HELO
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BP

Blood Pressure Measurement by HELO Wearable Devices Photoplethysmography

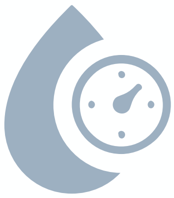
Version 1.0 - 1.2023

Abstract

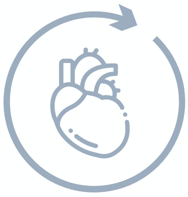
As an important vital sign, blood pressure is frequently measured to assess health, especially for those at high risk of developing heart disease. But despite the importance of this metric, capturing blood pressure can be both inconvenient and uncomfortable for the patient. Researchers have therefore explored the viability of alternatives to the traditional, cuff-based method of capturing blood pressure. These tend to focus on the known relationship between blood pressure, pulse wave velocity, and pulse transit time. Photoplethysmography (PPG) and electrocardiogram (ECG) can be used to cufflessly and non-invasively measure these values and extrapolate blood pressure. Once captured, algorithms are employed to accurately decipher the data and present a blood pressure measurement. Equipped with a cutting-edge PPG function, Helo wearable devices can record and report user blood pressure, leading to more informed health choices.

The Fundamentals of Blood Pressure

In general terms, blood pressure (BP) is the pressure of circulating blood against the walls of blood vessels. For many years, a sphygmomanometer cuff has been used to measure BP, expressed in millimeters of mercury in terms of systolic (or maximum) pressure over diastolic (or minimum) pressure, such as 120/80 mmHg.[1] Blood pressure below the desired range is considered hypotension; pressure within the desired range is normotension; and pressure consistently higher than the desired range is hypertension. The latter affects more than a billion people globally, making it a significant health concern.[2]



BP tends to fluctuate throughout the day, impacted by factors such as breathing, stress, exercise, sleep, external temperature, and more. BP is homeostatic, meaning following stimulation it will return to a reference set point.



Doctors typically capture BP as a vital sign for evaluating health. "Cardiovascular diseases (CVDs) are the world's biggest killer, and hypertension is the major modifiable contributory risk factor for the CVDs.

Hypertension is the most common and potentially lethal condition that may result in heart attack, stroke, myocardial infarction, cerebrovascular accident, congestive heart failure, myocardial ischemia, etc., if it is not detected early and treated appropriately."[3]

However, this same study states, “it becomes increasingly evident that the office BP is inadequate to reveal a patient’s true BP status, particularly for those with the masked hypertension - the hypertension that cannot be detected by the routine methods.”[4]

With that in mind, and because traditional BP measurement by sphygmomanometer “cause[s] inconvenience and discomfort to users,”[5] numerous research efforts have focused on a satisfactory cuffless method of measurement, which are bearing fruit. A 2021 study states, “Noninvasive and cuffless approaches to monitor blood pressure (BP), in light of their convenience and accuracy, have paved the way toward remote screening and management of hypertension.”[6]

Cuffless Methods for Measuring Blood Pressure

Measuring blood pressure without a cuff presents unique challenges in terms of matching the accuracy of sphygmomanometer readings. Several methods are especially suited for measurement by wearable device.

- Pulse wave velocity (PWV) is often used to assess arterial stiffness, as the velocity increases in stiffer arteries. This value is defined as the distance between two arterial sites divided by the travel time between sites, known as pulse transit time (PTT) - “the most commonly employed technique for cuffless BP estimation.”[7] After each heartbeat, it takes time for the blood to reach the body’s periphery. “PTT … indirectly depends on blood pressure. This circumstance can be used for the noninvasive detection of blood pressure changes.”[8]

- Stated another way, Morales et al report, “The PTT value is inversely proportional to the blood pressure (BP) value, so its evaluation is considered a promising method for continuous, noninvasive monitoring.”[9] In the simplest of terms, once the PTT value is known, “it can be translated into BP with a calibration procedure.”[10]

- One way to monitor PTT, and extrapolate to BP, is through photoplethysmography (PPG). This is an optical way to measure blood volume changes in a bed of tissue, such as a finger or earlobe, by illuminating the skin and measuring light absorption. Huttunen et al write, “Arrival of the pulse wave to distal arterial sites can be easily measured by using a photoplethysmogram […], for example, in a wearable device.”[11]

- Ganti et al deployed a wearable device for PTT-based blood pressure measurement, in a study to specifically demonstrate this was an effective method for medically underserved areas. Their results showed the device “accurately monitored diastolic blood pressure (DBP) and mean arterial pressure (MAP) in a diverse population (N=44 participants) with a mean absolute difference of 2.90 mm Hg and 3.39 mm Hg for DBP and MAP, respectively, after calibration.”[12]
- In a 2020 study, Wang and Lin developed a wearable device utilizing a piezoelectric-based measurement system. In their view, “the application of PTT-based methods is limited by technical considerations, including the appropriate two-channel physiological measurement, non-specific estimation models and a complex procedure of multiple calibrations.”[13]

With this wearable, “The piezoelectric sensor provides a sensing function of pulsation changes of the radial artery that converts pressure signals into electrical signals by the pressure sensitivity of the piezoelectric sensor.”

