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HEART RATE VARIABILITY IN ADULTS DURING 24-HOURS WITH A
FOCUS ON SLEEP PERIOD

By

ANKUR RAVIKANTH

A thesis submitted in partial fulfillment of the requirements
for the Honors Undergraduate Interdisciplinary Thesis Program in Mechanical Engineering
in the College of Engineering and Computer Science
at the University of Central Florida
Orlando, Florida

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Thesis Chair: Dr. Hansen Mansy, PhD

ABSTRACT

The objective of this study is to investigate heart rate variability (HRV) over a period of 24 hours with special focus on patterns during the sleep period. Comparisons were made between sleep and the full 24-hour data. The Polar M430 watch was used to record heart rate (HR) data for about 24 hours, and the subject kept a journal of the activities they performed throughout the day. The data was visualized as heart rate in beats per minute (BPM) as a function of time. To check the accuracy of the Polar watch, a 7-minute recording of HR from the watch was performed simultaneously with a gold standard (IX-TA 220 and IX-ECG12, iWorx, Dover, NH). The data was downloaded into Excel spreadsheet, then analyzed. Analysis included calculations such as: standard deviation, range, mean, and the Fast Fourier Transform (FFT). HR data analysis was performed for the 24hr and sleep period. Since daily activities (which can affect HR) were difficult to control in the study subjects, the sleep period was chosen for more detailed analysis. A trend of lower HR and HRV was seen during sleep. Although the watch had modest accuracy, it was able to show some HR patterns during sleep. FFT analysis of the sleep data suggested existence slow HR cycles <1 cycles per minute with significant variation below 0.2 cycles per minute (which corresponds one cycle every > 5 minutes).

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INTRODUCTION

Heart rate variability (HRV) can be defined as the variation in heart rate over time. Heart rate variability can also be detected from the variation in time between consecutive heartbeats (1). HRV is influenced by the autonomic nervous system (ANS), which regulates heart rate (HR), breathing, blood pressure and digestion (1). HRV is a possible way to measure the ANS function and as to whether it is working as expected in regulating the body function (1). If a person is more energized and alert, HRV is low, while if a person is in a relaxed state, HRV is high (1). In summation, the higher the HRV, the more indicative it is that the ANS is functioning normally in adapting to the situation at hand and providing flexibility; hence, a noticeable decrease in HRV is seen with age (1). A higher HRV usually shows greater fitness and a healthy lifestyle (1). An electrocardiogram, or ECG, and a heart rate sensor may be used to measure HRV. Heart rate variability is a great tool to compare heart health information, as well as to measure for patterns or cycles in an individual based on activity being performed, such as exercise, sleep, or consuming food. This paper illustrates HR over a 24-hour period in graphical form, and isolated and analyzed sleep data statistically through methods such as the Fast Fourier Transform, Mean, Standard Deviation, and Range. The mean, standard deviation, and range were used to statistically compare overall 24-hour HR data for subjects to isolated sleep data. The fast Fourier transform (FFT) method is a mathematical technique that turns a function of time into a function of frequency (2), and was used to visualize HR cycles during sleep.

RELEVANT LITERATURE REVIEW

HRV and Demographic Information

Age, race, and sex differences in autonomic cardiac function measured by spectral analysis of heart rate variability (3):

In this study, around 2,000 people aged 45-64 years old were studied for HRV. Resting position HRV spectral power data was collected on the subjects. ANS function predicts mortality after a myocardial infarction. Beat-to-beat HR shows repeating intervals due to interaction of sympathetic and parasympathetic nervous system activity. The repeating periods, or intervals, are found through spectral analysis. Low Frequency (LF) power is 0.025 to 0.15 Hz, and High Frequency (HF) power is 0.16 to 0.35 Hz. LF influences HRV through both the sympathetic and parasympathetic systems, while HF influences HRV through the parasympathetic system only. The HF/LF ratio is a representation of how parasympathetic and sympathetic nervous system function are balanced. The data found that black subjects have a lower Low Frequency (LF) component, higher High Frequency (HF) component, and higher High Frequency to Low Frequency (HF/LF) ratio component than white subjects. The study also found that women have a lower LF and higher HFLF compared to men. LF and HF were also found to be inversely related to age. HF/LF ratio was 0.41 for ages 45-54, and 0.39 for ages 55-64.

Effect of Age and Sex on Heart Rate Variability in Healthy Subjects (4):

This study monitored the effects of age and sex on HRV, and looked at the range for HRV in different demographic areas for extrapolation in healthcare-related areas. HRV data was taken from around 500 people without any known heart conditions, and short-term HRV data was

recorded with an ECG. The results found that total power, or overall autonomic activity of the heart, consistently decreased from ages 10 to 80, with a p-value of less than 0.001. As age increased, LF and HF declined, with a p-value of less than 0.05. Sex also was a key factor for HR, RR interval, HF, LF, and HF/LF ratio. Sex didn't significantly affect SDNN, or the standard deviation of RR intervals or total power, with a p-value of greater than 0.05, despite the fact that sex greatly influenced significant differences in HR, with a p-value of less than 0.05. This paper concluded that age has a greater impact on HRV than sex. This data is comparable to the data obtained from the Polar M430 watch so far, but further analysis on more people must be conducted before supporting or refuting the findings in this paper.

Influence of age, gender, body mass index, and functional capacity on heart rate variability in a cohort of subjects without heart disease (5):

This study looked at the time-domain and frequency-domain indexes of HRV in approximately 650 patients without known heart disease (no mitral valve prolapse, diabetes mellitus, subclinical hypothyroidism, mitral valve stenosis, and other conditions), in relation to demographic data such as sex, age and BMI. A FFT was used with VLF indexes of 0.003 – 0.04 Hz, LF index of 0.04 – 0.15 Hz, and HF indexes of 0.15 – 0.4 Hz, as well as the LF/HF ratio. HR indexes decreased as the age of the subject increased ($p < 0.05$). An inverse correlation was seen between HR and HRV in this study ($p < 0.001$). There was no notable correlation between BMI and HRV in this study. As age increased, HR decreased with age, and was much higher in women. As HR increased HRV would tend to decrease as the subjects tested got older. When comparing HR to BMI, there was no notable difference in gender. HRV data seemed to be consistent across the board regarding BMI. The study showed an inverse relationship between HR and HRV, with older subjects having lower

HRV but a higher heart rate. These findings are mirrored in the data gathered from the Polar M430, as seen in Figures 1-9 and Tables 1-2.

HRV and Sleep

Heart Rate Variability During Waking and Sleep in Healthy Males and Females (6):

This study intended to monitor HRV in males in females in 4 states of alertness: waking, Stage 2, Stage 4, and REM. 24 adults took part in the study. The results were monitored via ECG and polysomnographic (PSG) reading, and found that REM sleep had lower HF (0.15 – 0.4 Hz) and higher LF (0.05 – 0.15 Hz) power than NREM sleep. During REM sleep, men had a higher HF/LF ratio than women. Men also had higher HF when waking, as compared to the women. This study concluded that the greatest differences in HRV are between NREM and REM sleep, as vagal tone and the ANS changed drastically between these stages. In both males and females, the LF/HF ratio was significantly higher for REM sleep compared to NREM sleep. This data can be compared to the HRV data from the Polar M430 as seen in the periods of high and low HRV for the sleep data, and can be further affirmed or denied with other equipment such as an iWorx ECG.

Heart Rate Variability, Sleep and Sleep Disorders (7):

This study highlights how HRV is used to monitor the function of the ANS, using an ECG and PSG. This study found that HRV and HR decreases in NREM sleep and increases in REM sleep, aligning with how parasympathetic and sympathetic nervous system (SNS) control shifts during the sleep stages. The study also discovered that Obstructive Sleep Apnea (OSA) is related to abnormal cardiac control of HRV by the ANS. The results from this study also indicate how sleep

deprivation negatively impacts HRV. This study also discovers that effective continuous positive airway pressure (CPAP) depends on HRV changes during night and day.

Human Heart Rate Variability and Sleep Stages (8):

This study used the tools of an electroencephalogram, an electrooculogram, and electromyogram, an electrocardiogram, and a spirometry trace to measure HRV during the sleep stages to observe changes in sympatho-vagal tone. The LF index was 0.04 – 0.12 Hz, and the HF index was 0.15 – 0.35 Hz. The study found that from Sleep Stages 1 to 4, the LFHF ratio decreased due to an increase in HF. This means that during slow-wave sleep, the parasympathetic system was more active; this system is responsible for relaxing the body and bringing it away from fight-or-flight responses. During wakefulness, Stage 1 sleep, and REM, the LFHF ratio was close to 1, larger than the ratio for stages with less consciousness.

GOALS AND METHODS/PROCEDURE

This study focused on measuring HR over a 24-hour period in subjects with special attention during sleep. It is important to monitor HRV because it is indicative of stress levels, health abnormalities, and the change of bodily function as it ages. The main objective is to collect HR data for extended periods of time to measure patterns during sleep and 24-hour, which can be used as determinants of cardiac health. The gathering of HR data was accomplished through the usage of a Polar M430 (Kempele, Finland) watch and iWorx ECG Recorder with LabScribe software (iWorx, Dover, NH). As seen from the figures below, the Polar M430 tracks HR data every second. This data was downloaded as an Excel spreadsheet, and analyzed statistically to discover trends and/or differences seen between people between sleep and the full 24-hour period. Data was tracked for 24 hours using the Polar M430 Watch. The activities of the person over the long-term measurement was documented with a journal, to see how the type of activity being performed affects HR. Activities such as time of eating, time of sleep, and time of exercise were noted. To check the watch accuracy, the HR was simultaneously tracked for approximately 7 minutes, using the watch and the iWorx system. The iWorx measured ECG and calculates HR using the RR intervals.

In order to sync the iWorx ECG machine and the Polar M430 watch, the following procedure was performed:

1. Prepare iWorx EKG Machine.
2. Start measuring HR with Polar M430 and iWorx simultaneously.
3. Turn both systems on at the same time.

4. Sit on a chair comfortably for 3 minutes, monitor heart rate (~e.g. 70 BPM).
5. Get up and perform a mild activity (such as running in place) such that HR increase by 30-40% (100 bpm) for 1 minute.
6. Sit on the chair again for 3 minutes.
7. Stop recordings and compare HR data from both devices.

The following analyses were performed on the data through the usage of Microsoft Excel. The range was used to monitor the difference between highest and lowest values of heart rate, in order to find the overall magnitude of HRV per person for the overall 24-hour period, as well as for the isolated sleep period. The mean and standard deviation for the entire group were used to compare how heart rate variability differs between the full 24 hour period and the sleep period of the subjects. The frequency of peaks, or oscillation frequency, were examined for the data through the Fourier Transform (FFT) method. The FFT is used to analyze repeating patterns or cycles of HR during sleep. The HR standard deviation was also analyzed to measure how variable the HR in beats-per-minute (BPM) is in each person, to determine how much their heart rate can vary from their baseline average. Standard deviation shows how dispersed the subject's HR data is around the mean heart rate, and is a good measure of HRV.

