph devices do not give feedback to users or practitioners. However, being able to compare results to a national database would be helpful. Preliminary research indicates that activity trackers are generally accurate compared to

ActiGraph devices in the laboratory setting (Lewis, 2018). However, there is little information that compares the agreement between activity trackers and ActiGraph accelerometers in the daily living setting. Therefore, the purpose of this quasi-experimental study is to 1) determine the accuracy of activity trackers compared to research-grade accelerometers and 2) explore whether using activity trackers leads to a change in activity level.

Methods

Participants

Research activities were approved by a university institutional review board. Strict research ethics and protocols were adhered to throughout the course of the study. Participants included a convenience sample of 18 to 29-year-old college students and community members. Participants were recruited by word of mouth, flyers, social media posts, and email. Inclusion criteria were males and females aged 18- to 29-years-old able to a) wear both an ActiGraph GT3X+ accelerometer and activity tracker on the non-dominant wrist, and b) have a smartphone compatible with the activity tracker apps. Exclusion criteria included those with any type of body injury or condition (i.e. uses crutches, pregnancy), such that they had altered body movements or mechanics as these might affect accelerometer and activity tracker accuracy.

Power Analysis

A power analysis was done to determine an adequate sample using GPower 3.1 (Universität Kiel, Germany). The function “ANOVA: Fixed effects, omnibus, one-way” was used, setting power to 0.80, alpha of 0.05, medium effect size of 0.30, with 3 groups. This resulted in estimating that a total sample size of approximately 111 participants was required, or 37 per group. A sample size goal of 50 participants per group was selected, allowing for some attrition. This estimate is comparable to that of other similar accelerometry studies (Carr & Mahar, 2012; Neil E. Peterson et al., 2015; Sasaki et al., 2011).

Procedures

The three activity tracker devices were: Apple Watch (Series 2), Fitbit Surge, and Microsoft Band 2. All three of these devices are similar and gather activity information, such as steps, active minutes, calories burned, and heart rate. These same devices were validated in a laboratory setting (Lewis, 2018). Participants met researchers in a research center to review and complete consent forms. Basic demographic and body size (height and weight) were measured in duplicate and averaged. Participants were then fitted with an ActiGraph GT3X+ device over the non-dominant wrist and instructed to return exactly one week later. On the return visit, the participant was given a new, fully charged accelerometer and an activity tracker to wear on the non-dominant wrist. The selected activity tracker for the participant was systematically rotated from participant to participant. Participants were instructed to wear both the ActiGraph and activity tracker at the same time on the non-dominant wrist while awake, removing only for sleep or when they would get wet, such as swimming or bathing. Participants returned one week later to return both devices. Participants were compensated with $10 cash for completing all aspects of the study.

Instrumentation

ActiGraph GT3X+ Accelerometer. NHANES has used ActiGraph accelerometers attached to the right waist as the measurable standard in multiple waves. It is the most widely used and validated device in physical activity studies (Chomistek et al., 2017). In 2011, NHANES altered their measure standard of wearing the accelerometer from the right hip to placement on the non-dominant wrist, and this placement is still the current practice. Our study incorporates non-dominant wrist-based ActiGraph accelerometers to allow for comparison of the results to current NHANES standard and assess agreement between the research-grade accelerometer and commercially available activity trackers.

Activity Trackers. The three activity trackers tested were Apple Watch (Series 2), Fitbit Surge, and Microsoft Band 2. These devices were selected for two reasons. First, all of these devices are comparable in use, functional abilities, and design. Second, they represent the most popular bands on the market. All include similar metrics, such as step counts, active minutes, calories burned, and heart rate monitoring directly on the device, and all are worn on the wrist.

Statistical Analysis

Statistical analyses were performed using SPSS 25.0 (IBM Corp., Chicago, IL). Days with at least 600 minutes of accelerometer data were included in analyses. The first and last day of data of each week were dropped to reduce novelty bias and because these days usually lacked sufficient data. When comparing accelerometer and activity tracker data, validated wear-time from the ActiGraph and self-reported activity tracker wear-time from diaries had to be within 15 minutes to be considered eligible for analysis. Demographics were analyzed using simple descriptive statistics with univariate analysis. Bland-Altman analysis was used to compare activity tracker data to the criterion of the ActiGraph accelerometers. To determine if activity levels changed from pre-activity tracker (week 1) to post-activity tracker (week 2), a simple ANOVA was performed to determine if using one of the activity trackers was related to a change in activity level, as measured by the ActiGraph accelerometers. If ANOVA was significant, Bonferroni post-hoc tests were planned to determine which activity trackers significantly differed from baseline (week 1).