The outcome of this study “showed a reliable accuracy of systolic blood pressure (SBP) (mean absolute error (MAE) ± standard deviation (SD) 1.52 ± 0.30 mmHg) and diastolic blood pressure (DBP, MAE ± SD 1.83 ± 0.50), and its performance agreed with standard criteria of MAE within 5 mmHg and SD within ±8 mmHg.”[14]

Zhang et al also developed and tested a wearable, cuffless device for ECG and PPG-based monitoring. Their novel approach deployed “the PTT&HR-based SBP model to estimate the SBP, with the HR information estimated from the ECG heartbeats identified.” They found this approach “significantly outperform the PTT-SBP models. The testing performance is 1.63 ± 4.44, 3.68, 4.71 mmHg in terms of mean error ± standard deviation, MAE and RMSE, respectively.”[15]

Algorithmic Interpretation of Recorded Data

Because capturing the data through PPG or other method is only part of the solution, means must be devised to analyze and accurately interpret and report BP measurements. In the words of Khalid et al, “developing a single PPG-based cuffless BP estimation algorithm with enough accuracy would be clinically and practically useful.”[16]

As Ding et al relate, numerous studies have focused on developing analytical models to achieve BP estimation based on the established relationship of PTT and BP. Their study lists and evaluates many such attempts undertaken since 1995, with most (more than 70%) “algorithms … based on linear or nonlinear regression models.”[17]

The Ganti team developed a “physiologically inspired PPG selection algorithm” which “had an important role in reducing the BP estimation error.”[18] Additionally,

> *“Several recent machine learning approaches to use the PPG signal for BP estimation have shown that the systolic upstroke is one of the most important features of the waveform. Hence, the selection algorithm, by extracting information from these more reliable and clinically important arteries, was a central part of our ability to notice the demographic differences in arterial stiffness rooted in our calibration coefficients.”*[19]

Wang and Lin applied a “peak and valley detection” algorithm to analyze PPW signals from their wearable.[20]

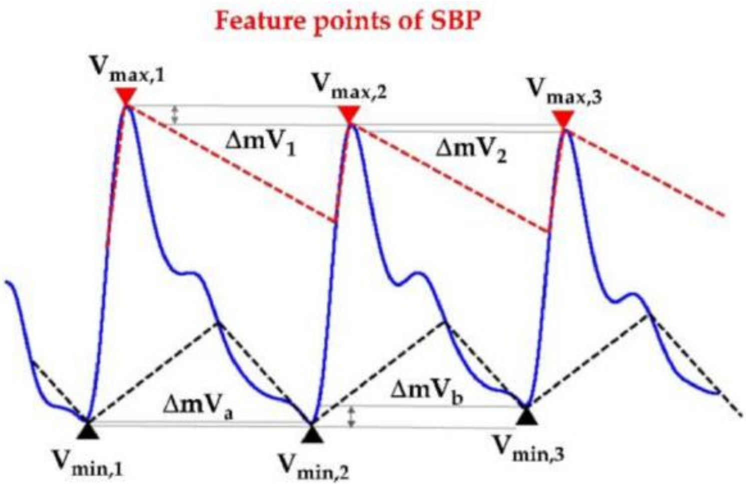


***Fig. 1**: Peak and valley detection algorithm for pressure pulse wave (PPW) signals.*[21]

BP Measurement with Helo Wearable Devices

Helo wearable devices put into practice the techniques and findings outlined above. From data capture through PPG to algorithmic analysis on the back end, these advanced devices provide an accurate blood pressure reading for consumers. With this information, conveniently captured right from the wrist, users can be more aware of health and take appropriate action under the guidance of a medical professional.

Conclusion

Photoplethysmography (PPG) can be used to capture blood pressure data, which, when interpreted by algorithm, reports user blood pressure with high accuracy. Helo wearable devices employ these methods to provide users with on-demand and simple blood pressure readings to help them to better understand the state of their health.

Legal Disclaimer

Unless otherwise specified, Helo wearable devices and related services are not medical devices and are not intended to diagnose, treat, cure, or prevent any disease. With regard to accuracy, Helo has developed products and services to track certain wellness information as accurately as reasonably possible. The accuracy of Helo's products and services is not intended to be equivalent to medical devices or scientific measurement devices.

Consult your doctor before use if you have any pre-existing conditions that might be affected by your use of any Helo product or service.

Useful Terms

Photoplethysmography (PPG): An optical way to measure blood volume changes in a bed of tissue, such as a finger or earlobe. Obtained by illuminating the skin and measuring light absorption.

Electrocardiogram (ECG): Used to measure and analyze electrical activity of the heart to detect abnormalities or heart arrhythmias. Components of an ECG are outlined in the following terms.

Pulse wave velocity (PWV): The measurable velocity of the pressure wave caused by the flow of blood through arteries.

Systolic: High pressure phase of heartbeat when heart contracts, pushing blood to extremities.

Diastolic: Low pressure phase of heartbeat when heart refills with blood, following the systole.

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