SCHOOL OF ENGINEERING

TAYLOR'S UNIVERSITY

ENG 61103

Data Measurement, Analysis and Experimental Design

Assignment Report

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Introduction

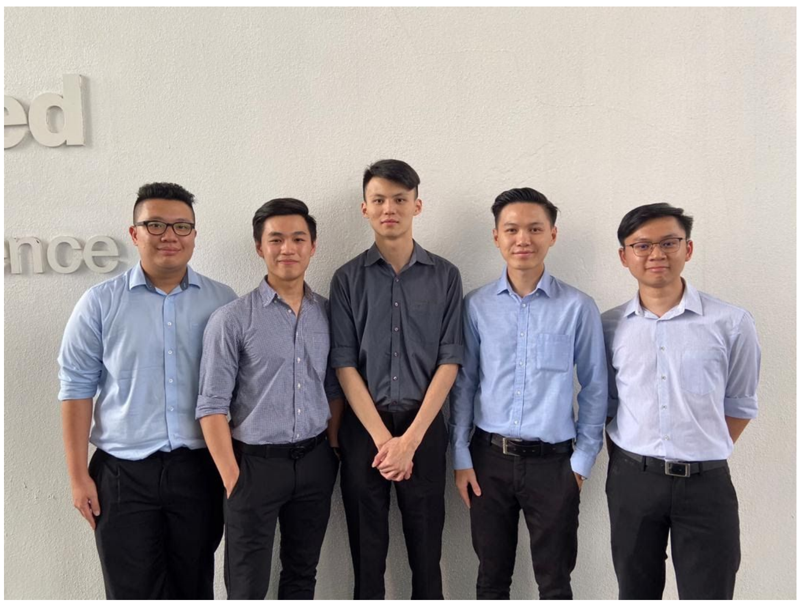
In the 20th century, the only way to keep track of health trends or to understand a person's own health was by visiting a physician or a doctor. The average person back in the 20th century did not have reliable means of obtaining accurate health data such as average heart rate, blood pressure, sleeping time, and step count. However, as technology advances, more and more advanced health devices begin to appear on the market, and now simple and compact health measuring devices are easily accessible to the average person in the form of smartwatches and smartphones such as FitBit, Mi Band, Samsung Galaxy Note 10, iPhones, and Apple Watch. These devices are able to obtain data using sensors such as a heart rate sensor, vibration sensor, gyroscope, and infrared sensors.

According to the University of Illinois, approximately one in five adult citizens in the US owns or has brought a health monitoring devices. With the use of health measuring devices, the average person generates terabytes of health related data over their lifetime, and with the widespread use of such devices, clinical research and health monitoring has never been easier [4]. The greatest challenge for today's healthcare industry would be to develop a seamless and reliable health monitoring system, and by using statistical analysis methods such as ANOVA 1 Way, improvements can be made to health monitoring devices across different brands and apps.

To understand the differences between different apps across different devices, an experiment was designed. The group used 4 different smartwatches/phones with their specific apps, namely, FitBit, MiBand 2, Fossil Watch, and Galaxy Note 8, to take the same type of reading, which is heart rate. An initial hypothesis was made, which is that all 4 different devices are able to obtain data that are the same. The group used an excel sheet to record obtained data for analysis, and the results are compiled in the results and discussion section below. The conclusion the group was able to obtain from the results was that the initial hypothesis, H_o was rejected, and the alternate hypothesis, H_1 is accepted. The four different devices were not able to obtain the same data.

For the results, analysis of the heart rate data was done using ANOVA 1 Way, which is used to determine whether there are any statistical differences between two or more independent groups of data. The use of ANOVA 1 way gives engineers the information that different groups of data contain statistical differences, and this allows engineers to apply further statistical techniques for analysis [4].

