EFFECTS OF ECCENTRIC CONTRACTION INDUCED MUSCLE DAMAGE ON STRETCH-SHORTENING CYCLE FUNCTION

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This experiment examined the effect of eccentric contraction induced muscle damage on the stretch shortening cycle (SSC). Ten moderately active adult volunteers participated in this study. Temporary muscle damage on the knee extensors was administered by a bout of eccentric contractions on an isokinetic dynamometer. Measurements were obtained of maximum voluntary force, and take off velocities for single leg countermovement jumps (CMJ), squat jumps (SJ) and drop jumps (DJ) performed on a specially constructed sledge and force plate apparatus. Measurements were obtained before and after the damage intervention. The undamaged leg was used as a control. The results indicated that eccentric muscle damage significantly affected SSC performance by causing relatively greater reductions in SJ performance than CMJ or DJ

KEY WORDS: stretch shortening cycle, muscle damage, eccentric contraction, jump

INTRODUCTION: The stretch-shortening cycle (SSC) is a very important phenomenon in human muscle contraction. It is observed in a wide range of activities from basic locomotor activities to more challenging actions such as throwing or jumping. Direct *in vivo* measurement of SSC dynamics is difficult since it requires identification of a SSC for isolated muscle actions and knowledge of instantaneous muscle forces and muscle lengths. Despite this, valid indirect and sensitive measurements can be made of SSC muscle dynamics. These measures usually involve comparing external forces and impulses generated by muscle action using a controlled eccentric-concentric SSC such as a countermovement jump (CMJ) or drop jump (DJ) with forces and impulses generated in a single concentric muscle action such as a squat jump (SJ), Komi (2000). It is known that eccentric contraction induced muscle damage can impair muscle contractile function by 50% or more (Clarkson et al, 1992). However, the effect of such loss of contractile function on the SSC phenomenon is not clear. The purpose of this investigation was to determine the effect of eccentric contraction induced muscle damage on the performance of the SSC phenomenon.

METHOD: Volunteers aged 18 to 40 years were recruited for this experiment. Five exclusion criteria were applied: (1) subjects with a recent or recurring knee injury, (2) subjects with a disease that affects cardiac function, (3) subjects with a disease that affects muscle function or repair, (4) subjects taking anti-inflammatory drugs, (5) subjects who take part in high intensity exercise or activities that involve frequent forceful contractions. Following this screening, ten moderately active adults participated in the study, consisting of four males aged 25 ± 2.2 years; mass 94 ± 21 kg, and six females aged 23 ± 2.3 years; mass 69 ±11 kg. Informed consent was obtained in writing, from all subjects prior to their participation in the study.

Procedures: Several measures of muscle function were obtained before and after a bout of eccentrically induced muscle damage on one leg. The undamaged leg was used as a control. An estimate of Maximum Voluntary Contractile Force (MVC), of the knee extensors was obtained with knee flexion at 90º. Subjects were secured to a modified Cybex chair and isometric MVC was measured by a force transducer securely anchored and attached to a cuff around the subject’s ankle. The exact positions of the cuff, chair, transducer linkage etc were recorded so that repeated measures of MVC on each subject were carried out on an identical set up. The subjects were allowed 3-5 attempts to obtain a maximum score. Visual feedback and standardised verbal encouragement were given during each attempt.

To examine SSC function, each subject performed three counter-movement jumps (CMJ), three squat jumps (SJ) and three drop jumps (DJ) on a sledge apparatus inclined at 30º as described by Horita et al (1996). The CMJ’s were performed with a maximum knee flexion angle of 90º,

the DJ's from a drop height of 0.30m and the SJ's from a static crouch with knee flexion at approximately 90º. Reflective markers were attached to the sledge and rails and sagittal plane SVHS video recordings (50 Hz.) were obtained. The video records were digitised using Peak Motus® (Peak Performance Technologies, Colorado, USA) and the velocity of the sledge from was calculated using a GCV quintic spline algorithm, Woltring (1986). Ground reaction force measurements were obtained for each jump using an AMTI OR6-5 force platform mounted at right angles to the sledge apparatus and sampling at 500 Hz and synchronised with the video using a Peak event and video control unit.
The resultant vertical ground reaction force time records were integrated with respect to time from t = 0 to t = take off. For the SJ and CMJ, t = 0 was the instant of first movement, in the DJ t =0 was the instant of impact. The velocity at take-off ($\boldsymbol{v}_{TO}$) can be derived from the integral of the resultant vertical ground reaction force (***RFy***) with respect to time using the following equation:

$$\boldsymbol{v}_{\mathrm{TO}} = \frac{\int_{t=0}^{t=\mathrm{TO}} \boldsymbol{RFy}.dt}{m} + u$$

