Can Personal Activity Trackers Be Used to Provide Insight into Sit-to-Stand Workstation Usage and Benefits?

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Abstract. We investigated whether activity trackers could be used to differentiate between sitting and standing at adjustable workstations and to determine if sit-to-stand workstation usage was associated with higher activity levels. A paired-t-test was used to assess the difference between the mean step counts measured using the activity trackers during sitting and standing periods among six office workers. Twelve office workers also wore activity trackers while self-reporting their standing as a percentage of total work time every week for six weeks. Spearman correlation was used to assess the relationship between standing percentage and step count. The difference in mean step count between sitting and standing was not statistically significant ($p = 0.113$) and the Spearman correlation between standing percentage and step count was weak ($\rho = 0.301$) and not statistically significant ($p = 0.342$). These findings suggest that basic activity trackers may not be useful in measuring sit-to-stand workstation usage.

Keywords: Wearable technology · Sit to stand workstations · Activity tracking

1 Background

Prolonged sitting at work is associated with health problems as is a sedentary level of physical activity. Sit-to-stand workstations have gained popularity as a means to decrease sitting and promote more physical activity. However, it is unclear whether sit-to-stand workstations are actually being used on a regular basis by those they are designed to help. There are also questions about whether the use of these devices is leading to a reduced risk of adverse health outcomes, which might be expected with an increase in physical activity.

Today's wearable activity trackers are no longer bulky plastic push button gadgets with a single function. Activity trackers are stylish and claim to monitor all your daily activities 24/7 to provide useful insights into your health. Activity trackers vary in design, but most are capable of tracking steps and calculating activity levels. Certain models have features that include stairs climbed, sleep monitoring, calorie consumption, and heartrate.

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According to the Consumer Technology Association, 33 million devices had been purchased in the US by the start of 2016 [3]. Across all emerging consumer tech categories, wearable activity trackers have the highest anticipated household purchase intent, at 11%, for 2016.

Activity trackers, largely, track your daily activities in terms of steps and calories burned through movement using GPS tracking and accelerometers. Accuracy depends on many factors to include the make and model of the activity tracker, where it is placed on the body, and the activity it is measuring. Most companies do not claim be highly accurate, instead they point to trending. The success of the products comes from empowering people to see their overall health and fitness trends over time—it is these trends that matter most in achieving their goals [1].

University of Nebraska researchers examined various fitness monitors (Jawbone, Fitbit, Nike Fuel Band, and Actigraph) and found they overestimated or underestimated energy expenditures by 10–15%, depending on the monitor [4]. A study published in the Journal of Physical Activity and Health compared the Fitbit to a lab-based method for estimation of energy expenditure for various activities during six-minute periods. The researchers found the Fitbit to either underestimate or overestimated energy expenditure by 1–25 calories. The smallest differences were seen in waking and treadmill running. The greatest underestimations were in cycling and stair stepping [4].

While 25 calories may not seem like a large amount, extend this out to an hour, and you are looking at 250-calorie underestimation for cycling or stair stepping. This obviously makes weight management and planning dietary intake for specific goals difficult and may deter individuals from continued efforts to improve their lifestyle. For example, when setting goals to move more by increasing step count.

How much of our day is spent seated? Staker [7] in an objective measure found that over 75% of the office workday is seated and much of that is accumulated in unbroken periods of 30 min or more [7]. The study linked physical inactivity to a premature mortality rate of 5.5% [2]. A 2008 Vanderbilt University study of 6,300 people published in the American Journal of Epidemiology estimated that the average American spends 55% of waking time (7.7 h per day) in sedentary behaviors such as sitting [6]. A solution is increased movement.

There is more muscular exertion in the lower extremities when standing vs sitting. In fact, the University of Minnesota Undergraduate Research Opportunities Program funded a study published in the *Journal of Physical Activity and Health* that analyzes the caloric expenditure when standing verses sitting. The results are quite convincing for advocating standing vs sitting. The University of Minnesota found that when assuming a standing posture, an additional 114 kcal are expended each day. This translates to approximately 20,461 kcal, or 5.85 lb, of additional caloric expenditure over a one-year period.