Organization Chart



Our group consists of 5 members, namely (left to right):

- **Tan Jia Hao** (Methodology)
- **Teoh Zhi Heng** (Results)
- **Hong Jian Hua** (Introduction)
- **Alwyn Yip** (Literature Review)
- **Jason Chong** (Discussion)

Literature Review

Electronic devices like smartphones, tablets and wearables has been significantly popular worldwide. A recent findings reported that there will be an approximately 7.7 billion mobile broadband subscription when 2020 comes while the usage of smartphone subscriptions are expected to equal 70% of the world's population. This increase in trend of the usage of smartphone increases the opportunity for the monitoring of healthcare through these devices**[1]**. For the past 2 decades, heart rate monitor(HRM) has been an essential personal health assistance which allows users to obtain heart rate in real time on wearables such as fitness bands and smart watches. HRM has been a hit as it is easy to use, relatively cheap and can be measured in most situations. In order to reach the full potential of mobile healthcare, validation of the HRM capabilities and also the accuracy of these technologies is needed.

In this study, four commercially known wearables and devices mainly the Samsung Galaxy Fit, Fitbit smartwatch, Mi band 2 and Fossil smartwatch were tested to check if all these smart wearables are able to provide consistent results. All these wearables are capable of allowing users to track their fitness and also record their heart rate. These devices also support both android and iOS devices.

Smartphone manufacturers, particularly Samsung, noticed this trend of obtaining heart rate in real time which prompted it to include a built in heart rate monitor into its latest smartphone. The HRM was first introduced by Samsung to the Galaxy S5 back in 2014. However, since it was the first generation of such a sensor, the sensor was limited to obtain measurement punctually and when the user is at rest **[2]**.

At the same time, S health was also introduced as a free application to Samsung users and iOS which serves as a health app which can track various aspects of our everyday life which include physical activity, pedometer, setting goals, diet and sleep. This application syncs with all the wearables and gadgets that are compatible. This application requires each user to key in the name, gender, weight and height to determine the optimum amount of their diet. At the homepage of S health, the app provides all the goals set and also the fitness count of every activities.

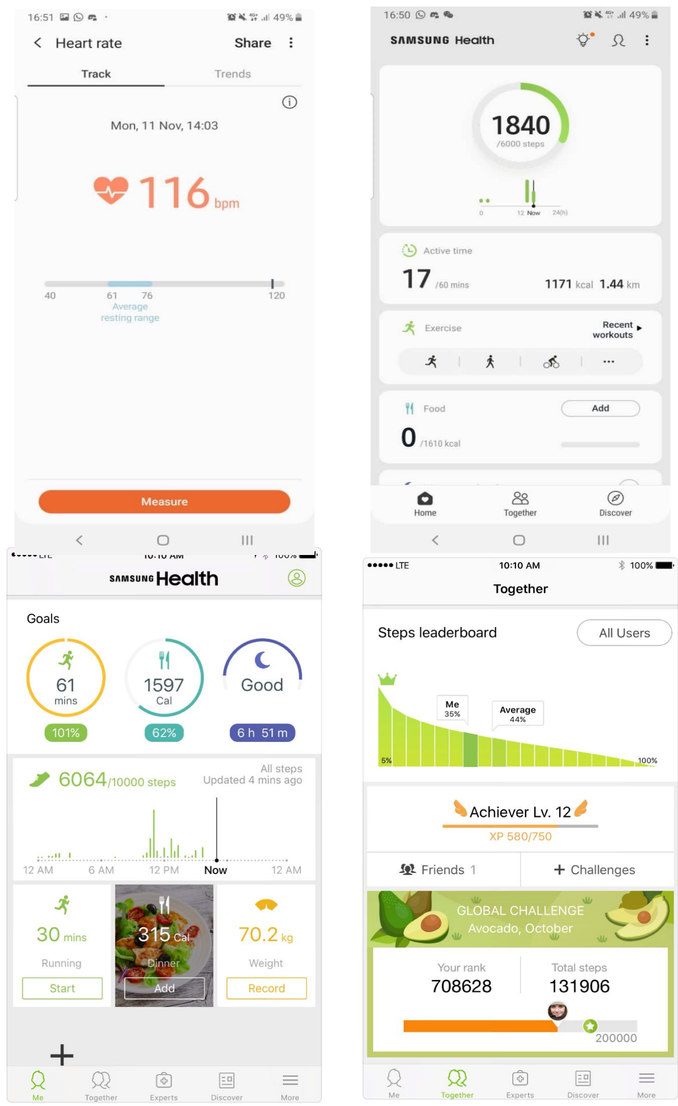


Figure 1. Home Screen of Samsung Health.