Results

Demographics

A total of 131 participants were in the study. Participants were evenly split between activity tracker type (see Table 1). The sample had slightly more males (54.2%) and were mostly white (83.2%). Despite taking place on a university campus, eight participants (6.1%) were community members. Average age of all participants was 22.7 years-old (*SD* = 2.0), and their body mass index was 24.1 kg/m^2 (*SD* = 3.7). Participants had below average sedentary time, exhibiting 288.4 min/day (*SD* 100.7) of sedentary behavior. They also surpassed United States physical activity standards, averaging 130.3 (*SD* 48.8) min/day of moderate-to-vigorous physical activity (MVPA). See Table 2 for full details.

Activity Tracker and ActiGraph Comparison

All activity trackers significantly differed from non-dominant wrist based ActiGraph accelerometers. The Apple Watch group had 72 valid comparison days. Limits of agreement by Bland-Altman analysis were ± 4.0 steps/min, with a mean difference of -1.5 steps/min ($p < 0.01$). The regression equation y = -2.6463 + 0.09846x had a significant intercept ($p < 0.01$) and non-significant slope ($p = 0.22$). This means the regression equation cannot be used to adjust Apple Watch steps/min to reflect ActiGraph accelerometer steps/min. (See Figure 1.)

The Fitbit Surge group had 85 valid comparison days. Limits of agreement by Bland-Altman analysis were ± 6.2 steps/min, with a mean difference of -0.7 steps/min ($p < 0.01$). The regression equation y = -4.0385 + 0.2958x had a significant intercept ($p < 0.01$) and significant slope ($p < 0.01$). This means that while the Fitbit Surge steps/min count was significantly different from the ActiGraph accelerometer, the regression equation can be used to adjust Fitbit Surge steps/min to reflect ActiGraph accelerometer steps/min. (See Figure 2.)

The Microsoft Band 2 group had 82 valid comparison days. Limits of agreement by Bland-Altman analysis were ± 6.7 steps/min, with a mean difference of -2.1 steps/min ($p < 0.01$). The regression equation y = -2.2308 + 0.0057x had a non-significant intercept ($p = 0.09$) and non-significant slope ($p = 0.96$). This means the regression equation cannot be used to adjust Microsoft Band 2 steps/min to reflect ActiGraph accelerometer steps/min. (See Figure 3.)

Change in Sedentary and Activity Level

Few significant changes in activity level transpired between week 1 and week 2. None of the devices significantly impacted SB (Apple Watch $t = -1.02$, $p = 0.32$; Fitbit Surge $t = 0.68$, $p = 0.50$; Microsoft Band 2 $t = -0.22$, $p = 0.83$). The Apple Watch group had a slight, but significant, decrease in MVPA min/day (128.8 vs 116.6, $t = 2.31$ $p = 0.03$) from week 1 to week 2. Fitbit Surge ($t = -0.50$, $p = 0.62$) and Microsoft Band 2 ($t = 1.17$, $p = 0.25$) groups did not significantly change their MVPA. According to validated accelerometer wear time and diary wear time reports, the Apple Watch 2 ($t = -0.16$, $p = 0.87$), the Fitbit Surge ($t = -0.20$, $p = 0.84$), and the Microsoft Band 2 ($t = 1.03$, $p = 0.31$) groups wore their devices the same amount of time both weeks.

Discussion

This study evaluated three commercial activity trackers in a daily life setting. They were compared to the ActiGraph, which is the gold standard and accelerometer of choice used by NHANES. Step counts between each of the activity trackers and ActiGraph were significantly different. Additionally, the number of steps from week 1 to week 2 did not increase. It is difficult to know if the participant's activity levels increased from baseline to week 1and were maintained during the two week tracking period. This means that the participants increased their activity level early because they knew it was being recorded. It is difficult to say whether the use of activity trackers changed the SB or PA profile of these participants. The Apple Watch group had the only statistically significant difference in MVPA among the three groups according to the ActiGraph data. This was a similar finding in a previous study, the Apple Watch showed a decrease in accuracy as the intensity of activity increased (Pope et al., 2019). Sedentary time between activity trackers was also not significantly different.

