Wearable Continuous Blood Pressure Monitoring through Smart Photoplethysmography-based Pulse Wave Velocity Measurement

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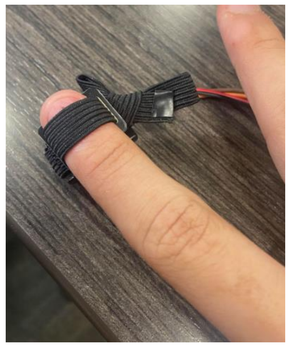
INTRODUCTION

Arterial stiffness, a consequence of aging and hypertension, compromises the ability to dampen pulse pressure, posing risks to organ perfusion.[1] Aortic stiffness, assessed via carotid-femoral Pulse Wave Velocity (cf-PWV), reliably predicts cardiovascular events and mortality.[2] Hypertension prevalence highlights the need for accurate blood pressure monitoring beyond conventional office measurements. Current out-of-office devices, including the Ambulatory Blood Pressure Monitoring (ABPM) and Home Blood Pressure Monitoring (HBPM), offer alternatives but face challenges of reproducibility and accessibility.[3] This project introduces a novel approach, employing wearable technology and photoplethysmography (PPG) to estimate blood pressure through Pulse Wave Velocity (PWV). Finger-toe PWV (ft-PWV) simplifies PWV measurement using photodiode sensors on finger and toe arteries, showing a strong correlation with cf-PWV.[2] Its simplicity and clinical acceptability offer promise for continuous blood pressure monitoring in diverse settings. This innovation underscores the potential for non-invasive devices to detect and manage hypertension and cardiovascular risk factors effectively.

METHODS

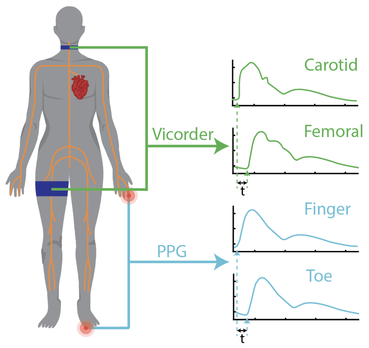
Overall, 25 healthy subjects were measured, 5 women and 20 men. The mean age was 28.2 years with a sd. of approximately 11.0 years. The mean blood pressure was systolic 122.9 mm Hg with an sd. of 12.0 mm Hg and diastolic 75.7 mm Hg with an sd. of 7.4 mm Hg. Participants' age ranged from 18-56 years old. The examinations were conducted in the Cardiometabolic Lab within the Department of Exercise and Sports Science at the University of North Carolina at Chapel Hill and authorized by the local IRB committee.

Figure 1a. PPG Device



Measurements were conducted at room temperature and in avoidance of external influences. Participants in the study were instructed to rest on a bench for 5 minutes to establish a baseline physiological state. Next, blood pressure (BP) measurements were obtained using a clinically validated automated BP cuff, iHealth Track Smart Upper Arm Blood Pressure Monitor. BP readings were taken three times, with a one-minute interval between measurements. These individual BP values were then averaged for each participant. Subsequently, the Vicorder device was applied, and pulse wave velocity (PWV) recordings were obtained during three separate sessions, each spaced one minute apart.

Figure 1b. Device Placement



ABSTRACT

Hypertension, a predominant contributor to global premature mortality and disability that results in 8 million deaths annually, underscores the imperative for proactive measures in disease prevention and diagnosis. The constraints inherent in traditional blood pressure (BP) monitoring instruments, characterized by inconveniences, discomfort, and limited applicability beyond clinical or home environments, accentuate the pressing need to advance and integrate continuous monitoring devices. Here, we present a noninvasive device based on photoplethysmography (PPG) signals to calculate Pulse Wave Velocity (PWV). Initial trials on 25 participants prove the capability of our hemodynamic sensor as a reliable BP measurement product and its feasibility and practical usability in precise BP control and personalized diagnosis schemes development. In addition to BP monitoring, the device can also serve to make pulse wave velocity a more beneficial tool in physical assessments.