The built in heart rate monitor in Galaxy Fit measures heart rate in the form of beats per minute by using an optical LED light and a LED light sensor. The user is always required to place a finger on the sensor while the LED light shines through the skin. The sensor will then measure by determining the amount of light that is reflected back. The difference in light reflections are referred as heartbeats. The light reflections will change as the blood pulses under the skin past the light. As for wearable, the user is required to remain calm and held the watch steadily. The wearable has to be fitted snugly on your arms **[3]**.

Figure 2. Heart rate sensor on Galaxy Fit.

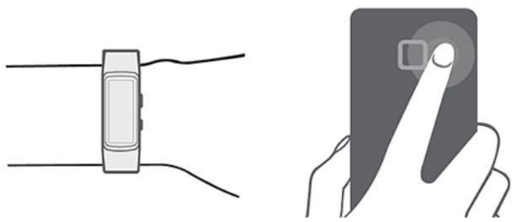


Figure 3. Shows the steps to take heart rate.

As for the Fitbit, they first launched their first smartwatch in 2017. This company focuses mainly on wearables which are able to measure fitness activities such as step count, heart rate, quality of sleep and also other activities. Fitbit is compatible for Andriod, iOS and Windows.

Figure 4. Heart Rate sensor on Fitbit.

Fitbit introduced PurePulse Technology which allows continuous and autonomous heart rate tracking system without clicking any button. This technology works by shining a green LED light which is reflected from the skin to detect the difference in blood flow. Blood capillaries expand and contract as the heart beats. PurePulse obtains the data which then translates into beats per minute.

Figure 5. Fitbit App.

This continuous heart rate allows from many benefits such as the ability to reach weight goals. As you are working out, Fitbit constantly tracks your heart rate and is able to record how much calories is burnt by the heart rate. Fitbit also optimises your time spent on exercise which calculate how much effort and time is needed to complete a certain activity. In addition, Fitbit also encourages user to manage stress level by relaxing with guided breathing session by tracking on your heart rate.

Figure 6. Heart rate sensor on Fitbit.

As for fossil smartwatch, it is integrated with Google’s Android operating system called Wear OS. This OS integrates an artificial intelligence called Google Assistance and mobile notifications into the smartwatch. This app is also compatible with both Android and iOS. This watch also integrates a heart rate monitor which also tracks your heart rate during fitness activities like yoga, jogging and others.

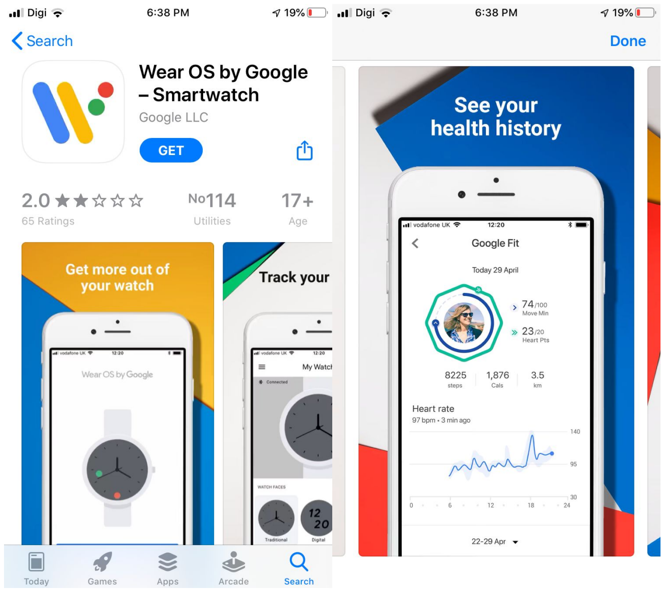


Figure 7. Home screen of the Wear OS.

As for our fourth wearable, Mi band 2, it works well with their own application which is Mi Fit. It is compatible with both iOS and Android. This application has a similar function as the above such as activity tracking, sleep analyzing and also evaluates your workout. This watch is equipped with an improved pedometer algorithm which filters out unnecessary movements which will improve the accuracy of the readings. In addition, it also has a built in motion sensor with is integrated with the heart rate sensor which allows the Mi band to know exactly when the workout begins. This prevents the need to switch between modes.

