

Head-Ballistocardiography Morphology From Smart Eyewear for Cardiovascular Fitness and Recovery

Sarah Solbiati¹, Federica Mozzini¹, Cornelia Dancs¹, Enrico Gianluca Caiani^{1,2}

¹Politecnico di Milano, Electronics, Information and Bioengineering Dpt., Milan, Italy

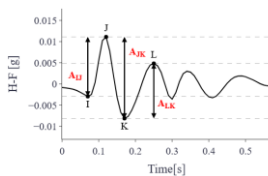
²IRCCS Istituto Auxologico Italiano, Milan, Italy

Cardiorespiratory fitness is a key marker of cardiovascular health, yet its reference standard assessment remains confined to resource-intensive laboratory testing, motivating the search for wearable solutions for real-world monitoring. Ballistocardiography (BCG) can provide physiological information beyond heart rate (HR), including markers related to cardiac output and contractility. In this study, we investigate whether novel morphological indices extracted from smart eyewear head-BCG (H-BCG) could capture changes across rest, breathing manoeuvres, and post-exercise recovery.

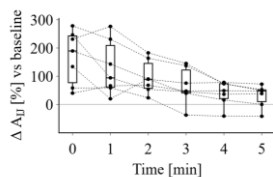
Data were collected during a Static protocol in 30 healthy volunteers, including breathing and apnoea manoeuvres, and a Dynamic protocol in 10 individuals during submaximal exercise followed by seated recovery. Simultaneous reference ECG and smart eyewear H-BCG signals were recorded. R peaks were identified on the ECG, while a ECG-free template-matching-based method was used for J-peak detection on the H-BCG. Characteristic fiducial points were identified on the H-BCG beats (I, J, K, L), from which amplitude and slope descriptors were derived.

Morphological descriptors varied with physiological condition. The head-foot acceleration and Roll angular velocity H-BCG axes emerged as the most informative, with excellent J-peak detection feasibility and good agreement between H-BCG- and ECG-derived HR. The head-foot axis showed stronger modulation across breathing conditions, with greater amplitudes and slopes during full-lung apnoea, which also increased after exercise and progressively declined during recovery mirroring HR and being generally more pronounced after treadmill exercise than after cycling.

These findings show that smart eyewear H-BCG morphology may provide unobtrusive digital biomarkers of cardiovascular fitness and recovery beyond HR.



H-BCG fiducial points.



Recovery trend after submaximal treadmill exercise.