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*Abstract*

# A Cervical Plethysmography System to Monitor Blood Vessel Pulses on the Neck †

**Antonino Proto [1,*], Anselmo Pagani [2], Paolo Zamboni [2] and Angelo Taibi [3]**

1 Department of Neuroscience and Rehabilitation, University of Ferrara, 44123 Ferrara, Italy
2 Department of Translational Medicine and for Romagna, University of Ferrara, 44121 Ferrara, Italy
3 Department of Physics and Earth Sciences, University of Ferrara, 44122 Ferrara, Italy
* Correspondence: antonino.proto@unife.it; Tel.: +39-0532-974375
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**Abstract:** A cervical plethysmography system has been developed to monitor blood vessel pulses on the neck area and at the same time to record the electrocardiogram signal. The system was tested on subjects in upright (90°) and supine (0°) position. The proposed cervical plethysmography system can be used as a biomedical tool for cardiovascular screening in the general population.

**Keywords:** jugular venous pulse; carotid arterial pulse; plethysmography; electrocardiogram

## 1. Introduction

Monitoring of blood flow on the heart–brain axis is very important for early diagnosis of cardiovascular diseases [1]. Internal jugular veins and common carotid arteries are the main vessels in the neck. The waveforms generated by the pulsation of these vessels are called jugular venous pulse (JVP) and carotid arterial pulse (CAP), and both are related to the electrocardiogram phases (ECG) [2].

The internal jugular vein connects to the right atrium, thus acting as a column for the blood in the right atrium. The arterial pulse is a measurement of the heart's contraction rate since a pulse wave is created when the left ventricle contracts [1]. To monitor these pulse signals in the neck area, plethysmography (PG) is a novel noninvasive and non operator dependent technique [3,4].

In this work, we propose a cervical PG system to monitor blood vessel pulses on the neck, along an individual normalized time consisting in a synchronized ECG trace. Particularly, we found that the subject's posture affects the measurement, since when the subject is supine the recorded pulse refers to the JVP, while when the subject is upright the recorded pulse refers to the CAP.

## 2. Materials and Methods

The cervical PG system includes a wearable capacitive stretch sensor to measure blood vessel pulses, i.e., JVP and CAP, and a three-lead electrode to carry out ECG measurements. The system also includes a portable electronic unit (PEU) to acquire these signals and send them to a PC through a Bluetooth connection to display data in real-time and save information in .txt files [4,5].

To carry out experimental tests, male subjects were subjected cervical PG by tipping them from the upright (90°) to supine (0°) position using a motorized chair. Obtained data were post-processed on MATLAB.

## 3. Discussion

Figure 1 shows all data acquired in the test (Figure 1A) where the raw signals are displayed in grey. Figure 1B shows an interval of 4.5 s in the filtered signal when the subject was in the upright position, while Figure 1C shows an interval of 4.5 s in the filtered



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signal when the subject was in the supine position. The enlarged PG signals, shown in Figure 1B,C, were filtered with appropriate band-pass filters [6].

