REDUCTIONS IN STRETCH SHORTEN CYCLE FORCE ENHANCEMENT WITH INCREASED COUPLING TIME DURING MAXIMAL KNEE EXTENSIONS

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INTRODUCTION

The Stretch Shorten Cycle (SSC) occurs when an active musculotendinous unit is forcibly stretched before it shortens, giving rise to increased levels of force production during the shortening. There are a number of mechanisms suggested for this phenomenon (discussed in a review edition of the Journal of Applied Biomechanics, Issue 4 volume 13, 1997) but the exact contribution to overall performance is still equivocal. Introducing a delay, Coupling Time (CT), between the eccentric and concentric actions in a SSC reduces the force enhancement in an exponential manner [1].

Previous experiments that varied the CT used compound actions such as bench pressing, squatting or jumping. These motions present: variable rather than maximal activation throughout the SSC; often occur over short time frames; and have large changes in velocity. All these contribute to the difficulty in comparing their results with those from *in vitro* and *in situ* studies that are normally performed under far more controlled stretch and hold conditions or stretch and shorten conditions.

The aim of this research is to examine the effect of CT on SSC enhancement during well controlled pseudo-isovelocity conditions with maximal voluntary activation.

METHODS

Seven athletic subjects (5 male, 2 female, age 22.4 ± 0.6 years; height 178 ± 12 cm; weight 79.8 ± 8.7 kg) gave informed consent in accordance with Loughborough University ethical committee. Two sets of maximum voluntary knee extensions were conducted on a CON-TREX dynamometer (CMV AG, Switzerland).

The first set were maximum effort eccentric-isometric-concentric contractions. These were performed for six isometric coupling times (CT) (0.07, 0.3, 0.6, 1, 2, 4 s) and three velocities (30°s^{-1}, 60°s^{-1} and 100°s^{-1}). Initial knee angle was set to 10° of flexion and subjects were asked to maximally resist forced flexion through a 70° range of motion (to 80° of flexion) and to continue pushing maximally throughout the isometric and concentric phases. The second set were maximum effort isometric-concentric contractions. These employed the same isometric angle (80° of flexion) (held for 2 s) and concentric velocities as in the first set of trials.

The torque at 10°, 20° and 30° into the concentric movement was evaluated for each trial and normalised based on the values for the shortest coupling time (0.07 s) at the same velocity.

RESULTS AND DISCUSSION

In the eccentric-isometric-concentric trials normalised concentric torque appeared to decrease exponentially with increasing isometric coupling time (Figure 1, Eqn. 1) with a half life of 0.7 seconds.

$$\frac{T}{T_{ct=0.07}} = 0.759 + 0.259\exp(-1.002ct) \qquad \text{Eqn. 1}$$

This half life is comparable with the half life of 0.85 s determined by [1] during bench pressing, but shorter than half lives seen in the some lower limb compound movement experiments, which have claimed half lives to up to 4 seconds [2]. This value is also falls within the range of values found for the half life of active force enhancement decay. This tends to have a range between 0.5 to 1.1 s, determined from muscle fibre experiments [3] and in situ whole muscle experiments [4]. It would appear that the longest half lives determined from older data during compound lower body movements are not the norm. We have also previously determined half lives between 0.8 and 1.1 s for SSC

enhancement decay during countermovement jumps [5].

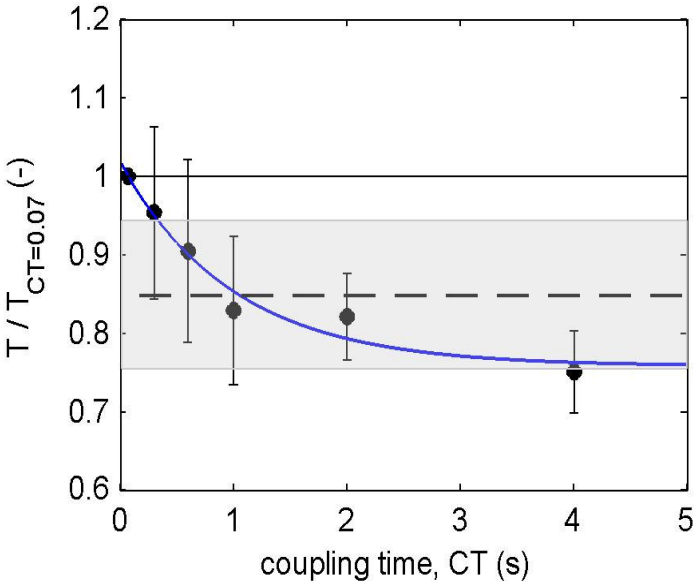

Figure 1: Normalised concentric torque (normalised to 0.07 s CT value) versus CT. Black circles are mean ± SD from eccentric-isometric-concentric trials averaged over all velocities, all concentric positions and all subjects. Solid blue line is the exponential fit. Dashed line and shaded region are the mean ± SD from isometric-concentric trials averaged over the same conditions.

As other studies have shown [6], the improvement in SSC performance is not as great when compared to isometric preload as when compared to purely concentric contractions. The SSC performance was only significantly better than the isometric-concentric performance for the shortest coupling times and was worse at the longest CT. This would support the idea that a significant proportion, but not all, of the improvement from the SSC can be accounted for by the increased time to increase activation prior to the start of the concentric contraction. Here, when more time is allowed in the form of an extended isometric hold performance dropped back to that of a pure isometric fore-period illustrating a distinct dynamic contribution to the concentric force enhancement.

It may also warrant consideration, given the relatively small number of points used in various studies to fit the exponential decay, that the exponential decay could be an artifact of choosing a single function to fit the data. This could arise with the results in Figure 1 due to the first 2 or 3 data points decreasing in value as a short term stretch related enhancement dropped off; points 3, 4 and 5 being constant and approximately equal to the isometric-concentric trials; and the last point dropping off due to greater fatigue within the SSC trials. Maximal effort in the SSC trials would have been required for up to 7 seconds but only for up to 3 seconds in the isometric-concentric trials.

These results suggest that improvements due to the active stretching last no longer than 1 s. However, the exact load at the start of the concentric phase has not been explicitly accounted for and the EMG activity of the quadriceps also needs quantifying.

CONCLUSIONS

Torque appears to decay exponentially with increasing CT. The half life seen in this experiment was similar to the active force enhancement decay, seen in muscle fibre experiments [2] and in situ whole muscle experiments [3].

A SSC for maximum voluntary knee extensions can have a significant advantage over isometric preload on the concentric torque generation, but only for low CT. This supports the idea that a high proportion of the improvement from the SSC can be accounted for by the increased time to develop pre-activation prior to the start of the concentric contraction. However, it also highlights that a distinct dynamic component is present which decreases with increasing CT.

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