Estimation of hamstring muscle forces during resistance training: Insight into structural muscle alterations and adaptations

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Summary

Recent *EMG-driven* approaches have been developed for estimating muscle forces during resistance training. However, these approaches have not yet been rigorously confronted to experimental data. This study presents two experiments: They examines the relationship between the distribution of forces and i) the distribution of muscle damage and ii) the distribution of muscle hypertrophy among hamstring heads, after an acute and chronic resistance training, respectively. The main results show that in controlled tasks, muscle forces distribution is strongly related to the distribution of muscle damage. These links appear to be reduced in more ecological and repetitive tasks.

Introduction

Resistance training has become widely recognized for its role in maintaining health and enhancing sports performance. However, the inter-individual variability in muscle alterations/adaptations, such as muscle damage/hypertrophy [1], limits our ability to predict the effects of training protocols. *EMG-driven* neuromusculoskeletal models represent elegant approaches to estimate muscle forces for each individual, and in turn, predict muscle alterations/adaptations [2]. However, these force estimations have not yet been validated against experiment outcomes from muscle responses associated with resistance training. This study presents two experiments: They examines the relationship between the distribution of forces and i) the distribution of muscle damage and ii) the distribution of muscle hypertrophy among hamstring heads, after an acute and chronic resistance training, respectively.

Methods

Surface bipolar Electromyography (EMG), Inertial Measurement Units (IMUs) and force sensors were used as input to an *EMG-driven* neuromusculoskeletal model (CEINMS,[3]) to estimate Semimembranosus (SM), Semitendinosus (ST) and Biceps Femoris long head (BFlh) relative muscle forces.

Experiment 1 (acute). 24 participants performed 5 sets of 15 maximal eccentric contractions on a dynamometer. Shear modulus variation (before vs 30min afterward) was used to quantify the distribution of muscle damage across SM, ST and BFlh [4].

Experiment 2 (chronic). 24 participants were assigned either to a control (CON, *n*=12) or a Nordic Hamstring Exercise (NHE, *n*=12) group. Resistance training being performed 3 times a week for 9 weeks. SM, ST and BFlh hypertrophy was estimated from changes in the muscle volume using 3D freehand ultrasound (3DUS).

Results and Discussion

Experiment 1 (acute). We found a higher distribution of muscle damage on the ST (73.7±23.4%) than that the SM (2.9±21.7%) and the BFlh (23.4±20.3%). The distribution of relative muscle force was also higher on the ST (40.0±4.9%) than that the SM (26.9±4.1%) and the BFlh (33.5±5.7%). For individual and pooled muscles, we found a significant moderate ($r > 0.60$) to high correlation ($r = 0.78$) between the distribution of relative muscle forces and distribution of muscle damage, except for the SM ($r=0.36$).

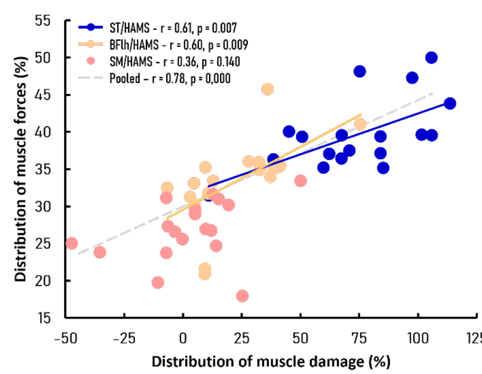

Figure 1: Relation between muscle forces distribution and muscle damage distribution.

Experiment 2 (chronic). *Part of the data is currently processing.* We observed that hamstring hypertrophy was larger in the ST (74.0±17.8%) compared to the SM (11.7±10.7%) and the BFlh (14.5±14.8%). During NHE, the relative muscle force was also greater on the ST (39.8±27.7%) than on the SM (28.8±28.6%) or the BFlh (31.4±28.9%). The linear correlation between force distribution and hypertrophy was small ($r>0.30$) to moderate ($r = 0.55$ for ST).

Conclusions

These results provide the first impetus that the distribution of muscle force estimated using an EMG-driven approach is an elegant approach to predict the location of resistance training related alterations and adaptations.

References

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