Screening Stage-2 Hypertension from Finger Photoplethysmography

Davide Valeriani, Hao-Wei Su, Sebastien Baur, Wei-Hung Weng, Mayank Daswani | hwsu@google.com

Introduction

Blood pressure (BP) is a strong predictor of cardiovascular (CV) disease and a key input for the calculation of established risk scores, such as Framingham's and atherosclerotic CV diseases risk scores [1].

Hypertension awareness remains very limited in the general population and especially in young adults [2]. In 2015, 8.5 million deaths were associated with hypertension worldwide [3], especially in low- and medium-income countries.

We propose a system for screening stage-2 hypertension from finger photoplethysmography (PPG), a non-invasive and low-cost technology available on increasingly ubiquitous devices such as smartphones [4].

Methods

DATASET

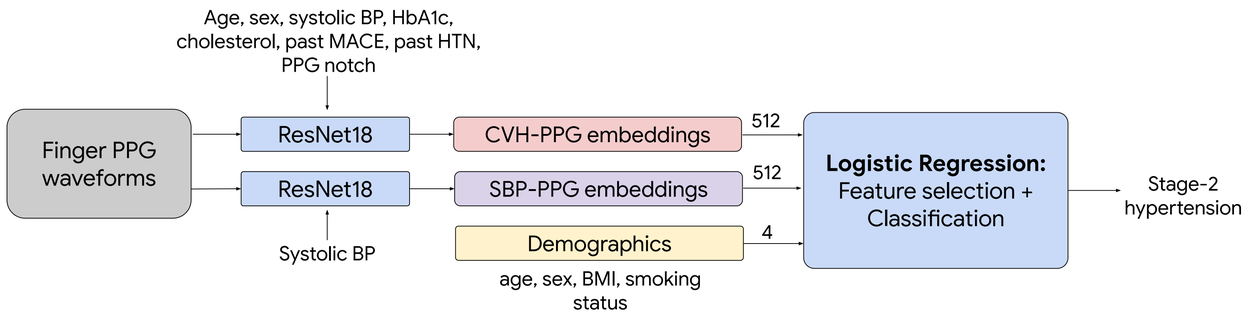
We used the UK Biobank dataset to retrieve finger PPG data from **180,329 participants aged 40-74 years old** and not receiving any hypertension medications. Three splits:

- Training set: 89,869 users
- Validation set: 40,063 users
- Test set: 50,397 users

Participants were labeled as having stage-2 hypertension if systolic blood pressure (SBP) ≥ 140 mmHg *or* diastolic blood pressure ≥ 90 mmHg, following American Heart Association guidelines (43% of users).

MODEL

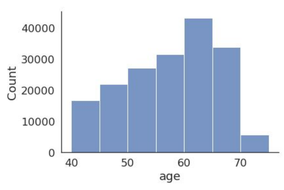
Trained two **one-dimensional residual neural networks** (ResNet18): one with multiple heads to learn cardiovascular health PPG embeddings (CVH-PPG) [5], and one with single head (SBP) to learn SBP-specific PPG embeddings (SBP-PPG).
Used **L1-regularized logistic regression** to classify people with stage-2 hypertension from **PPG embeddings and demographics** (age, sex, body mass index, smoking status).

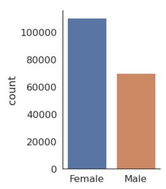


Results

Selected **53 features:**

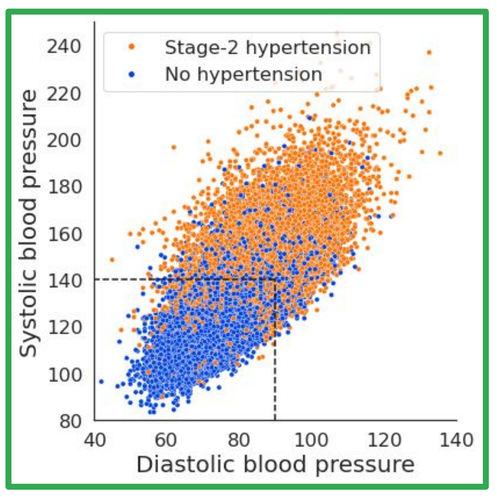
- Age
- Sex
- Body mass index
- 27 CVH-PPG embeddings
- 23 SBP-PPG embeddings