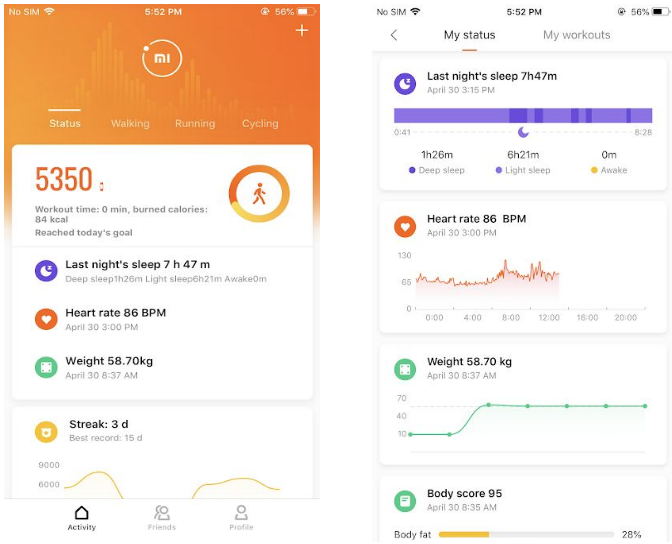


Figure 8. Home screen of Mi Fit App.

Figure 9. Mi Band 2.

Methodology

The topic of research that we choose is the precision of services available in smart gadgets, particularly the heart rate applications that is able to identify the heart rate of the user. In order to do so, we must first identify the proper steps to carry out the experiment in order to obtain a reasonable and justifiable data for further analysis.

After deciding the research topic, we proceed to carry out the experiment. The main objective was to determine whether the heart rate reading display by these smart gadgets were valid and consistent. Rather than testing different variations of the same product by the same company, we decided it was better to test the same product made by different companies. Reason behind this decision was due to different company uses different technologies and algorithms when designing their product. The results of testing multiple versions of the same product made by the same company might provide a consistent heart rate result, however there is no way of knowing whether the results are accurate. Hence, we decided to collect results from four different companies products. The brands that we choose to test were Fitbit, Samsung Note 8, Fossil smart watch and Mi band 2. We choose these brands in particular due to their accessibility as the price on these watches were affordable which is the primary factor of consideration when an individual is purchasing an electronic device.

The next step after identifying what product to use is decide on the testing conditions. The heart rate of a person is dependant on the activities that the person was carrying out at that moment. For example, a person that is walking has a higher heart rate than that of a person that is sitting down. The reason behind the difference in heart rate is due to the physical exertion that the individual is experiencing. A body provides energy to allow an individual to carry out an activity, and oxygen is an essential component of that process. The faster the heart pumps, the more oxygen is used which means more energy. Since walking requires more energy than sitting down, we can conclude that the heart rate of an individual is higher during walking. The initial testing condition was to collect the heart rate of an individual after walking across the corridor.

However, the results obtained from this testing condition could be inconsistent. Due to the nature of the testing condition, this would require an individual to walk back and forth a corridor for a long period of time at a constant speed in order to collect sufficient data for analysis. As the experiment proceed further, the heart rate of a person increases in order to ensure that the body has sufficient oxygen as they exert more and more physical stress to their body. Hence, we decided to collect the heart rate of an individual while sitting down in a quiet and comfortable space. Throughout the experiment, the individual has to maintain its position as different position such as standing up or lying down could change the heart rate of the individual. Another factor to this experiment was the surrounding of the experiment as the comfortability of a person is dependant on its immediate surroundings. We choose to carry out the experiment in the bedroom of the individual. This is to eliminate the possibility of any external interruptions such as loud conversation. Carrying the experiment in space that is familiar to the individual would also affect the outcome of the date collect as unfamiliar surroundings might cause an individual to become anxious or nervous and this could elevate the heart rate of the individual.

The duration of the testing for each watch would be around 300 seconds, which is roughly 6 minutes. The person conducting the experiment would put on the smart watch and rest their arms on their lap. The watch would then measure their heart rate for 20 seconds, then the data obtained would be recorded and then rest for 10 seconds before repeating again. The reason for the 20 seconds measure was to ensure that the heart rate measure was of the individual in a calm state and maintain the heart rate. The data provided after wearing the smart watch for 10 seconds might not be accurate as the individual might be anxious, hence we decide to take the heart rate over 20 seconds. The 10 seconds interval between each measurement was to allow the individual to record the data obtained and adjust themselves before proceeding to measure their heart rate again. 10 data was collected for watches to ensure we have an adequate sample for comparison and analysis.

