Walking Distance Covered During Golf: A Comparison of Fitbit and GPSports Devices

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Abstract

The purpose of this study was to determine the accuracy of distance measurements obtained using a Fitbit device compared to a highly accurate GPS-embedded accelerometer device. The participants of this study completed two, 18-hole rounds of golf on two different courses. Prior to each round, participants were fitted with Fitbit device worn on the wrist and a GPSports device secured to the lower back. The participants were eight student-athletes on the Virginia Tech Women's golf team who completed the quantitative case study that assessed the accuracy of the Fitbit devices. The objective of this project was to provide those who play golf with a better understanding on whether or not a Fitbit can be trusted to provide accurate results when competing in a round of 18 holes of golf. A t-test was used to analyze the data once collected. Results of this study show signs that the Fitbit underestimates the distance traveled when compared with the GPS device. For future research we recommend using more specific ranges when comparing the two devices rather than just the two separate 18 hole rounds.

Key words: Fitbit, GPS, accuracy, underestimate

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Introduction

Technology in health and fitness has advanced tremendously over the years and the popularity of tracking devices has grown. Tracking steps, distance traveled and exercise are some of the popular uses of a tracking device. The accuracy of these devices is often the common concern for people that cause hesitation when purchasing the produce. Consumers specifically are concerned when they are completing activities that don't require moving the body entirely, but the devices seem to still track steps or distance (Mammen, 2012). There are many different types of distance tracking devices, for example the pedometers, which are designed to be placed on the hip and used to calculate the amount of steps an individual takes based off of their movement. There are GPS devices that specifically measure distance traveled using satellites. Another device commonly used are Fitbits™, which are commonly placed on the wrist and worn to calculate the number of steps and the distance traveled (in miles) based off of movement. Fitbits have been known to cause some controversy by individuals simply just move their arms, but not the whole body, and the Fitbits have still calculated steps taken, for instance when swinging a golf club (Mammen, 2012). Often times when playing a round of golf with a Fitbit placed on one's wrist, the Fitbit seems to pick up extra steps from the swinging motion. The placement of these devices on the body are a key component to determining if excess steps are gained from the Fitbits when compared with other devices (Schneider, 2004). Since there is are some concerns about the Fitbit devices a study was conducted to test the accuracy of the Fitbit when compared to a highly accurate GPS device. The purpose of this work is to compare the accuracy of the two devices within the Virginia Tech Women's Golf Team during a several rounds of 18 holes.

Background and setting

Fitbit's

Fitbits have become a popular tool for counting steps, measuring distance traveled and tracking other health related functions, especially for people who are trying to improve their activity and movement. With about 25.4 million active Fitbit users, Fitbits have gone from being extremely unaffordable to very reasonable, fashionable, and reliable for individuals wanting to learn and apply more about their fitness (Evenson, 2015). Fitbits are generally worn on the wrist, but that doesn't always give the most accurate reading for step count. Fitbits worn on the bra strap, waist line, and in pocket have been shown to have increased accurate results as opposed to other placements on the body (Mammen, 2015). Individuals may experience some differences in step count depending on where the Fitbit is placed on their bodies (Diaz, 2015). Feehan (2018) looked at the accuracy of the Fitbit based on systematic reviews and narrative syntheses of quantitative data, it showed results of several different variables, but specifically related to steps of participants with Fitbits placed on the torso, wrist, and ankle. The data was assessed based on the accuracy of the step count based on varying speeds of ambulation, body placement, and the variations on how the body moved during activity (Feehan, 2018).

The results showed that the Fitbit actually underestimated steps majority of the time, but "within the different speeds of ambulation, measurement error was within ±3% more than 50% of the time for jogging or normal ambulation speeds. More than 50% of the time, measurement error was below –3% for self-paced, slow, and very slow ambulation speeds." (Feehan, 2018).

Based on the location of the Fitbit the data found that "error was within ±3% more than 50% of the time for comparisons with torso or ankle placement, whereas 70% of the time measurement error was below –3% for wrist placement (Feehan, 2018).

Fitbits can collect a variety of data besides step count. Depending on the model warn, Fitbits have the capacity to measure distance traveled, heart rate, calories consumed, calories burned, the amount of daily active minutes, and sleep patterns. The goal of the Fitbit is for an individual to gain a certain amount of steps throughout the day, by leisurely walking, running, playing different sports such as golf, basketball, football, etc. Fitbits are very useful and beneficial for all and appear to be accurate and reliable in measuring step counts (Mammen, 2012).

