AN EXAMINATION OF THE SLOW AND FAST STRETCH SHORTENING CYCLE IN CROSS COUNTRY RUNNERS AND SKIERS

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Performance in fast and slow stretch shortening cycle (SSC) activity was examined. 13 NCAA Div. I cross country skiers and runners performed a countermovement jump (CMJ) and a drop jump (DJ) on a force platform. These jumping actions were classified as slow and fast SSC activities respectively based on ground contact times. In the slow SSC subjects achieved significantly greater jump heights while in the fast SSC subjects produced greater peak ground reaction force and measured higher on the reactive strength index. A weak correlation was found between slow SSC and fast SSC ability suggesting that training in slow SSC tasks might not accrue benefit in fast SSC ability and vice versa. Consideration to ground contact duration and the principle of specificity should be given when using the CMJ or the DJ as a testing tool or as a training exercise.

KEY WORDS: force, jumping, reactive strength index.

INTRODUCTION:

The stretch shortening cycle (SSC) involves the stretching of musculature immediately prior to being rapidly contracted. This eccentric/concentric coupling produces a more powerful contraction than concentric action alone. One view has been that the concentric phase is enhanced by the storage and release of elastic energy. During the eccentric phase the active musculature is pre-stretched and absorbs energy which is temporarily stored and reutilized during the following concentric contraction. Additional mechanisms have been proposed to contribute to the SSC including the neural potentiation of the contractile machinery during the eccentric phase, reflex contributions from the muscle spindle and increased time to develop force. Schmidtbleicher (1992) has suggested that the SSC can be classified as either slow or fast. The fast SSC is characterized by short contraction times (<0.25s), small angular displacements and can be observed in depth jumping while the slow SSC involves longer contraction times, larger angular displacements and is observed in countermovement jumps. The precise mechanisms which underpin any given SSC activity may be determined by the demands of that SSC criterion task. For example, the muscle spindle reflex is dependent on a fast rate of eccentric stretching (Bobbert et al., 1987) and elastic energy contribution may rely on a short transition period between eccentric and concentric phases (Bobbert et al., 1987). Decay in the magnitude of potentiation has been observed as the transition time between eccentric and concentric contraction increases (Wilson et al., 1991). These mechanisms then are more likely to contribute to the fast SSC which has a faster eccentric velocity and a shorter transition period than the slow SSC (Bobbert et al., 1987). Performance enhancement in slow SSC activities is more reliant on neural potentiation of the contractile machinery during the eccentric phase and increased time to develop force (Bobbert et al., 1996; Walshe et al., 1998). As a result, the slow and fast SSC may represent drastically different muscle action patterns, affecting performance in different ways. The purpose of this study was to examine performance in slow and fast SSC activity in measures of jump height, force production and reactive strength and to assess if performance in one form of SSC activity can predict performance in another. The examination of these variables allows for the opportunity to observe if specific performance differences exist between the slow and fast SSC.

METHOD:

Thirteen NCAA Div. I cross country skiing and cross country running athletes were recruited to participate in this study consisting of ten females and three males. The group was of age (mean ± S.D.) 20 ± 1.5 years; height 170 ± 11 cm and mass 67.6 ± 9.7 kg. The University's research ethics committee approved the study and all subjects provided signed informed consent.

Procedures: Measures of lower limb performance were obtained with a force platform using two jumping protocols: a countermovement jump (CMJ) and a rebound jump (RBJ). In the CMJ, subjects were instructed to stand on the force platform, with their hands on their hips and from that standing position to jump as high as possible. No instruction was made as to how fast the jumping action should be or to what depth the athlete should move to in the countermovement. The RBJ protocol comprised of a CMJ immediately followed by a fast depth jump (DJ). Subjects were instructed to perform a CMJ but upon landing to immediately jump again. It was stressed that in this second jump, the DJ, that subjects were to minimize ground contact time, jump high and use a "stiff" jumping action. In the RBJ, only data from the DJ portion was analysed. Before each jump, subjects were given a visual demonstration and allowed to practice the appropriate action before performing each protocol once in a randomised order. Ground reaction force measurements were obtained for each jump using an AMTI force plate sampling at 1000 Hz. Using the acquired ground reaction force traces, the points of take-off and landing and the peak vertical ground reaction force (Fy_{peak}) were identified in both jumps. In both CMJ and DJ, flight time (FT) was calculated as the time between take-off and landing. Jump height (JH) was calculated as $(9.81 * FT^2)/8$. The initial onset of eccentric movement was identified in the CMJ at the point at which the measured force began to continuously deviate below subjects' stationary bodyweight. The point of first ground contact was identified in the DJ. Contraction and ground contact times (CT) in the CMJ and DJ were calculated as the time between onset of eccentric movement and take-off or the point of first ground contact and take-off, respectively. The reactive strength index (RSI) was calculated as JH divided by CT (Young, 1995). The reliability of the RSI in similar jumping activity has been established, with single measures intraclass correlations of > 0.97 observed (Flanagan et al., 2007).