One reason for that wrist-based accelerometry needs to be evaluated is because the NHANES standard for measuring activity has changed from the right hip to placement on the non-dominant wrist. However, the wrist-worn ActiGraph underestimates both SB and PA compared to the hip placement (Lewis, 2018). Wear time, though, has increased in the wrist location and improved compliance (Kerr et al., 2017). In addition to improved compliance, the longer wear time provides more opportunity to capture PA (Kerr et al., 2017). Longer wear time also better predicts sedentary time. However, with the activity trackers being significantly different from the ActiGraph in activity measurement, additional studies would need to be done to evaluate if location and placement of activity trackers improves compliance and longer wear times.

Despite the activity trackers significantly differing from the ActiGraph in step counts, the Fitbit still shows promise for being useful for measuring activity. Our findings show we can use a regression equation to translate Fitbit data to comparable ActiGraph data. Thus, Fitbit could potentially be a device used for research in similar populations. Apple Watch and Microsoft Band 2, however, did not have a significant equation to convert their data to the ActiGraph equivalent.

Overall, the sample used for this study had extraordinarily low amounts of SB and unusually high amounts of MVPA. Over the course of a day, participants averaged just under 5 hours of SB and over 2 hours of MVPA per day. According to NHANES, typical adults aged 20–29 spend on average 6.6 hours per day being sedentary and 0.7 hours per day in MVPA (Matthews et al., 2016).

This activity profile seems reflective for this type of student population. For example, Peterson et al. (2018) found that university age students are both highly active and highly sedentary, averaging 10.0 hours of sedentary time and 1.2 hours of MVPA. Similarly, a systematic review of college age students, measuring accelerometry-based activity, accumulated 9.8 hours of sedentary time per day (Castro et al., 2020).

This information could be useful for other populations with similar activity profiles. For example, one study of marathon runners and athletes showed they had similar SB and PA behaviors (Whitfield et al., 2014). Groups like these are unique, being both highly active and also accumulating high amounts of sedentary time. For these groups of people, researchers have coined the term "active couch potato." They meet national activity requirements for MVPA, but also sit for prolonged periods (Whitfield et al., 2014).

In some ways, this research group is similar to the U.S. population in general. University students have the potential to be exposed to high levels of sitting, similar to many adults who have prolonged SB related to their occupation. University student's SB levels are comparable to, or likely exceed, those of desk-based office workers (Moulin & Irwin, 2017).

Although young adults may have a healthy activity profile while in college, this lifestyle may not be continued after graduation. Factors relative to work often require long commute times, work travel, lack of equipment for PA, etc., all of which contribute to SB. Along with this new work environment, total screen time, such as computers, phones, and tablets, increase in adulthood. Du et al. (2019) noted that sedentary time among all adults has increased in the last decade across all sub-groups, such as university students and working adults. These findings suggest SB interventions need to be put in place to impede the metabolic consequences of SB in a way that is sustainable as students transition from the campus-lifestyle to career.

Promotion of PA in young adults is important to instill healthy habits to carry-over into adulthood. Campuses are usually pedestrian friendly, with many students walking or biking for transportation. However, this lifestyle is likely to change after graduation. University graduates are likely to work in white-collar occupations. Office occupations are associated with higher levels of sitting during workdays compared to other occupations (Castro et al., 2020). Thus, changes in activity profile post-graduation could lead to major weight gain. Cementing healthy habits, like walking to work, biking, and taking the stairs, can carry into their new phase of life. Addressing PA as a vital sign, opens up the conversation of how much PA a person is getting each week. Healthcare workers and providers can reinforce the relationship between PA and wellness. Savvy and supportive practitioners are likely to fortify young adults to maintain an active lifestyle by counseling about activity level at every office visit. Activity trackers may be a positive, non-invasive way for practitioners to identify barriers and give direction with goals to promote PA, although it may have minimal impact in active groups similar to those in this study.