Fitbits use a 3-axis analog accelerometer that is designed to observe the intensity and certain gestures of individuals when they are walking or running. Individuals with more activities during the day that require more are movements can experience more steps calculated on their device (Mammen, 2012). Although there are some downfalls in accuracy, fitbit's and activity trackers alone have been a great way to get individuals out and moving to better their daily lives (Diaz, 2015).

GPSport Technology

Global positioning systems are run by satellites that are divided within six different orbital planes. GPS devices have become a widespread with many different applications throughout the world today. Many people use a GPS for directions when driving a car, or to track the mileage traveled on a run. GPS devices have escalated from a large system that is used only

in a car, to a small device that people can wear on their wrist, or on their waist band. GPS devices have become useful in many different applications, such as surveying, navigation, and even geophysics (Verhagen, 2002). GPS devices have even gone from being used for strictly directional purposes to becoming tracking devices for many sports related activities.

The use of GPS devices within a team sport works to measure different aspects of a players position, velocity, and movement patterns (Cummins, Orr, O'Connor, & West, 2013). GPSports is a technology company that provide athletes with wearable technology that is used to measure distance, speed and acceleration, body load, and impact, along with heart rate. These GPS devices are often used in high endurance and high impact sports to help measure the physiological demands of performance and can give a better understanding of how to appropriately train (Williams & Tessaro, 2018). Although golf is not a high endurance or impact sport, playing the game of golf requires covering an abundant amount of distance. These GPS devices can be used on the golf course to help track acceleration and distance traveled for a player. The most up to date model of the GPS device is the SPI HPU GPSport. This device contains a 15Hz GPS unit, a 100 Hz-10G accelerometer and a 50 Hz magnetometer. Majority of the information and data that has been collected on these devices in involved with sports like soccer, rugby, and Australian rules football (Williams & Tessaro, 2018). The GPS devices have been tested many times and have showed they are reliable and accurate devices to use when measuring distance and movement. The GPS devices are assessed using a Bland-Altman plot. A Bland-Altman plot is used to evaluate bias between mean differences and estimates an agreement interval. These plots can be expressed using a unit difference plot, or as percentage differences

(Giavarina, 2015). The GPS device for this study will be used to track only distance traveled and will be worn on the participants' waistband while they complete 18 holes of golf.

Literature Review

Golf is a sport that requires a lot of walking resulting in a lot of steps. It is estimated that the average golfer takes over the recommended 10,000 steps per day when walking in just one round of golf (Macmillan, 2017). Peterson (2006) conducted a study to test the volume and intensity of activity each individual has while walking 18 holes. He broke the accelerometer results down into categories labeled sedentary, light, moderate, and vigorous activity. The study used the pedometer to calculate total steps taken and a GPS device to measure the total distance traveled, along with a heart rate monitor used to measure heartbeats per minute. The results showed that the average golfer spends 105.4 minutes doing moderate to vigorous activity and covers over 12,000 steps per round (Peterson, 2006). Jordan Spieth, a professional golfer, used a tracking device to measure steps and it is estimated that his step count was over 54,000 steps for four rounds, averaging 13,500 steps per round, at the Open Championship in 2016 (Craig, 2016). The estimated amount of steps per round of golf is about 11,948 +/- 1,781 steps per 18 holes (Kobriger, 2006). This estimation is just that though because most data is dependent on the golf course set up, as well as the individual's personal step, which can be all different measurements based off of someone's height. Golf courses can be all types of shapes and sizes, depending on geography, the weather, and the athlete competing. Steps taken on a golf course can also depend on the round of golf that an individual is having. Relative handicap is very relevant to the amount of steps an individual's takes. Although the step count is also very dependent on someone's step

length (Peterson, 2006). This study shows that walking during a round of golf involves quite a bit of physical activity and a lot of steps are taken during this activity.

