Comparison of Bioelectric and Biomechanical Electromyography Normalization Techniques in Disparate Populations

Authors : Drew Commandeur, Ryan Brodie, Sandra Hundza, Marc Klimstra

Abstract : The amplitude of raw electromyography (EMG) is affected by recording conditions and often requires normalization to make meaningful comparisons. Bioelectric methods normalize with an EMG signal recorded during a standardized task or from the experimental protocol itself, while biomechanical methods often involve measurements with an additional sensor such as a force transducer. Common bioelectric normalization techniques for treadmill walking include maximum voluntary isometric contraction (MVIC), dynamic EMG peak (EMGPeak) or dynamic EMG mean (EMGMean). There are several concerns with using MVICs to normalize EMG, including poor reliability and potential discomfort. A limitation of bioelectric normalization techniques is that they could result in a misrepresentation of the absolute magnitude of force generated by the muscle and impact the interpretation of EMG between functionally disparate groups. Additionally, methods that normalize to EMG recorded during the task may eliminate some real inter-individual variability due to biological variation. This study compared biomechanical and bioelectric EMG normalization techniques during treadmill walking to assess the impact of the normalization method on the functional interpretation of EMG data. For the biomechanical method, we normalized EMG to a target torque (EMGTS) and the bioelectric methods used were normalization to the mean and peak of the signal during the walking task (EMGMean and EMGPeak). The effect of normalization on muscle activation pattern, EMG amplitude, and inter-individual variability were compared between disparate cohorts of OLD (76.6 yrs N=11) and YOUNG (26.6 yrs N=11) adults. Participants walked on a treadmill at a self-selected pace while EMG was recorded from the right lower limb. EMG data from the soleus (SOL), medial gastrocnemius (MG), tibialis anterior (TA), vastus lateralis (VL), and biceps femoris (BF) were phase averaged into 16 bins (phases) representing the gait cycle with bins 1-10 associated with right stance and bins 11-16 with right swing. Pearson's correlations showed that activation patterns across the gait cycle were similar between all methods, ranging from $r = 0.86$ to $r = 1.00$ with $p < 0.05$. This indicates that each method can characterize the muscle activation pattern during walking. Repeated measures ANOVA showed a main effect for age in MG for EMGPeak but no other main effects were observed. Interactions between age*phase of EMG amplitude between YOUNG and OLD with each method resulted in different statistical interpretation between methods. EMGTS normalization characterized the fewest differences (four phases across all 5 muscles) while EMGMean (11 phases) and EMGPeak (19 phases) showed considerably more differences between cohorts. The second notable finding was that coefficient of variation, the representation of inter-individual variability, was greatest for EMGTS and lowest for EMGMean while EMGPeak was slightly higher than EMGMean for all muscles. This finding supports our expectation that EMGTS normalization would retain inter-individual variability which may be desirable, however, it also suggests that even when large differences are expected, a larger sample size may be required to observe the differences. Our findings clearly indicate that interpretation of EMG is highly dependent on the normalization method used, and it is essential to consider the strengths and limitations of each method when drawing conclusions.

Keywords : electromyography, EMG normalization, functional EMG, older adults
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