RESULTS

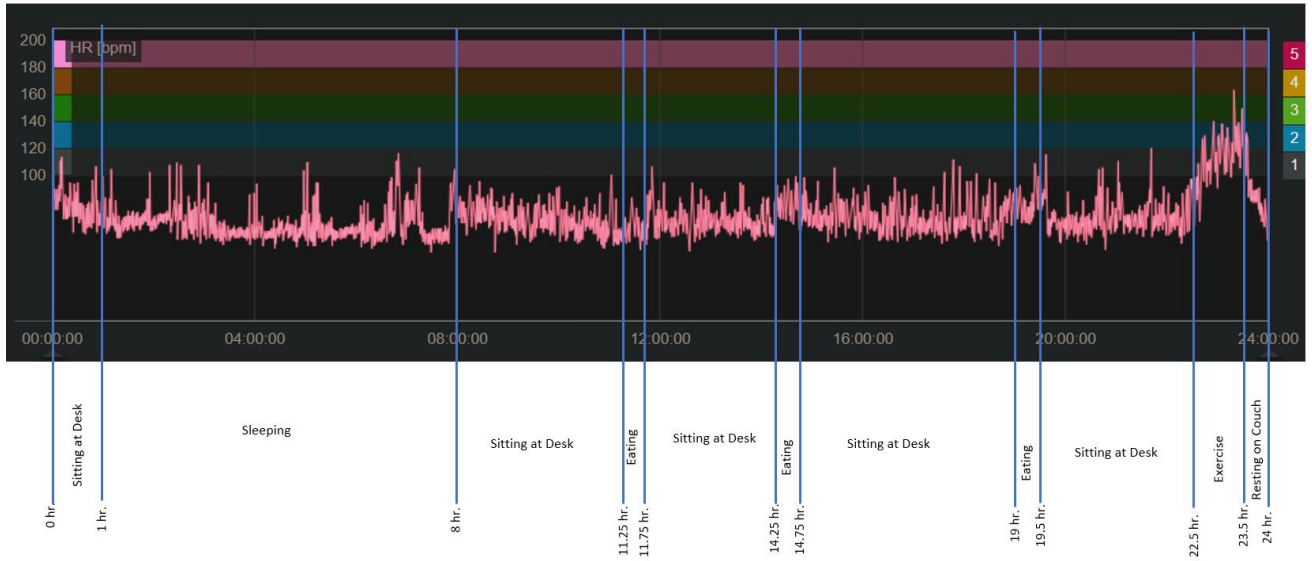


Figure 1. 24-Hour HR Data for 21 Year Old Male.

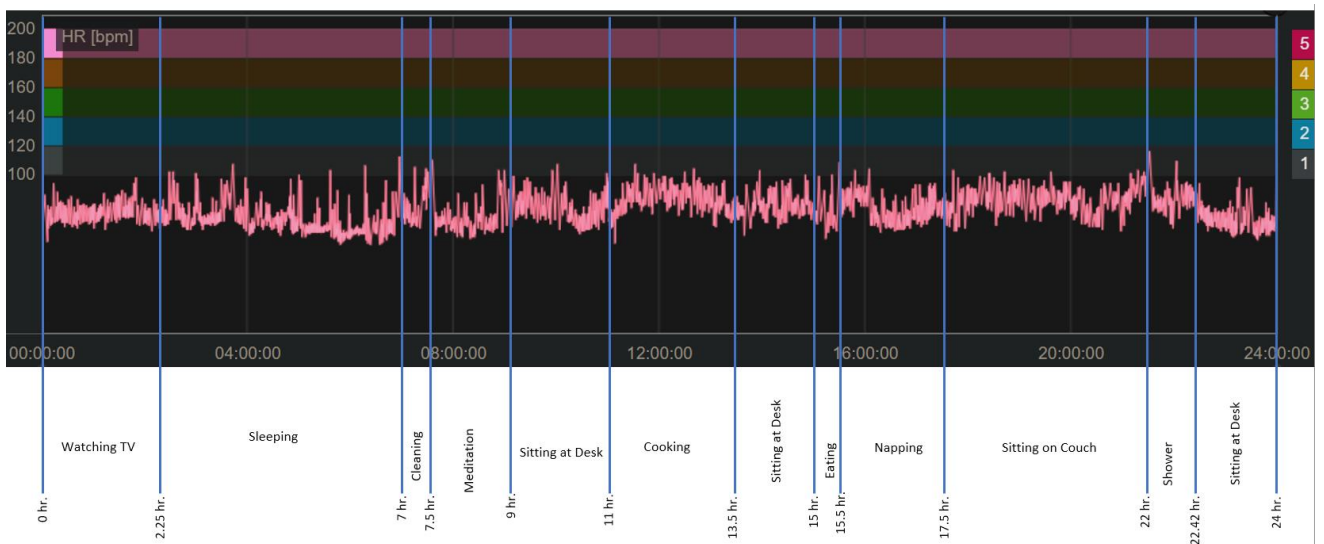


Figure 2. 24-Hour HR Data for 51 Year Old Female (Menopause).

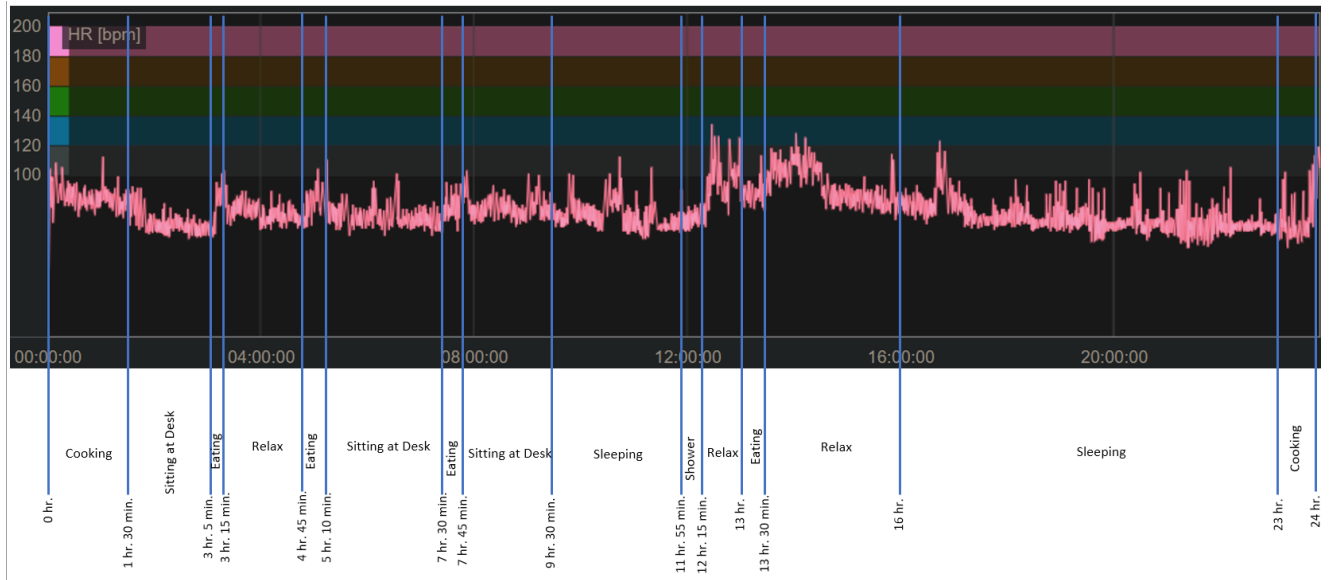


Figure 3. 24-Hour HR Data Date for 53 Year Old Male (Type 2 Diabetes).

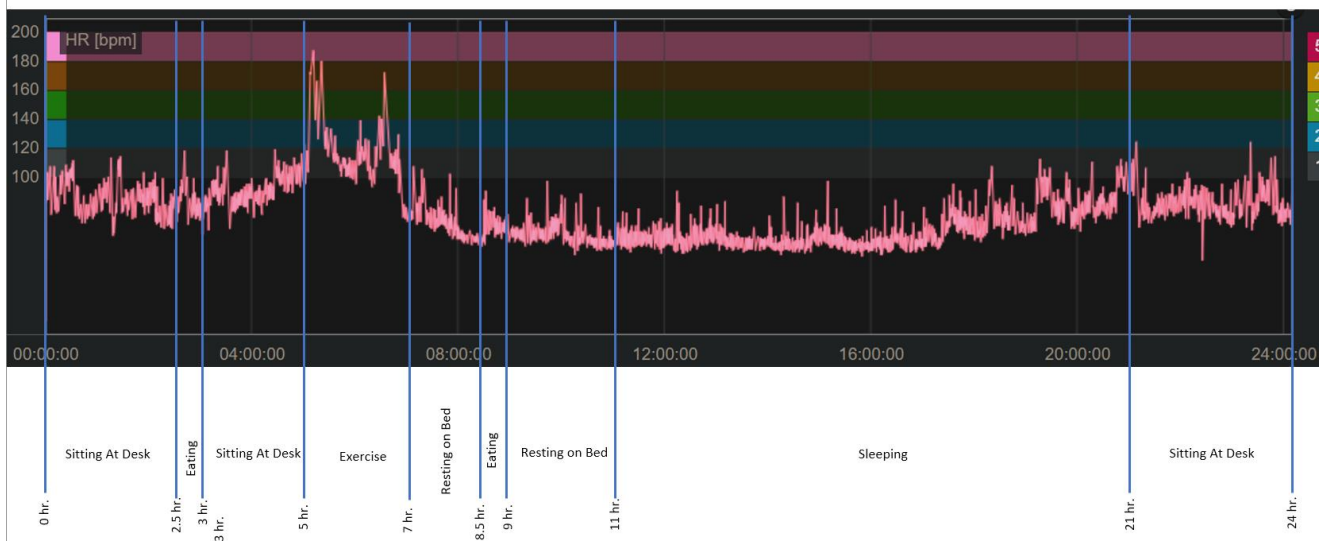


Figure 4. 24-Hour HR Data for 19 Year Old Male.