Where: ***RFy*** = resultant ground reaction force.
m = Body mass + mass of the sledge chair
u = initial velocity (t = 0)

A series of pilot tests on the experimental set up obtained high correlation (R=0.998) between measured impact velocity and predicted velocity based on height of drop.
Muscle Damage Protocol: Eccentric contractions were performed on a Contrex isokinetic dynamometer, (CVH AG, Dübendorf, Switzerland). Each subject performed seven sets of ten maximal eccentric contractions of the knee extensors at a velocity of 1.05 rad.s^{-1}. Between each contraction, the leg was returned passively to the start position. Subjects were encouraged to apply maximal force throughout each contraction. Visual feedback was provided by real time displays and summary graphs at the end of each set. Figure 1 provides a schematic representation of the experimental design.

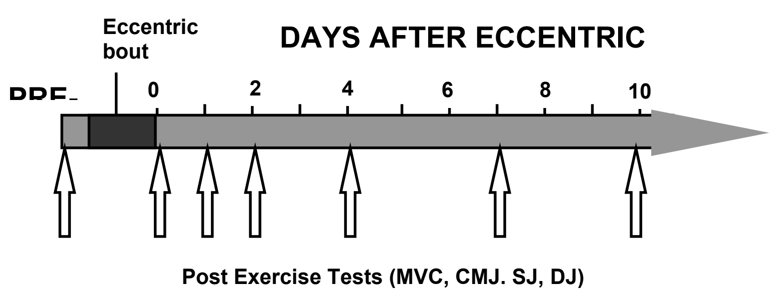

Figure 1 - Schematic diagram of experimental design for the experiment.

Statistical Analyses: Statistical analysis of the data was carried out in SPSS © using a general linear model (GLM) Multivariate ANCOVA with repeated measures. The GLM had three within-subjects factors and one covariate, namely, maximum percentage force loss on the damaged leg, (FLD):

Factor 1: Jump (with 3 levels: CMJ, SJ and DJ)
Factor 2: Leg (with 2 levels: damaged and control)
Factor 3: Time (with 2 levels: pre-test and day of lowest MVC)

The dependent variable was $\boldsymbol{v}_{TO}$ and the model included all interaction terms. Since it is impossible to precisely control the extent of muscle damage across all subjects, the covariate FLD was used to account for this variable effect.

RESULTS AND DISCUSSION: The effect of the muscle damage intervention on the MVC for each subject is shown in table 1. These data show a high degree of between subject variation in MVC force loss between the pre-test and of the day of greatest reduction. Figure 2 shows the $\boldsymbol{v}_{TO}$ scores in each of the three types of jump in the pre test and on the post test day of greatest loss in MVC force. It is clear that the damage protocol caused significant reductions in v_{TO} in the damaged leg ($p < 0.01$). This is consistent with the results of the MVC test results and appears indicate that eccentric damage caused a general loss of force generation capacity in isometric contraction and all jump actions. Without obtaining a stimulated MVC it is difficult to evaluate if this loss was due to structural damage of muscle, under-recruitment or simply the pain response to delayed onset muscle soreness.

Table 1 Maximal Isometric Force Production for the Damaged Leg. Data in brackets show the FLD values and when these occurred.

