Eccentric and Concentric Calf muscle loading: Effect of Speed on the Biomechanical properties of Triceps surae

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INTRODUCTION

Achilles tendinopathy is a painful condition occurring in and around the Achilles in response to overuse. Whilst it is common in athletes and prone to recur, the optimal methods of managing the condition remain unclear. The main conservative treatment is heavy load eccentric calf muscle training (ET), which involves lengthening the muscle-tendon unit during the application of load. This is the opposite of concentric training (CT) where the muscle-tendon unit gets shorter and differs from isometric exercises, in which the muscle tendon unit length remains unchanged. ET has been reported to be effective in various controlled clinical trials and systemic reviews but it is unclear why ET has been shown to be more effective than CT.[1] Moreover, it is unclear at what speed the eccentric calf muscle exercises should be performed to treat the condition with optimal efficacy, and the lack of consensus may explain the mixed results reported in recent studies.[2, 3]

We hypothesized that eccentric and concentric actions performed at different speeds would provide different stimuli to the tendon. The aim of our study was to compare these modalities in terms of the muscle activity and tendon force at two commonly employed speeds.

METHODS

The study was approved by the local ethics committee and all participants gave informed consent. Twelve healthy volunteers (6 male and 6 female, mean age = 22.7 ± 1.4 years (SD)) performed ET and CT at two different speeds. For ET, subjects were asked to stand on the toes of one foot with the heel raised, before lowering the heel in a controlled manner. The exercise was performed off the edge of a step to allow full dorsi-flexion to be reached (Fig.1 A). For CT, subjects started with the heel below the toes and raised the heel during the exercise in the same controlled manner (Fig.1 B). In order to keep speed consistent, subjects were guided by a metronome to complete the heel raise or drop at speeds of 0.170m/s (fast) or 0.03m/s (slow).

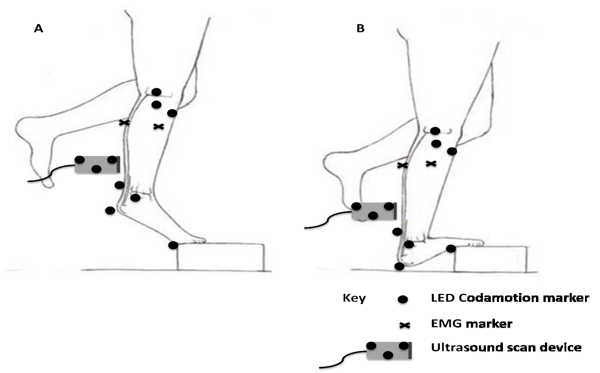

Figure1. Set up used in the experiment

Three sets of data were recorded for each loading paradigm for each subject, in a randomized order. Tendon force and extension were measured during each exercise. An active infra red motion analysis system (CODA, CX1, Charnwood Dynamics, Rothley, UK) was used to determine gross movements of the leg, with simultaneous ultrasound (Voluson e, GE Healthcare, UK), tracking of the medial gastrocnemius muscle-tendon junction. In addition, electromyography (EMG, Noraxon, USA) recordings were used to determine muscle activity, using dual electrodes with a 20mm inter-electrode distance, placed on the belly of the lower leg muscles following the SENIAM guidelines. EMG data was rectified and smoothed in MATLab, in order to compare the activation patterns during ET and CT. A four way ANOVA was performed on the data and statistical significance accepted at $p<0.05$.

RESULTS

While some inter-subject variability was apparent, CT and ET resulted in distinctly different loading patterns across all subjects when performed at slow speed while no significant difference was observed in loading pattern during fast speed (Fig. 2a). Rate of change of tendon force was greater in the two fast loading groups, even when data was normalized over a cycle period, highlighting the notably greater loading speeds in the fast test groups (figure 2a).

A similar peak tendon force was recorded in all conditions except CT slow, which was significantly lower (figure 2b; $p < 0.01$).

By contrast, when looking at EMG data both the rate of change of muscle activation and the maximal activation values were significantly higher ($p < 0.01$) in CT slow or fast than ET slow or fast (Figure 3; $p<0.01$).

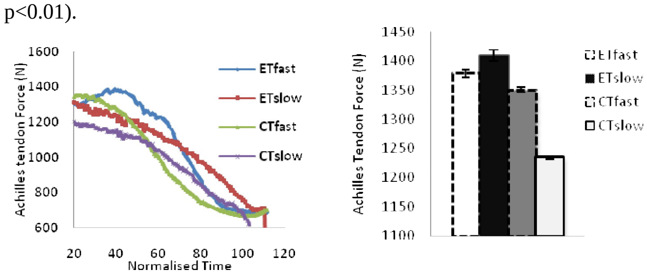

Figure2. a) Mean curves showing normalized Achilles tendon force with time during each training modality and (b) mean data for the peak tendon force in each condition.

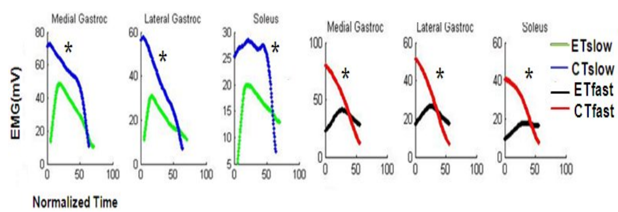

Fig.3. Smoothed EMG curves showing the muscle activation comparison.

DISCUSSION

This study demonstrates that, when performed at slow speed, eccentric calf muscle loading produces higher peak forces within the tendon than concentric loading, with lower muscle activation levels. By contrast, no difference in tendon force was found between the two modalities at fast speed although the muscle activation was significantly lower during ET than CT, consistent with the previous studies.[2, 3, 4]

If the mechanism of action of ET is via higher force fluctuation, these differences may have therapeutic relevance.[5] Higher tendon forces may lead to improved matrix anabolism, thus improving the structural and mechanical properties of the tendon after an ET regime as compared to the CT performed at slower speeds

A comparatively lower EMG activity during eccentric action has previously been reported.[4] CT muscle activity remained largely independent of the speed whilst ET activation was found to be significantly dependent on the speed. The combination of the EMG and force data indicates that eccentric contractions required lower levels of voluntary activation by the nervous system to achieve a given muscle force at a given speed, influencing the resulting tendon load environment. It may be that the associated energy preservation during ET, via ATP sparing, allows a greater volume of exercise to be carried out under eccentric conditions than concentric when comparing the slow speed.

These findings suggest a need to explore the effect of typical ET or CT training program performed at different speed on the tendon structural and material properties. Future, imminent, work will clarify group stress – strain relationships.

REFERENCES

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