Limitations

Only healthy young adults, mostly college students, participated in this study. Those who participated were unusually active with low SB at baseline. The possibility of activity change between baseline and week 1 is also something to consider. The participants could have increased their activity profile knowing they were being monitored. Time period for the study was also short, with participants using the accelerometers for 2 weeks and activity tracker for 1 week. Given the short amount of time the study was completed, it would be hard to determine if the activity trackers are motivating. Generalizing the findings to other populations who do not have a similar activity profile or demographics would be difficult. However, this study provides good baseline data that could be used to compare to other groups who are in need of increasing their PA and decreasing their SB, such as overweight and obese groups.

Conclusion

The purpose of this study was to examine the accuracy of activity trackers in a daily living setting, and to explore their use of motivating PA. With regard to accuracy, Apple Watch and Microsoft Band 2 did not correlate with the wrist-based ActiGraph GT3X+ accelerometer. Fitbit was also significantly different from the ActiGraph, but it had a significant regression equation that could be used to convert the step count into the accelerometer equivalent. With regard to activity trackers motivating PA, there was not a change in activity level in this group of participants who were already highly active with low amounts of sedentary time compared to national averages. A more activity-diverse population needs to be studied to determine if activity trackers provide meaningful changes in PA. The results of this study highlight the uniqueness of this university population sample as it relates to SB and PA. Despite differences between activity tracker readings and ActiGraph data, healthcare providers can use this information when counseling patients in similar circumstances and should be aware of helping patients set goals to remain active when transitioning out of the college student role.

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Table 1.
Demographics and Study Descriptives

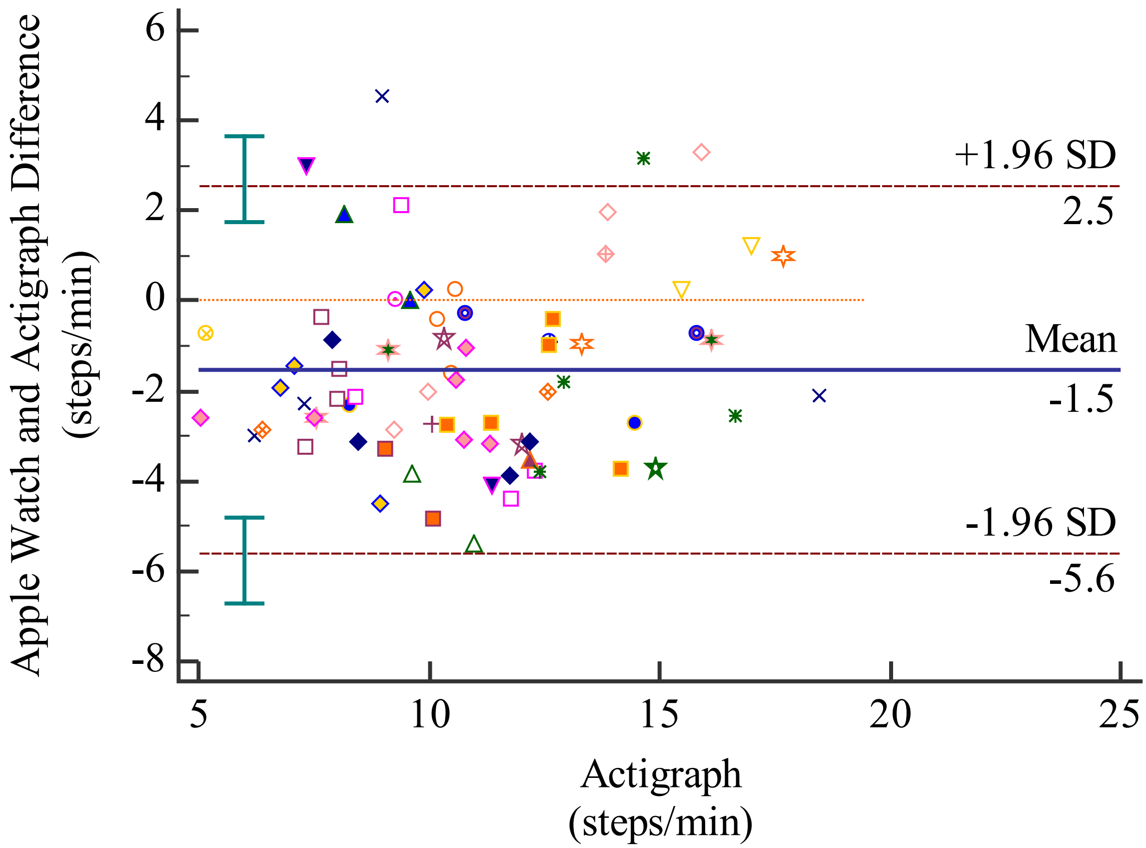
Characteristic	n	%	M	SD	Min	Max
Activity Tracker	131					
Apple Watch	41	31.3				
Fitbit Surge	44	33.6				
Microsoft Band	46	35.1				
Sex						
Female	60	45.8				
Male	71	54.2				
Race						
White	109	83.2				
Asian	12	9.2				
Hispanic	7	5.3				
Other	3	2.3				
Status						
Student	123	93.9				
Community Member	8	6.1				
School Year						
Freshman	4					
Sophomore	22					
Junior	40					
Senior	47					
Graduate Student	10					
Age (years)			22.7	2.0	18	29
Body Mass Index (kg/m^2)			24.1	3.7	17.4	38.0
Underweight (< 18.5 kg/m^2)	3	2.3				
Normal Weight (18.5-24.9 kg/m^2)	83	63.3				
Overweight (25.0-29.9 kg/m^2)	38	29.0				
Obese (≥ 30.0 kg/m^2)	7	5.3				