Mammen (2012) conducted a study that compared four Fitbit and four Yamax pedometers across three different experiments, 20 step test, motor vehicle test and treadmill test. During the 20 step test both the Fitbit and the pedometer were placed on the hip and individuals were asked to walk at a normal pace. There were six trials conducted, three with the devices on the left hip and three with the devices on the right hip. The results of this experiment showed that neither the Fitbit nor the Yamax had a greater error than +/- 5% (Mammen, 2015). The second experiment consisted of a car driving on paved roads while the Fitbit and the pedometer were inside. The results of this experiment showed that the Fitbit didn't record any steps, while the Yamax calculated 3 steps. The third experiment tested the step counts at walking speeds of 2, 3, 4.5 and 6 km/h^{-1} and running speeds of 8, 9,10 and 11 km/h^{-1}. This experiment tested the different speeds with the Fitbit in the pocket, waist, and collar of the individual participating, compared with the Yamax. The results of this study showed that there was statistically significant differences between observed steps and detected steps for the Yamax at speeds of 2, 3, and 4.5 Km/h^{-1} and the waist mounted Fitbit at 2 km/h^{-1}. The steps calculated at 3 and 4.5 km/h^{-1} for the Fitbit were valid and there were no differences detected. There were difference spotted for the Fitbit during the running of 8, 9 and 10 km/h^{-1}. This study helped to support that the Fitbit is an accurate and reliable step counter when compared to the Yamax pedometer (Mammen, 2012).

Project Objectives

The purpose of this study was to test the accuracy of the Fitbit placed on one's wrist compared to a GPS device placed on one's hip, while playing 18 holes of golf. There have been studies conducted that show a hip-based Fitbit outperforms the waist-based Fitbit (Diaz, 2015). With the pedometer placed on the waist, the hope is to compare the two measurements to help make a more realistic mind set for golfers about their Fitbit data.

This study will provide golfers, as well as the general public with a better and more accurate mind set when it comes to wearing a Fitbit. While golf is very strenuous and time consuming, it would be nice to have an accurate comparison when it comes to the amount of exercise one is actually completing. The ultimate hope is that this study will give individuals a better understanding of the actual amount of steps alone that it takes to walk 18 holes of golf as well as the specific distance covered (in miles).

Research question

What differences arise in distance traveled (in miles) when playing a round of golf between a Fitbit and a highly accurate GPS device?

Hypothesis:

- The null hypothesis (H0) represents if the Fitbit and the GPS device have equal number of steps meaning there is no significance between the placement of the Fitbit and the GPS device.
- The alternative hypothesis (H1) represents a difference between the Fitbit and the GPS device, but the difference is not known to be positive or negative.

- The alternative hypothesis (H2) represents a negative relationship between the Fitbit and the GPS device results, suggesting that the GPS device calculated more distance than the Fitbit.

- The alternative hypothesis (H3) represents a positive relationship between the Fitbit and the GPS device results, suggesting the Fitbit calculated more distance than the GPS device.

Methodology

Research Design

A case study design was chosen to look at the difference between the steps that a Fitbit tracks versus the distance that a GPS tracks while individuals are walking a round of 18 holes of golf. A case study was chosen because it is one of the most flexible research designs and it was suitable with the concept behind this study (Creswell, 2018). It allows researchers to maintain complete characteristics of real-life events while exploring experiential designs. During this study the participants were asked to complete a round of golf while wearing both a Fitbit (on the wrist of their choosing) and a GPS device (secured in a pouch attached to the waistband). This study helped to give clarity to the accuracy of wearing the Fitbit on one's wrist verses wearing another device.

Participants

The participants of this study were all student-athletes on the Virginia Tech Women's Golf Team. All were NCAA eligible for play and between the ages of 18-23. There are a total of nine Virginia Tech golfers, but only eight choose to participate in the study. Participants agreed to wear both a Fitbit on their wrist and a GPS device on the back of their waistband to track their

steps and distance traveled. The participants were asked to play 18 holes of golf on two different days. One day consisted of play at the Pete Dye River Course in Fairlawn, Virginia and another round of golf was completed at Blacksburg Country Club in Blacksburg, Virginia.

No personally identifiable data were collected about the subjects (e.g. height, weight, age). Fitbit and GPS devices were randomly numbered and distributed to the players. The data were then downloaded using the number assigned to the device. As personal identifiers were also not collected, none of the instrument data can be associated with a participant.