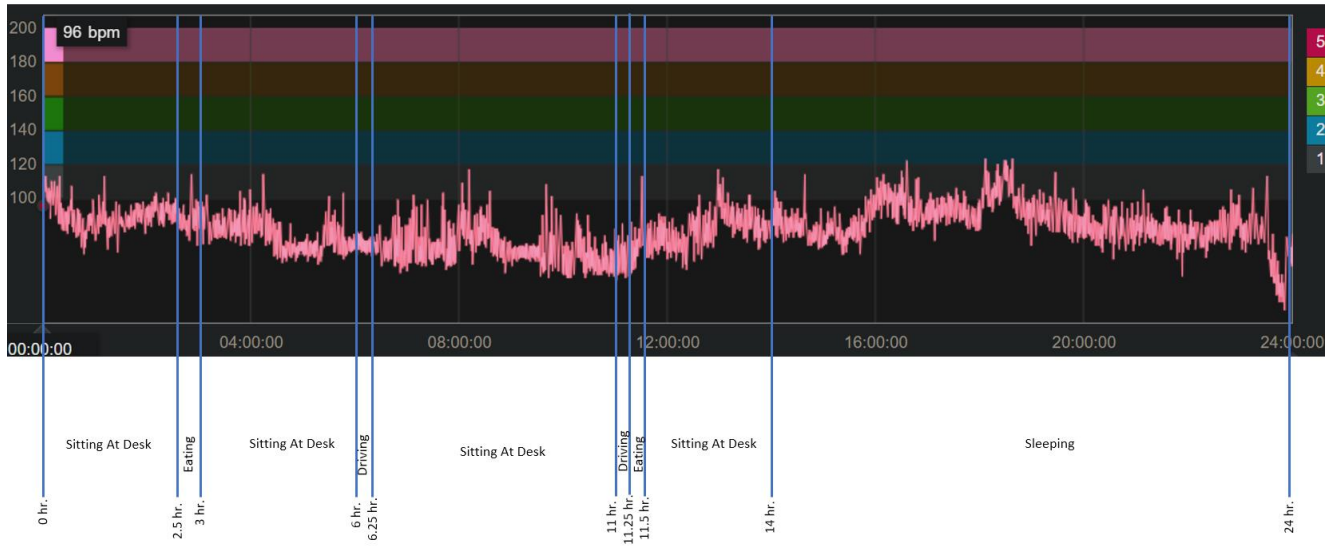


Figure 5. 24-Hour HR Data for 20 Year Old Male.

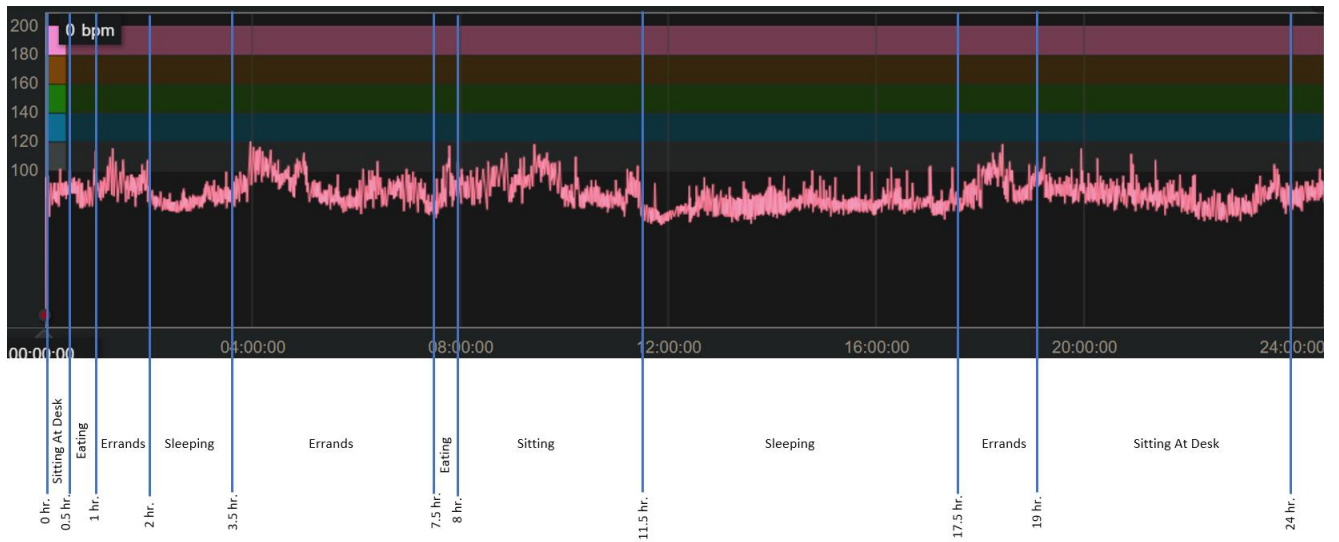


Figure 6. 24-Hour HR Data for 46 Year Old Female.

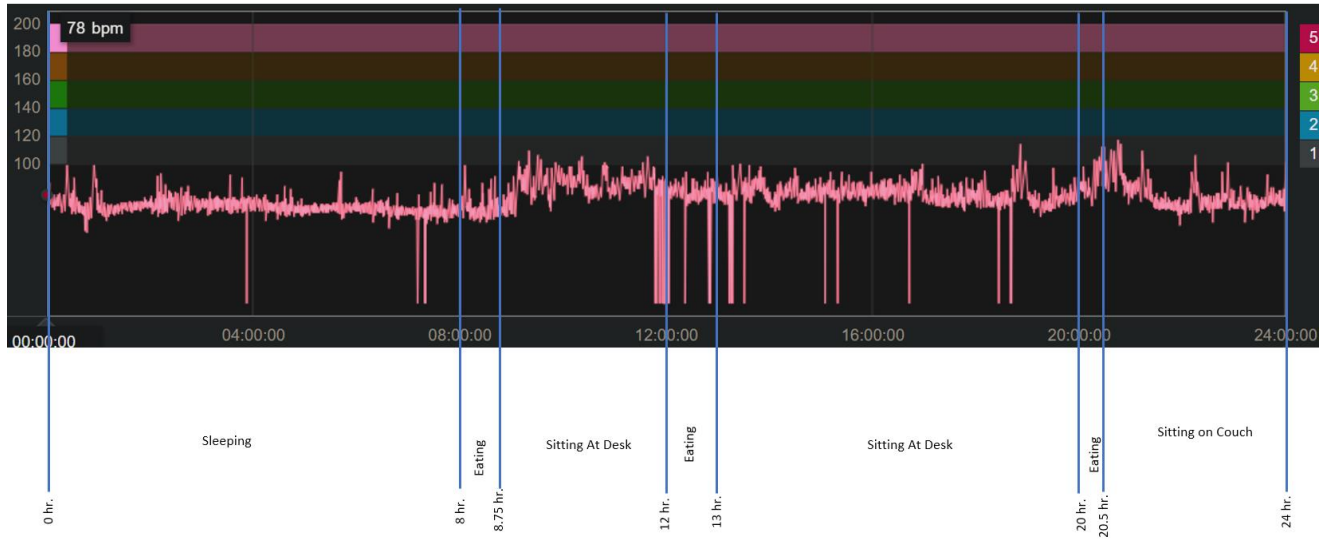


Figure 7. 24-Hour HR Data For 49 Year Old Male.

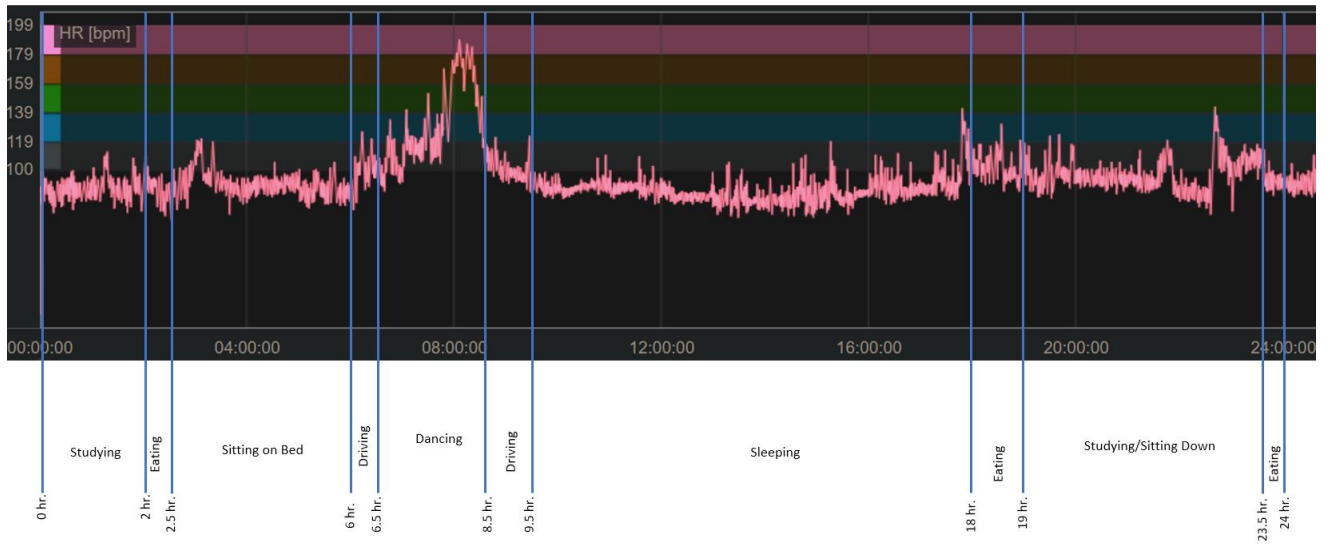


Figure 8. 24-Hour HR Data for 21 Year Old Female.

