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Abstract

Experimental Development and Validation of an E-Textile Sleeve for Surface Electromyography †

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Abstract: This work describes the development of a leg sleeve with embedded e-textile electrodes for surface electromyography (sEMG). The novel device is a textile substrate with embedded circular electrodes made of conductive fabric, which can be connected to EMG acquisition systems. The performances of the novel prototypical device were validated in comparison with standard sEMG electrodes. The experimental study involved 11 healthy volunteers, and general features extracted from the signals were compared using statistical methods. The results underline the absence of significant differences between the two systems, suggesting that the e-textile novel device is a viable alternative to conventional electrodes for collecting sEMG data.

Keywords: e-textile; surface electromyography; tibialis anterior muscle; wearable sensors

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1. Introduction

The concept of a wearable device corresponds to a technology that can be comfortably attached to a person for long time, that is easy to hold and use, and that is 'as unobtrusive as a piece of clothing' [1]. The current challenge is to further improve these technologies by embedding electronics directly into garments, resulting in so-called E-textiles. This technology offers several advantages over traditional electronic devices, and can be widely exploited in the medical field [2]. Fabrics are comfortable and flexible, making them ideal for creating sensors in direct contact with the skin. Considering these advantages, several solutions have been proposed for applications in the medical field [3–5]. The aim of this research is to introduce and validate the performance of a novel device with embedded e-textile electrodes to detect surface electromyography (sEMG) from leg muscles.

2. Materials and Methods

The wearable device consists of an elastic fabric in which e-textile electrodes are embedded. The electrodes are made with conductive knitted fabric (Adafruit Inc., New York, NY, USA), and are fixed in the internal side of a textile elastic sleeve, in appropriate positions for recording the electrical activity of the anterior tibialis muscle, in accordance with the placement suggested by SENIAM (Figure 1a). Other conductive buttons on the outside of the sleeve represent the interface with the acquisition system (Figure 1b).

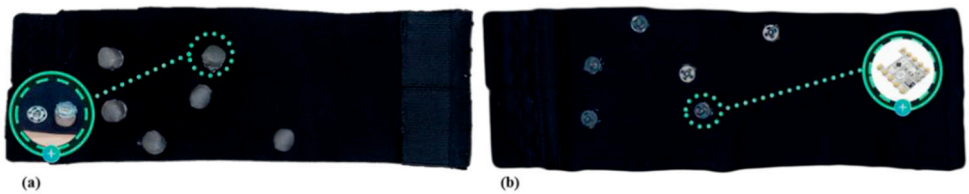

Figure 1. Smart textile sleeve: (**a**) internal view of textile electrodes; (**b**) external view of it connected to the acquisition system.

The study involved 11 healthy volunteers (8 women, aged 25.7 ± 1.7, with a height of 168.3 ± 5.9 cm, and a weight of 62.2 ± 5.9 kg), and evaluated the performance of the e-textile sleeve for sEMG in comparison with Ag/AgCl electrodes. The BITalino (r)evolution system (Plux wireless biosignals Inc., Lisboa, Portugal) was used as an acquisition board. The evaluation was performed by comparing the performance of the two systems in detecting sEMG signal characteristics during a maximal voluntary isometric contraction (MVIC) of the tibialis anterior muscle. Each volunteer performed two trials (with the textile sleeve and with standard electrodes), each consisting of five MVICs, lasting five seconds, separated by rest periods of 30 s. The area and root mean square (RMS) were extracted from the rectified signal in the 5 s contraction windows, and then averaged over a trial. Data processing was performed using MATLAB R2022a (MathWorks, Inc., Natick, MA, USA). The Wilcoxon–Mann–Whitney test was used to verify the statistical significance of differences, considering the non-normal distribution of data. Statistical analyses were performed using R version 4.0.3 (R Foundation, Vienna, Austria).

3. Results and Discussion

Table 1 shows the results of the statistical analysis. The paired t-test emphasizes the absence of statistical significance in the difference between the data samples. Based on this, it can be stated that the novel device produces measurements comparable with those taken using conventional electrodes. The wearable and comfortable nature of the device could facilitate its use in a wide range of applications, from rehabilitation to sports activity.

Table 1. Descriptive statistics and results of statistical analysis in terms of *p*-value. The statistical significance of the test is indicated by an asterisk, and the absence of significance is indicated by *ns*.

	AREA Tibialis (mV·s)		**RMS Tibialis (mV)**	
	Textile Sleeve	**Ag/AgCl Electrodes**	**Textile Sleeve**	**Ag/AgCl Electrodes**
Media ± StD	198.4 ± 90.2	195.2 ± 76.5	55.5 ± 25.3	54.8 ± 21.5
Normality-test	0.015 *		0.012 *	
Paired *t*-test	0.314 *ns*		0.334 *ns*	

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Data Availability Statement: The raw data supporting the conclusions of this article will be made available by the authors on request.

Conflicts of Interest: Author Giuseppe Tombolini was employed by the company Officine Ortopediche Tomboline. The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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