ELECTROMECHANICAL DELAY AND REACTIVE STRENGTH INDICES OF SPRINT AND ENDURANCE TRAINED ATHLETES

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This study compared reactive strength indices and electromechanical delay in muscle of competitive sprint and endurance athletes. Reactive strength indices were obtained from five sprinters and six endurance athletes who completed drop jumps on a force-sledge apparatus at various drop heights. Electromechanical delay times were also obtained on the ankle plantar flexors while performing a simple heel raise activity. The results indicated that sprinters had significantly higher RSI scores at all drop heights. Sprint athletes also had significantly shorter electromechanical delay times indicating a capacity for generating force more rapidly and the likelihood of stiffer musculotendinous structures.

KEY WORDS: Muscle-tendon stiffness, running, stretch shortening cycle, jumping

INTRODUCTION: In athletic activities such as running and jumping, the ability to generate force quickly through the musculotendinous structures is critically important. Reactive Strength Index (RSI) can be defined as the ability to change quickly from an eccentric to a concentric contraction, (Young, 1995), and encompasses the ability of the neuromuscular system to produce the greatest possible impulse in the shortest possible period of time. It is usually determined as height jumped divided by ground contact time. The qualitative expression of reactive strength index is thought to be "dependent on the structures of the innervation pattern and the training state of the musculotendinous structures in terms of their contractile and elastic qualities" or could be described as the "capacity of dynamic realization" Schmidtbleicher (1985). Reactive strength index was developed as a performance measure that could be utilised by coaches as it was simple, and gives a valid interpretation of the ability of the athlete to produce their greatest impulse in a short period of time. McClymont and Hore (2003) stated that "the test provided an effective and useful tool in the preparation of elite athletes". Large variation exists in the use of reactive strength index by coaches. However, in practice RSI tests are often used with little control of extraneous movements of the upper body during jumping activities and this introduces sources of unwanted variability in the measurement. Such sources of variation can be controlled by measuring RSI using a force sledge apparatus as described by Komi (1992).

The role of muscle stiffness in controlling performance in running and jumping has been described using linear spring mass models and there is strong evidence that leg-spring stiffness is related to cadence and running speed, (McMahon and Cheng, 1990). Leg spring mass models assume the numerous musculoskeletal springs combine so that the entire musculoskeletal system can act as a single linear spring (McMahon and Cheng, 1990). Such models do not isolate the structural spring mechanisms such as the tendon from the contractile elements, therefore the contribution of structural elements to leg-spring stiffness remains unknown. The electromechanical delay (EMD) during muscle contraction gives an indication of the musculotendinous stiffness that is one of many aspects that contribute to leg stiffness. "In general the passive joint stiffness, the intrinsic muscle stiffness and stretch reflexes each contribute significantly to the net joint stiffness" Arampatzis et al, (2001). Winter and Brookes (1990) have shown that the compliance or stiffness of the musculotendinous structures can be effectively estimated by determining electromechanical delay (EMD). Furthermore, Winter and Brookes (1991) proposed the EMD can be subdivided into two periods, one representing the delay between muscle activation and force registration (FDT) and the second period representing Elastic Charge Time (ECT) which describes the delay between the first registration of force and movement. It is proposed that ECT is affected by the compliance of the musculotendinous structures.

The purpose of this study was to compare the RSI performance and EMD times in sprint athletes with endurance athletes and in doing so, examine the link between stretch – shortening cycle performance and musculotendous compliance or stiffness.

METHODS: Eleven competitive intervarsity or national level athletes participated in this study. The subjects were separated into two groups: Group 1 consisted of 3 male and 2 female sprint athletes and Group 2 consisted of 3 male and 3 female endurance athletes. The study had obtained ethical approval from the University Research Ethics Committee and written informed consent was obtained from all subjects prior to their participation in the study.

Table 1 Physical characteristics of the subjects.

Group		Age (years)	Height (m)	Mass (kg)
Sprint	Mean (±SD)	27.5 (±3.96)	1.73 (±0.09)	67.0 (±10.2)
Endurance	Mean (±SD)	29.0 (±5.12)	1.73 (±0.07)	63.5 (±10.9)

All subjects completed a simple heel raising activity to obtain estimates of EMD as described by Winter and Brookes (1991). In this procedure, subjects sat on a plastic chair with a 90° angle at the knee joint. The ball of the foot was rested on the edge a force plate and the remainder of the foot on the floor. A foot switch was placed under the heel of the foot and EMG electrodes were attached to detect changes in electrical activity from the soleus muscle. On the command, 'Go' subjects were required to raise their heel as fast as possible. EMG analysis was performed using a BioPac/Powerlab 2/20 system (AD Instruments). The change in activation of the muscle was determined by inspection of the EMG records. Following pilot work, a change of ±0.015 mV in the EMG signal was used to indicate increased muscle activation. The instant of foot plantar flexion force was detected from the force platform records and the heel movement was detected by the foot-switch. EMD was defined as the time period between muscle activation and heel movement. Elastic Charge Time (ECT) was defined as the time interval between the registration of force on the force platform and movement of the heel. Force development time (FDT) was defined as the time interval from the muscle activation to the registration of increased force and was calculated by subtracting the ECT from the EMD time, (Winter and Brookes, 1991). Subjects completed 10 trials with approximately 30 to 60 seconds between trials.

