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Fitbit Accuracy Depends on Activity Pace and Placement Location

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Abstract. This study is designed to measure the concordance of step counts recorded by Fitbit activity trackers when the devices are placed on multiple locations of the body and while subjects climb stairs at fast, slow, and medium paces. Nine participants wore 5 Fitbit trackers concurrently while performing the stair-climbing activity. The level of concordance was characterized by variability metrics derived from five step counts obtained for each study participant at each climbing pace. Results of one-way ANOVA analysis revealed statistically significant difference between mean variance, standard deviation (SD) and range of step count measurements depending on location of tracker and pace of movement. Stair climbing at a 'medium pace' produced the least variance (25.9±24.5) with smallest SD (4.0±2.3), whereas the 'slow pace' trial produced the greatest variance (1770.9±3307.5) and SD (27.6±27.1). Discordance between Fitbit step count measurements obtained at different activity levels may affect overall accuracy of step count reporting.

Keywords. Movement Measurement, Tracker Position Affects, Activity Tracking, Measurement Accuracy

1. Introduction

Wearable fitness trackers are an increasingly popular consumer item, catering to a wide variety of users on the premise that collecting data may improve fitness and subsequently health. These devices are typically outfitted with micro electro-mechanical sensors (MEMS) and optical sensors that track numerous metrics such as heart rate, blood oxygen saturation, step counts, and more. In recent years, however, there has been growing scrutiny regarding the underlying evidence - or lack thereof - that demonstrates how these sensors have been tested and validated [1]. There are now multiple discussions about the validity of the data acquired by these wearables.

Prior studies have demonstrated significant variability of step counts using pedometer functions from multiple manufacturers; measurements may be influenced by health status of the wearer, gait, speed of movement, indoor/outdoor walking, and presence of stairs, among many other conditions [2-4].

This study is designed to investigate how step count results from Fitbit fitness trackers may vary depending on their locations on the body and the speed of movement as participants climb and descend stairs.

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2. Methods

2.1. Study Design

A case series study design was employed to examine the impact of Fitbit placement on the accuracy of resulting step readings depending on climbing pace.

Nine healthy adults (7 males, 2 females, all right-handed), performed three phases of stair climbing while concurrently wearing 5 Fitbit activity trackers. Stair climbing phases were divided by pace; participants were instructed to climb up and down a stairwell at fast, slow, and medium paces, respectively. Actual speed was up to the participant to interpret, as appropriate to the pace. Between each phase, participants were given 3 minutes rest. Fitbit trackers were attached to five different positions of each participant's body, including both wrists, both ankles, and the waist, as per Figure 1.

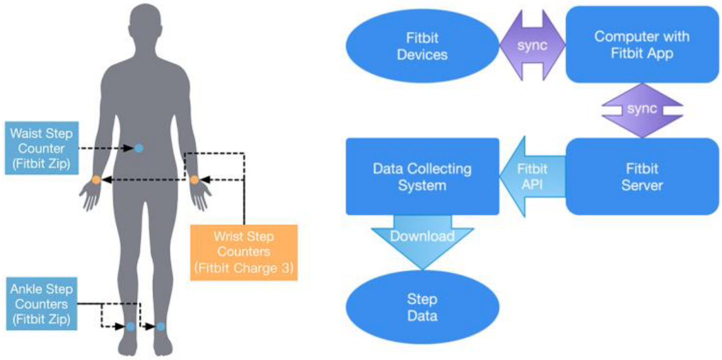

Figure 1. Activity tracker locations and data collecting system design

2.2. Data Collection

The data collection system was developed to record minute-to-minute step data from the Fitbit activity trackers. Fitbits are small wearable devices that use a three-dimensional accelerometer to measure the movement of a user. In this project, after each participant finished the experiment, data from all five trackers were uploaded to a local Fitbit server through a Fitbit application on a Windows computer. To ensure data integrity, each tracker was configured with a separate Fitbit account. The data collection system ran continuously on a local server built with Python and Go (Figure 1). Variance indicators were calculated based on step counts collected from 5 activity trackers.

3. Results

Overall, nine healthy adults (two females) were recruited with mean age 36±13, ranging from 25 to 58 years old. Average Body Mass Index (BMI) was 24 ± 2.5, ranging between 19 and 27. Average Step counts grouped by pace are displayed in Figure 2.