To analyze the data, we decided to use ANOVA 1 Way as previously learnt in lectures. Since there were four watches that were used during the experiment and each watch were of different brands, technology and algorithms, we can consider this experiment to have 4 levels. Hence, ANOVA 1 Way was the appropriate method that we chose to use as our method of analysis.

Results and calculation

Table 1. Heart beat rate from different devices.

	Observed Heart Beat Rate (BPM)											
Devices	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Total, $y_{i.}$**	**Average, $\bar{y}_{i.}$**
Samsung Watch	94	83	84	81	79	79	78	72	76	77	803	80.3
Mi Band	71	73	77	75	75	73	78	75	70	74	741	74.1
Fit-Bid	72	75	78	77	78	76	78	76	77	79	766	76.6
Fossil (Google)	75	81	77	82	80	77	74	80	81	78	785	78.5
											$y_{..}$ = 3095	$\bar{y}_{..}$ = 77.375

The table above shows the results of heart beat rate obtained from different devices such as the Samsung Watch, Mi Band, Fit-Bit and Fossil watch when the person wearing it is in a resting condition. From the table above we can deduce that the Samsung Watch has the highest average heart beat rate compared to the others and the Mi Band has the lowest. From here, the method of analysing the data is by using Anova 1 way because it is a method used to compare the means of two or more groups by using the F distribution to test that the devices have the same variance and to compare the means of this experiment. In this experiment, the first hypothesis, h_0 that we assume is that all different devices will produce the same results of heart beat rate whereas the second hypothesis, h_1 is that all the different devices will produce different results of heart beat rate. To calculate the results for F_0, we will be using the data from Table 1 and the equations from Figure 9 below.

- Analysis of Variance Table (One Way, Fixed Model)

Table 3-3 The Analysis of Variance Table for the Single-Factor, Fixed Effects Model

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F_0
Between treatments	$SS_{\text{Treatments}} = \frac{1}{n}\sum_{i=1}^{a} y_{i.}^2 - \frac{y_{..}^2}{N}$	$a - 1$	$MS_{\text{Treatments}} = \frac{SS_{\text{Treatments}}}{a-1}$	$F_0 = \frac{MS_{\text{Treatments}}}{MS_E}$
Error (within treatments)	$SS_E = SS_T - SS_{\text{Treatments}}$	$N - a$	$MS_E = \frac{SS_E}{a(n-1)}$	
Total	$SS_T = \sum_{i=1}^{a}\sum_{j=1}^{n} y_{ij}^2 - \frac{y_{..}^2}{N}$	$N - 1$		

Figure 9. Equations for Anova 1 Way test.

Table 2. Results from the Analysis of Variance table.

Source of Variation	**Sum of Squares**	**Degree of Freedom**	**Mean Square**	**F_0**
RF Power	211.475	3	70.49166	5.354927
Error	473.9	36	13.16388	
Total	685.375	39		

Discussion

After completing the experiment, we were able to analyze the data and draw a conclusion on the precision of the smart watches used. Based on the results obtained, the value of F_0 is 5.354927 and the value for F at significant level of 5% and 1% are $F_{(5,3,36)}$ = 2.866 and $F_{(1,3,36)}$ = 4.377 respectively. Since the value of F_0 is larger than both $F_{(5,3,36)}$ and $F_{(1,3,36)}$, the null hypothesis H_0 proposed which was all four devices would produce the same or similar results is rejected. The reason that H_0 was rejected is because according to the F distribution graph the value for F_0 lies on the rejection area for both significant level of 5% and 1%. This indicates that the heart rate displayed by all four devices are different which also indicates that all four companies are using different types of technology when building their devices and also different algorithms and have their own database of heart rate at which would indicate different heart rate of the users under different levels of activity.