The *Take a Stand Study* published by in 2011 addresses the question regarding the benefits of short duration standing incorporated into sedentary work and found that with one hour of increased standing time: 87% of participants felt more energized; 71% felt more focused; and 50% felt reduction in pain [2].

These finds are supported in an unpublished study conducted by Stack in 2009 at a Navy worksite. Eighty workers that received sit to stand work stations between 2005 and 2009 were surveyed, 76 responded to the study, a 95% response rate. Seventy percent felt more productive, 40% reported a dramatic decrease in pain or discomfort and 55% reported a decrease in discomfort or pain. One hundred percent would recommend an adjustable workstation to their peers. A study published in 2015 by the Cochrance Database of Systematic reviews found a low quality evidence that sit-stand desks can reduce sitting time at work. They note a need for high quality cluster-randomized trials to assess the effects of different types of interventions on objectively measured sitting time [5].

Given the popularity and availability of both sit-to-stand workstations and personal activity trackers, we investigated whether or not activity trackers could be used to (1) differentiate between sitting and standing at adjustable workstations, and (2) determine if sit-to-stand workstation usage was associated with higher activity levels at work.

2 Methods

Two studies were conducted to determine the reliability of an activity tracker to measure changes in sedentary activity. Subjects documented personal standing time while using a sit to stand workstation and seated time during the regular workday. Additional data were collected directly from a Fitbit, on a minute to minute basis, with a synchronized software program called Fitabase®. The software provides similar outputs on activity as the regular Fitbit application but provides greater fidelity. The Fitbit application averages data over a 15 min period where as the Fitabase® software records minute by minute data points. The two studies were approved by the University of Montana Institutional Review Board.

A group of 41 potential candidates were identified as having a sit-to-stand workstation. Out of the 41 individuals, 16 responded and agreed to partake in the study, a resulting 39.0% (16/41) response rate. Participants were recruited using a University of Montana Institutional Review Board approved email. Recruitment was based on having largely sedentary occupations and similar occupational environments. Any interested candidates were able to partake in the study if they met the following inclusion criteria:

1. Full time employees (32 h per week, minimal).
2. 50.0% of their workday consisted of sedentary work (sitting or standing).
3. Had a sit-to-stand workstation.
4. Agreed to complete a weekly sit-to-stand workstation survey.
5. Agreed to wear a Fitbit r every day at work during the study period.

Equipment. The studies focused on step count data collected via Fitbits. Sit-to-stand workstation designs varied amongst participants. Some participants utilized sit-to-stand workstations previously provided by the employer, that allowed for the workstation monitor and keyboard to be raised or lowered via an articulating arm. Other participants utilized makeshift stations that allowed them the capability of working unhindered in either position. An example of a makeshift station was the utilization of a metal desk organizer to elevate the workstation to allow a standing work position. For study 2, weekly self-reporting surveys were sent out via Qualtrics, an online research software. Participants without an Fitbit were provided with a Fitbit Flex for their participation in the study. Participants that successfully completed the study were allowed to keep the accelerometer for personal use upon the conclusion of the study. If participants already possessed a Fitbit activity tracker, they were allowed to enroll their device in the study and received a gift card of equivalent value for their participation.

Study 1. A self-reporting study was conducted on six office workers. Participants conducted sixteen 30 min sessions of sitting and standing, noting to the minute the time spent in either position. Participants were instructed to record data only while in their workstation setting. If excursions out of the work area occurred, participants would cease logging data for the time gone and resume upon arrival back to their workstation. Standing was again performed at a sit-to-stand workstation and Fitbit data was synced using the Fitabase® software. A total of 4 h of standing and 4 h of sitting data were collected for each participant to determine if an activity tracer\ is capable of detecting differences between sitting and standing sedentary positions. These data sets were used to calculate a sitting step total and standing step total for each participant.