Data Collection

Participants were outfitted with the same marked GPS device for each trial, which was worn on the back of the waistband, as well as a Fitbit that was worn around the wrist, chosen by the player for a golf match of 18 holes. Before the start of the first hole, the time, number of steps, and distance previously on ones Fitbit was recorded on a sheet of paper. The GPS devices were turned on by the investigator and play was started. Each participant walked the course and carried their own equipment. At the end of the round, the finish time was recorded, the step count and distance traveled data from the Fitbit was collected and cataloged on the initial sheet of paper. The GPS devices were turned off and stored for off-line analysis.

Equipment

A numbered Fitbit and GPS device was provided to each participant and used to calculate distances and the number of steps taken during the rounds.

The Fitbit uses a 1Hz GPS and tri-axial accelerometer. Distances and steps are computed using a proprietary algorithms. Prior to the start of each round, initial distances and step counts

were recorded. These were again recorded at the end of each round. Differences between initial and final values were used as the distance covered and steps executed.

The GPSports SPIHPU uses a 10 Hz GPS coupled with a 100Hz / 16g accelerometer and 50Hz magnetometer. Distances are determined using by combining the GPA and accelerometer output to interpolate speed at 15Hz. Speed is then integrated to achieve distance. The accuracy and reliability of the GPSports SPIHPU has been previously determined and has shown to be accurate within <2% error (Tessaro and Williams, 2018). Following each round, the data were downloaded and analyzed using the manufacturer's software (Team AMS). For each players and each round, total distance covered were recorded.

The Golf Courses

Data collection took place at the Blacksburg Country club in Blacksburg, Virginia. Pete Dye River Course in Radford, Virginia. Blacksburg Country Club is measured at 6645 yards (6076 m).from the back, black tees (see Figure 1) ("Blacksburg Country Club," 2017) which equals about 3.77 miles. The Pete Dye River Course is measured at 7685 yards (7027 m) from the very back, black tees (see Figure 2) ("Pete Dye River Course of Virginia Tech ", 2018), which is 4.33 miles. These mileages do not account for the distance between holes and the amount of walking that is done while on the putting green. After taking those factors into consideration a rough estimate for the average total distance of Pete Dye River Course comes out to be about 6.33 miles total and Blacksburg Country Club is about 5.77 miles.

Data Analysis

To compare distances recorded by the Fitbit and GPS devices, paired t-tests were used as well as Pearson Product Moment correlations. For the mean differences between devices, effect sizes were calculated using Cohen's d and interpreted as <0.2 = small; 0.2-0.5 = medium; <0.5 = large. In addition, Bland-Altman plots were constructed to determine the agreement between the GPS and the Fitbit devices. The bias and limits of agreement were calculated along with the root mean square errors.

Results

Typical movements during the rounds are shown in Figure 1 and 2. The red lines represent the walking path within and between each hole. The larger red areas represent movements that occurred while preparing for and executing each shot.

Figure 1. Movements during a round of golf played on the Blacksburg Country Club course. The red line represents the walking path of a single player.

The distances measured by the GPS differed from the measured distances of both courses. For the Blacksburg Country Club, the recorded distance was 10,069.10 ± 161.47m compared to the published length of 6076 m. For the Pete Dye River course, the recorded distance was 10,843.75 ± 149.33m compared to 7027m. Thus, players walked 66 and 54% more distance than the listed distances.

Overall the data between the Fitbit underestimated the distance traveled compared to the GPS device (see Table 1).

Figure 2. Movements during a round of golf played on the Pete Dye River Club course. The red line represents the walking path of a single player.

Table 1. Total distances covered using the GPS and Fitbit devices.

	GPS	**Fitbit**
Meters	10456.43 ± 150.69	9876.81 ± 332.42*
Miles	6.49 ± 0.09	6.14 ± 0.21*

Values are mean ± SEM

Significance was established at p=0.1195, which suggests the distances recorded by the two devices were not significantly different. Also, the effect size between the two devices was 0.41 which is considered medium.

A correlation between the GPS device and the Fitbit is shown in Figure 3. The "goodness of fit" using a linear model was r^2=0.0137 ($p<.05$). The correlation coefficient (r^2) is a statistical measure of how close the data points are to the regression line. By general rule the higher the r^2 value the better the model will fit into the data with 1.0 being a perfect fit. The r^2 of these data was relatively low suggesting the distances determined by the two devices were poorly correlated.