However, if the significant level was reduced to 0.1%, the value for $F_{(0.1,3,36)}$=6.75. In this case the value of F_0 is smaller than $F_{(0.1,3,36)}$ and it does not lies on the rejection area. Therefore for this case, we will accept the null hypothesis,H_0 whereby all the devices will produce similar results for heart beat rate. The reason why H_0 is accepted is because 99.9% of the data is taken into account and every result is very close to the mean average of heart beat rate during resting. This means that the rejection region had high variance because of 0.1% significant level. Hence it is less accurate. However due to majority H_o that is rejected for the significant level for 5% and 1%, H_1 is chosen to be accepted rather than H_0. This can further be proven by plotting the Normal Assumption Graph and the Residual Graph.

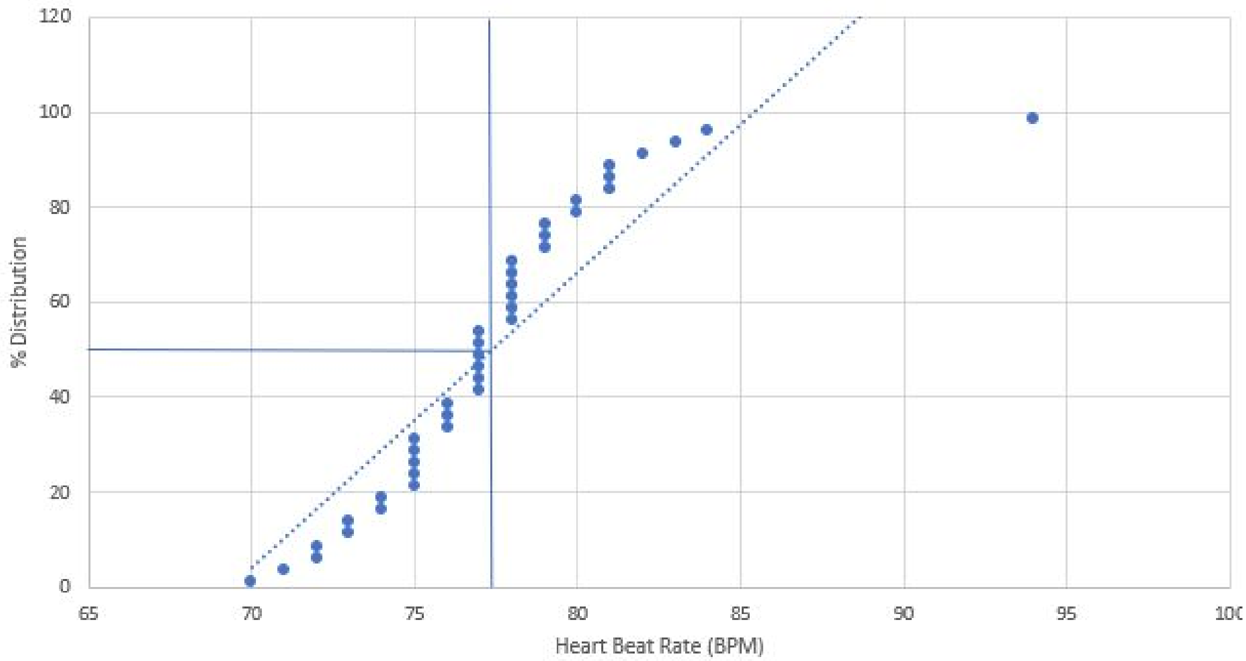


Figure 10: Normal Assumption Graph

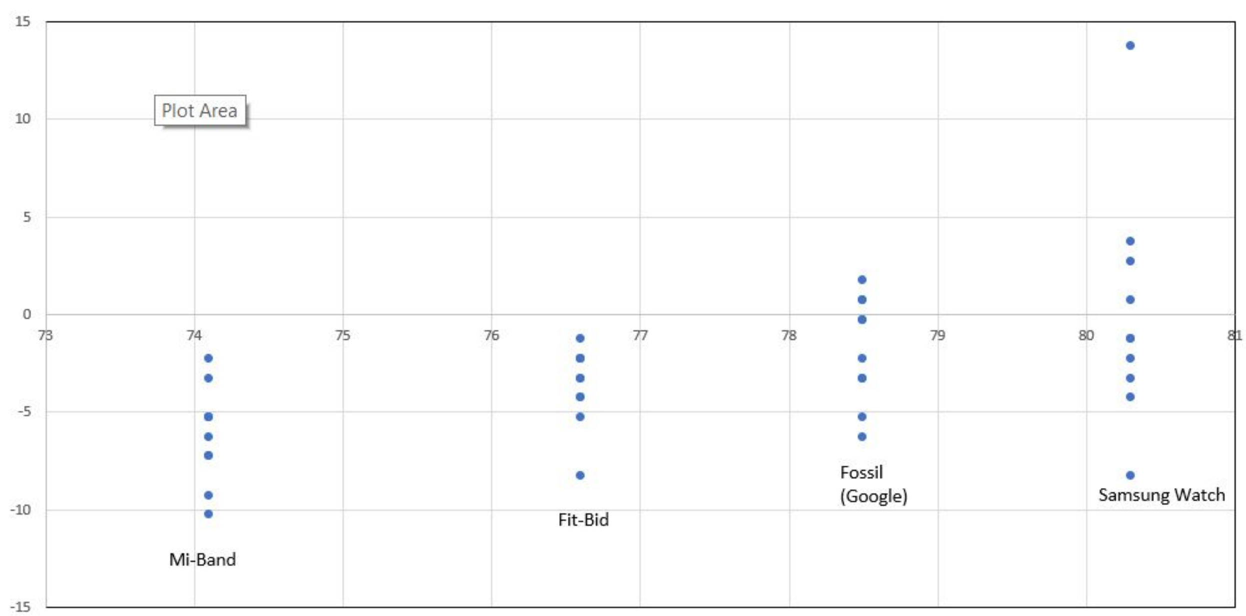


Figure 11: Residual Graph

Based on the graph for the normal assumption, the data is all close the best fit line which means that the data is precise however this does not determine the data is accurate. To determine the accuracy of the data the mean distribution of 50% is drawn to when it connects the best fit line and a vertical line is drawn as shown in Figure 10. From the figure above, we can conclude that majority of the value is near the mean value however there is an outlier in the graph which is the first data that is collected by the Samsung Watch is the outlier which inaccurate. From the Normal Assumption graph we also can analyze if the null hypothesis, H_0 is accepted or rejected. In this case, H_0 is rejected because the total number of data above and below the best fit line is not the same without taking the outlier into account therefore H_1 is accepted. Based on the Residual Graph, we can deduce that most of the devices is close to the average value accept for Samsung Watch due to the outlier which sets far apart from other data. Because of H_1 being accepted, the grand average of heart beat rate during rest is calculated and used to calculate the difference in average for each device.

