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A COMPARATIVE STUDY OF THE MUSCLE SYNERGY PATTERNS IN HEALTHY AND ACL-DEFICIENT SUBJECTS

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Introduction and Objectives: It is believed that human gait is controlled by a muscle synergistic pattern [1]. This can be represented by signal factorization of muscle activations or electromyography (EMG) in Neural Commands (NCs) and Synergy Vectors (SVs). NCs are time dependent signals, and SVs represent the weight factors of each muscle to the NCs. As far as the authors know, no muscle synergy analysis has been applied for the study of ACL-deficient subjects. The goal of this study is to investigate whether there are observable differences in NCs and SVs between healthy and ACL-deficient subjects.

Methods: Ten healthy subjects, five men and five women (age 31.5 ± 12.9 years), and eighteen ACL-deficient subjects, twelve men and six women (age 32.3 ± 10.99 years), volunteered as participants in this study. All injured subjects were classified as adapters [2]. They were asked to walk some gait trials over ground. EMG signals of 16 muscles (8 from each leg) were measured (Biometrics, Newport, United Kingdom). The 8 muscles are the main contributors to the human gait (Extensor Digitorus Longus, Tibialis Anterior, Soleus, Gastrocnemius Lateralis, Vastus Lateralis, Rectus Femoris, Semitendinosus and Gluteus Maximus). Ground Reaction Forces (AMTI, Watertown, MA) and trajectories of 2 foot markers (NaturalPoint, Corvallis, OR) were also measured to identify the gait cycle.
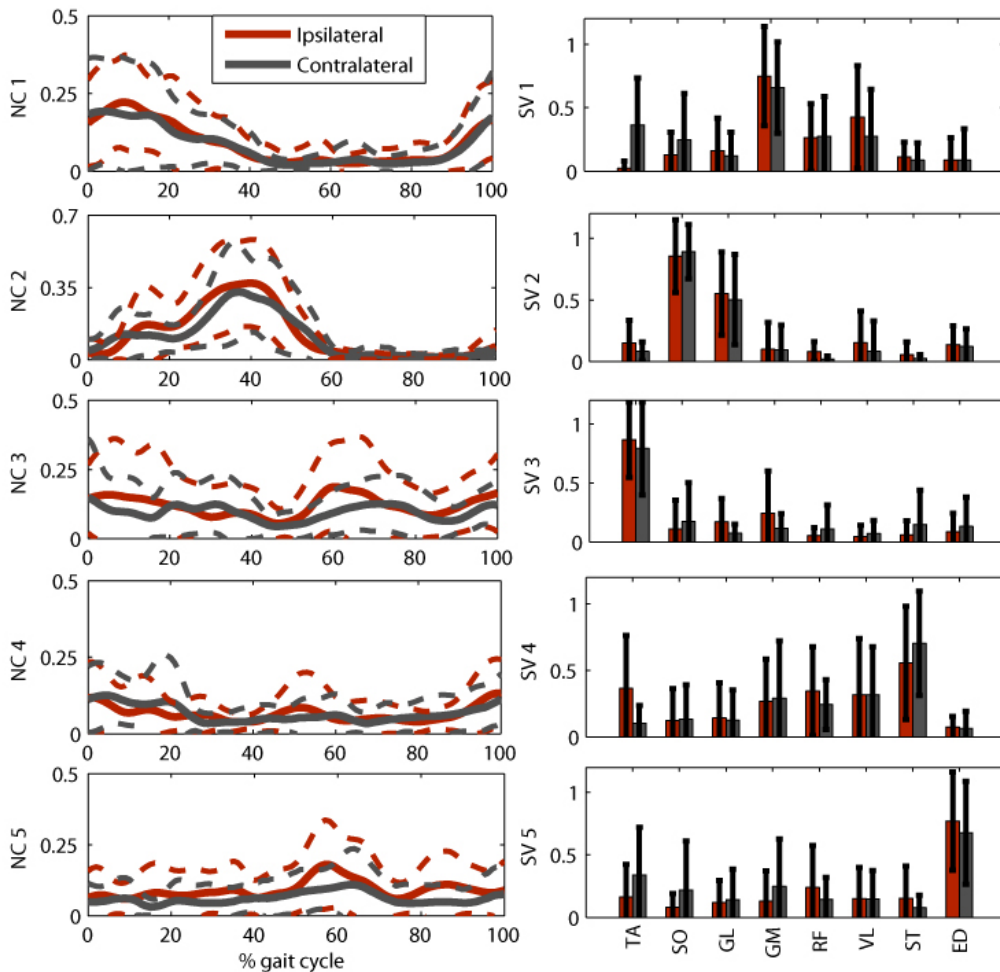
EMG data were filtered and normalized to maximum values obtained after doing certain MVC exercises. The processed EMG signals were factorized by means of a Non-Negative Matrix Factorization (NNMF) algorithm based on a non-linear least squares algorithm that minimizes the error between the reconstructed and the experimental EMG signals [3]. NCs and SVs were calculated when factorizing data with 1 to 6 modules. For each set of data, VAF (variance accounted for) was calculated for each muscle to evaluate the dimensionality.

The subjects were divided in three groups: Control (healthy subjects), Ipsilateral (injured subjects' injured legs) and Contralateral (injured subjects' non-injured legs). SVs and NCs were compared between groups.

Results: The analysis of dimensionality showed that 5 modules can account for ≥ 90% of the variability for each individual EMG signal. There were no significant differences regarding the dimensionality among groups, therefore, muscle synergy components of all three groups were compared using 5 modules.

The correlations among NCs and SVs from two modules of different groups were calculated (Table 1). The obtained patterns showed similar tendencies (Figure 1), but some differences were observed. The most representative ones are that the Ipsilateral NC of module 2 has two peaks, whereas the same NC of the Control group shows only one peak; and that modules 3 and 4 have higher Ipsilateral's NC values compared with the ones obtained for the Control group.

Figure:

Caption: Figure 1. NCs (left) and SVs (right) of Control and Ipsilateral groups. Both cases show the mean value (solid line and bar) and the standard deviations (dashed line and error bar).

Conclusion:

NCs and SVs were in general comparable with other published studies [4-5]. The fact that there were no significant differences in the dimensionality of the signal factorization means that the pattern of all groups has the same complexity.

The observed differences in NCs and SVs among groups can be associated with the changes in the strategy that the Central Nervous System uses to activate the muscles in ACL-Deficient subjects. The higher values of NCs that contain basically activations of ankle plantar flexors and dorsiflexors (modules 2 and 3) during the stance phase, suggest that there is a transfer of the leg control away from the injured knee joint.

This study on muscle synergy analysis can be useful at two levels. In a clinical field, to evaluate the progress during the rehabilitation treatment of ACL-deficient subjects; and, in a computational dynamic analysis, to reduce the indeterminacy in the muscle force calculation of ACL-deficient subjects.

Table:

Groups	SV	NC
Controls vs. Ipsi.	0.70/0.99/0.96/0.80/0.96	0.86/0.94/0.69/0.77/0.81
Controls vs. Contra.	0.91/0.99/0.95/0.93/0.96	0.84/0.92/0.43/0.79/0.73
Ipsi. vs. Contra.	0.82/0.99/0.96/0.77/0.87	0.69/0.96/0.49/0.98/0.72

Caption: Table 1. Correlation values among the 5 modules of different groups (Control, Ipsilateral and Contralateral).

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Disclosure of Interest: None Declared