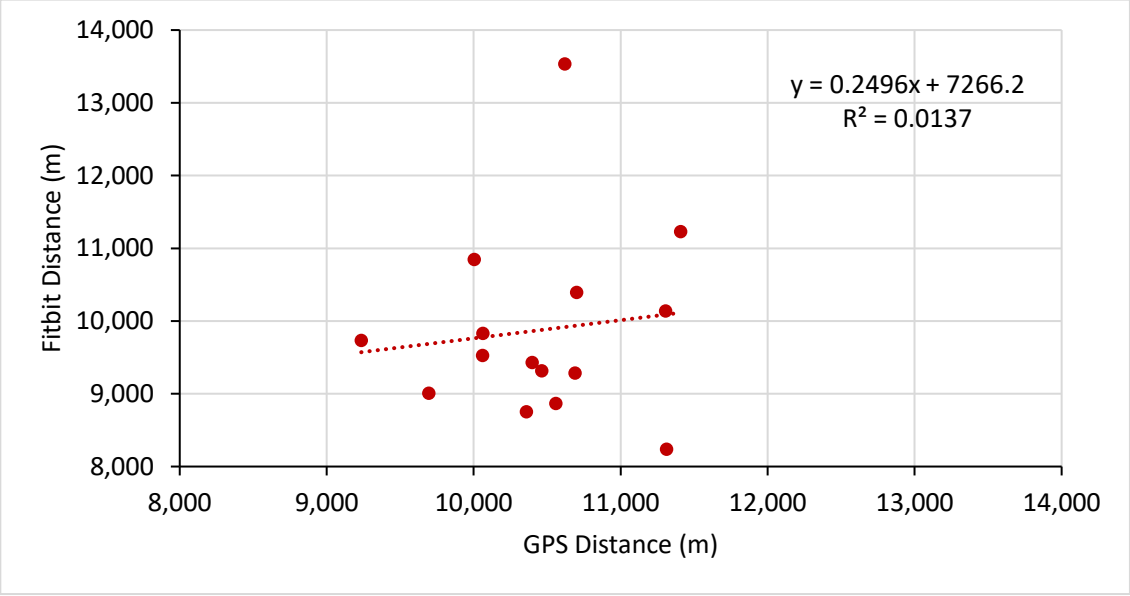

Figure 3: Pearson-Product Moment correlation of Fitbit and GPS determined distances

Bland-Altman plots were used to compare the distances recorded by the two devices. Figure 4 shows the absolute and relative differences between devices. The bias values were 580.76 ± 339.14m and 2.26 ± 3.21%. The limits of agreement were -2078.14 to 3239.76m and -18.98 to 31.40%. In addition, the root mean squared errors were 370.13m and 3.58%.

Individual differences varied considerably. In one case, the Fitbit overestimated distance by 2900m or 24%. In another, the devices were quite comparable with differences of 173.6m and 1.5%. Overall, the Fitbit was found to underestimate distance by about 580.8m and 6.3%