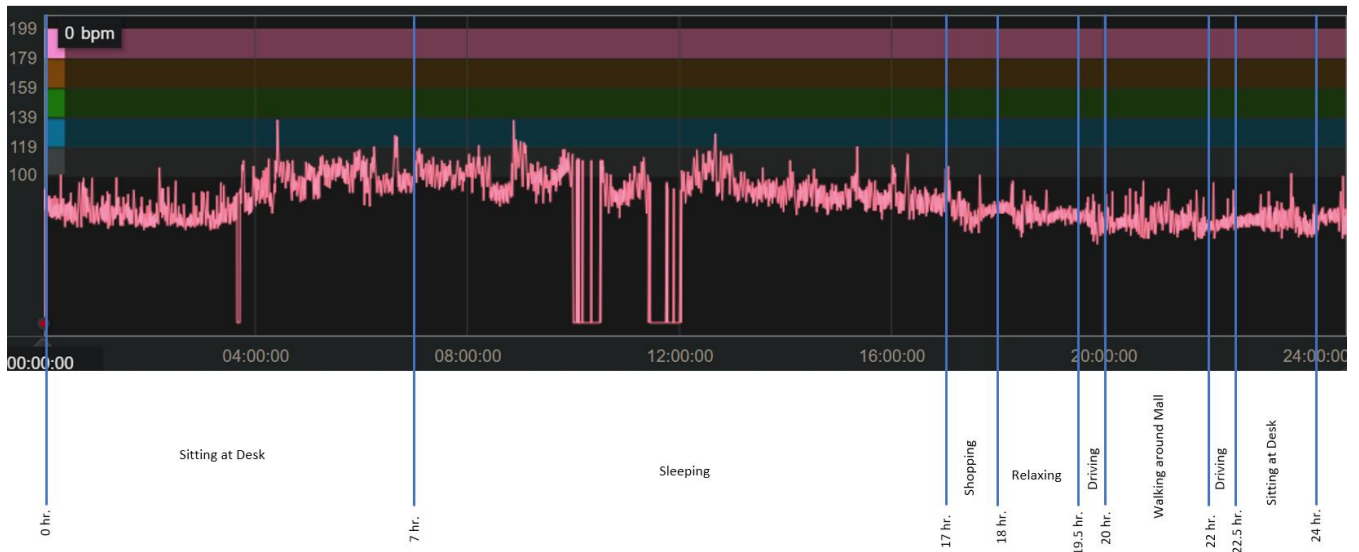


Figure 9. 24-Hour HR Data for 21 Year Old Male.

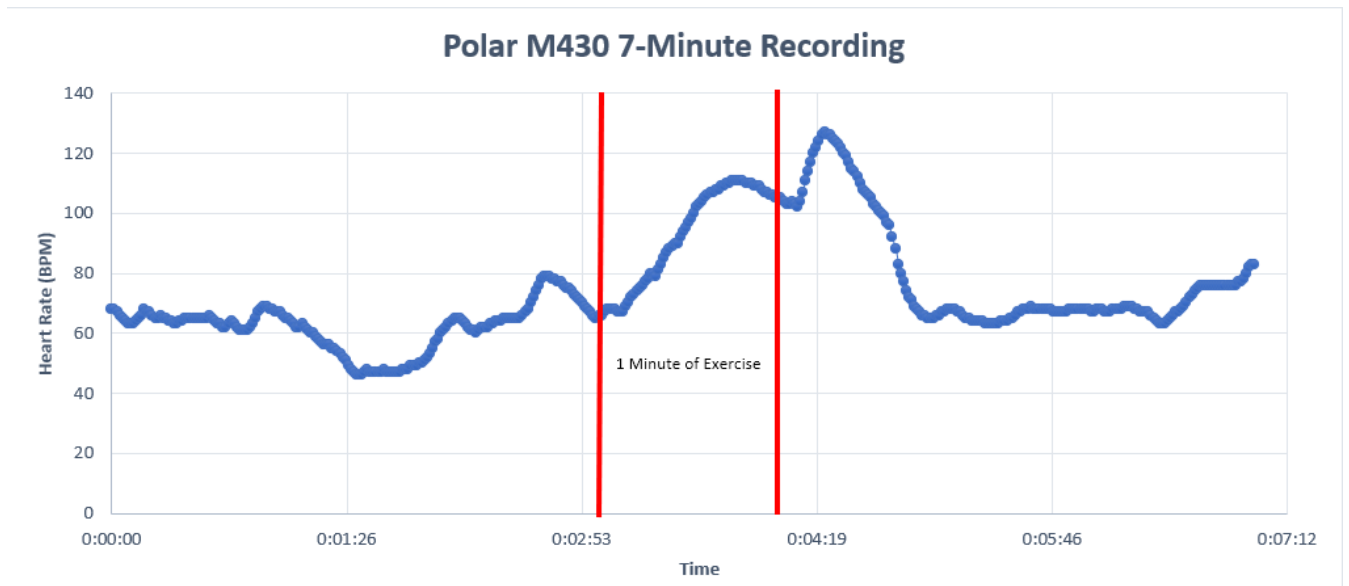


Figure 10. Graph of Polar M430 7-Minute Recording.

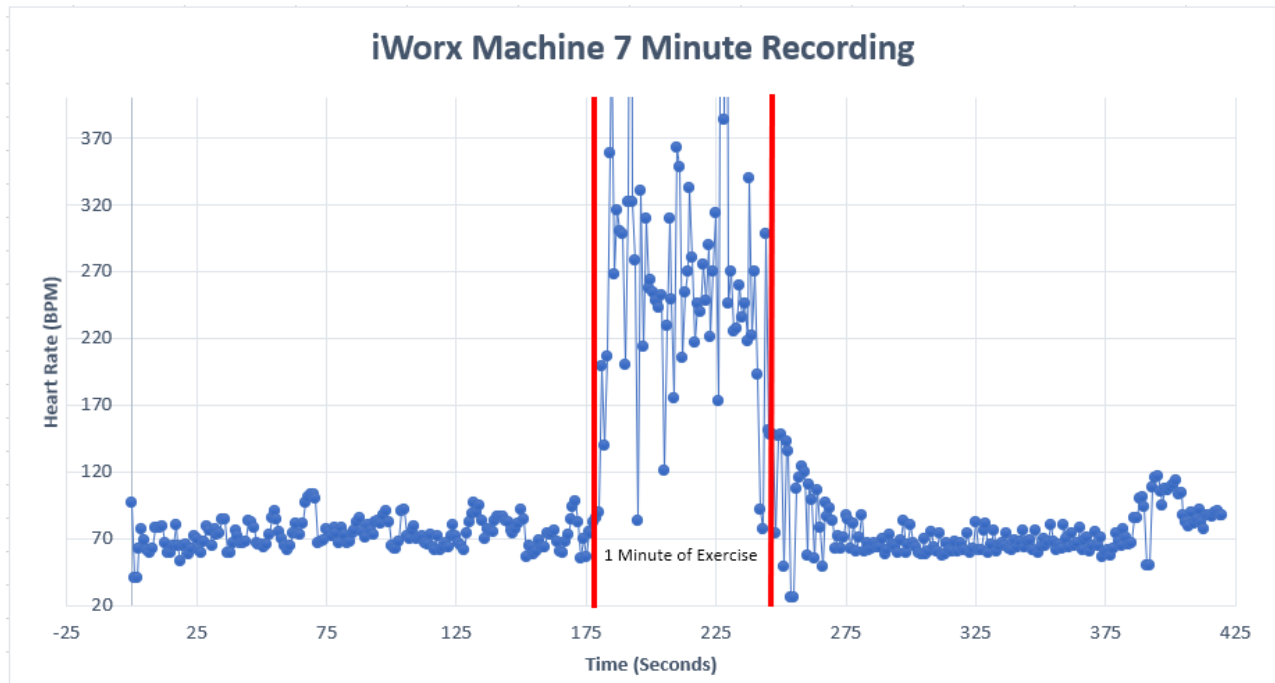


Figure 11. Graph of iWorx 7-Minute Recording.

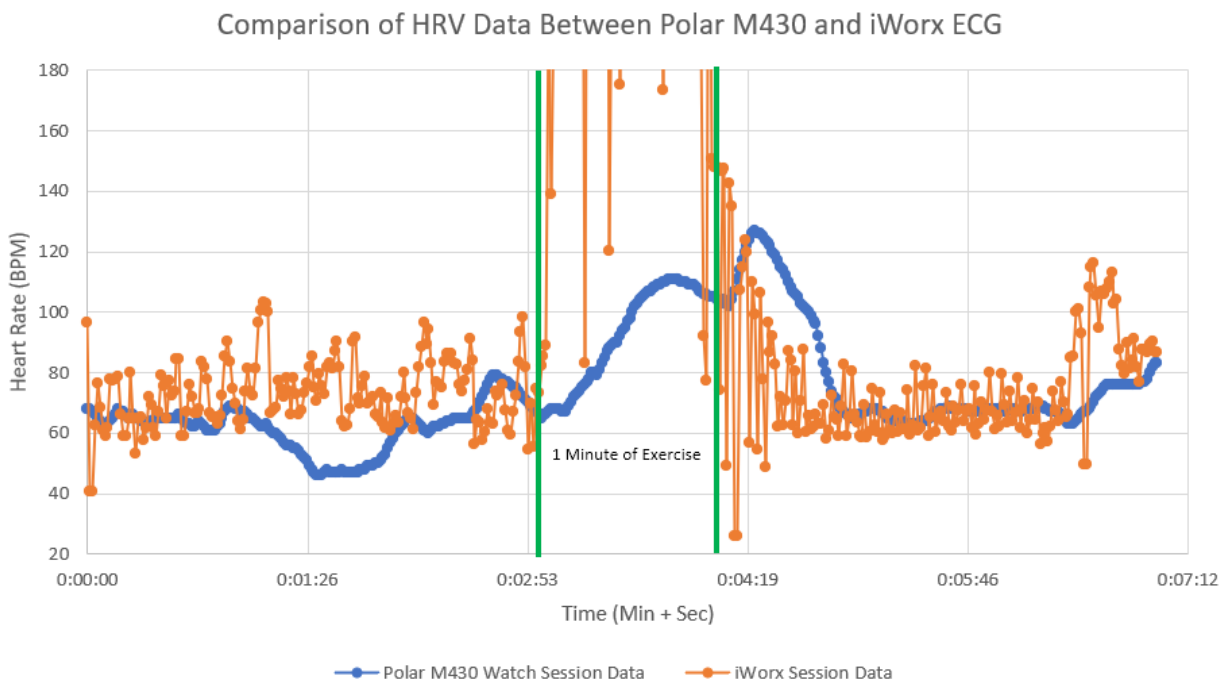


Figure 12. Comparison of iWorx and Polar M430 HR Data.

Table 1. Statistical Analysis of HR 24-Hour Data.

Subject + Age:	Mean Heart Rate (BPM):	Range (BPM):	Standard Deviation:	Lowest HR (BPM):	Highest HR (BPM):
1 (21 Y.O.)	69	121	14.6888602	42	163
2 (51 Y.O.)	76	65	10.04698043	51	116
3 (53 Y.O.)	76	83	12.25144548	51	134
4 (19 Y.O.)	75	145	21.00770899	42	187
5 (20 Y.O.)	82	89	12.0172977	34	123
6 (46 Y.O.)	83	58	9.064662411	62	120
7 (49 Y.O.)	76	66	8.778535903	51	117
8 (21 Y.O.)	94	124	16.86962578	65	189
9 (21 Y.O.)	84	84	13.85279161	53	137

Table 2. Statistical Analysis of HR Data During Sleep.

