Katie Weatherwax
Dr. Hasler
Sweet Dreams
State of the Art Wrist Worn Heart Rate Monitors

Introduction

Heart rate monitoring used to be used by medical professionals for vitals monitoring and diagnosing cardiac issues and now monitors are on the wrists of most consumers wrists on a daily basis. Wrist worn heart rate monitors have become standard in the smart watch market mostly used for fitness purposes. As the use for heart rate monitoring changed, so did the technology behind the measurements. The wrist worn heart rate monitors are less accurate than the medical grade devices which leads to question the irregularity notifications many of the devices claim to detect. The commercial application, technology and building blocks of wrist worn heart rate monitors, specifically the Apple watch and Fitbit, elaborate on the accuracy.

Commercial Application

The current well-known products on the market for wrist heart rate monitoring devices are the Apple Watch and the Fitbit. To begin, the most current Apple Watch on the market is the Apple Watch Series 6 beginning at $399 in the United States. The features of this device are an always-on retina display, GPS, blood oxygen measurement, an electrocardiogram measurement, as well as the heart rate monitor that provides notifications of irregular, high or low heart rates. The overall product is marketed towards a watch wearing market as the main functions continue to cater towards Apple and watch users. The newest Fitbit with a heart rate monitor to come to market is the Fitbit Charge 5. The Charge 5 includes an electrocardiogram measurement, an electrodermal activity scan, a stress management score, oxygen saturation monitoring, heart rate variability, breathing rate, and skin temperature tracking with other smart watch capabilities. The Charge 5 costs $179.95 in the United States. The Charge 5 target market is the fitness community as an overall health tracker with smart watch capabilities.

Underlying Technology

The underlying technology of an Apple Watch is a photoplethysmography. Photoplethysmography is “a simple non-invasive optical method that detects beat-to-beat pulsatile changes in blood flow” (Khushhal et al., 2017). Heart rate monitors that use this technology are less accurate than an echocardiogram, the technology used in hospitals for monitoring and diagnosing cardiac diseases. The purpose of a photoplethysmography is to estimate heart rate using an optical approach

detecting skin level pulsations caused by blood flow. Blood flow and the cardiac cycle causes small pulsations at skin level, which is how both technologies measure heart rate. However, the optical measurements have issues with accuracy. The accuracy is affected by motion, such as walking, jogging, and running, the color of the user's skin as the optical measurements do not measure darker skin accurately, and the frequency of measurements.

The underlying technology for the Fitbit Charge 5 is a photoplethysmography installed in the underside of the watch. The Fitbit's photoplethysmography, "consists of a light source and a photodetector that registers variations in reflected light caused by changes in blood volume with each left ventricular contraction" (Haghayegh et al., 2019). The photoplethysmography obtains the estimation of the heart rate as the green light source bounces off the skin and returns to the photodetector. As the technology estimating the heart rate is the same between the Apple Watch and the Fitbit Charge 5, it can be determined that this is how most wrist worn heart rate monitors take the measurement. As consumers utilize the product, they can visually see the light emitting source at the back of the watch. These heart rate monitors are not as accurate as electrocardiograms or electroencephalography.

Building Blocks of Implementation

As the Apple Watch and Fitbit Charge 5 have similar technology, the building blocks of their technological implementation will be similar. The hardware that is used for the heart rate monitor include phototransistors, infrared LEDs and a microprocessor to read and analyze the signal returned from the phototransistor. There are many other hardware parts that are needed for a photoplethysmography such as resistors, potentiometers, capacitors, and diodes however the use of these components will vary depending on the company creating the device. The use of an infrared LED is ensuring a deep penetration of the light to yield the best measurement of the blood flow in the tissue (Quinn, 2016). The light is then scattered and absorbed by the skin, tissue and blood then returning to the phototransistor which is being used as a photodetector. The phototransistor is an optical sensitive receiver which will measure the light refracted by the blood to measure the heart rate. Finally, the microprocessor calculates the heart rate. The microprocessor is where the software aspect of a photoplethysmography. The software will activate the LED and the photodetector. The software will record the maximum and minimum value of the skin pulsation. As these values are repeatedly measured, the algorithm will calculate how many beats per minute.

References

Apple. 2021. *Watch*. [online] Available at: <https://www.apple.com/watch/> [Accessed 6 October 2021].

Fitbit.com. 2021. *Advanced fitness + health tracker | Shop Fitbit Charge 5*. [online] Available at: <https://www.fitbit.com/global/us/products/trackers/charge5?sku=421BKBK> [Accessed 6 October 2021].

Khushhal, A., Nichols, S., Evans, W., Gleadall-Siddall, D., Page, R., O'Doherty, A., Carroll, S., Ingle, L. and Abt, G., 2017. Validity and Reliability of the Apple Watch for Measuring Heart Rate During Exercise. *Sports Medicine International Open*, 1(06), pp.E206-E211.

Quinn, S., 2016. Plotoplethysmography - (IR Heart Rate Monitor). [Blog] *instructables.com*, Available at: <https://www.instructables.com/Photoplethysmography-IR-Heart-Rate-Monitor/> [Accessed 6 October 2021].

Shahab Haghayegh, Sepideh Khoshnevis, Michael H. Smolensky & Kenneth R. Diller (2019) Accuracy of PurePulse photoplethysmography technology of Fitbit Charge 2 for assessment of heart rate during sleep, Chronobiology International, 36:7, 927-

933, DOI: 10.1080/07420528.2019.1596947

Wang, R., Blackburn, G., Desai, M., Phelan, D., Gillinov, L., Houghtaling, P. and Gillinov, M., 2017. Accuracy of Wrist-Worn Heart Rate Monitors. *JAMA Cardiology*, 2(1), p.104.