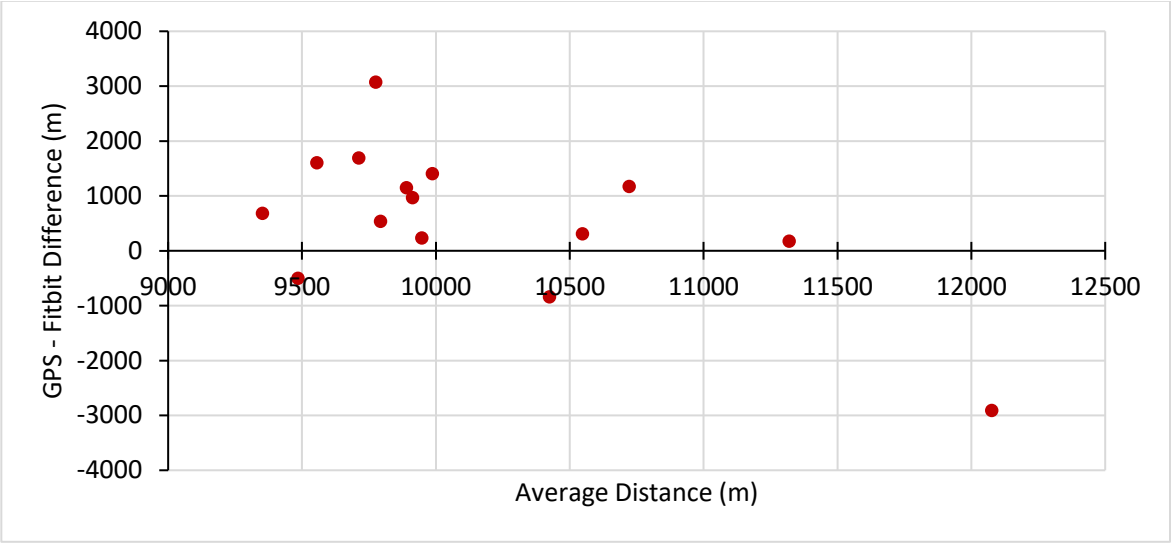

Figure 4a. Bland-Altman plots comparing distances determined by the Fitbit and GPS devices. Differences between devices are expressed in meters.

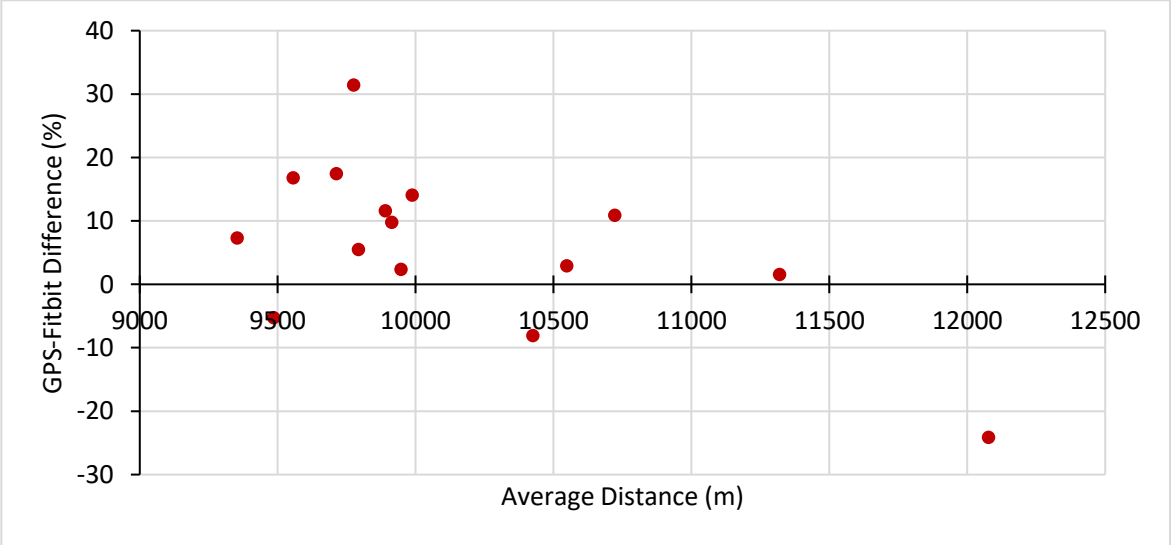

Figure 4b. Bland-Altman plots comparing distances determined by the Fitbit and GPS devices. Differences between devices are expressed in percent.

Because the Fitbit devices also provide a measure of "steps" executed during activity, it was of interest to examine the relationships between steps and distances recorded by the devices. These results are shown in Figure 5. The r^2 values for the comparisons of steps to Fitbit and GPS distances were 0.1179 and 0.0740 ($p>.05$), respectively.

