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# Photoplethysmography signal analysis to assess sauna exposure, arterial elasticity, and recovery

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## 1 Introduction

The basic biomedical information on illnesses is increasing, however, diseases like arteriosclerosis (AS) is becoming a common cardiovascular disorder among elderly people, especially in females. It is predicted that the negative impacts of AS on young people can be greater than on the elderly people in the long run. Degenerative changes in the vascular tree have many causes in addition to the life style. Arterial elasticity (AE) would provide a direct indicator for cardiovascular healthiness and predict AS. Photoplethysmography (PPG), and especially its response pulse wave decomposition, envelope analysis, and its second order derivative (SDPPG) opens us to determine the instantaneous heart rate (IHR) which is used to seeing on fitness equipment, sports watches, and consumer heart rate devices.

The hemodynamic responses to the sauna exposure have specific effects which are not caused by one single stimulus. The responses, which are caused by the sauna exposure, can depend on thermoregulatory responses, age, gender, the circulatory and respiratory system, as well as traditions related with the exposure time and temperature of the Finnish sauna [1, 2].

PPG measurement receives interest because of the simplicity, but the difficulty of adjusting parameters restrict applications. However, its second order derivative (SDPPG) opens us to determine the instantaneous heart rate (IHR) which is  $60/(t_{An-1}-t_{An})$  where  $t_{An}$  is the  $n^{th}$  A peak of SDPPG. The sauna exposure can be recommended mainly in order to easier recover after physical exercise, and the various

pain problems. The sauna exposures in long term effect on the motion system increases arterial elasticity. It reduces the viscosity of the blood so that blood flow easier and increases diameters of blood vessels and the joints' mobility. The IHR and variation of arterial elasticity with blood pressure are caused by the sauna exposures on healthy subjects. Regular sauna bathing is shown to be protective from cardiovascular disease [2, 3]. Our vascular system responds to interval training, especially by the sauna exposures the body to heat alternating between sauna heat and normal temperatures, the arteries are stimulated to expand and contract.

## 2 Method and Subjects

Accurate determination of start and peak of a PPG signal plays a central role in arterial stiffness, instantaneous heart rate, and its variability. For analysis of four PPG signals correspond to each other perfectly at a given frequency, as in the case of finger IR (infra red) and red LED. In PPG technology, the main difficulty is its quantitative analysis. PPG based on phase sensitivity technic has proved very good. In our measurements the light intensities and wavelengths (red 640 nm & infrared 920 nm) are fixed. The studies were approved by the ethical review boards of the Oulu University, University Hospital, and the Finnish National Supervisory Authority of Health and Welfare (VALVIRA). Our needs to analyze the signal on a case by case basis we don't have the proper automatic measurement and analysis system. For automated clinical diagnosis based on PPG would be also important in the future healthcare.

## 3. Results and discussion

The heart rate increased almost linearly in many cases during the sauna exposures. In each case, it is important to have the same resting period. It would be difficult that all the subjects arrive at 8 in the morning to the sauna, and we have no parallel measurement system.

## References

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