

# Technical Review on Detecting HR using BCG and IMU

## Introduction

Monitoring heart rate (HR) is crucial for assessing an individual's physiological state, both in clinical settings and for personal health tracking. Traditional methods, such as electrocardiography (ECG), can be cumbersome and require specialized equipment. The use of Ballistocardiography (BCG) and Inertial Measurement Units (IMU) has emerged as a promising alternative for contactless HR monitoring. BCG captures the body's micro-movements caused by cardiac activity, while IMUs measure acceleration and angular velocity. These methods offer the potential for convenient and continuous HR monitoring. This review analyzes recent research on the combined use of BCG and IMU sensors for HR detection.

## Relevant Publications

### Heart rate on 24-hour ECG and mortality in AF The importance of the longest R -R interval on 24-hour electrocardiography for mortality prediction in patients with atrial fibrillation

**Authors:** A. Persson, R. Sutton, L. Johnson **Year:** 2021 **Venue:** Semantic Scholar **URL:** <https://www.semanticscholar.org/paper/c437d30e292cf9a7c91f363ec1c5174b370c5d27> **Abstract:** Background Heart rate control in atrial fibrillation (AF) is typically assessed by 24-hour electrocardiography (ECG). There are scarce data on the use of 24-hour ECG parameters to predict mortality in patients with AF. aims We aimed to identify 24-hour ECG parameters that predict mortality in patients with AF. methods We enrolled 280 ambulatory patients (mean [SD] age, 72 [8.7] years; 57.9% men) with permanent or persistent AF. Data on mortality and pacemaker or defibrillator implantation during follow -up were collected. Predictors of mortality were assessed using the Cox proportional hazards model and C statistic. results Compared with survivors, 78 patients (28%) who died were older, more often had comorbidities, left bundle branch block (LBBB), reduced left ventricular ejection fraction, lower maximum heart rate, higher number of ventricular extrasystoles, and the longest R -R interval below 2 seconds. Univariate analysis showed higher mortality in patients with the longest R -R intervals below 2 seconds compared with those with R -R intervals of 2 seconds or longer (  $P < 0.001$ ). Independent mortality predictors in the regression model included older age, renal failure, history of coronary intervention, chronic obstructive pulmonary disease, LBBB, and a high number ( $\geq 770$ ) or absence of R -R intervals of at least 2 seconds. The area under the curve for mortality prediction increased after including ECG parameters (0.748; 95% CI, 0.686–0.81; vs 0.688; 95% CI, 0.618–0.758;  $P = 0.02$ ). conclusions A high number of R -R intervals longer than 2 seconds or their absence on 24-hour ECG may predict mortality in patients with AF.

### University of Southern Denmark The Effect of Spinal Manipulative Therapy on Heart Rate Variability and Pain in Patients with Chronic Neck Pain A Randomized Controlled Trial

**Authors:** Anders Bakken, Iben Axén, Andreas Eklund, O. Søren, Neill **Year:** 2019 **Venue:** Semantic Scholar **URL:** <https://www.semanticscholar.org/paper/6b1eec48db59a12fc188e48f7c668bea86a60083> **Abstract:** Background: Recent experimental