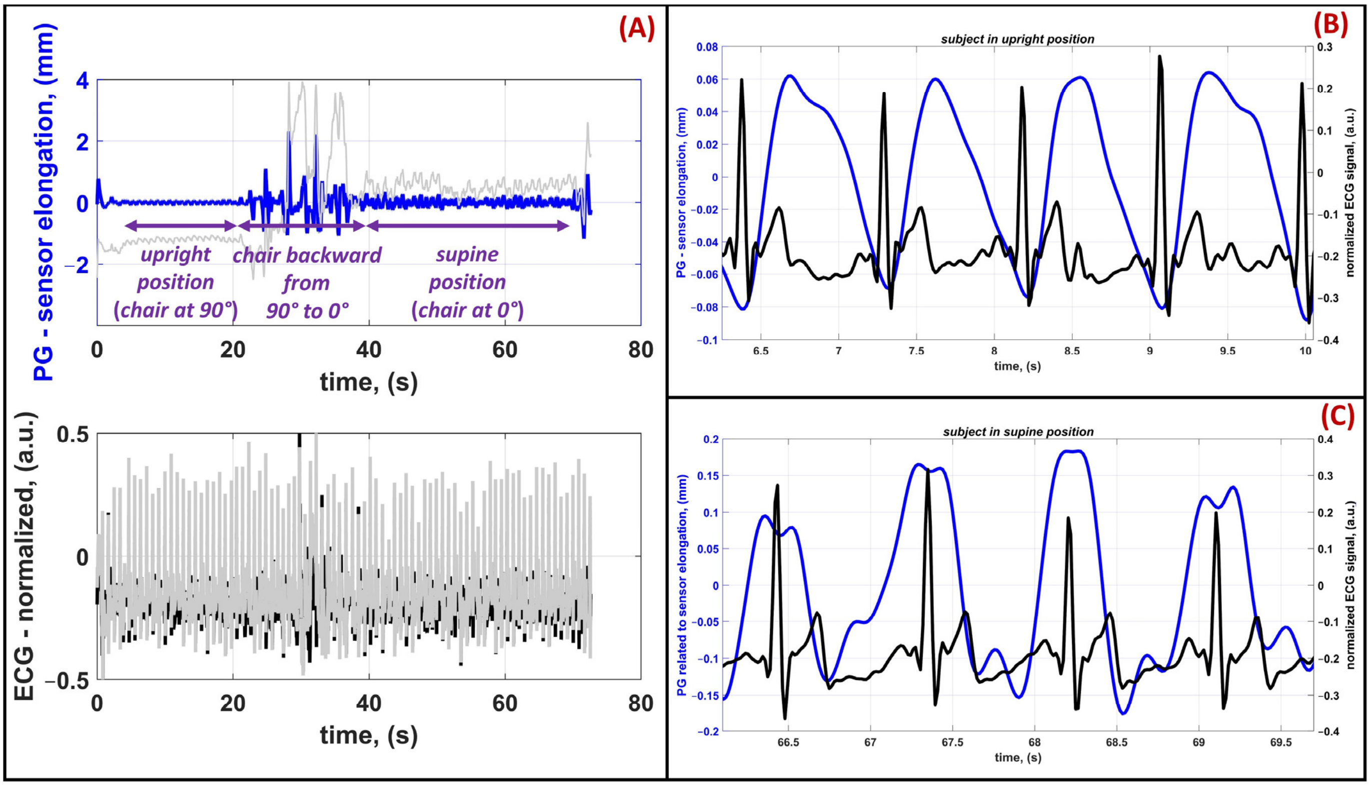


**Figure 1.** Entire data acquisition: grey color for raw signals (**A**); filtered signals (4.5 s) for subject in upright position (**B**); filtered signals (4.5 s) for subject in supine position (**C**).

When looking at Figure 1B,C, the former relates to the subject in the upright position and it is clearly visible that the monitored blood vessel pulse is like the CAP. Conversely, the latter refers to the subject in the supine position and in this case the monitored pulse is like the JVP. The ECG signal served as a reference for the measurements [7]. Moreover, with the proposed system it is possible to differentiate dissimilar activities. Indeed, when the chair was tilted backward from 90° to 0°, the acquired signals had large peaks (Figure 1A), which can be analyzed with machine learning techniques for activity recognition purposes [8].

The proposed system can be used as a screening tool for monitoring the health and wellness of people [9]. It can monitor blood vessel pulses on the neck with the synchronization of the ECG signal.

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**Informed Consent Statement:** Informed consent was obtained from all subjects involved in the study.

**Data Availability Statement:** The data that support the findings of this study are available from the corresponding author, [A.P. (Antonino Proto)], upon reasonable request.

**Conflicts of Interest:** The authors declare no conflict of interest.

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