Stair climbing at a 'medium pace' produced the least variance (25.9±24.5) with smallest SD (4.0±2.3), whereas the 'slow pace' trial produced the greatest variance (1770.9±3307.5) and SD (27.6±27.1). Based on the one-way ANOVA test, the mean SD in three groups was statistically significantly different ($F=5.5$; $p<0.01$).

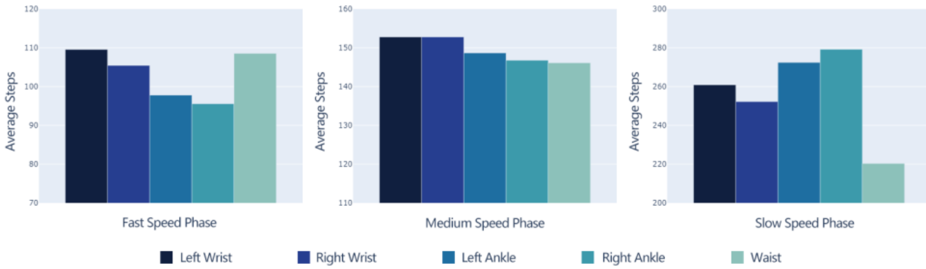

Figure 2. Average step counts by tracker location, for each pace.

Additional analysis (Table 1) revealed that the discrepancy range measured as a difference between the maximal and minimal value of step counts obtained in each experiment (MAX-MIN) was highest in the 'Slow Pace' group (73.0 ± 63.1), followed by the 'Fast Pace' group (23.3 ± 10.5), and then the 'Medium Pace' group (10.8 ± 5.9).

Table 1. Variability of step reporting depending on Fitbit placement and climbing pace (Mean±SD)

Pace	Variance	SD	MAX-MIN	% Mean
Slow	1770.9±3307.5	27.6±27.1	73.0±63.1	44.5±61.0
Medium	25.9±24.5	4.0±2.3	10.8±5.9	8.6±6.3
Fast	113.1±106.7	8.7±4.0	23.3±10.5	26.2±15.8

The average "MAX-MIN" expressed as percentage of mean count value in each experiment (% Mean) varied from 8.6 ± 6.3% at medium pace to 44.5 ± 8.6% at slow pace.

4. Discussion

Our results demonstrate a large variance depending on movement pace, with statistically significant standard deviations between groups. Interestingly, the 'slow pace' measurements corresponded with the greatest variance and standard deviation. This pace may best represent patients with limited mobility, advanced age, or even novices just beginning an exercise regimen. Thus, the results suggest that these devices may be poorly suited to track step counts for such a population.

The 'fast pace' trial demonstrated the second-highest variance and standard deviation, whereas 'medium pace' produced the smallest. On these particular activity trackers, step count results for anyone moving at a pace other than 'medium pace' may be sub-optimal.

The implications of such extreme variance are amplified further when combining step counts across multiple paces; results from a single session with multiple speeds (e.g. interval training) and/or analyzing results longitudinally across multiple sessions (e.g. tracking progress) should be taken in context.

Previous studies indicated the necessity for clear delineation of potential limitations of wearable devices [5-6]. Our results also highlight the need for transparency and review of the validation studies of wearables' sensors before their use is considered in a professional context. Sensors must be subjected to the same level of scientific rigor and validation as have been applied to other patient monitoring devices. This includes establishing test accuracy and precision as compared to gold standard, and establishing a reportable range / linearity under various testing conditions and in different subject subgroups.

Studies of patients with chronic health conditions such as obstructive pulmonary disease, diabetes and multiple sclerosis suggest that these patients in particular may benefit from decisions informed by wearables' data [7-9]. However, there must be a thorough understanding of data quality before appropriate data-driven decisions can be made.

Future studies to explore the relationship between tracker position, handedness, and variance are clearly warranted. Larger sample sizes that include an even distribution of self-reported sex and/or gender identity would address some of the drawbacks of this relatively small pilot study. Additionally, controlled speed measurements such as on a treadmill would offer more granular information about how speed affects these devices.

5. Conclusions

Step count results from Fitbit wearables may vary significantly depending and the pace at which the user moves, and by the location of the device on the body. Fitbit step count results demonstrate the least variance when used to record measurements on stairs at a 'medium pace'.

Acknowledgments

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