Subject + Age:	Mean Heart Rate (BPM):	Range (BPM):	Standard Deviation:	Lowest HR (BPM):	Highest HR (BPM):
1 (21 Y.O.)	63	74	10.3156066	42	116
2 (51 Y.O.)	69	60	9.647635685	52	112
3 (53 Y.O.)	71	72	8.938790805	51	123
4 (19 Y.O.)	63	67	13.02138758	45	112
5 (20 Y.O.)	86	89	11.6857586	34	123
6 (46 Y.O.)	76	41	4.879304064	62	103
7 (49 Y.O.)	69	48	4.776006774	51	99
8 (21 Y.O.)	85	75	7.856974758	67	142
9 (21 Y.O.)	93	67	9.957347501	70	137

Table 3. Difference Between 24-Hour and Sleep Period Data for Subjects.

Subject + Age:	HR Range Difference (BPM):	HR SD Difference (BPM):
1 (21 Y.O.)	47	4.373
2 (51 Y.O.)	4	0.399
3 (53 Y.O.)	11	3.313
4 (19 Y.O.)	78	7.986
5 (20 Y.O.)	0	0.332
6 (46 Y.O.)	17	4.185
7 (49 Y.O.)	18	4.002
8 (21 Y.O.)	49	9.012
9 (21 Y.O.)	17	3.895

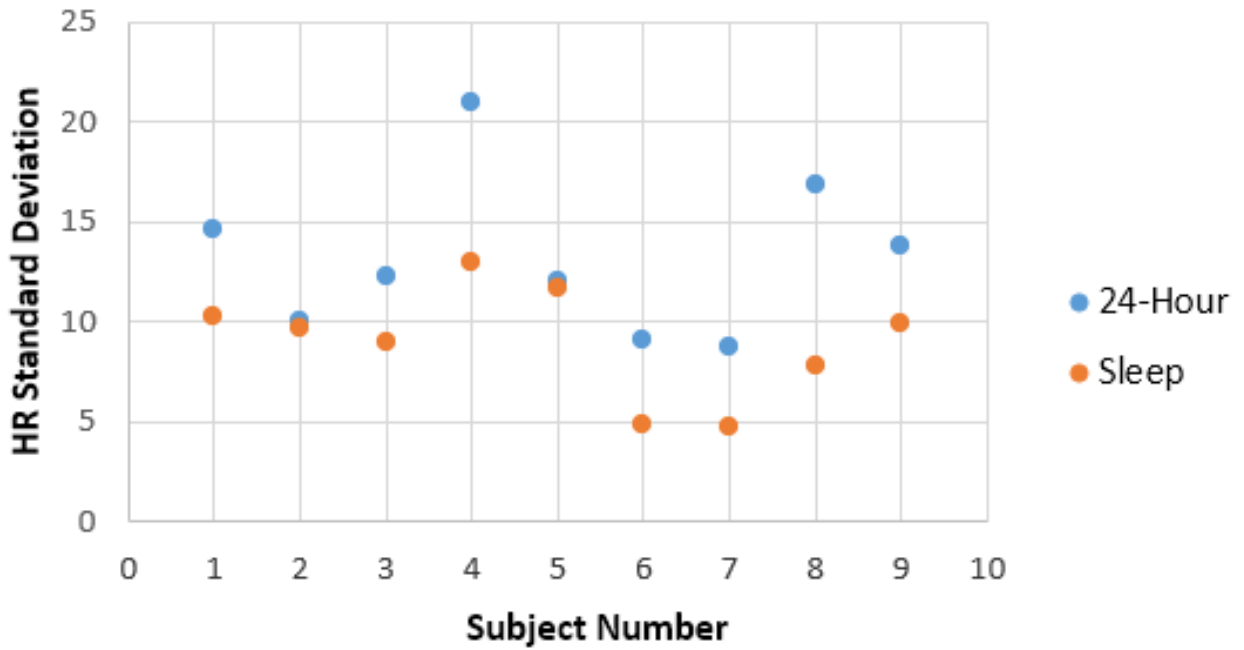


Figure 13. Comparison of HR Standard Deviation For 24-Hour and Sleep Periods ($p = 0.0013$, paired t-test).

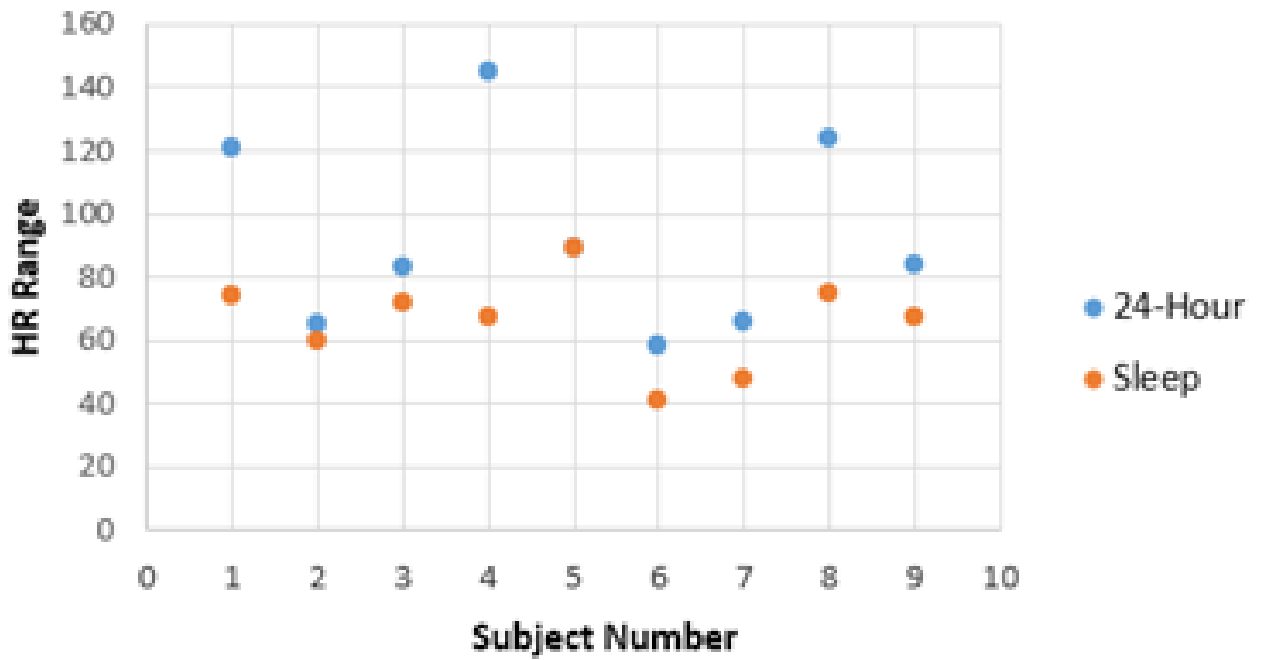


Figure 14. Comparison of HR Range For 24-Hour and Sleep Periods ($p = 0.0068$, paired t-test).

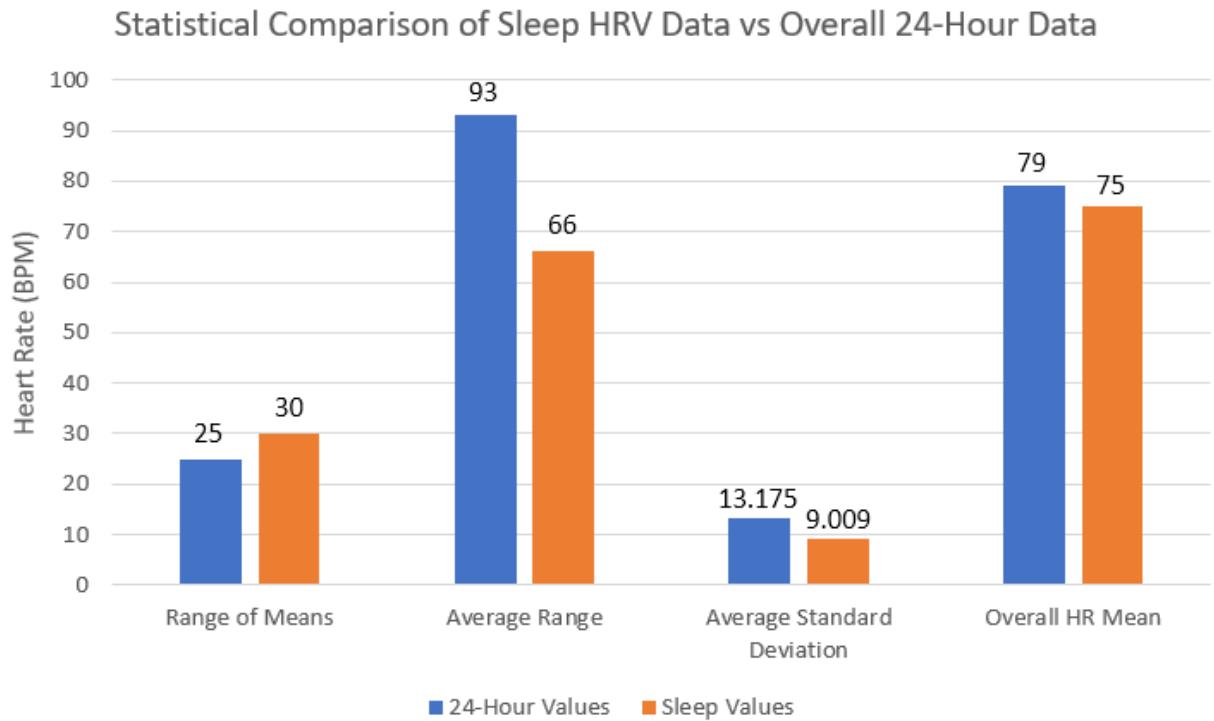


Figure 15. Graphical Analysis of Statistical HR Data.