Table 2

Sedentary Behavior and Physical Activity Time

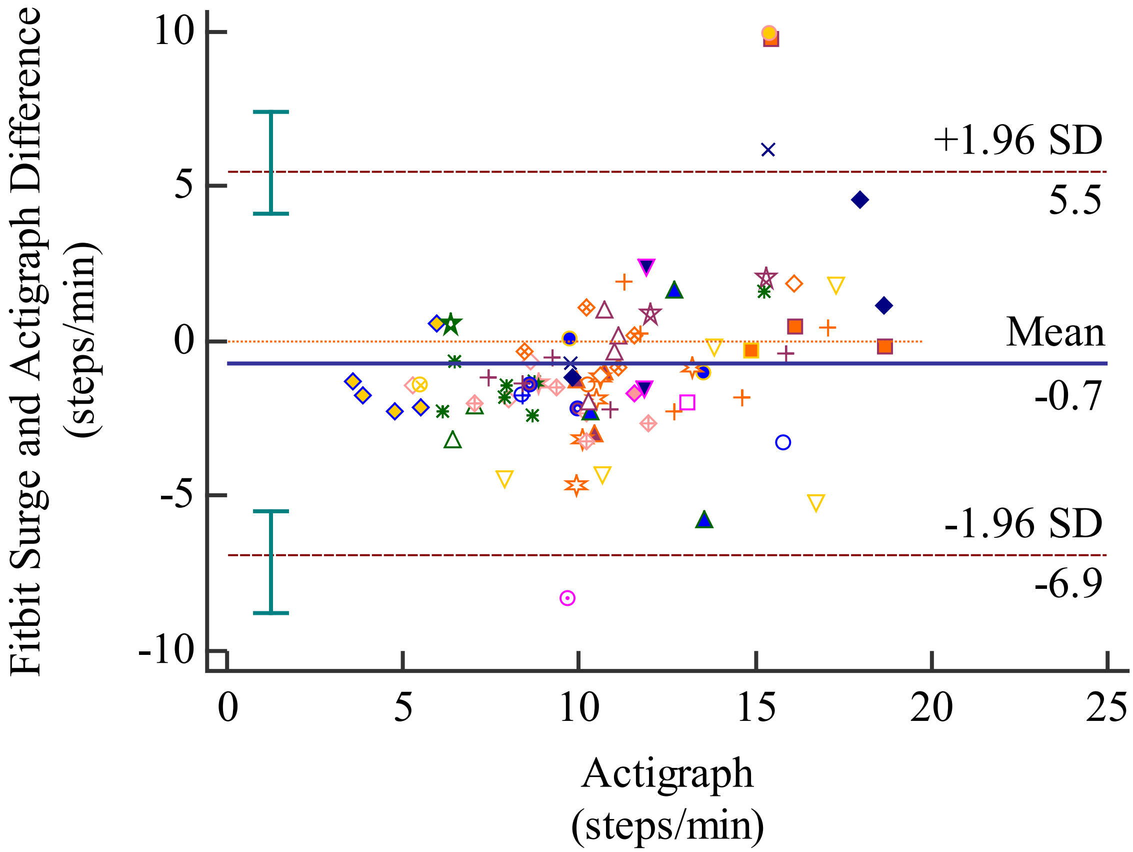
Behavior	M	SD	Min	Max
Week 1 Sedentary time (min/day)	286.3	109.6	74.4	735.3
Week 2 Sedentary time (min/day)	290.6	115.7	102.0	985.3
Week 1 MVPA (min/day)	133.0	52.4	17.3	295.0
Week 2 MVPA (min/day)	127.7	51.1	25.0	281.2