RESULTS

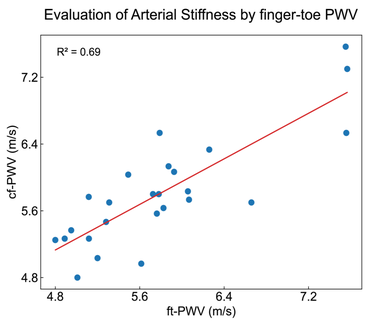


Figure 2a. Experimental cf-PWV versus experimental ft-PWV

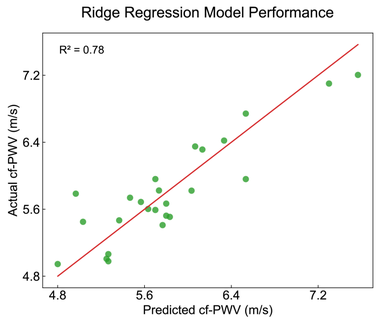


Figure 2b. Evaluation of machine learning model prediction accuracy

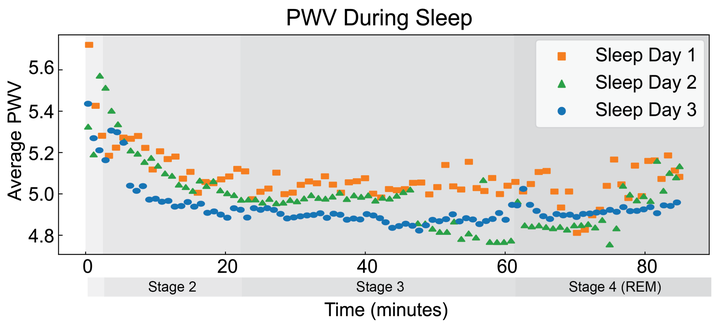


Figure 3. PWV from device across first 90 minutes of sleep, three trials

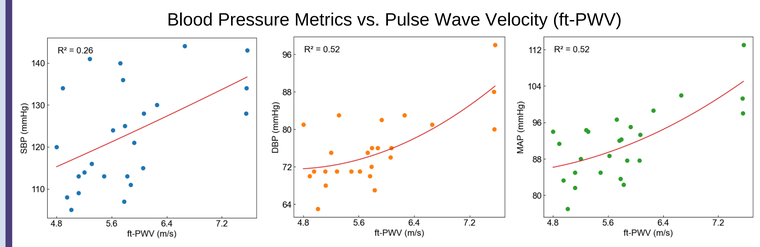


Figure 4. Correlation between Pulse Wave Velocity and Systolic, Diastolic, and Mean Arterial Pressure

CONCLUSION

The results showed strong correlations between the experimentally measured ft-PWV and cf-PWV (Figure 1). Utilizing the ridge regression model to forecast cf-PWV based on ft-PWV and additional participant features (age, weight, sex, height) led to improved estimations (Figure 2). Our device's PWV detection proved consistently reproducible across three sleep trials, displaying an initial decreasing trend within the first 20 minutes followed by a plateau (Figure 3). Overall, the results give us strong reason to believe that the device is a reliable indicator of PWV.

There is room for improvement in connecting the reliable detection of PWV to the reliable prediction of blood pressure (SBP, DBP, and MAP) since there is no a strong correlation (Figure 4); however, there is still a positive correlation with DBP and MAP, which is consistent with other literature.

FUTURE DEVELOPMENT

Our future developments will focus on several key areas. We plan to eliminate the need for wires by implementing Bluetooth technology, simplifying the setup process and enhancing user convenience. The integration of protective casings and secure bands will minimize variability caused by pressure changes, enhancing the reliability of our measurements. Additionally, we will refine our algorithms to account for minor motion artifacts, allowing users greater flexibility during data recording without the need for absolute stillness.

With ongoing improvements and refinements, our device holds great promise in the field of blood pressure monitoring and stands to become a valuable asset in providing accurate, user-friendly, and non-invasive BP monitoring across diverse healthcare settings.

REFERENCES

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