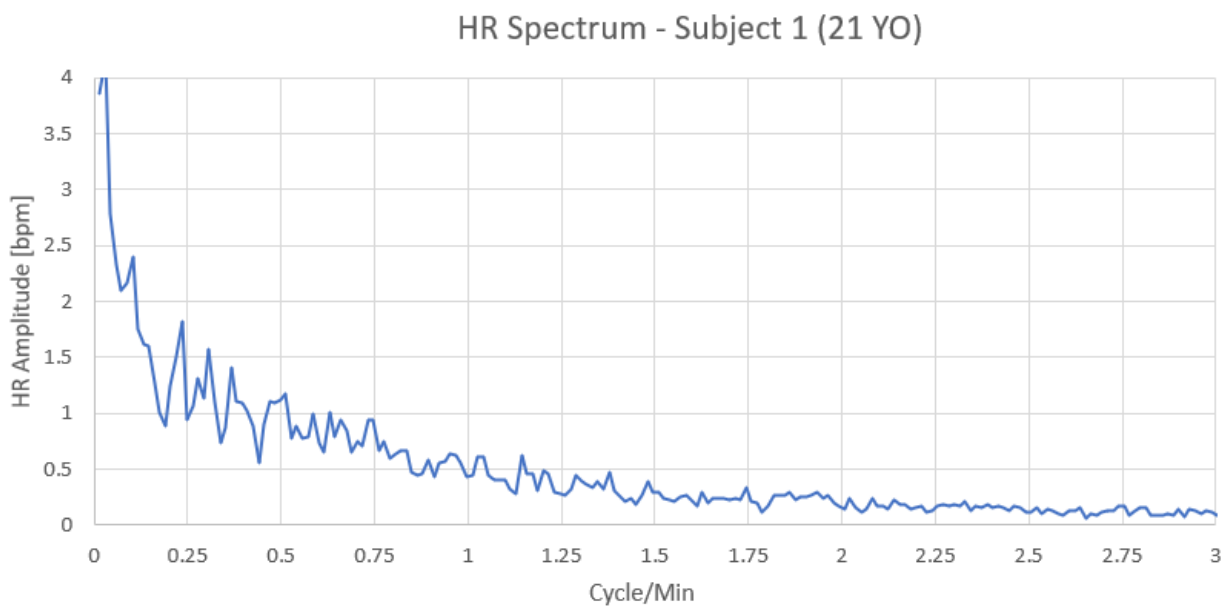


Figure 16. FFT for 21 Year Old Male.

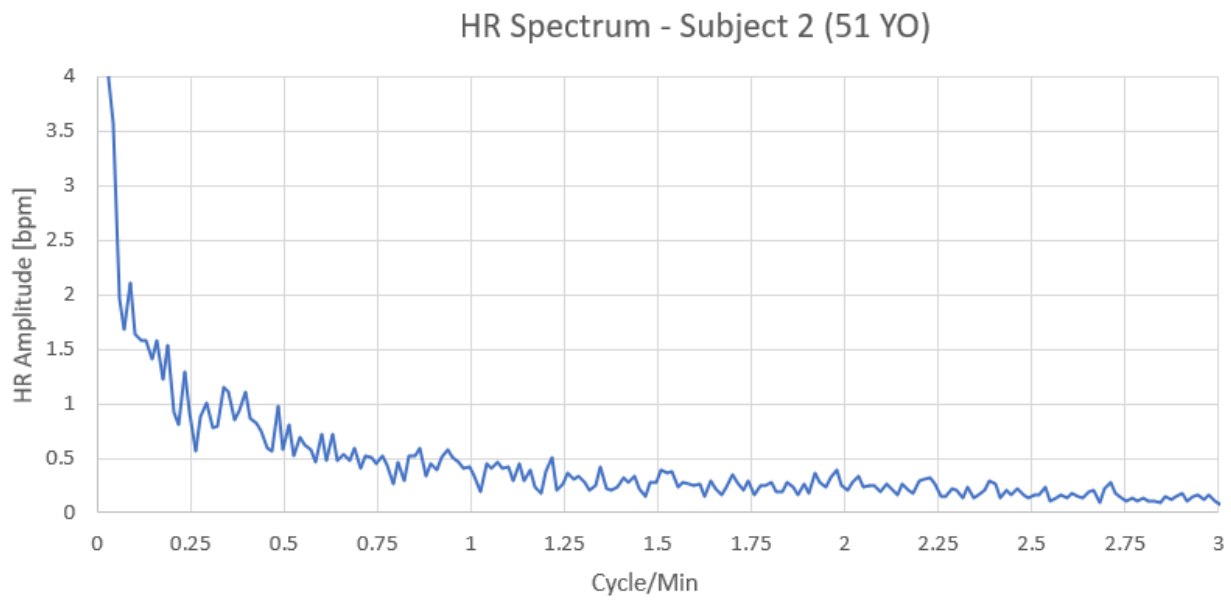


Figure 17. FFT for 51 Year Old Female.

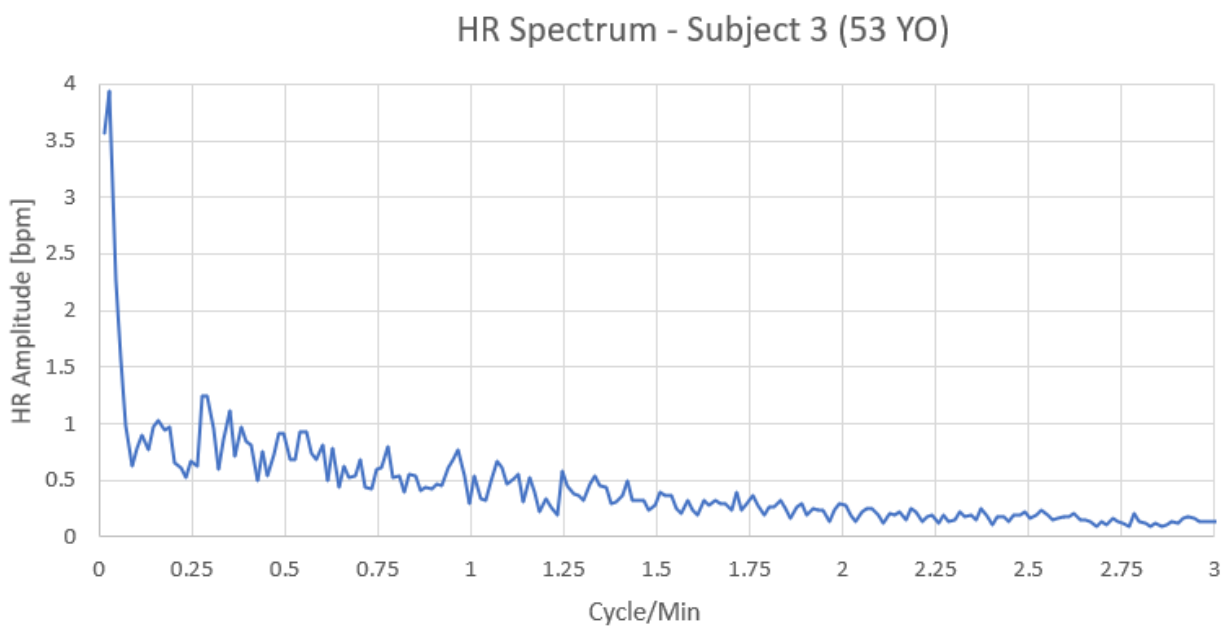


Figure 18. FFT for 53 Year Old Male.

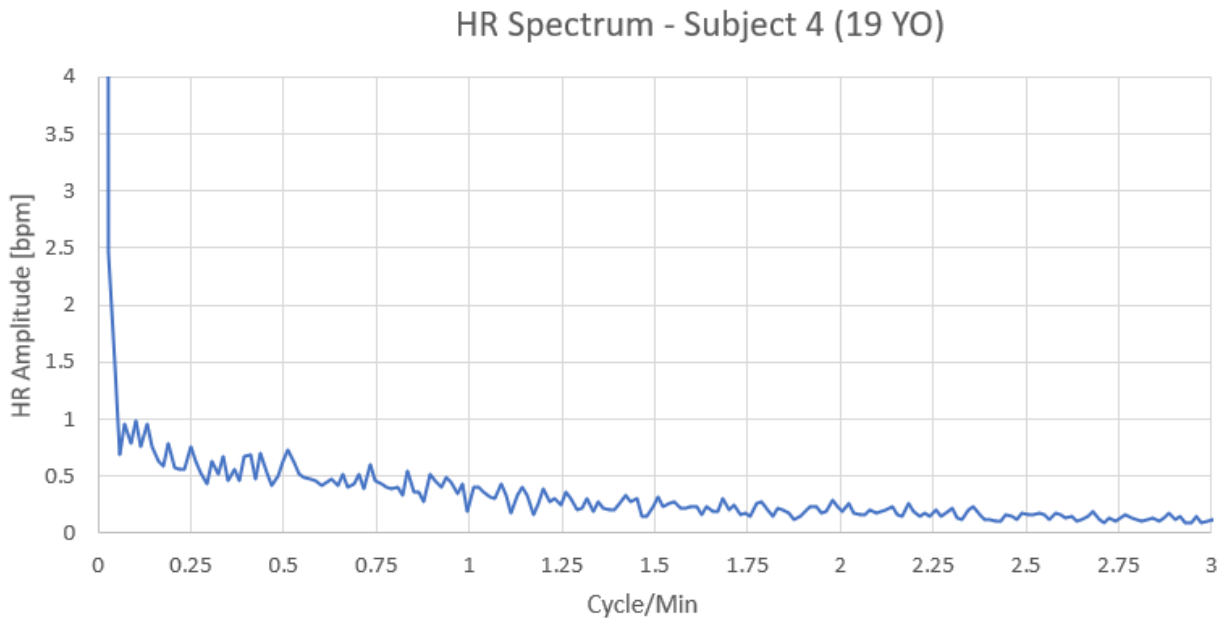


Figure 19. FFT for 19 Year Old Male.

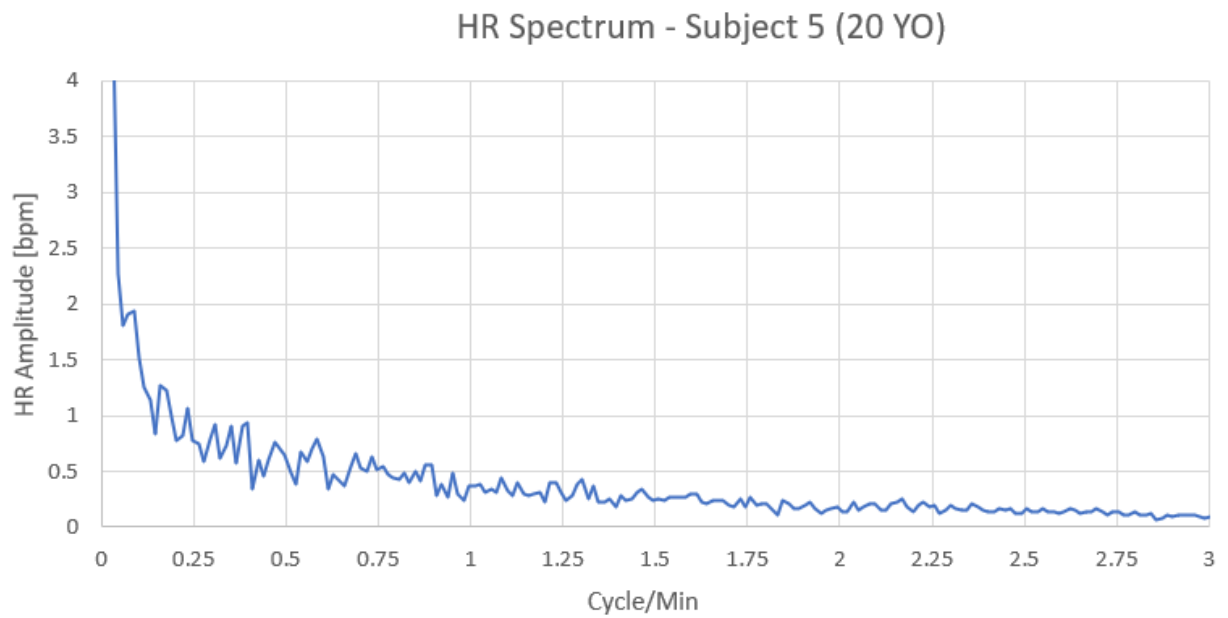


Figure 20. FFT for 20 Year Old Male.

