A machine learning approach to detect hypertension, diabetes and cardiovascular disease from PPG

George Searle[*], Stefan van Duijvenboden, Julia Ramírez, Andrew Tinker, Patricia Munroe, Pier Lambiase, Alun Hughes, Michele Orini
Institute of Cardiovascular Science, University College London, UK

Background. As the burden of cardiovascular disease increases due to aging and lifestyle, novel early risk stratification methods are needed. The photoplethysmogram (PPG) is a non-invasive, low-cost signal rich in cardiovascular information that is embedded in mobile phones and smartwatches. Hypertension and diabetes are global leading causes of death and are often undiagnosed despite being on the rise. Previous PPG studies have suffered from relatively small sample sizes.

	Feature Set	AUC (95% CI)
HT	M0	0.70 (0.70-0.71)
	M1	0.74 (0.74-0.75) †
	M2	0.79 (0.79-0.80) †
T2D	M0	0.69 (0.67-0.70)
	M1	0.73 (0.72-0.74) †
	M2	0.77 (0.76-0.78) †
MACE	M0	0.62 (0.60-0.64)
	M1	0.69 (0.68-0.70) †
	M2	0.73 (0.71-0.74) †

Table 1. AUC and 95% confidence intervals. † for M1 indicates an AUC significantly higher than M0, and † for M2 indicates a result that is significantly higher than M1.

Aim. To develop and test a machine learning approach to detect hypertension (HT), type 2 diabetes (T2D), and past major adverse cardiovascular events (MACE) from PPG.

Methods. Forty morphological PPG features were derived from a signal-averaged PPG waveform in 165,340 UK Biobank study participants (age 60 (52-65), sex 53% female). A machine learning model (XGBoost) was trained in 80% of the dataset and tested in the remaining 20%. Three models were developed, which included the following predictors: PPG features (M0); age, sex and body mass index (M1) and M0+M1 (M2). Discrimination was assessed using the area under the ROC curve (AUC).

Results. Prevalence of hypertension, T2D and MACE was 54.7%, 6.0% and 5.5%, respectively. Models based on PPG features (M0) discriminated clinical outcomes with an AUC ranging between 0.62 and 0.70, while models based on demographics (M1) showed AUCs between 0.69 and 0.74 (Table 1). Combining PPG features with demographics data (M2) significantly improved discrimination, with AUC reaching 0.79, 0.77 and 0.73 for hypertension, T2D and MACE, respectively, with narrow confidence intervals (Table 1). In the case of HT and T2D, PPG features were also found to be more important than age, sex, or BMI in discrimination.

Conclusions. In this large study, a machine learning approach showed that features extracted from the signal-averaged PPG waveforms can improve discrimination of primary cardiovascular risk factors and events.