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The Accuracy of Pedometers in Measuring Walking Steps on a Treadmill in College Students

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ABSTRACT

International Journal of Exercise Science 10(1): 146-153, 2017. Pedometers are a popular way for people to track if they have reached the recommended 10,000 daily steps. Therefore, the purpose of this study was to determine the accuracy of four brands of pedometers at measuring steps, and to determine if a relationship exists between pedometer cost and accuracy. The hypothesis was that the more expensive brands of pedometers (the Fitbit Charge™ and Omron HJ-303™) would yield more accurate step counts than less expensive brands (the SmartHealth – Walking FIT™ and Sportline™). While wearing all pedometers at once, one male and eleven female college students (mean ± SD; age = 20.8 ± 0.94 years) walked 400 meters on a treadmill for 5 minutes at 3.5 miles per hour. The pedometer step counts were recorded at the end. Video analysis of the participants' feet was later completed to count the number of steps actually taken (actual steps). When compared to the actual steps, the Sportline™ brand (-3.83 ± 22.05) was the only pedometer that was significantly similar. The other three brands significantly under-estimated steps (Fitbit™ 55.00 ± 42.58, SmartHealth™ 43.50 ± 49.71, and Omron™ 28.58 ± 33.86), with the Fitbit being the least accurate. These results suggest an inverse relationship between cost and accuracy for the four specific brands tested, and that waist pedometers are more accurate than wrist pedometers. The results concerning the Fitbit are striking considering its high cost and popularity among consumers today. Further research should be conducted to improve the accuracy of pedometers.

KEY WORDS: Activity trackers, step counts, physical activity, daily steps, exercise tracking

INTRODUCTION

How many steps should people take each day to maintain optimal health? A generally accepted and widely promoted criterion today is 10,000 steps (which is roughly equivalent to five miles) per day, established from the "10,000 Steps a Day" walking club program that started in Japan in the 1960's (6). A very popular method employed to measure one's steps is wearing a step-counting device such as a pedometer. There is a variety of different brands and

types readily available to consumers. The three main ways that brands of pedometers are different from one another is in their cost, mechanism, and the sensitivity threshold (8). Accelerometers and spring-loaded systems are two common mechanisms utilized in modern pedometers. Those with a built-in accelerometer can measure the vertical acceleration of the hip or the wrist to track steps. The person's vertical acceleration must be higher than the force sensitivity threshold that the manufacturer built it with in order for a step to be counted (10). The more traditional yet still produced spring-load models use a coiled spring or hairspring mechanism that uses a horizontal lever-arm that moves up and down to count steps (10).

Despite the wealth of research available concerning pedometers, very few studies have tested the accuracy of pedometers solely within the college-student population. Past studies have used an extremely wide age range of participants (anywhere between 18-69 years old) in order to generalize the results to a broad population (2, 8). However, there may be great variability in such studies with large populations, and a larger variety of gait patterns. Therefore, perhaps research should be done on smaller age ranges to determine if specific populations can trust the latest pedometers to accurately measure the steps they take on a daily basis. College students tend to be a very health-conscious population, and they take more than the recommended 10,000 steps per day (7). Therefore, the ability to reliably monitor their health if they so choose to invest in a pedometer for this purpose is of the utmost importance. In addition, the relationship between cost of pedometers and accuracy has yet to be determined. Cost is an important factor for college students when buying products. More research needs to be done to determine if the cost of the pedometer has a positive correlation to its accuracy. Finally, there is a shortage of studies that have been conducted in the past decade to test the accuracy of the newest and most popular brands of pedometers on the market today, such as the Fitbit™.

The purpose of this study was to determine the absolute accuracy of four brands of modern, accelerometer-based and spring-loaded pedometers at measuring steps among college students while walking on a treadmill, and to determine if there was a relationship between pedometer cost and its accuracy. This was done by using predetermined gait velocities, a healthy population with normal gait patterns, and a treadmill. A predetermined gait velocity is one in which all participants walk at the same speed. This was achieved by programming the treadmill to a specific speed, such as 3.5 miles per hour (mph). The hypothesis was that when comparing two waist and two wrist pedometers that are commercially available, the more expensive brands would yield more accurate step counts than the less expensive brands. Among the two accelerometer-based wrist pedometers, it was expected that the Fitbit Charge™, $130, would be more accurate than the Smart Health – Walking FIT™, $40. Among the two waistband pedometers tested, the accelerometer-based Omron HJ-303™, $40, was expected to be more accurate than the spring-loaded Sportline™, $5.