HR Spectrum - Subject 6 (46 YO)

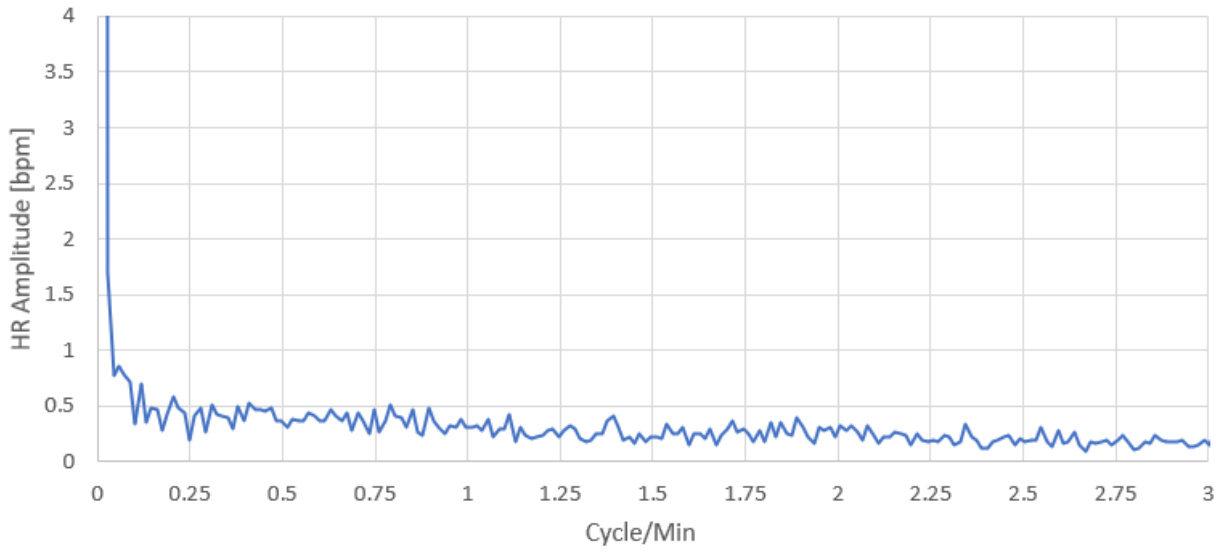


Figure 21. FFT for 46 Year Old Female.

HR Spectrum - Subject 7 (49 YO)

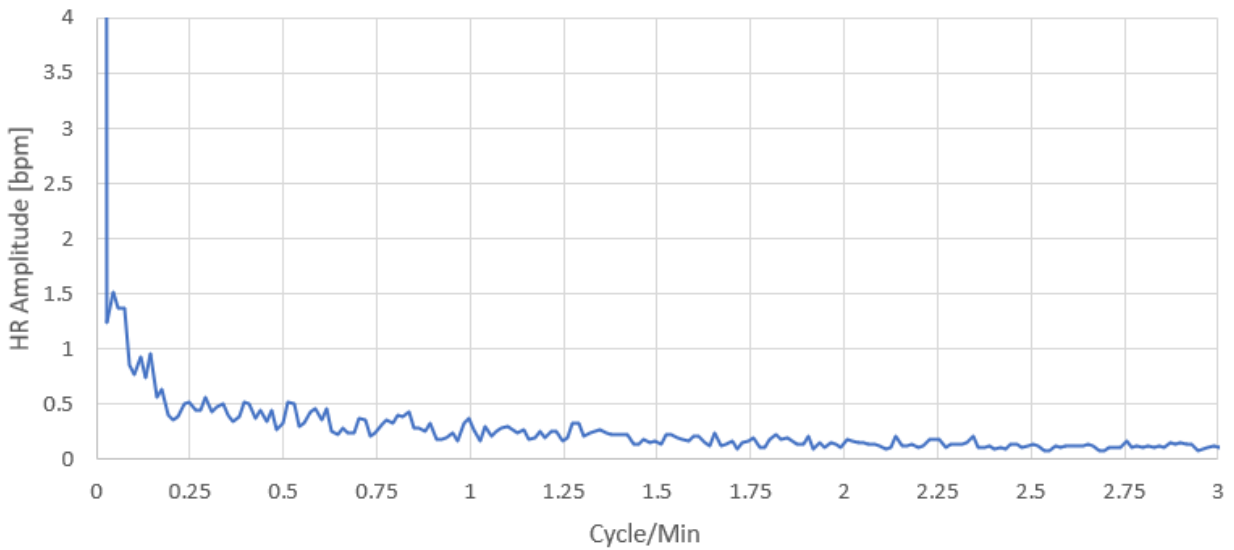


Figure 22. FFT for 49 Year Old Male.

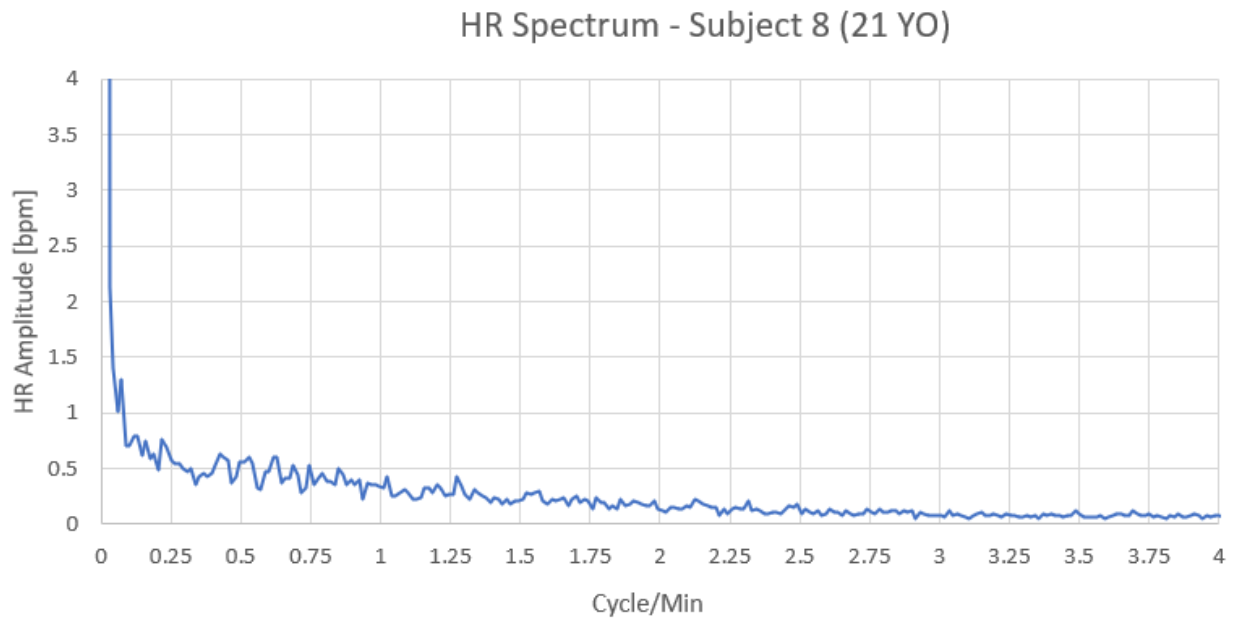


Figure 23. FFT for 21 Year Old Female.

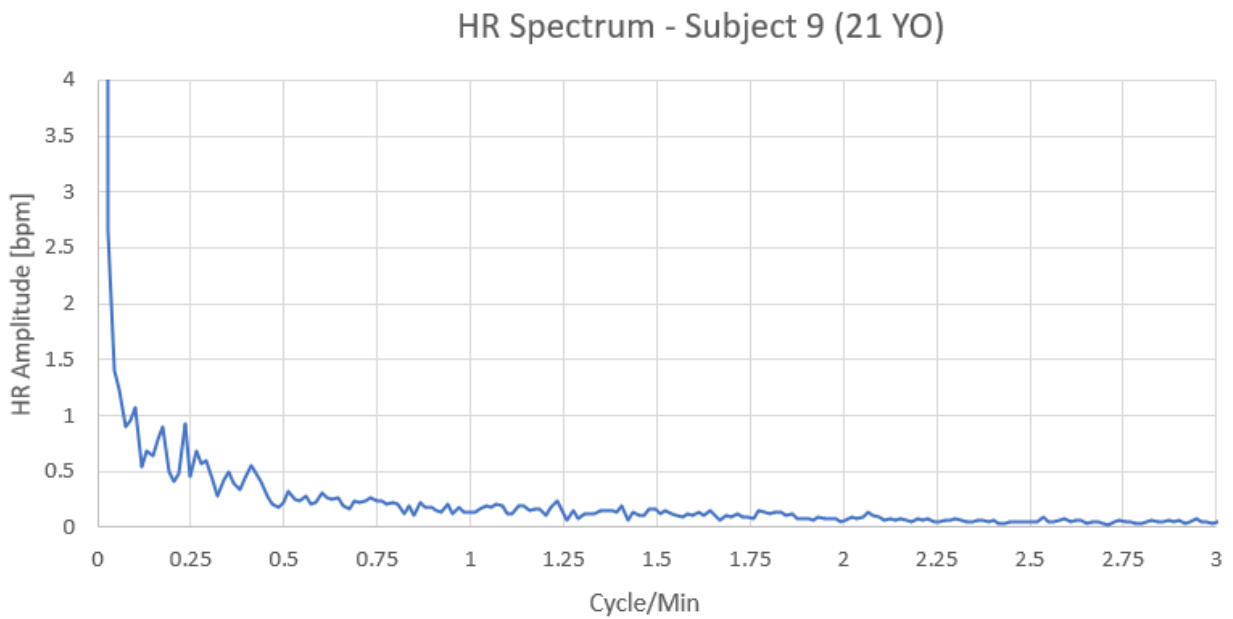


Figure 24. FFT for 21 Year Old Male.