All subjects completed five single leg drop jumps at each of 30 cm, 40 cm and 50 cm drop heights on their preferred leg. All jumps were performed on a force-sledge apparatus. This consists of a sledge with attached chair sliding on a fixed track inclined at 30° to the horizontal. A winch with a quick pull-release mechanism is located at the top of the track. This can be attached to the sledge and used to hoist subjects to desired heights for dropping. A force plate is positioned at right angles to the base of the track. Subjects were instructed to jump maximally and to minimise their ground contact time. Subjects were secured in the chair with a harness and straps at the waist and shoulders to prevent any upper body movement during the jumps. Ground reaction force measurements were obtained for each jump using an AMTI force plate which sampled at 1000 Hz. Instants of initial foot contact, take-off and landing were identified using from the ground reaction force traces. Flight time (FT) was calculated as the time between take-off and landing. Ground contact time (CT) was defined as the time between initial foot contact and take-off. Reactive Strength Index (RSI) was defined as the ability to change quickly from and eccentric to concentric contraction (Young, 1995). In the derivation of RSI an intermediate calculation of jump height was required and this was estimated from FT. Since the sledge rails were inclined at 30°, gravity related force acting down the rails was g/2 and therefore the Height and Reactive strength Index (RSI) were calculated from using the equations:

$$Height = \frac{9.81 \times FT^2}{16} \quad ; \qquad RSI = \frac{Height}{CT}$$

Statistical Analyses: All statistical analysis of the data was carried out in SPSS © (Release 12.0.1). A general linear model (GLM), split plot ANOVA with repeated measures was used to determine significant differences in RSI scores between drop heights and between sprint and endurance group. A second GLM ANOVA was carried out on the EMD results to determine differences between sprint and endurance groups on EMD, ECT and FDT scores.

RESULTS AND DISCUSSION: Figure 1 presents the results of the EMD analysis on sprint and endurance groups. Winter and Brooks (1991) proposed that FDT is an indication of the conduction of the action potential along the T tubule and the subsequent release of calcium by the sarcoplasmic reticulum, and ECT is the time between the development of tension and actual movement. The results of this experiment indicated that no significant difference was found between sprint and endurance groups for FDT but there were differences for EMD and ECT. These results suggest that the shorter EMD and ECT times are indicative of greater musculotendinous stiffness in sprinters compared to endurance runners. This finding is consistent with Wilson, et al (1994) who proposed that "a stiffer musculotendinous system should conceivably improve the initial rate of force development".

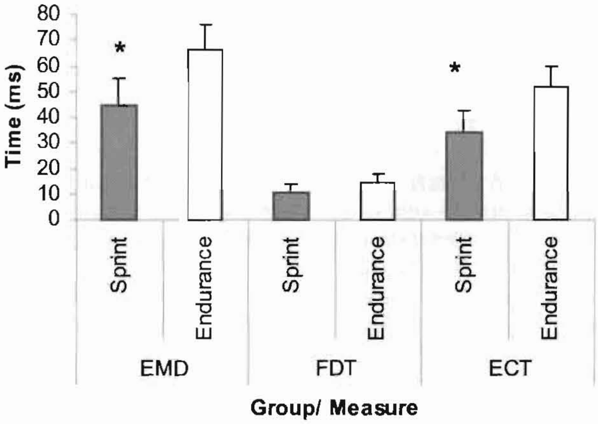

Figure 1 Mean EMD, FDT and ECT scores with 95% Confidence intervals for sprint and endurance groups. (* indicates a significant difference between groups).

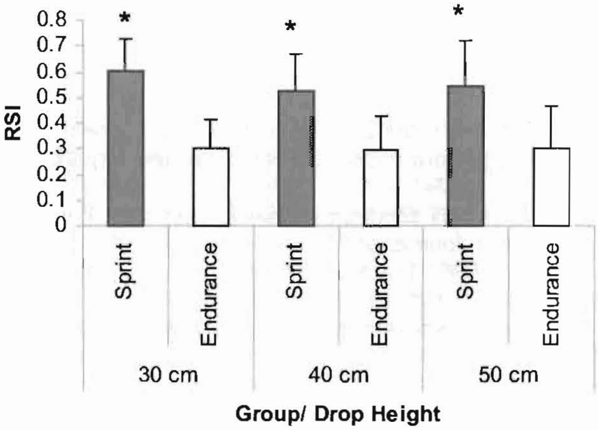

Figure 2 Mean RSI scores with 95% Confidence intervals for sprint and endurance groups while performing drop jumps at 30 cm, 40 cm and 50 cm. (* indicates a significant difference between groups).

Figure 2 presents the results of the RSI test and indicates that there were significant differences in RSI between sprint and endurance groups at all drop heights, ($p < 0.05$). No significant differences were found between drop heights in RSI or height ω group interaction. The results showed that sprint athletes were capable of generating higher RSI's at all drop heights compared to endurance athletes and this indicates that sprinters are capable of generating higher impulses in shorter time periods.

Taken together the results of the EMD analysis and the RSI results provide evidence that musculotendon compliance/stiffness may play a significant role in the rate of force generation in jumping or running activities. The importance of leg stiffness in running has been variously demonstrated by Farley and Ferris (1997), Arampatzis et al (1999) and Kerdok et al (2002), however, measures of stiffness in these studies applies to the overall stiffness of the leg as a spring mass model in running. The results of the EMD analysis indicate that in addition to the important role that muscle plays in controlling the leg-spring stiffness in running, the structural elements of the muscle and tendon also have a significant contribution to stiffness control in running and jumping. Further work to determine the trainability of musculotendinous stiffness using similar measurement techniques is recommended.

CONCLUSION: This study shows that sprint athletes generate significantly higher RSI and lower EMD times compared with endurance athletes. This suggests that musculotendon stiffness plays an important role in controlling leg stiffness in maximum effort running and jumping.

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