METHODS

Participants

Recruited participants (n = 12) consisted of Nebraska Wesleyan University students aged mean = 20.8 ± 0.94 years old. Inclusion criteria included being deemed healthy enough to engage in mild aerobic walking exercise on a treadmill for five minutes and a legal adult in Nebraska. Students who fit among this population criteria were recruited through flyers placed around the campus. One male and 11 females were recruited. Ethical guidelines were followed as all participants signed an informed consent form before participating in this study. The Nebraska Wesleyan University Health and Human Performance Department approved the study.

Protocol

All participants were in the same experimental group and performed the same protocol. The absolute accuracy of the step-counting function of four pedometers was assessed and compared with the actual number of steps taken. The four pedometers included the Fitbit Charge - Wireless Activity Wristband™, plum (Fitbit Inc., San Francisco, California, United States), Smart Health – Walking FIT EKG Accurate Heart Rate Watch with Automatic Tracking™, white (Smart Health, Fremont, California, United States), Omron HJ-303™ (Omron Electronics LLC, Hoffman Estates, Illinois, United States), and Sportline™ (Sportline, Elmsford, New York, United States). An analysis between brand, cost, and accuracy was completed (see Discussion). The experiment took place in the exercise physiology laboratory at Nebraska Wesleyan University. Participants visited the laboratory one time and walked for 400 meters (m) on a Star Trac™ treadmill (NOVA Fitness Equipment, Omaha, Nebraska, United States) at a speed of 3.5 mph. A SONY HD Handycam video recorder was also utilized (Sony Corporation of America, New York, New York, United States). The distance of 400 m was chosen based on a previous study that used this distance, and also to encourage participation by making the time commitment of the study short (3). Participants were given a 30 second warm-up period so they were adequately accustomed to walking at 3.5 mph. All participants were instructed on the desired walking form for safety reasons, to reduce compounding variables, and to ensure participants walked in the same fashion as one another. They were encouraged to swing their arms during the first few small steps as the treadmill gained speed. The arm swinging was emphasized because a previous study has suggested that doing so may yield more accurate results for wrist pedometers, as they may have trouble registering small steps (9). Participants were also instructed to stay on the conveyor belt of the treadmill during the periods it sped up and slowed down (as opposed to immediately hopping off to the sides when the Stop button was pushed), and to not grab onto the rails while walking.

Once participants understood the procedure, the participants stood still on the treadmill while the pedometers were placed on them. The Fitbit™ and Smart Health™ models were worn on the wrist just proximal to the styloid process of the ulna, with the Fitbit™ on the right wrist and the Smart Health™ on the left. The Omron™ and Sportline™ were worn on the waistband at the hips at the anterior superior iliac spine. The Omron™ was placed on the right hip while the Sportline™ was placed on the left. Once the pedometers were in place, the Smart Health™, Omron™, and Sportline™ pedometers were set to zero while the initial step count on the Fitbit™ was recorded. After the researcher started the video recorder, the test began as soon as

the researcher started the treadmill. The participants took their first steps while the treadmill gradually increased speed up to 3.5 mph. After 400 m were walked, which took just over 5 minutes, the researcher stopped the treadmill and the conveyer belt gradually slowed down to 0 mph. The participant stood still after taking the last step while the pedometer-measured steps were recorded by the researcher at the conclusion of the test. The researcher then turned off the video recorder.

To accurately count the number of actual steps taken, the video camera was angled so that the participants' feet were clearly visible in the video. Then, an online clicker-counter (http://textmechanic.com/Online-Tally-Counter.html) was utilized to count the steps while the researcher watched the video during a later analysis.

Statistical Analysis

The data are presented as mean ± the standard deviation. The statistical analysis included four independent t-tests. The difference between the actual steps from each participant and the pedometers was compared to the gold standard of the difference between actual steps and actual steps counted (which was 0 ± 0 as it is assumed the manual count is accurate). All statistical calculations were completed using Microsoft Excel 2013 software. The 0.05 level of significance was used in all statistical analyses.

RESULTS

As shown in Figure 1, the only pedometer that was statistically similar to the actual steps was the Sportline™ brand (-3.83 ± 22.05 steps, $p = 0.28$). The other three brands significantly under-estimated step count ($p < 0.05$). The largest difference was the Fitbit™ (55.00 ± 42.58 steps, $p < 0.001$). The Smart Health™ pedometer (43.50 ± 49.71 steps, $p < 0.01$) and the Omron™ (28.58 ± 33.86 steps, $p < 0.01$) also under-estimated the step count.