Study 2. An observational study was conducted on 16 Montana Tech faculty and staff members. The objective was to determine if the duration of standing time using a sit-to-stand workstation while at work is associated with daily activity level. Participants were requested to comply by wearing a Fitbit daily, continue normal work behavior, and to report the amount of time spent sitting and standing per day on a weekly basis. Data were collected via an online survey created and tracked by Qualtrics. Fitabase® collected Fitbit step and activity data, on a minute by minute basis.

Study 2 was conducted over a 6-week period from April 2016 to mid-May 2016. The study examined activity during a 5-day work week, Monday through Friday, from 8:00 AM to 5:00 PM. Participants were requested to sign a consent form and were assigned randomly generated identification numbers to protect their identity and keep personal information confidential. Participants were asked not to alter their normal work behavior and to report the amount of time spent sitting and standing each day on a weekly basis.

Fitbit step data were used to calculate mean daily step count per individual, by dividing the total number of steps per person by the number of days in the study. Data from the Qualtrics surveys were used to determine the overall average percent standing and percent sitting times per week per participant. Percent standing times were first averaged per week, then averaged over the total number of days for which a questionnaire was successfully completed per individual, providing an overall average standing time percentage.

Analysis Study 1. Statistical analyses of the data were processed utilizing Minitab 17 Statistical Software, State Collage PA Minitab, Inc. A final sitting step total and standing step total for each participant was calculated and paired for each subject. The mean number of steps registered while sitting was compared with the mean number of steps registered while standing utilizing a paired t-test. A paired t-test was chosen to test that more activity would occur with a standing position as opposed to a sitting position (Ha: $\mu_d > 0$). The difference between the number of registered steps while sitting vs. while standing was calculated and included in the analysis. The assumptions of the t-test were met by having a continuous dependent variable and the independent variable were matched pairs. The difference between the two variables contained no significant outliers and was normally distributed.

Analysis Study 2. Statistical analyses of the data were preformed utilizing Minitab 17 Statistical Software, State Collage PA Minitab, Inc. Self-reported standing percentages and mean daily step counts were first calculated in Microsoft Excel. Standing percentages and mean daily step counts for each participant were analyzed using Spearman correlation. The Spearman correlation method was chosen given that the data did not meet the assumption of being linearly distributed. The Spearman correlation was performed under the null hypothesis that no relationship would exist between standing percentages and mean daily step counts (Ho: r = 0). The Ho hypothesis would be rejected if a relationship was found to exist between the two variables (Ha: $r \neq 0$). The p-value will determine the statistical significance of the relationship between variables if found to be less than α (0.05).

3 Results

Study 1. Seven individuals were recruited to participate. Of the seven, six successfully completed all required components of the study, 85.7% (6/7). One participant failed to comply with the study parameters, thus resulting in exclusion from data analysis. The total number of registered steps while sitting and the total number of registered steps while standing were calculated and paired per participant. The total number of steps registered while standing varied substantially between participants, ranging from 0 steps to 814 steps. The total number of steps registered while sitting varied less, ranging from 0 steps to maximum of 314 steps. The difference in the total number of registered steps was calculated for each participant, ranging from −23 steps to 500 steps. The negative value here resulted from a participant having more while sitting than while standing *(0 (standing) − 23 (sitting) = −23 steps).*

Analysis of the total number of steps registered while standing found a mean of 309, standard error mean of 139, and a standard deviation of 340. The total number of steps registered while sitting for participants revealed a mean of 67, a standard error mean of 49, and a standard deviation of 122. Based off of the paired t-test analysis, no statistically significant difference was detected between the total number of steps registered while sitting and the total number of steps registered while standing (p-value = 0.113). The distribution for the number of steps registered while standing and number of steps registered while sitting can be seen in Fig. 1.