DISCUSSION

Analysis of Results

As can be seen from the data in Figures 1-9, there is noticeably higher HR in subjects during the day when they are conducting various activities such as eating, exercising, or working, than during sleep. Some HR patterns are visible during sleep, with periods of high and low HR. The increase and decrease in HR for certain periods may be indicative the cycling between different stages of sleep. When analyzing the data for the 24-hour recording periods, a noticeable decrease in average heart rate, as well as HR in general, is seen during sleep, as the body is conducting less activity. Less HRV is seen for the full 24-hour period in older adults compared to younger adults, although the number of subject in the study has too small to have strong evidence. Figures 7 and 9 show a weakness of the Polar M430, in that it sometimes loses signal for a small time period and is unable to record any HR data at all.

The study also focused on HR during sleep, and shows how it compared to the entire 24-hour period. There was lower heart rate and heart rate variability during sleep, when there is less physical activity. This is seen in Figures 13 and 14, where the p-value for Figure 13 is 0.0013, and the p-value for Figure 14 is 0.0068. Since both p-values are less than 0.05, there is a statistically significant drop in HR range and standard deviation during sleep, showing that HR variation decreases during sleep. For the entire group, the overall average heart rate, the average range of HR values, and the average standard deviation are all lower for sleep, indicating that generally heart rate variability and heart rate decreases in the night due to less physical activity and variation than in the day. Tables 1 and 2 show that in general for each person, the standard deviation and HR range values decrease noticeably during sleep in Table 2, compared to the overall 24-hour

recording values in Table 1. Sleep data can be more controlled, as during the day, no subject shares the exact same schedule, and there is less variability from differing activities.

In Figures 10-12, the Polar M430 and iWorx are compared for a 7-minute recording taken synchronously on both. There is 3 minutes of rest, 1 minute of light exercise (jogging in place), followed by 3 minutes of rest. The iWorx is an ECG, and uses LabScribe to calculate the HR data through measuring the distance in time between RR intervals. In comparison, the Polar M430 lists the HR measurements directly in accordance with time. As can be seen in Figure 12, the iWorx tends to show more HR variation compared to the Polar M430. Agreement between the 2 devices was modest with some differences > 10 BPM at certain times. But HR data generally overlapped, indicating that the Polar M430 acceptable as a modest tool for HR measurements. For the iWorx, extremely high values for HR are seen for the 1 minute of exercise, reaching values as high as 500 BPM. This is a source of error of the iWorx ECG or the LabScribe software configuration. The ECG electrodes may not have been applied properly, or the iWorx program may not have been properly calibrated for exercise.

Tables 1 and 2 show a numerical representation of statistical data for all 9 subjects, including average HR, HR range, and HR standard deviation. The range is the difference between the lowest and highest HR for the recording period, and the standard deviation is variation from the mean, or average, HR for a recording period. The results in these tables show that the older a subject is, the lower their HRV. For example, in Table 2, when comparing 20-year-old Subject 5 to 49-year-old Subject 7, the HR Range for Subject 5 is 89 BPM and the HR Standard Deviation is 11.68 BPM, while for Subject 7 the Range is 48 BPM and the Standard Deviation is 4.78 BPM. Subject 7's HR range is 41 BPM lower than Subject 5's, and Subject 7's Standard Deviation is 6.9

BPM lower than Subject 5's, for sleep data. There may be a decrease in HR range and standard deviation with age. When comparing an older adult subject in the study to a younger study subject, either for 24-hour data or sleep data, a marked decrease is seen in range and SD, indicating that HRV may decrease with age. Further analysis with a larger group of subjects is needed to more concretely define the effect of age on HR and HRV. Another noteworthy observation in Table 1 is that for subjects of a similar age group, those that exercise have a higher standard deviation than those that do not. For example, when comparing the SD data for Subject 1, who exercised for approximately 1 hour during their Polar HR recording, to Subject 9, who did not exercise during their 24-hour recording, Subject 1 has a SD of 14.69 BPM, while Subject 9 has a SD of 13.85 BPM. There is a difference of 0.84 BPM between the two subjects, indicating that the higher HR values achieved during physical activity increase overall deviation from the mean for the subject. However, one important note to keep in mind is that the sample size in this study was very limited, and further analysis with a larger population must be conducted to confirm validity of the aforementioned results. Table 3 is a numerical representation of Figures 13 and 14, showing the decrease in values between the 24-hour period to the sleep period.

Figures 13 and 14 show the difference in HR variation for each subject, based on the values from Tables 1 and 2. Figure 13 shows the difference in Standard Deviation values between the Sleep period and 24-Hour period for each subject. As can be seen, the standard deviation values are generally lower during sleep than for the full 24-hours. The p-value (obtained through paired t-test) for Figure 13 is 0.0013, which is less than 0.05. This means that the difference in SD values are statistically significant, and that there is a significant drop in HR standard deviation values between 24-hours and sleep. Figure 14 shows the difference in HR range values between 24-hours

and sleep periods. As can be seen, the HR range are lower for each subject during sleep than for the full 24-hours. The p-value for Figure 14 is 0.0068, which is less than 0.05. This means that the data is statistically significant, and that there is a significant drop in HR range values between the full 24-hour HR period and the sleep period.

In Figure 15, the range of the means of heart rate for the sleep period is 30 BPM, compared to 25 BPM for the overall period. This means that there is more variation in average heart rate between each person during sleep than the full 24-hour period, when the people are awake. The reasons for this trend needs further investigation. Figure 15 also shows that the average range of heart rate is lower during sleep at 66 BPM, compared to an average range of 93 BPM during the full 24-hour period. This indicates that there is more HRV when the subject is awake, and that HRV decreases during sleep. Figure 15 shows that the average standard deviation in heart rate for all individuals is lower during sleep at 9.009 BPM, compared to 13.175 BPM for the full 24-hour period, which reaffirms the finding that there is less variation during sleep. The smaller HR standard deviation suggest that the HR was typically be closer to the mean heart rate during sleep, and will be further from the average heart rate when the subject is awake. Finally, Figure 15 shows us that the average heart rate for all individuals in BPM is higher over the full 24-hour period at 79 BPM compared to 75 BPM during sleep. The findings shown in Figure 15 illustrate that HRV and HR tend to decrease during sleep.

In Figures 16-24, the FFT analysis was performed for the isolated sleep data for all subjects. The FFT results showed noticeable peaks < 1 cycles per minute with the higher HR spectrum seen < 0.2 cycles per minute, meaning that the latter slow HR cycles repeat over > 5 minute. In the FFT, each peak is a variation in HR at a certain amount of cycles per minute. From the results, it can be

identified that there are higher amplitude values at less than 0.2 cycles per minute, meaning that at every 5 minutes at minimum, HR tends to vary by 0.5 to 1 BPM at least, with variation in some subjects reaching higher than 4 BPM.

Strengths, Limitations, and Future Studies

There were many strengths to this study. The collection of data was very straightforward and easy to obtain, with the subject wearing the watch for a 24-hour period and keeping a journal of their activities. The data could be easily exported to an Excel spreadsheet format and statistically analyzed. The data from the watch synchronized digitally with the Polar website that automatically graphed HR data, making analysis easier. The data and findings from this study can be used as a basis for future studies that measure HR and spirometry during sleep, in order to determine how HR varies with sleep phases such as rapid-eye-movement (REM) and non-REM (NREM).

There were a few limitations to the study as well. Subjects' recording of journals were not always accurate, with some being a recall or assumption from memory, and were not done synchronously. Monitoring of the subject while data was being recorded was not possible, as the subject took the Polar M430 home with them and independently recorded data without supervision and with limited communication. The study also faced limitations due to the onset of the COVID-19 pandemic, as communication with the professor and lab staff was virtual only, and access to lab equipment such as the iWorx ECG was not possible until August of 2021. The pandemic also presented challenges with obtaining data from a larger group of subjects, limiting the scope of the study. The Polar M430 watch is limited in that it does not track respiration, which will allow a true

analysis of HRV; it is limited to tracking HR only, from which statistical analysis of HR variation was performed.

Future studies may provide more direct analysis of HRV, rather than interpretation of variation through HR values. Modification of iWorx to include spirometry data during recordings will allow HRV analysis directly with respiration. Future studies can analyze respiration changes between sleeping and awake subjects in conjunction with HR and obtain more comprehensive data in a large number of subjects. HRV is a function of spirometry/respiration data, and a limitation of the Polar M430 was that it did not measure respiration. A Holter Recording (7) can be used to measure HR and possibly respiration over 24-hour periods.

REFERENCES

1. Marcelo Campos, M. (2019, October 24). Heart rate variability: A new way to track well-being. Retrieved November 25, 2020, from <https://www.health.harvard.edu/blog/heart-rate-variability-new-way-track-well-2017112212789>
2. Erik Cheever, S. (n.d.). Introduction to the Fourier Transform. Retrieved November 25, 2020, from <https://lpsa.swarthmore.edu/Fourier/Xforms/FXformIntro.html>
3. Liao, D., Barnes, R., Chambless, L., Simpson, R., Sorlie, P., & Heiss, G. (2000, July 20). Age, race, and sex differences in autonomic cardiac function measured by spectral analysis of heart rate variability-The ARIC study. Retrieved November 25, 2020, from <https://www.sciencedirect.com/science/article/abs/pii/S0002914999802604>
4. Zhang, J. (2007, June 14). Effect of Age and Sex on Heart Rate Variability in Healthy Subjects. Retrieved November 25, 2020, from <https://www.sciencedirect.com/science/article/abs/pii/S0161475407001224>
5. Antelmi, I., Paula, R., Shinzato, A., Peres, C., Mansur, A., & Grupi, C. (2004, January 27). Influence of age, gender, body mass index, and functional capacity on heart rate variability in a cohort of subjects without heart disease. Retrieved November 26, 2020, from <https://www.sciencedirect.com/science/article/pii/S0002914903015054>
6. Elsenbruch, S., PhD, Harnish, M. J., PhD, & Orr, W. C., PhD. (1999, December 01). Heart Rate Variability During Waking and Sleep in Healthy Males and Females. Retrieved November 26, 2020, from <https://academic.oup.com/sleep/article/22/8/1067/2749955>
7. Stein, P., & Pu, Y. (2011, June 11). Heart rate variability, sleep and sleep disorders. Retrieved November 26, 2020, from <https://www.sciencedirect.com/science/article/abs/pii/S1087079211000293>
8. A.. Baharav, S., R.. Furlan, S., W.. Haustein, J., A.. Malliani, M., M.. Pagani, F., N.. Pomeranz, R., . . . A.W.. Zbrozyna, D. (1995, January 01). Human heart rate variability and sleep stages. Retrieved November 26, 2020, from <https://link.springer.com/article/10.1007/BF01997720>