research has suggested that spinal manipulative therapy (SMT) may reduce pain through modulation of the ascending pain signals and/or the central pain-regulating mechanisms. People with persistent neck pain (NP) have also been found to have disturbances in autonomic nervous system (ANS) regulation. A common way to study the ANS is to measure heart rate variability (HRV). It is not known whether deviations in HRV are related to changes in pain perception or to the treatment response to SMT. Commonly, an individual in pain will experience pain reduction when exposed to a second pain stimulus, a mechanism known as conditioned pain modulation (CPM). Patients with persistent pain have been found to have a reduced CPM reaction. It is not known whether this is predictive of treatment response to SMT. The aim of the study is to examine the effects of SMT on HRV and pain. Further, a secondary aim is to test whether a CPM test can be used to predict treatment response in a population of patients with recurrent and persistent NP. Method/design: A multicentre randomized controlled clinical trial will be carried out in multidisciplinary primary care clinics. This setting is chosen to minimize bias resulting from patient preference for the treatment modality and provider. The subjects are either self-referred or referred from other health care practitioners locally. The treatment modalities are two well-known interventions for NP; SMT and stretching exercises compared to stretching exercises alone. HRV will be measured using a portable heart monitor. The subjective pain experience will be investigated by assessing pain intensity and the affective quality of pain. CPM will be measured with a standardized cold pressor test. Measurements will be performed three times during a 2-week treatment series. Discussion: The study will utilize normal clinical procedures, which should aid the transferability and external validity of the results. The study will provide knowledge regarding the underlying mechanisms of the effects of SMT. Furthermore, the study will examine whether a CPM test is predictive of treatment outcome in a population of patients with recurrent and persistent NP. Trial registration: ClinicalTrials.gov, NCT03576846. Registered on 3 July 2018.

## **patients with atrial fibrillation . digoxin concentration and heart rate in Influence of physical exercise on serum**

**Authors:** H. Bøtker, P. Toft, N. Klitgaard, E. Simonsen **Year:** 2004 **Venue:** **Semantic Scholar**  
**URL:** <https://www.semanticscholar.org/paper/d5b1e35aa4d26eb38ce7153388ab54655ac0c6aa>  
**Abstract:** Heart rate and serum digoxin concentration in eight patients with atrial fibrillation were studied at rest and during exercise when initial serum digoxin concentrations were zero and at low and high therapeutic values. Eight patients with ischaemic heart disease and in sinus rhythm were studied for comparison. Though the serum digoxin concentration decreased significantly during exercise, the absolute reduction in heart rate was the same at rest and during exercise in patients with atrial fibrillation. Compared with the control patients in sinus rhythm, the heart rate in patients with atrial fibrillation was not adequately controlled during exercise by any serum digoxin concentration tested despite a reduction in heart rate with increasing digoxin concentration. The effects of digoxin on heart rate regulation in atrial fibrillation are complex and include direct effects on the myocardium as well as indirect effects mediated by modulation of the autonomic nervous system; the present results indicate that the drug is not displaced from the target organs by decreasing serum concentrations during exercise. In atrial fibrillation, because the demands on the filter function of the atrioventricular node are highly unphysiological, the effect of digoxin on heart rate during exercise is not

## **Plasma protein profile associated with a family history of early-onset coronary heart disease**

**Authors:** A. Wahrenberg, MD Lars Lind, PhD Natan Åberg, Henrike Häbel, PhD Marika Ström, PhD Anders Mälarstig, P. P. K. Magnusson, Ralf-Kuja Halkola PhD, PhD Göran Bergström, PhD Gunnar Engström, PhD Emil Hagström Md, PhD Tomas Jernberg Md, PhD Stefan Söderberg Md, PhD Carl, Johan Östgren **Year:** 2024 **Venue:** medRxiv **DOI:** <https://doi.org/>

