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APPLICATION OF PRINCIPAL COMPONENT ANALYSIS IN MYOELECTRIC SIGNAL DURING RUNNING IN PATIENTS WITH ANTERIOR KNEE PAIN

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SUMMARY

Principal component analysis (PCA) was applied to obtain a standard distance (SDT) as a score to discriminate electromyogram (EMG) analyzed in time and time-frequency domains from healthy and anterior knee pain (AKP) runners. Additionally, SDT was compared with root mean square (RMS) and instantaneous median frequency (IMF) results. Five runners reporting AKP (PG) and eight controls (CG) participated of this study. EMG of vastus medialis was assessed during treadmill running at 13 km/h. Isolated 160 ms segments from ten running strides were used for computing sequences of RMS and IMF values with 10 ms resolution and the average sequences were used for PCA. SDT showed higher values in PG compared to CG ($p = 0.0016$), while the RMS and IMF parametric analysis did not evidence difference between groups. Therefore, SDT was more accurate than traditional EMG analysis for classifying EMG pattern in runners with AKP.

INTRODUCTION

In clinical practice, muscle activity is conventionally assessed by extracting amplitude, timing and frequency [1]. Parametric techniques offer a limited description of the complexity of the electromyogram (EMG) pattern. Hence, continuous progress towards adequate methods for reliable extraction of information from EMG is required.

Principal component analysis (PCA) is a multivariate statistical technique that allows analyzing signals, taking into account the complete time series. This technique is widely used in gait analysis to classify normal and abnormal gait patterns [2,3], as well as to calculate normalcy indexes to quantify gait abnormalities [4]. However, few studies have applied PCA to analyze EMG signals [1] and none, of our knowledge, has evaluated normal and abnormal EMG pattern during running.

Therefore, this study aims at testing the application of PCA to obtain a standard distance as a score to discriminate time and time-frequency domains from vastus medialis (VM) EMG pattern between healthy and anterior knee pain (AKP) runners, as well as to compare the standard distance with traditional root mean square (RMS) and instantaneous median frequency (IMF) analysis.

METHODS

Thirteen male recreational runners were organized into two groups: Pain Group (PG), containing five individuals reporting running related AKP (averaged age 27.8 ± 4.9 years, body mass 74.9 ± 9.9 kg, height 1.8 ± 0.1 m); and Control Group (CG), with eight pain-free subjects (averaged age 27.9 ± 3.1 years, body mass 73.2 ± 10.1 kg, height 1.7 ± 0.1 m). All subjects signed a written informed consent approved by a local ethics committee.

The VM EMG was assessed according to SENIAM recommendations [5]. EMG was captured and amplified by an electromyograph EMG800 (EMGSystem, Brazil) at sampling rate of 2.1 kHz. The EMG data was collected in the most symptomatic lower limb for PG and in the right limb for CG. Subjects were assessed during treadmill running at 13 km/h for 2 min, after 10 min adaptation on barefoot condition. A high-speed camera (Casio Exilim FH-20, USA – 210 Hz sample rate) set 2 m behind the treadmill was employed to visually detect the heel strike events, using SkillSpector software version 1.2.4 (Video4coach, Denmark). Kinematic data was synchronized with EMG using a custom-made trigger system. Raw EMG signals were filtered by a 2nd order, bidirectional band-pass Butterworth filter (20 - 400 Hz). Ten successively running strides within a trial were used in the analysis (Figure 1a). During running, each VM activation was extracted into a 160 ms epoch of effective muscle activity (EMA), starting at 60 ms before the heel strike (Figure 1b).

Each EMA was analyzed in time and time-frequency domains. For the time domain analysis, a sequence of RMS values with 10 ms time windows was calculated (Figure 1c) and normalized by the maximum RMS value across the whole analyzed signal. The IMF of each EMA was obtained by means of the discrete Choi-Williams distribution. The mean IMF values were also calculated for each 10 ms interval of the EMA (Figure 1d). The average of the 16 sequential values of RMS and IMF over ten consecutive running cycles from each subject was analyzed.

Running EMG data were arranged in a matrix [13 x 32], where each row corresponded to one subject and columns contained standardized RMS and IMF data (zero mean and unit variance). PCA was applied to the respective correlation matrix [32 x 32] [6], and the scree criterion used to select the relevant principal components (PC) for the analysis. Afterwards, the PC scores were used as input data to calculate the standard distance [7]. This index represents the distance between each PC scores from AKP subjects to the center of the hyperelliptic boundary of PC scores from control subjects. For classifying the status of normality of EMG patterns, the cutoff point between indexes from the CG and PG was obtained by logistic regression [3]. The classifier performance was evaluated by computing overall accuracy, sensitivity and specificity by the leave-one-out cross-validation technique.

