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Wireless evaluation of muscle abilities with Aging using CCA approach

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Abstract

The aging of the population is a major public health concern, according to World Health Organization (WHO, OMS), the proportion of people aged 60 and over will almost double between 2015 and 2025 [1], the effects of aging on the person are many; such as the loss of autonomy and increased risk of falling. This generates very important economic, social and psychological costs. Current clinical examinations are not accurate and robust enough to assess the motor status of older people. It is interesting to use new technologies to develop tools able to assess motor decline and to serve as an indicator in a prevention approach or in functional rehabilitation. The objective of our study is to exploit the technology of high-density surface electromyography (HD_sEMG), in order to evaluate the muscular activation in the population faced to aging by using wireless connected ambulatory equipment connected (TMSi) and Blind Source Separation (BSS) approach with Canonical Correlation Analysis (CCA). Obtained results are promising and indicated a clear difference between the young tested subjects and the older one. Furthermore, the estimated sources seems to be sensitive to the anatomical and functional modifications with aging.

Keywords: *gerontechnology, sarcopenia, HD_sEMG, connected device, musculoskeletal system, CCA algorithm.*

I. INTRODUCTION

The way of aging is different from one individual to another. It is a function of many factors such as the biological and physiological changes of the organs, the environmental conditions as well as the way of life of the person. The consequences of these factors can divide the older population into two categories; the first is a population with a healthy aging mode, and the second is a category that suffers from a pathological aging with a decrease in autonomy, caused by the loss of muscles capacity, which causes difficulties to perform simple physical tasks during his daily life.

Sarcopenia, a loss of muscle mass and functionality, is among the consequences of unhealthy aging, in this context, developing new non-invasive approaches and early evaluation of sarcopenia is a major challenge [2]. Our motivation is to develop a medical device based on high-definition surface electromyography (HD-sEMG) technology, a non-invasive and portable technology, for the diagnosis of sarcopenia. It will allow advances not only for clinical practice in terms of diagnosis to implement appropriate management, but also as a judgment criterion in the screening of therapeutic trials for anti-sarcopenic drugs, nutritional supplements or dietary supplements. Other interventions that slow down the effects of sarcopenia, with a view to prevention / functional rehabilitation. The scientific issues of this study are twofold: clinical by the evaluation of aging change and methodological issues through development of a diagnostic software, compatible with E-health platform, based on the analysis of HD-sEMG signals.

Preliminary study obtained in young and older patients [3] by using the HD-sEMG and accelerometer techniques separately have shown that HD-sEMG descriptors related to muscular activity and the trunk maximum acceleration are discriminant with the age. In this study, we will record the electrical activity during contraction of the Rectus Femoris muscle (RF) during Sit To Stand test (STS) by using a recent wireless connected and ambulatory portable device and apply a recent BSS formalism, the CCA approach to analyze the estimated sources for motor decline screening. The final goal is a remotely monitoring of elderly, as well as the simplicity of the noninvasive acquisition procedure that guaranties acceptability by maximum of patients.

II. METHODS & RESULTS

A. Experimental protocol

1) Participants

In this study, sixteen subjects participated in the recording of the experimental signals, divided into two categories (H1 & H2) with the following characteristics:

| Category | H1 | H2 |
|--------------------------|-------------|-------------|
| Sex | 4M/4F | 4M/4F |
| Range of age | 30.62 ±5.92 | 61.87 ±7.98 |
| BMI (Kg/m ²) | 23.95 ±3.08 | 23.46 ±3.38 |

Table 1: Cohort description

All participants provided their written consent according to Patient Protection Committee (PPC) coordinated by AP-HP Hospital. The subjects did not have any history of muscular or neurophysiological disorder at the lower limbs.

2) Experimental setup

The movement to be realized in this protocol is Sit to Stand (STS) movement with spontaneous pace. The studied muscle is the RF muscle. The choice of this muscle was motivated on the one hand by its position on the surface, moreover it is the most solitary muscle in the daily gesture of the lower limb. On the other hand, this muscle is mainly activated in the STS movement [4].

The positioning of grids HD-sEMG on the muscle is done according to very precise standards. Indeed, the positioning of the grid is an important source of error; this is why it is important to ensure some repeatability. To do this, it was necessary to follow the European recommendations concerning electrode placement procedures and signal processing methods for surface electromyograms, at the SENIAM project site (Surface ElectroMyoGraphy for the Non-Invasive Assessment of Muscles) [5].