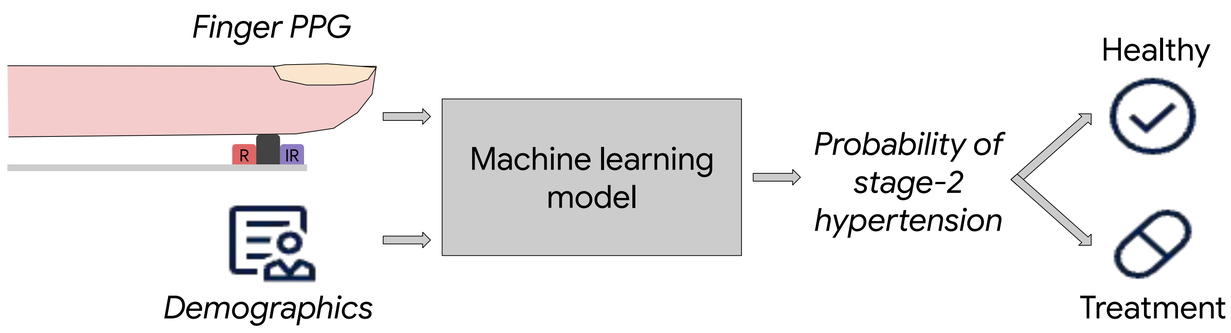
Compared performance of different models based on subset of features and models from the literature.

Model	AUC	Sensitivity	Specificity
PPG + Demographics	**0.808**	**0.679**	**0.775**
Demographics only	0.688	0.588	0.675
PPG only	0.762	0.655	0.726
Demographics + lifestyle [5]	0.77	-	-
Clinical PPG + ECG [7]	-	0.744	0.939



Conclusion

- **Finger PPG and demographics can help screen for stage-2 hypertension** and **increase people's awareness**
- Future work: can **PPG sensors in wearable and mobile devices** help reduce the underdiagnosis of hypertension globally?



References

[1] M. A. Said, R. N. Eppinga, E. Lipsic, N. Verweij, and P. van der Harst, "Relationship of Arterial Stiffness Index and Pulse Pressure With Cardiovascular Disease and Mortality," *J. Am. Heart Assoc.*, vol. 7, no. 2, Jan. 2018, doi: 10.1161/JAHA.117.007621.
[2] B. Everett and A. Zajacova, "Gender differences in hypertension and hypertension awareness among young adults," *Biodemography Soc. Biol.*, vol. 61, no. 1, pp. 1–17, 2015.
[3] B. Zhou, P. Perel, G. A. Mensah, and M. Ezzati, "Global epidemiology, health burden and effective interventions for elevated blood pressure and hypertension," *Nat. Rev. Cardiol.*, vol. 18, no. 11, pp. 785–802, Nov. 2021.
[4] A. Chandrasekhar, C.-S. Kim, M. Naji, K. Natarajan, J.-O. Hahn, and R. Mukkamala, "Smartphone-based blood pressure monitoring via the oscillometric finger-pressing method," *Sci. Transl. Med.*, vol. 10, no. 431, Mar. 2018, doi: 10.1126/scitranslmed.aap8674.
[5] W.-H. Weng *et al.*, "Predicting Cardiovascular Disease Risk using Photoplethysmography and Deep Learning," *arXiv [cs.CV]*, May 09, 2023. [Online]. Available: http://arxiv.org/abs/2305.05648
[6] K. Tsoi *et al.*, "Applications of artificial intelligence for hypertension management," *J. Clin. Hypertens.* , vol. 23, no. 3, pp. 568–574, Mar. 2021.
[7] Y. Liang, Z. Chen, R. Ward, and M. Elgendi, "Hypertension Assessment via ECG and PPG Signals: An Evaluation Using MIMIC Database," *Diagnostics (Basel)*, vol. 8, no. 3, Sep. 2018, doi: 10.3390/diagnostics8030065.