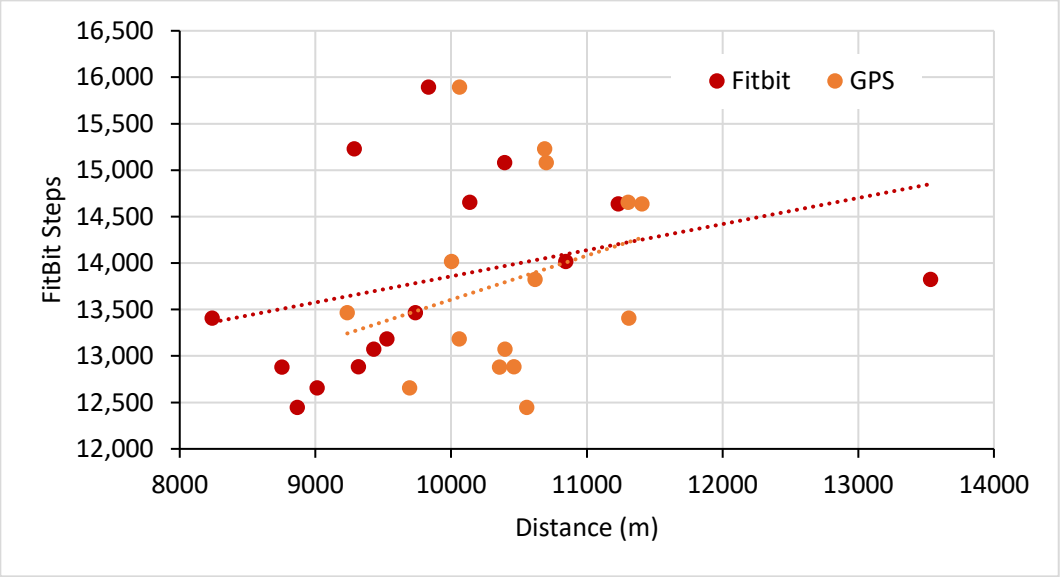

Figure 5. The relationships between Fitbit steps and distances recorded by the two devices (red = Fitbit, Orange = GPS).

Discussion

Using Fitbits during a round of golf has become regular custom for golfers. Fitbits are useful when calculating the distance traveled for golfers, however accuracy issues do exist. A high concern when purchasing a Fitbit device is the accuracy and reliability of the device when related to distance traveled. Based on the Virginia Tech Women's golf team study, this statement still exists. We found that overall the data supported the alternative hypothesis (H2) that represents a negative relationship between the Fitbit and the GPS device results, suggesting that

the GPS device calculated more distance than the Fitbit. The data showed that Fitbit's were more likely to underestimated the distance traveled when compared to the highly accurate GPS devices for each of the golfers that completed the study.

The distances recorded by the GPS device were greater than the published course length. It is likely that these difference are explained by the method of course measurement. The course it typically measured as the sum of straight-line distance between estimated shot placements on each hole. As note earlier, this does not account for distances between holes. In addition, the GPS records all distances covered which includes non-linear paths taken from one shot to the next and movements around the ball when setting up a shot. For example, some players "walk around" on the green more than others when evaluating ball placement and setting up a putt. Thus, the actually distances covered during a round of golf appears to be ~60% greater than the published course length.

The difference between the devices could be caused by a number of different factors such as the location that the devices were worn, the quality of the device, and the fact that the Fitbits use an algorithm to calculate steps and distance as opposed to the GPS devices using highly dependable satellites. The differences between the devices could be a concern for those individuals who are looking for highly specific and accurate data regarding a Fitbit. The GPS units have been validated and are highly accurate and reliable. Differences between devices are varied, ranging from 174 to 2914m or 1.5 to 24.1% with mean values of 581m and 6%. When considering individual Fitbits, the data suggests that the accuracy differs considerably between devices. However, on average, the Fitbit error is reasonably small, depending on the application. For the typical golfer interested in quantifying the workload accomplished during a round of

golf, an error of less that 500m and 6% may be acceptable. However, as a research device, such an error makes the Fitbit a questionable research tool. This is especially the case when looking at interventions that might alter distances covered during a round by <6%.

Limitations

There are a number of factors that could have contributed to the variation in the results. There were several limitations within the progression of the study on of which included malfunction of a device. During the first trial of the study one of the Fitbit's became dysfunctional and stopped working making the data collected by that participant irrelevant for that trial. Another limitation of the study was that the Fitbit's were not specifically programmed for the participant's specific body type. This might have affected calculated distances and step counts. Alternatively, the Fitbit's were worn on the wrist of the players choosing, therefore not using the same wrist (right or left) could have played a role in different data collected. A final limitation of the study consisted of there is no clear understanding of what the exact specification of what "distance traveled" means when using the GPS, suggesting that excessive movement when using the device could have calculated excess mileage within the device. Such distances may be more or less impacted by the location of the device (wrist versus trunk).