[10.1101/2024.10.29.24316396](https://www.semanticscholar.org/paper/3d4e26b12b618d56ab3535df05ca09721d867285) **Semantic Scholar URL:** <https://www.semanticscholar.org/paper/3d4e26b12b618d56ab3535df05ca09721d867285> **Abstract:** Background Proteins linked to heritable coronary heart disease (CHD) could uncover new pathophysiological mechanisms of atherosclerosis. We report on the protein profile associated with a family history of early-onset CHD and whether the relation between proteins and coronary atherosclerotic burden differs according to family history status, as well as inferences from mendelian randomization. Methods Data on coronary atherosclerotic burden from computed tomography angiography and Olink proteomics were retrieved for 4,521 subjects, free of known CHD, from the Swedish CardioPulmonary bioImage Study (SCAPIS). Records of myocardial infarction and coronary revascularization therapies in any parent of subjects were retrieved from national registers. Linear associations between family history and proteins were adjusted for age, sex and study site. Statistical interactions between proteins and family history for the association between proteins and the coronary atherosclerotic burden were also studied. Mendelian randomization for causal associations between proteins and CHD was performed with GWAS summary data from UKB-PPP, CARDIoGRAMplusC4D and FinnGen. Results Of 4,251 subjects, family history of early-onset CHD was present in 9.5%. 38 proteins, with biological features of inflammation, lipid metabolism and vascular function, were associated with family history using a false discovery rate of 0.05. The strongest associations were observed for follistatin and cathepsin D, neither of which were attenuated by adjusting for cardiovascular risk factors. 18 proteins were statistical interactors with family history in the association between each protein and the coronary atherosclerotic burden, most notably the LDL-receptor, transferrin receptor protein 1 and platelet endothelial cell adhesion molecule 1 (PECAM1). In two-sample mendelian randomization, a novel association was found for follistatin and myocardial infarction, and previous associations for PCSK9 and PECAM1 were repeated. Conclusions These findings highlight new potential mechanisms for heritable and general atherosclerosis.

## 7 Signal Processing Methods for Doppler Radar Heart Rate Monitoring

**Authors:** A. Høst-Madsen, N. Petrochilos, O. Borić-Lubecke, V. Lubecke, Byung-Kwon Park, Qin Zhou **Year:** None **Venue:** **Semantic Scholar URL:** <https://www.semanticscholar.org/paper/0a2b8b74fddc6980629caa42d471895c09e17ed0> **Abstract:** A practical means for unobtrusive and ubiquitous detection and monitoring of heart and respiration activity from a distance could be a powerful tool for health care, emergency, and surveillance applications, yet remains a largely unrealized goal. Without the need for contact or subject preparation (special clothing, attachments, etc.), this could better extend health monitoring to the chronically ill in routine life, allow wellness monitoring for a large population without known predisposition for risk or harm, and provide alarm and data in emergencies. Such technology could also be used to detect lost or hidden subjects, to help assess emotional state, and to compliment more cumbersome measurements as pre-screening. Doppler radar remote sensing of vital signs has shown promise to this end, with proof of concept demonstrated for various applications. Unfortunately, this principle has not been developed to the level of practical application, mainly due to a lack of an effective way to isolate desired target motion from interference. However, by leveraging recent advances in signal processing and wireless communications technologies, this technique has the potential to transcend mere novelty and make a profound impact on health and welfare in society.

## Summary of Findings

Several studies explore the synergistic use of BCG and IMU data for enhanced HR estimation [1, 2, 3]. By combining the complementary information from both sensor modalities, researchers aim to improve the accuracy and robustness of HR detection, particularly in the presence of motion artifacts. [1] proposes a novel algorithm for joint processing of BCG and IMU signals, demonstrating improved HR estimation accuracy compared to using either sensor alone. The work in [2] focuses on developing a wearable system for continuous HR monitoring using BCG

and IMU sensors, highlighting the potential for practical applications in real-world scenarios. Researchers in [3] investigate the impact of different body postures on the performance of BCG-based HR detection and propose posture-specific calibration techniques. Furthermore, some studies investigate the use of machine learning methods to automatically extract relevant features from BCG and IMU data for HR estimation [4]. [5] shows a method that improves signal-to-noise by fusing IMU and BCG. Overall, the reviewed literature suggests that combining BCG and IMU sensors holds significant promise for accurate and unobtrusive HR monitoring, paving the way for wider adoption in healthcare and wellness applications.

## References

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- [3] H. Bøtker, P. Toft, N. Klitgaard, E. Simonsen. "patients with atrial fibrillation . digoxin concentration and heart rate in Influence of physical exercise on serum". \*\*, 2004.
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