	Heart Beat Rate (BPM)		
Devices	Average, $\bar{y}_i$.	Grand Average	Difference between Grand Average & Average
Samsung Watch	80.3	77.375	-2.925
Mi Band	74.1	77.375	3.275
Fit-Bid	76.6	77.375	0.775
Fossil (Google)	78.5	77.375	-1.125

Figure 12: Grand Average Table

Based on the Grand Average table, we can deduce that the Fit-Bid is the closest to the grand average which means it is the best device among all. Moreover, this can conclude that most of the devices does not produce the same heart beat rate during resting because most of the devices has a higher difference than the grand average. Mi Band has the highest value in difference between the grand average and average of the Mi Band. Therefore Mi Band is not suitable to use to measure the heart beat rate.

References

[1] Samsung Electronics America*,* "Samsung Heart Rate Sensor", 2019. [Online]. Available: https://www.samsung.com/us/heartratesensor/. [Accessed 16 Nov 2019].

[2] T. Coppetti et al., "Accuracy of smartphone apps for heart rate measurement", *European Journal of Preventive Cardiology*, vol. 24, no. 12, pp. 1287-1293, 2017. Available: 10.1177/2047487317702044 [Accessed 16 November 2019].

[3] D. Weiler, S. Villajuan, L. Edkins, S. Cleary and J. Saleem, "Wearable Heart Rate Monitor Technology Accuracy in Research: A Comparative Study Between PPG and ECG Technology", *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, vol. 61, no. 1, pp. 1292-1296, 2017. Available: 10.1177/1541931213601804 [Accessed 16 November 2019].

[4] University of Illinois, "Big Data and Wearable Health Monitors: Harnessing the Benefits and Overcoming Challenges", [Online]. Available: https://healthinformatics.uic.edu/blog/big-data-and-wearable-health-monitors-harnessing-the-benefits-and-overcoming-challenges/ [Accessed 17 November 2019].