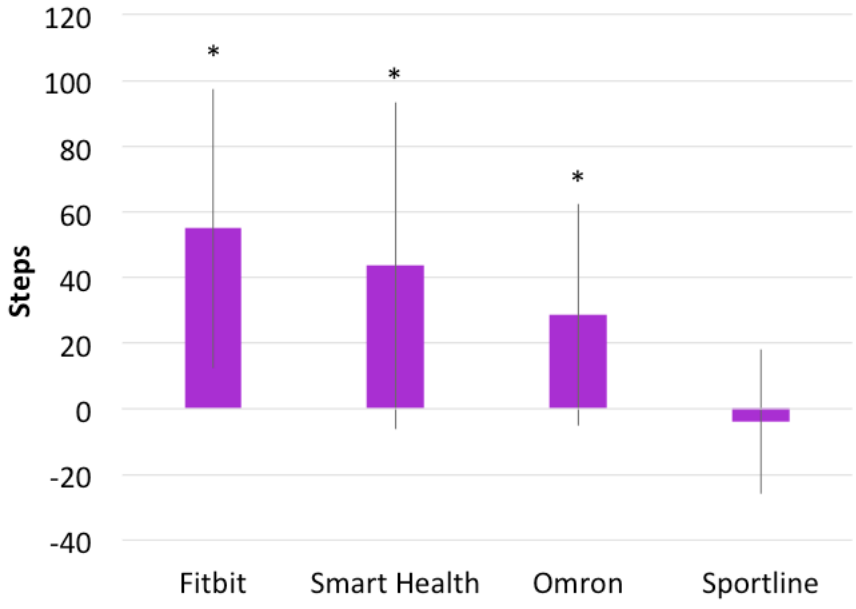

Figure 1. Step counts from video analysis ("Actual Steps") and from the four brands of pedometers, the Fitbit™, Smart Health™, Omron™, and Sportline™. Values are mean ± SD. An asterisk (*) indicates statistical significance with regards to variance from the Actual Steps (*$p < 0.05$, Pedometer vs. Actual Steps).

DISCUSSION

The order of pedometers from most to least accurate in this study were: Sportline™, Omron™, Smart Health™, and Fitbit™. The hypothesis was contradicted in every way, as the less expensive pedometers in the waist and wristband categories were more accurate. The Fitbit™ was less accurate than the cheaper Smart Health™, while the Sportline™ was more accurate than the costlier Omron™ pedometer. The Sportline™ pedometer was the only pedometer that was not significantly different from the actual steps. This is fascinating as the Sportline™ is the least expensive brand and has the more traditional spring-loaded mechanism for counting steps. The other three brands significantly underestimated the steps, despite their higher cost and more modern built-in accelerometer mechanism for measuring steps. With the specific brands tested, this study suggests an inverse relationship between cost and accuracy, contradicting the initial hypothesis that cost and accuracy would be directly proportional. This study has many implications for pedometer users. Even though the widely used Fitbit™ is the most expensive pedometer in this study, it is the least accurate for counting steps. This is a compelling result considering that the Fitbit™ is extremely popular today.

The finding concerning the Omron™ brand is in agreement with previous studies that tested older models. The Omron™ brand was shown to significantly underestimate steps (1, 3, 8). The finding concerning the Fitbit™ is also consistent with relatively recent research that found that the brand (specifically the Fitbit Ultra™ model) tends to underestimate steps (9). Regardless of the precise model, it is apparent that both of these brands in general continue to struggle with accuracy in counting steps today. This suggests that the manufacturers should lower the sensitivity threshold in their pedometers' accelerometer mechanism. No apparent research has been done on the Smart Health™ brand, which leaves an opening for future research to confirm or contradict the results of this study.

It appears that the Sportline™ brand, on the other hand, has greatly improved in accuracy over time, as it was shown to significantly underestimate steps in previous studies (3, 8). It is unknown what this specific brand's intra-model reliability is. Past models were shown to have low reliability (8), opening up further research opportunities for the latest model used in this study. Future research should also focus on the Sportline™ brand's accuracy over time, as spring-loaded pedometers have been shown to lose accuracy over long periods of time as the spring can wear out with use (10). For now, from the results of this study, consumers can assume that this is a trustworthy brand to use.