Conclusion

When comparing the Fitbit and the GPS device there was not a significant difference between the two. The Fitbit did slightly underestimate the amount of steps, which was not the original thought when beginning this project. Since the Fitbit's only showed a slight difference in distance traveled when compared to the GPS device, they could be beneficial to use to track distance traveled when playing a round of golf. Although there were limitations to this study that

are mentioned above, the Fitbit did show beneficial signs of being a useful device to track distance traveled when playing golf. More research needs to be done to help provide further evidence that the Fitbit is the "best fit" for a device to use during golf, but they did show signs of benefit.

Future Recommendations

Future recommendations for this study could consist of using a wider range with more specific distance markers for the data collection. Some examples could include a more specific and direct setting, such as breaking each data point down hole-by-hole, or completing different 9 hole or 18 hole matches, in order to create a better correlation and more accurate readings for the comparison of both devices. Using a diverse population other than just female participants. Another aspect could be to place each of the devices of different parts of the body in order to test accuracy further. By implementing the future development of this study the hope is to develop a sports specific device that will accurately calculate the specific movements that golfers take during a golf swing and provide immediate feedback to golfers.

References

Diaz, Keith M., Krupka, D., Chang, M., Peacock, J., Yao, M., Goldsmith, J., Schwartz, J., Davidson, K. (2015). Fitbit^{R}: An accurate and reliable device for wireless physical activity tracking. *International Journal of Cardiology, 185,138-140.* *http://dx.doi.org/10.1016/j.ijcard.2015.03.038*

Creswell, J.W., Creswell, J.D. (2018). *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches: 5th edition.* Thousand Oaks California: Sage Publications, Inc.

Evenson, K. R., Goto, M. M., & Furberg, R. D. (2015). Systematic review of the validity and reliability of consumer-wearable activity trackers. *International Journal of Behavioral Nutrition & Physical Activity*, *12*(1), 59. https://doi-org.ezproxy.lib.vt.edu/10.1186/s12966-015-0314-1

Feehan, L. M., Geldman, J., Sayre, E. C., Park, C., Ezzat, A. M., Yoo, J. Y., ... & Li, L. C. (2018). Accuracy of Fitbit devices: Systematic review and narrative syntheses of quantitative data. *JMIR mHealth and uHealth*, *6*(8), e10527.https://doi-org.ezproxy.lib.vt.edu/10.2196/10527

Kobriger L., K., Jay, S., John H., H., & Aynsley M., S. (2006). The Contribution of Golf to Daily Physical Activity Recommendations: How Many Steps Does It Take to Complete a Round of Golf? *Mayo Clinic Proceedings*, 81(8),1041-1043. https://doi.org/10.4065/81.8.1041

Mammen, G., Gardiner, S., Senthinathan, A., McClemont, L., Stone, M., & Faulkner, G. (2012). Is this bit fit? Measuring the quality of the Fitbit step-counter. *The Health & Fitness Journal of Canada*, *5(4),* 30-39. https://doi.org/10.14288/hfjc.v5i4.144

Schneider, Patrick L., Crouter, S. E., Bassett, D. R. Jr., (2004). Pedometer Measures of Free-Living Physical Activity: Comparison of 13 Models. *Journal of American College of Sports Medicine. 36(2),331-335*. https://doi.org/10.1249/01.MSS.0000113486.60548.E9

Blacksburg Country Club. (2017). Retrieved from https://www.blacksburgcc.com/Golf/Blacksburg_Country_Club.aspx

Cummins, C., Orr, R., O'Connor, H., & West, C. (2013). Global positioning systems (GPS) and microtechnology sensors in team sports: a systematic review. *Sports Medicine, 43*(10), 1025-1042.

Giavarina, D. (2015). Understanding Bland Altman analysis. *Biochemia Medica (Zagreb), 25*(2), 141-151. doi:10.11613/bm.2015.015

Pete Dye River Course of Virginia Tech (2018). Retrieved from http://www.petedyerivercourse.com/

Verhagen, S. (2002). *Performance analysis of GPS, Galileo and integrated GPS-Galileo.* Paper presented at the Proceeding of the 15th International Technical Meeting of the Satellite Division of the Institute of Navigation (ION GPS-2002).

Williams, J., & Tessaro, E. (2018). Validity and reliability of a 15 Hz GPS Device for court-based sports movements. *Sports Performance & Science Reports.*