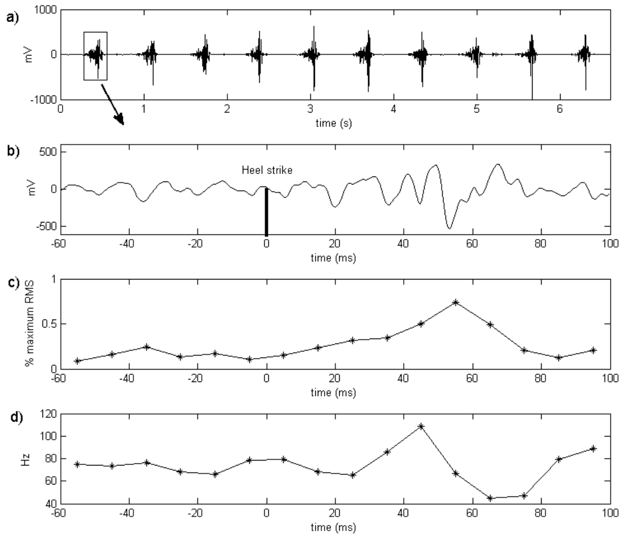

Figure 1: EMG signal from 10 strides (a), a zoom of an effective myoelectric activation (b), RMS (c) and IMF (d) from b with 10 ms window. Heel strike was identified by kinematic data and 60 ms before and 100 ms after was analyzed in each contraction.

The original RMS and IMF parameters of each 10 ms EMG interval, as well as the standard distance values were compared between CG and PG using non-parametric Mann-Whitney test. The significance level was set at $\alpha = 0.05$. All signal processing procedures and statistical tests were implemented in Matlab 6.5 (The Mathworks, USA).

RESULTS AND DISCUSSION

The scree test indicated that five PCs should be retained in the analysis, explaining 81% of the total data variance. CG subjects presented average lower standard distance compared to PG ($p = 0.0062$) with cutoff point of 2.5. All PG subjects presented indexes above this value (Figure 2), suggesting abnormal VM myoelectric activation. This index represents a geometric interpretation of PCA [7], finding a single measure that reflects how close a given EMG pattern approaches to CG. The standard distance allowed the classification with 92% accuracy, 80% sensitivity and 100% specificity, being similar to previous normalcy indexes applied in gait studies [3]. Additionally, the highest values, 10.82 and 8.35, were found on the PG subjects who presented clinical diagnostic of patellar tendinopathy and chondromalacia patellae, respectively. Therefore, these results suggested a quantitative assessment of the level of EMG pattern modification in AKP subjects by the standard distance.

The comparison of RMS and IMF in each 10 ms interval did not present statistical difference between CG and PG for all comparisons. Therefore, the standard distance was more accurate than traditional parametric analysis for classifying EMG pattern from subjects with AKP. Although widely employed, the traditional RMS and IMF comparisons do not consider the high degree of correlation among successive samples [1]. Moreover, the reduced number of PCs produced clear distinction between normal and abnormal EMG data, since multivariate methods can uncover more complex relationships between the dependent variables [2].

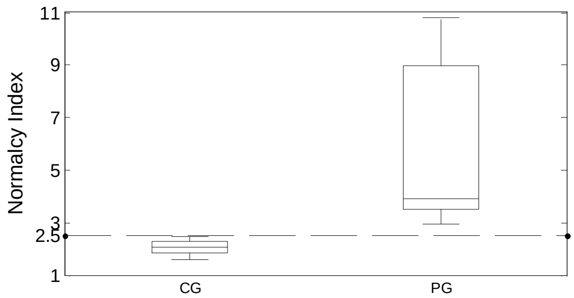

Figure 2: Box-and-whisker diagram containing standard distance values from CG and PG. The horizontal line represents the cutoff point (2.5) giving by logistic regression.

Although this is a preliminary study with small sample size, the standard distance results pointed to a potential power for classifying abnormal EMG patterns. Quantitative studies with larger data samples would permit generalization, as well as conclusions about mechanisms related to EMG changes in subjects with AKP during running.

CONCLUSIONS

The standard distance based on PCA was more accurate than traditional EMG approach for classifying EMG activity in subjects with AKP during running. This index separated vastus medialis EMG from CG and PG, being significantly higher in the PG, evidencing a modified EMG pattern in those subjects.

ACKNOWLEDGEMENTS

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