Statistical Analyses: All statistical analysis of the data was carried out in SPSS © (Version 13.0). Comparative analysis, between the CMJ and the DJ utilized a paired student t-test for analysis of each dependent variable. Dependent variables analysed were JH, CT, RSI, and Fy_{peak}. Effect sizes (ES) were calculated using Cohen's d_z. A bivariate correlation was used to examine the relationship between RSI produced in the CMJ versus the DJ. A significance level of 0.05 was adopted for all statistical analysis of the data. A Bonferroni correction was applied to control for possible inflation of alpha and adjusted the p value to 0.0125 (0.05/4) for each statistical test.

RESULTS AND DISCUSSION:

Table 1 presents the mean (± S.D.) CT for both the CMJ and DJ. The mean CT in the DJ was 0.24s which is below the 0.25s threshold for fast SSC as proposed by Schmidtbleicher (1992). 11 of 13 subjects scored below this threshold, with one subject scoring between 0.25s and 0.3s and one subject scoring over 0.3s. The mean CT in the CMJ was 0.82s with all 13 subjects scoring drastically higher than the 0.25s threshold. The mean CT in the CMJ was observed to be significantly higher than in the DJ, with a very large effect size ($p < 0.01$, ES = 3.2). This data suggests that the CMJ and DJ activities are appropriate representations of the slow and fast SSC respectively. While CT is not a direct measure of eccentric/concentric coupling time, the significantly shorter CT in the DJ suggests that this SSC activity is likely to have a faster eccentric and concentric phase and a shorter transition period between the eccentric and concentric phases compared with the CMJ. Previous research has suggested that fast eccentric phases are likely to stimulate the muscle spindle reflex to enhance concentric muscular contraction (Bobbert et al, 1987; Wilson et al, 1991). It has also been demonstrated that the shorter the transition period between the eccentric and concentric phases, the greater the potentiation effect in the concentric contraction (Bobbert et al, 1987; Wilson et al, 1991). In accordance with this previous research, we speculate that the significantly slower CT observed in the CMJ in the present study, casts doubt as to whether these two mechanisms (the muscle spindle reflex and elastic energy contributions) could be as active in this slow SSC performance compared with the fast SSC activity of the DJ.

Figure 1 displays JH, RSI and Fypeak in the CMJ and DJ. Subjects jumped significantly higher in the slow SSC activity compared with the DJ, with a large effect size ($p < 0.01$, ES = 0.9). Previous research examining performance between CMJ and purely concentric squat jumps (Bobbert et al.,1996) and between SSC and concentric only squatting exercise have suggested that the muscle spindle reflex and elastic energy contributions are not as active in slow SSC activity and that increased performance is due to long CT allowing for the musculature to develop a higher level of active state and also being afforded an increased time to develop force. These mechanisms may explain why the performance outcome of JH was greater in the CMJ than the DJ.

While JH was reduced in the fast SSC activity, subjects did produce significantly greater Fy_{peak} ($p < 0.01$, ES = 4.5) and scored much higher on the reactive strength index ($p < 0.01$, ES = 3.5). In any given jumping action, the RSI is an index derived from the height of the jump and the time spent developing the forces required to make that jump. Young (1995) has described the RSI as an individual’s ability to change quickly from an eccentric to concentric contraction and can be considered as a measure of “explosiveness”. Explosiveness can be considered as a coaching term which describes an athlete’s ability to develop maximal forces in minimal time (Zatsiorsky & Kraemer, 2006). This data illustrates that the DJ is a faster, more explosive jumping task than the CMJ and generates far greater ground reaction forces. While the outcome measure of JH was higher in the CMJ task, the RSI data indicates that the magnitude of increase in JH was not proportional to the increased time spent generating the necessary forces to achieve such a jump. Jump height in the DJ was lower but the jumping action was performed far quicker and is a much more explosive activity.

Table 1: Mean (± S.D.) and range of CT for the CMJ and DJ. * denotes significant difference observed between CMJ and DJ ($p < 0.01$).