Note: MVPA = Moderate-to-Vigorous Physical Activity



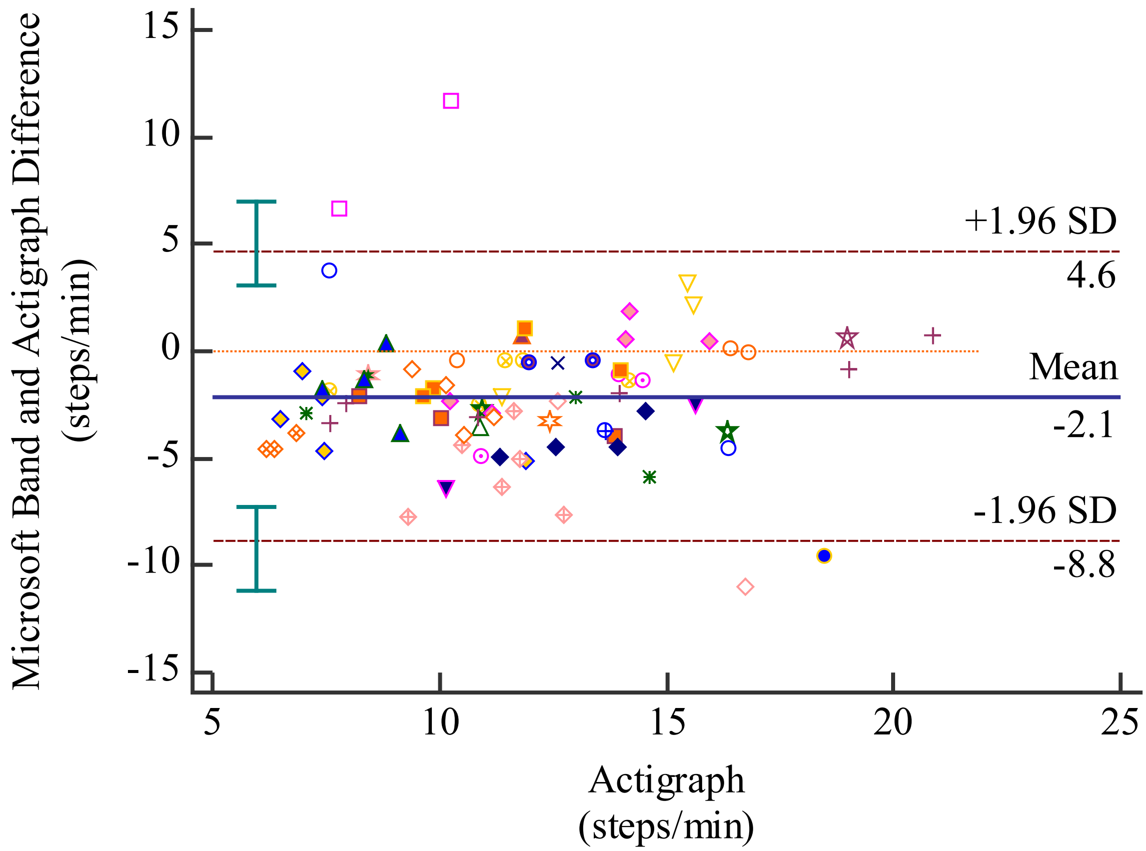
Note: Symbols of the same shape and color reflect repeated measures of the same participant.

Figure 1. Apple Watch and Actigraph Bland-Altman Plot.



Note: Symbols of the same shape and color reflect repeated measures of the same participant.

Figure 2. Fitbit Surge and Actigraph Bland-Altman Plot



Note: Symbols of the same shape and color reflect repeated measures of the same participant.

Figure 3. Microsoft Band and Actigraph Bland-Altman Plot