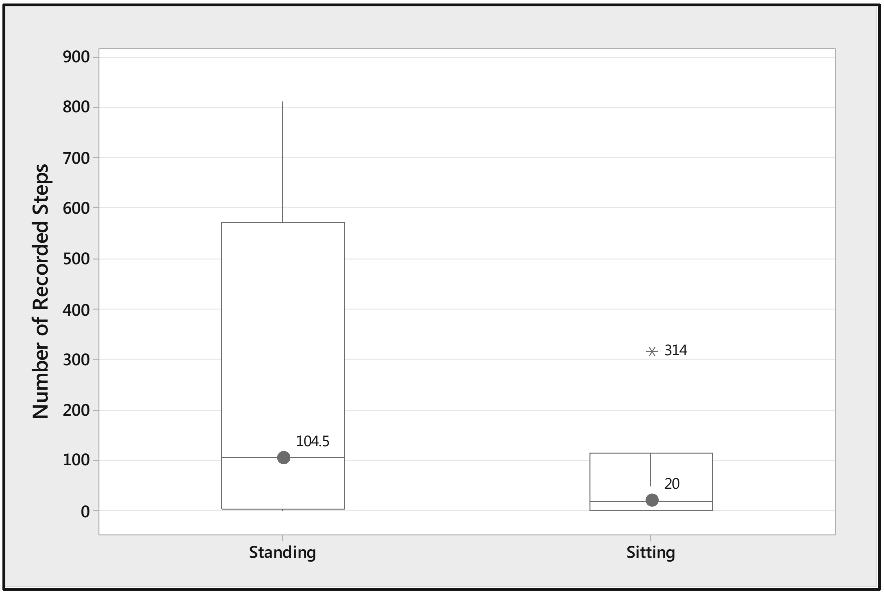

Fig. 1. Box and whisker plot of total number of steps registered while standing compared to total number of steps registered while sitting.

Study B. Of the 16 individuals that agreed to participate, 12 successfully completed all required components of the study, 75.0% (12/16). Four participants failed to either register their activity tracker or synchronize their daily sit-to-stand workstation usage with Fitabase, thus resulting in exclusion from data analysis. The 12 remaining participants were monitored for the 30-day (5 days × 6 weeks) study period. The mean standing percentage, mean daily step count, and number of days with questionnaire entries were paired by participant for the 12 participants that successfully completed the study parameters. Mean standing percentages varied noticeably between participants, ranging from 27–86%. Mean daily step counts ranged from as low as 3,033 steps to as high as 7,094 steps. The number of recorded self-reporting surveys also varied, with 58.3% (7/12) participants having 30 recorded questionnaire entries, 25.0% (3/12) having 25 recorded entries, and 16.7% (2/12) having only 20 recorded entries; see Table 1. The comparison between mean standing percentage and mean daily step count per participant can be seen in Fig. 2.

Analysis of the self-reported mean standing percentages revealed a mean of 49, a standard error mean of 6, and a standard deviation of 20. Mean daily step count data for the participants revealed a mean of 5,052, and a standard error mean of 444, a standard deviation of 1539. The Spearman correlation analysis revealed a weak relationship ($\rho = 0.301$) between participants' self-reported standing time percentages and their respective average daily step value. Furthermore, the correlation was not statistically significant between a participant's mean standing percentage and mean daily step count

Table 1. Self-reported standing percentage, daily step average, and number of recorded questionnaire days observed per participant.