Subject	Pre (N)	Post (N)	1 Day$_{Post}$ (N)	2 Day$_{Post}$ (N)	3 Day$_{Post}$ (N)	7 Day$_{Post}$ (N)	11 Day$_{Post}$ (N)
1	812	602	723	**547 (↓33%)**	796	820	825
2	583	**455 (↓22%)**	562	599	510	540	509
3	546	514	411	**408 (↓25%)**	504	522	545
4	343	169	181	201	**156 (↓55%)**	186	230
5	438	317	**238 (↓46%)**	275	291	352	395
6	507	298	266	305	**240 (↓53%)**	281	335
7	649	426	**253 (↓61%)**	291	517	569	669
8	941	390	376	**250 (↓73%)**	257	306	360
9	525	302	258	**232 (↓56%)**	364	398	441
10	575	**341 (↓41%)**	436	383	456	482	514
Mean	**592**	**381**	**370**	**349(↓41%)**	**409**	**445**	**482**

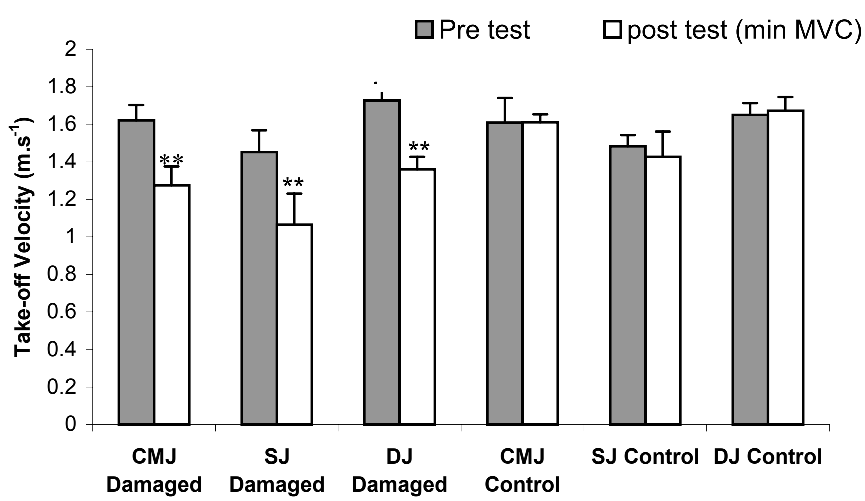

Figure 2 - Mean v_{TO} scores for the damaged and control legs on pre test and post test day of greatest force loss. (**significant difference between damaged and control, $p<0.01$)

SSC function is usually observed as an increase in v_{TO} between CMJ and SJ or DJ and SJ therefore, figure 2 does not provide clear indication of the effect of eccentric damage on SSC performance. From table 2 it appears that the CMJ/SJ and DJ/SJ ratios were increased by the muscle damage intervention, which would suggest that damage enhanced the SSC. However, the reason for this change appears to be that muscle damage caused a relatively greater reduction in SJ $\boldsymbol{v}_{TO}$ than CMJ or DJ. The GLM ANCOVA with repeated measures was used to establish whether muscle damage significantly affected SSC function. Table 3 shows selected results of the ANCOVA test that relate to the effect of muscle damage on SSC function. The data reveals three significant interaction terms: Jump×Leg×Time, Jump×Leg×FLD and Jump×Leg×Time×FLD with $\boldsymbol{v}_{TO}$ as the dependent variable. These data clearly showed that when account was made for variation in the extent of force loss, FLD, that the SSC was significantly affected by the muscle damage.

Table 2 The Relative Effect of Damage on the CMJ/SJ and DJ/SJ Ratios

Test (Group)	CMJ/SJ Ratio	DJ/SJ Ratio
Pre test (Damage)	1.12	1.19
Post test (Control)	1.09	1.12
Pre test (Damage)	1.20	1.28
Post test (Control	1.13	1.17

Table 3 ANCOVA results of Within-Subjects Effects and Interactions on $\boldsymbol{v}_{TO}$

Source/ Interaction	Hypothesis: Error Degrees of freedom	F-Ratio	Probability
Jump	2 : 7	1.904	0.219
Jump × Leg	2 : 7	0.533	0.609
Jump × Leg × Time	2 : 7	4.849	0.048
Jump × Leg × FLD	2 : 7	0.139	0.038
Jump × Leg × Time × FLD	2 : 7	6.554	0.025

The exact mechanism by which muscle damage affects the SSC cannot be derived from this experiment alone. However, the data indicate the potential of this intervention technique for gaining greater understanding of the mechanism(s) involved in the SSC.

CONCLUSION: The results of this experiment indicated that eccentric muscle damage does significantly affect SSC function as determined by the CMJ/SJ or DJ/SJ ratio. The reduction of contractile function following muscle damage appears to be relative greater in SJ compared with CMJ or DJ, although performance of all type of jumps was reduced.

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