Missing muscle excitations prediction during walking through a muscle-synergies based calibration method

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Introduction

Surface electromyography (sEMG)-driven models are a powerful tool for personalized rehabilitation protocols. However, their use outside of laboratory settings remains hampered due to the high number of required sEMG signals [1]. Muscle synergy analysis has been proposed to predict unmeasured muscles excitations from the measured signals [2]. Nevertheless, as best of authors' knowledge, the reliability of a calibrated muscle-synergies approach to predict unmeasured muscles excitations, considering few sEMG recordings as muscle primitives, has not been previously investigated.

Methods

The sEMG data of 4 healthy individuals (age = 60.0±2.1 years, BMI = 26.7±4.1 kg/m^2) have been recorded during walking. The electrical activity of the gluteus medius and maximus, adductor longus, tensor fasciae latae, sartorius, bicep femoris, semitendinosus, rectus femoris, vastus medialis and lateralis, gastrocnemius lateralis and medialis, soleus, peroneus longus and tibialis anterior was collected. Fifteen trials for each subject were divided into a calibration set (10 trials) and a test set (5 trials) after being filtered with standard procedures and normalized to the maximum value over all the trials [3]. Firstly, the calibration set was used to extract the muscle synergies primitives ($W_{k,C}$) and weights matrix ($H_{k,C}$) through non-negative matrix factorization methods. k was the factorization number and varied between 2 and 6 and corresponded to the number of muscle synergies used. The root mean squared difference between the experimental excitations and $W_{k,C}$ was used as metric to determine which subset of k sEMG better resembled $W_{k,C}$ ($\hat{W}_k$), while a scale factor was defined as S_f = mean($W_{k,C}$)/$\hat{W}_k$. The average of each $H_{k,c}$ for all the calibration trial was considered as subject-specific weights matrix ($\hat{H}_k$). Then, for each trial of the test set, the same muscles defined in $\hat{W}_k$ were selected as "measured" sEMG signals ($\hat{W}_{k,T}$) while the others were treated as "unmeasured". $\hat{W}_{k,T}$ was then multiplied by S_f and $\hat{H}_k$ to reconstruct the complete set of muscle excitations ($\hat{W}_{k,T}$*C*$\hat{H}_k$). The actual trial-specific primitives ($W_{k,T}$) and vector of weights ($H_{k,T}$) have been extracted and used to predict the muscle excitations ($W_{k,T}$*$H_{k,T}$) with the one obtained with the proposed method. The variance accounted for (VAF) was used as metric to compare the performance against the experimental excitations.

Results

In Figure 1 the experimental muscle excitations against the predicted ones using 5 muscle synergies are reported as example. High values of *VAF* are reported in Table 1 for both methods, suggesting an accurate prediction of the experimental measures.

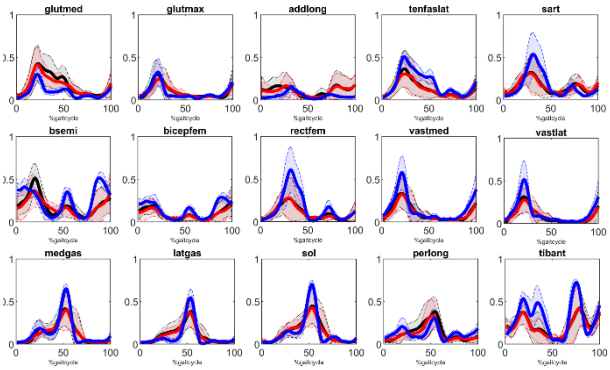

Figure 1: Muscle excitations of the 4 subjects (average of the test trials ± 1 standard deviation). In black the experimentally recorded excitations, in blue the excitations reconstructed via muscle synergy analysis (5 primitives), in red the excitations reconstructed via the proposed method (5 muscles excitations as primitives).

Synergies	VAF_s	VAF_p	*p-value*
2	.987 ± .005	.964 ± .011	< .001
3	.993 ± .003	.977 ± .008	< .001
4	.996 ± .003	.978 ± .008	< .001
5	**.998 ± .001**	**.986 ± .004**	**< .001**
6	.999 ± .001	.984 ± .005	< .001

Table 1: Average VAF as total of each considered muscle for the two different methods (VAF_s standard; VAF_p proposed) to reconstruct the experimental muscle excitations.

Discussion

The reliability of the proposed method to track the "unmeasured" excitations was assessed. This could be pivotal in the creation of reliable iHealth sEMG-driven models considering a minimal experimental setup transferable in daily living conditions where the major requirements are a reduced number of sensors and the maintenance of a reliable characterization of the research subject's neuromuscular status.

References

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