3) HD-sEMG recording chain

Surface electromyography (EMG) consists of detecting the electrical activity generated by muscle fibers during a voluntary muscle contraction effort. Surface EMG technique has developed through various events until we arrive at innovative and precise acquisition techniques such as high-density electromyography (HD-sEMG). It is a non - invasive technique with high precision due to the large number of electrodes in each grid. This makes it possible to analyze the muscular contraction in a large area and in a non-invasive way; it is the main advantage of this technique.

The fundamental principle of electromyography is based on measuring the excitability of the muscle cell. Indeed, the signal EMGs corresponds to the sum of the action potentials (AP) produced by the active UMs and detected on the surface of the skin [6].

The acquisition of HD-sEMG signals is done thanks to the MOBITA device, it is a multi-channel amplifier designed by TMSi, through 32-electrodes square grids (4x8), which is characterized by 4 mm diameter electrodes and an inter-electrodes distance of 8.57 mm.

The contact surface from one gate to the other changes and therefore the impedance of the electrodes also changes. However, this difference in impedance can be neglected because of the large input impedance of the device (of the order of 100 MΩ). This contributes to obtaining a good signal-to-noise ratio. It is not necessary to perform impedance checking, which facilitates the clinical use of the device.

The system includes the TMSi Polybench® processing software for customizing the configuration of the measurement interface. The sampling frequency is 1000 Hz on a 24-bit resolution. After sampling, the data are transmitted to the laptop/smartphone by Wi-Fi protocol.

B. Classification of HD-sEMG signals using CCA Algorithm

The CCA method is a Blind Source Separation (BSS) method that measures the linear relationship between two multivariate random variables [7]. It has been successfully used for sEMG signal analysis [7], [8], [9].

It suggests the use of the source vector as the first multidimensional variable and its temporally delayed version as the second [7]. In addition, it proposes to solve the BSS problem by finding the bases vectors so that the projections of the variables onto these vectors are mutually maximized [7]. Thus, the CCA algorithm attempts to extract the original sources having maximum autocorrelation value (at a specific time delay) and minimum intercorrelation value with each other. For this purpose, we assume that a multidimensional random variable $\mathbf{X} = [x_1, x_2, \dots, x_n]$ (with n being the number of sensors) is the result of an unknown mixture of unknown source signals $\mathbf{S} = [s, s, \dots, s_n]$. The mixing is assumed to be linear, Therefore, reducing the mixing to a matrix multiplication allows to write [6]:

$$\mathbf{X} = \mathbf{A} \mathbf{S} \quad (1)$$

Where \mathbf{S} , \mathbf{X} are the source and the grid signals matrixes respectively of dimension ($\mathbf{n} \times \mathbf{m}$) with n being the number of sensors and m the number of samples, and \mathbf{A} is the mixing matrix of dimension ($\mathbf{n} \times \mathbf{n}$). The goal here is to retrieve the original source signals \mathbf{S} by estimating the mixing matrix \mathbf{A} . This can be achieved by introducing the demixing matrix \mathbf{W} such that:

$$\mathbf{Z} = \mathbf{W} \mathbf{X} \quad (2)$$

Where the matrix Z approximates the source matrix S by a scaling factor. Let Y be the delayed version of the source

matrix X such that $Y(k)=X(k-1)$ where k represents the sample number. The one sampling period delay was chosen after multiple denoising trials using different delays between X and Y . The CCA algorithm obtains two sets of basis vectors, one for X and the other for Y , such that the correlations between the projections of the variables onto these basis vectors are mutually maximized.

The algorithm therefore extracts the original sources of the signal having a maximum autocorrelation value and a minimum inter-correlation value between them. The advantage of this separation is that the sources are sorted according to their correlation coefficient value. Thus, the first source will have the highest autocorrelation approximately equal to 1 and the last source will have the lowest autocorrelation close to 0. We propose to evaluate the obtained correlation coefficient set according to two age categories (young versus old) to evaluate its discriminative power.