The results of this study also suggest that pedometers worn on the waist are more accurate with counting steps than those worn on the wrist. Although the Omron™ still significantly underestimated the steps, it was closer to statistical insignificance than the two wrist pedometers. It has been suggested in previous research that pedometers worn on the wrist might not register small steps (9). Participants were told to exaggerate arm movements during the first couple of small steps, as a previous study has suggested this may yield more accurate results for activity trackers worn on the wrist (9). Also, the fast walking pace of 3.5 mph was chosen because past research concluded that faster speeds increase the accuracy of pedometers

(2, 3, 4, 5). Despite these compensations, the two wrist pedometers and the Omron™ still underestimated walking steps. Conversely, it has also been suggested that wrist pedometers may overestimate steps when people engage in activities that require a lot of arm movement (such as racquet sports) (9). More research into this area should be conducted, as anecdotally, people notice that the Fitbit™ records steps when moving the arms but not taking any steps.

Another important item for users to consider is that the most accurate pedometer in this study only had one function: counting steps. This is in contrast to the other three activity trackers that not only count steps, but also track other functions. Consumers would miss out on tracking the other functions that come with the other three activity trackers (with pedometer functions) that were included in this study, such as distance travelled, the time of day, heart rate, energy expenditure, sleep patterns, and stairs climbed, if they decided to use the Sportline™ pedometer. Consumers ultimately must decide what features they want in a pedometer or activity tracker. If buyers do not care as much about the accuracy of the steps, and they want to have more features to track, then they can choose the less accurate activity trackers used in this study. Further research into the accuracy of other functions available on activity trackers should be conducted.

Future psychological research concerning people's perceptions and preferences of the type, style, appearance, and accuracy of pedometers would be both useful and fascinating information for pedometer companies and for those working in the exercise and fitness industry. Perhaps the preference and trend toward wrist pedometers such as the Fitbit™ today is due to its design, which offers the convenience of wearing it like a watch. It is reasonable to conclude that it is more convenient and quicker to check a device that is easily accessible on the wrist than it is to check a pedometer worn on the waistband, which has to be taken off in order to be checked. This convenience might override a person's concern about its accuracy.

Yet another point to consider is that from a health standpoint, one can argue that it is better to under-estimate steps than over-estimate, because the result is that people engage in more activity. There were specific trials when the Sportline™ pedometer overestimated (though not statistically significantly overall). If a pedometer regularly overestimated steps, it would cause a person to think they did more work than the reality. On the opposite spectrum, however, underestimating steps may lead people to exercise more, which is also misleading but not necessarily a dangerous or harmful result. This would be a regular occurrence with the three brands that significantly underestimated steps in this study.

Another compelling area of future research should compare the accuracy of pedometers on treadmills versus their accuracy in free walking conditions during activities of daily living. In a study that examined free walking conditions, participants walked on an outdoor track at a self-selected pace (8). Older Sportline™ and Omron™ models were tested, and they were found to underestimate the steps taken (8). The other 8 brands of pedometers, however, were accurate (8). Another study compared pedometer accuracy on a sidewalk and rubberized outdoor track, with no significant differences in accuracy found between these two conditions

(2). No studies to date have compared free walking conditions with treadmill walking in the same study.

It is acknowledged that a limitation of this study is the small number of participants recruited, the limited age range of participants, and the unequal number of recruited men and women. Also, having each participant undergo a second test on a different day could have determined the test-retest reliability of the pedometers. Finally, only four pedometer brands were studied, even though there are numerous others available. Therefore, future research should continue to study and compare the accuracy of the latest pedometers available for users today, including those from this study as well as the numerous others on the market. The findings should then be used to refine and improve the accelerometer and GPS systems used to measure steps, adjusting the sensitivity threshold as needed so that consumers can trust the accuracy of pedometers.

The specific brands tested constitute a novel area of study for pedometer accuracy. Confounding variables were limited as much as possible through the use of a treadmill, a healthy population with a normal gait, and having participants perform the same protocol. The Sportline™ pedometer was the only brand that was statistically similar to the actual steps taken in 12 college students while walking on a treadmill for 400 m at the brisk walking pace of 3.5 mph. The other three brands (Omron™, Smart Health™, and Fitbit Charge™) were significantly different, and therefore inaccurate. These results refute the hypothesis that cost and accuracy would have a directly proportional relationship.

The importance of increased research and resources for improving pedometer accuracy cannot be emphasized enough. As motivating as pedometers may be among consumers, people ultimately should be able to trust that the devices they are using are accurate, which is why ongoing research in this area is crucial.

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