Assessing Muscle Contraction Force

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Introduction

The ability to judge the forces generated when we contract our muscles is important to control the movements we make every day.

This "sense" of muscle contraction force is one component of *"kinesthesia"* [1]. Kinesthesia comprises our sense of limb position and movement and helps us time muscular contractions and control the forces our muscles produce.

The ability to judge contraction force may rely on sensory feedback from receptors in muscle or central motor commands from the brain.

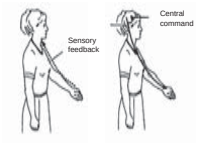


Figure 1. Components of proprioception[1].

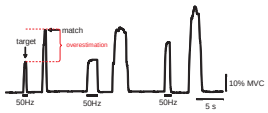


Figure 2. Dorsiflexion torque overestimation.

However, humans are poor at judging contraction force when their assessment is based solely on sensory feedback[2,3]. Figure 2 shows that participants overestimate contraction forces produced during electrically-evoked "target" contractions when they attempt reproduce the target force with their own voluntary contraction.

Purpose

Determine whether both sensory feedback and central motor commands are required to accurately judge muscle contraction force.

Hypotheses

We tested two hypotheses;

1. When subjects remain relaxed they would significantly overestimate forces generated during electrically-evoked target contractions.
2. When subjects held a small voluntary contraction they would accurately match electrically-evoked target contractions.

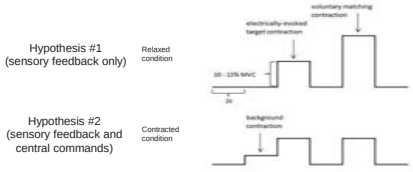
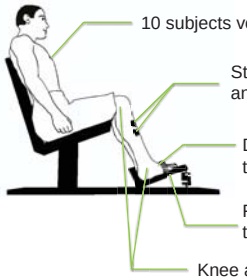


Figure 3. Hypothesis for relaxed and contracted conditions.

Methods



10 subjects volunteered to participate in this study

Stimulating electrodes placed on tibialis anterior (TA) to electrically evoke contractions

Dorsum of foot anaesthetized with topical Lidocaine

Foot strapped to dynamometer to measure torque or contraction force from dorsiflexion

Knee and ankle joints flexed to 90°

- Trials were collected in pairs of electrically-evoked "target" contractions followed by voluntarily-generated "matching" contractions
- Subjects were asked to "match the force they felt in the muscle"
- 40 trials in relaxed condition; 40 trials in contracted condition
- Statistical analyses done with repeated measures ANOVA and Wilcoxon matched pairs test

Results

Subjects were better at matching contraction forces when both sensory feedback and central motor commands were available.

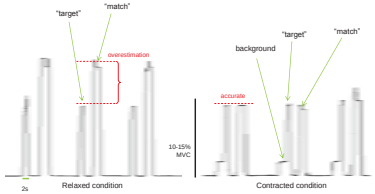


Figure 4. Contraction forces recorded while one participant tried to match electrically-evoked target contractions delivered while they were relaxed (left) or while they held a small voluntary contraction (right).

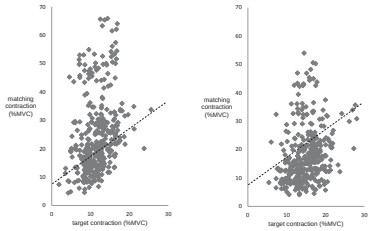


Figure 5. All 400 contraction pairs (ie. "target" x-axis versus "match" y-axis) from the 10 participants. If participants matched the target contractions perfectly, all the data would fall along the dotted line.

Results

When the target contraction was generated in the relaxed condition, and only sensory feedback about contraction force was available, participants significantly overestimated contraction force.

When participants held a small voluntary contraction, and both sensory feedback and central motor command were available, subjects accurately matched target contraction forces.

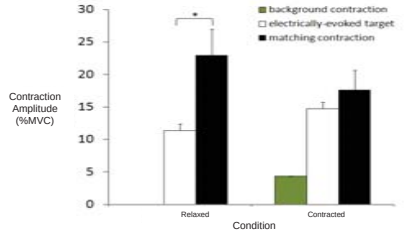


Figure 6. Group data (n=10) showing average contraction amplitudes. When relaxed, subjects significantly overestimated forces generated by the electrical stimulation, producing "matching" contractions approximately twice as large (xx%, $p<0.05$) as the "target" contractions. When subjects held a voluntary contraction, there was no significant difference between the forces generated during the "matching" and "target" contractions.

Conclusion

The central nervous systems requires a combination of sensory feedback and central motor commands to accurately judge the forces generated during voluntary contractions.

An ongoing comparison of these two sources of information about contraction force may help "calibrate" our kinesthetic sense of contraction force as muscles lengthen, strengthen, weaken or fatigue during activities of daily living or throughout ones life.

References

1. Gandevia (1996) *Handbook of Physiology*, Section 12, : 128-172.
2. Wolpert, Bays, Flanagan (2006). *PLoS Biology*. 4(2):281-284.
3. Walsh, Taylor & Gandevia (2011). *J Physiol.* 589.3:547-557.

Future Directions

Further studies can consider using electromyography to monitor potential contribution of other muscles or quantify the correlation between background contraction size and difference between matching and target contractions.