C. Results

the calculation of the correlation of CCA component in the two age groups showed a strong correlation in the elderly (H2); the average correlation is 0.90 ± 0.091 compared to the young (H1) is 0.86 ± 0.16 . Student test showed significant difference between H1 and H2 (table2). This higher correlation coefficients observed in the elderly group can be related to spectral contain of the muscle electrical activity that seems to be different than the young group one. This could be related to anatomical and functional modifications related to aging. Further studies are needed to better explain the complex underlying mechanisms of muscle aging.

| | H1 (young) | H2 (elderly) | t_Test (P value) |
|---------------------------------------|----------------------|-----------------------|-------------------------------------|
| SNR | 18.13 ± 4.59 | 18.12 ± 4.86 | |
| Mean Correlation coefficient | 0.86 ± 0.0775 | 0.90 ± 0.0785 | $1.7557e-04$ $P < 0.001^{***}$ |
| Std of correlation coefficient | 0.16 ± 0.0396 | 0.091 ± 0.0631 | $2.8115e-16$ $P < 0.0001^{****}$ |

Table 2 : t-test results for H1 and H2 groups

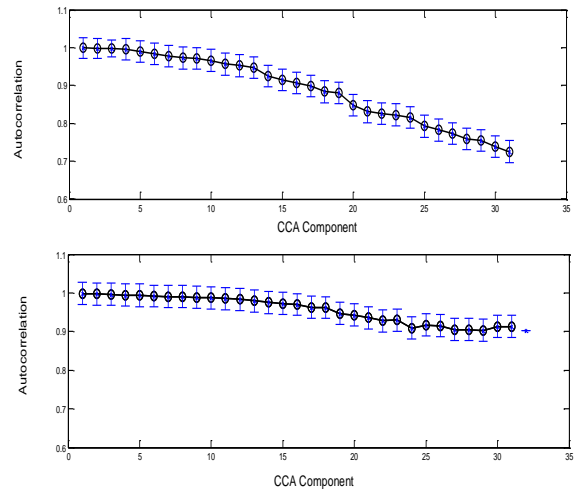


Figure 1: Obtained correlation coefficients for the 31 estimated sources for young (H1) “up” and elderly (H2) “down” groups.

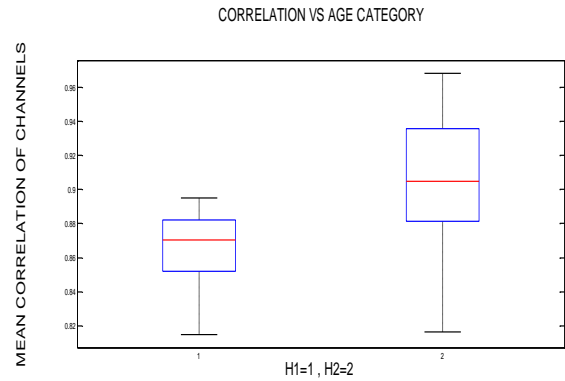


Figure 2: Boxplot of the mean correlation coefficient of the estimated sources for H1 (young) and H2 (elderly) groups.

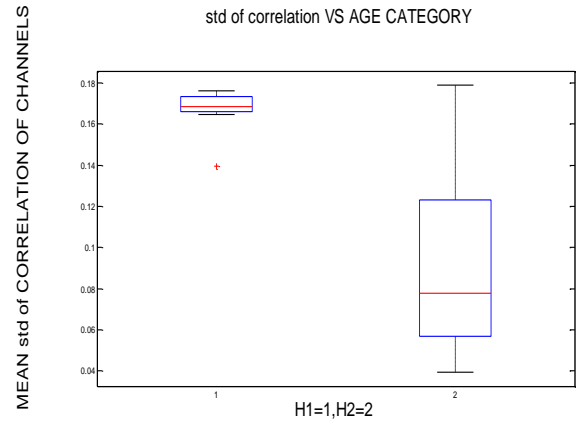


Figure 3: Boxplot of standard deviation of correlation coefficients for the estimated sources for H1 (young) and H2 (elderly) groups.

III. CONCLUSION AND PERSPECTIVE

This study allowed us to unveil the potential of CCA approach in a deeper screening of the change of muscular capacity with age, starting from the idea of helping therapeutic treatment to the prevention of risks in the elderly. Expected benefits is not only for the elderly, but also for the young, to alert their sedentary lives to avoid the future dangers that can be produced with age as sarcopenia.

Obtained results indicated clear modifications in the electrical activity related to muscle contraction during daily live gesture with aging. These modifications should be related to anatomical and/or functional changes and be better investigated in future works. Finally, through this study, the HD-sEMG ambulatory used device demonstrated its usefulness in rapid and wireless evaluation of muscle capacities, opening the door for clinical application related to E-Health and personalized medicine.

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