	Mean (s)	Minimum	Maximum
CMJ	0.82 (± 0.18)*	0.50	1.041
DJ	0.24 (± 0.05)*	0.21	0.389

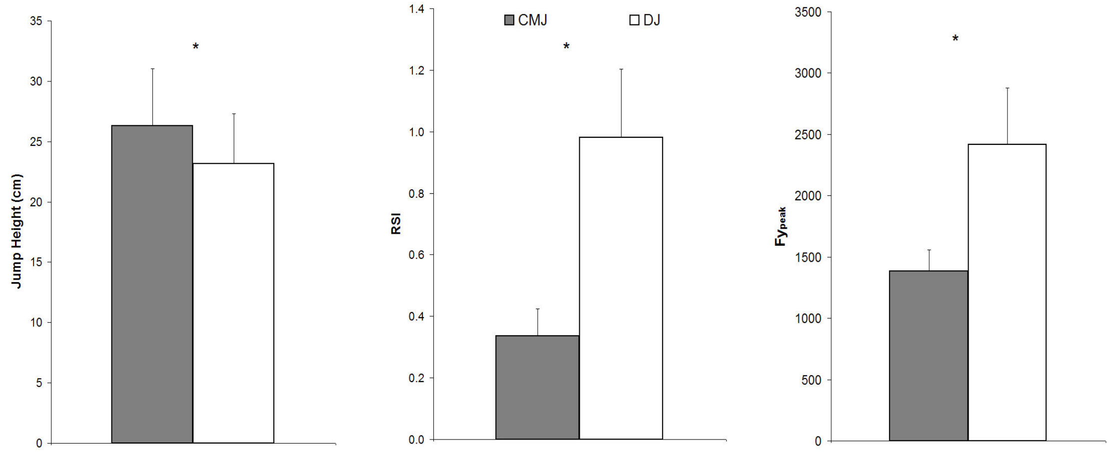

Figure 1: Mean (± S.D.) JH, RSI and Fy_{peak} in the CMJ and DJ. * denoted significant difference observed between CMJ and DJ ($p < 0.01$).

Figure 2 displays the correlation between the RSI measured in the slow and fast SSC activities. A statistically significant correlation was observed ($r = 0.59$) however considering the similar nature of these tasks, this is representative of a very weak correlation as performance in one task does not account for 65% of the variability present in the other ($r^2 = 0.35$). This indicates that performance in the slow SSC is a poor predictor of performance in the fast SSC and vice versa. This suggests that the slow and fast SSC may represent different action patterns and may be underpinned by different contributing mechanisms. The principle of specificity suggests that practice in one of these tasks may not accrue major benefit in the other. The CMJ test may be a more appropriate testing or training method for athletes where increased jump height is the primary training goal or for athletes in sports with prolonged ground contact phases such as cross country skiing. The DJ may be a more appropriate test or training method for athletes where more explosive performance is required or for athletes in sports with short ground contact phases such as sprinting.

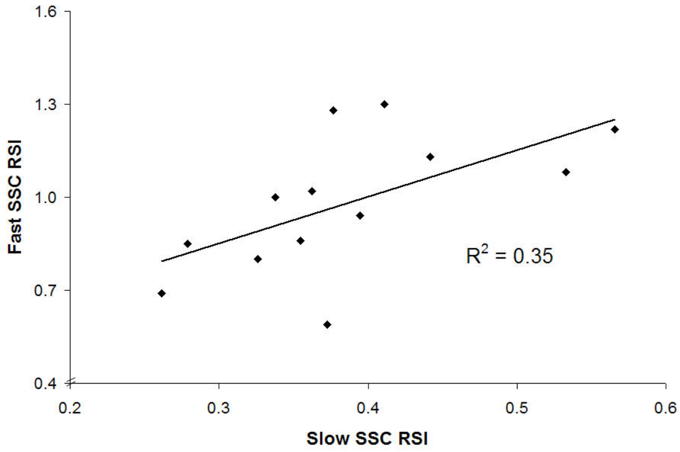

Figure 2: Mean RSI in the fast SSC vs. mean RSI in the slow SSC. R^2 = 0.35

CONCLUSION:

The data presented here is largely in agreement with Schmidtbleicher's previous assertion that fast and slow SSC activity can be identified through examination of ground contact phases. In the DJ task, mean CT was 0.24s with 11 of 13 subjects under Schmidtbleicher's proposed 0.25s threshold, while in the CMJ jump activity all CTs were above this cut-off point and significantly greater than CT in the DJ. Analysis of these slow and fast SSC activities revealed that the CMJ is a slow movement but one which maximizes jump height, while the DJ is a faster, more explosive activity in which much greater peak ground reaction forces are developed. Weak correlation was observed between RSI in the slow and fast SSC task suggesting that, in accordance with the principle of specificity, there may be limited transfer of training adaptation between slow and fast SSC training. This data demonstrates that careful consideration to the principle of specificity should be given when using the CMJ or the DJ as a testing tool or as a training exercise.

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