Participant	Mean standing percentage (%)	Mean daily step count	# Days with questionnaire entries
1	47	5149	30
2	86	4399	30
3	31	5183	30
4	54	3515	20
5	83	5354	30
6	69	6452	30
7	29	7094	30
8	28	3730	25
9	53	5291	20
10	35	3448	25
11	52	7979	25
12	27	3033	30

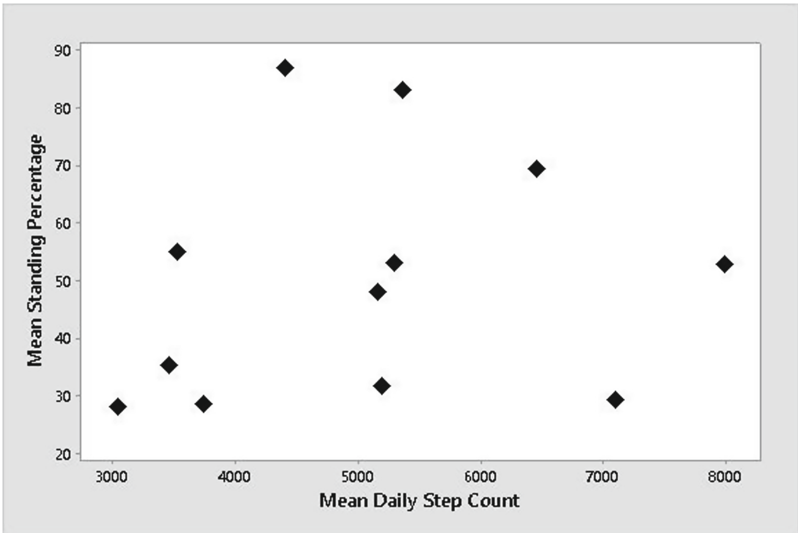

Fig. 2. Scatterplot graph of mean daily step count compared to participant mean standing percentages for each subject.

(p-value = 0.342). Only a 3.5% (R^2) of the variability in step count was accounted for due to percent standing. As shown in the scatterplot in Fig. 2, no clear relationship between the participant's mean standing percentage and mean daily step count is evident.

4 Discussion

Activity trackers such as Fitbit have been determined capable of distinguishing between varying levels of activity, categorized as low, medium and high. The differences in activity level classification is based on step count and a cut point, 99 steps in 5 min is low, whereas 100 steps in 5 min may be medium. Standing still does not generally produce a high enough steps to meet the cut point between low and medium, therefore a user will not see an increase in their percentage of activity in the medium category with increased standing time. They may also not see an increase in steps overall. On the other hand, activity trackers erroneously record steps where none have been taken, this was apparent in our studies and is in line with other findings. This finding should be conveyed to workers who are using activity trackers to monitor their activity level. Standing may have physiological benefits but using step count and activity level on a Fitbit does not appear to measure them. Heartrate may be a better metric.

The main strength of the studies was investigating whether an activity tracker could distinguish between sedentary sitting vs sedentary standing positions, which has not been previously attempted. Despite our results showing that no significant difference in the standing steps and sitting steps could be seen, the amount of steps registered while standing was generally higher than the number of steps while sitting. This finding is important as it suggests that activity trackers, in this case Fitbits, may be useful in ergonomic studies monitoring sit-to-stand workstation usage, but further research is needed to determine if a statistically significant difference can be detected with larger data sets. Additional research will also help establish how researchers and employers can utilize the data to measure the degree of sit-to-stand workstation usage and to determine if sit-to-stand workstations result in changes in activity of the users.

Suggestions for future research include repeating Study 2, but account for time spent sitting, standing and walking in the self-reporting questionnaire, so that activities can be correctly correlated with the mean daily step counts; expanding Study 2 to include a larger sample size to verify the significance of the Fitbit's ability to distinguish between sitting and standing positions. Activity trackers capable of physiological measure should also be explored.

Our findings suggest that basic activity trackers may not be useful in measuring sit-to-stand workstation usage. Furthermore, there was no evidence to indicate a meaningful relationship between increased sit-to-stand workstation utilization, as a percentage of time at work, and increased physical activity while at work. Activity trackers capable of measuring heart rate may hold promise as a means to differentiate between sitting and standing during office work. Further research is needed to determine if greater sit-to-stand workstation usage increases physical activity in general, not just at work.

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