LEG STIFFNESS CHANGES IN DROP JUMPS WITH DIFFERENT STRETCH AMPLITUDE

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The purpose of this study was to investigate the adjustment of leg stiffness and the relative electromyography (EMG) magnitude of different phases with shallow and deep drop jump (DJ) in order to understand the neuromuscular and contraction characteristics of different stretch amplitudes of SSC movement. There were 12 subjects tested in this experiment including jumpers and volleyball players whose ages are 20.5±1.93, heights are 181.01± 6.23cm and weights are 71.95±4.93Kg. Kistler forceplatform, PEAK high speed video camera and EMG Biovision system were used to record the ground reaction force, kinematics data and the EMG-signals of gastrocnemius and rectus femoris. The results of this study were that the leg stiffness between two different drops jump had the significant difference at the concentric and transmission phases in the progressive loads ($p<0.05$). It was suggested that the result observed was the interventions of stretch reflex which favor the transmission of force and release of stored energy. However, autogenetic inhibition of the tonic stretch reflex occurred at the 80cm of drop height. It was recommended to avoid the high load intensity which had the disadvantages for the enhancement of plyometric training.

KEY WORDS: leg stiffness, EMG magnitude, stretch reflex.

INTRODUCTION: Plyometrics is the training, according to the mechanism of stretch-shorting cycles (SSCs), improving muscle power output(Norman & Komi 1979;Komi 1984). The potentiation induced by the prestretch of SSC is favored by the muscles to build up a high level of active state at the beginning of the positive work (Bosco & Viitasalo, 1982) and the positive initial force allows the muscle to produce more work in the start of the shorting phase (Bosco *et al.*, 1987). In addition to the efficiency of the prestretch, many researches suggested that the stored elastic energy also enhanced work and efficiency in the SSC(Marsh, 1994; Marsh & John-Alder, 1994; Komi, 1992; Komi & Bosco,1978), even if although there is no decisive evidence to either or reject the claim(Van Ingen-Schenau et al., 1998). Stretch reflex may play an important role during SSCs. Because of the prestretch that triggers spinal reflexes and longer latency response, the increased muscle stimulation generates the higher level of muscular activation (Bobbert *et al.*, 1996; Komi, 2000). It has been suggested that induced stretch reflex during the eccentric and transmission phase of SSC may be one of the factors for the modulation of musculotendinous stiffness (Andreassen,1981; Houk, 1978) which also represented the actual state in the contractile machinery of the muscle, with the filament overlap between actin and myosin, and then closely related to the force production(Ford *et al.* 1986). In vivo measurement(Cavagna & Citterio, 1974), the series elastic component (SEC) tends to meet two opposite requirements (a) an increase in stiffness during stretching which will favor a better transmission of force and will reduce the transmission time, and (b) a decrease in stiffness during shorting that will allow a better release of potential energy. This result was obtained in isolated and whole muscles (Bressler *et al.*, 1988; Stienen & Blange, 1981). Recently, the spring-mass system was used to investigate the average stiffness of the lower extremity (Ferris 1999, Ito *et al.*, 1983; Alexander, 1988; Farley *et al.*, 1991; Blickhan & Full, 1993; McMhaon & Cheng, 1990), and so it was reasonable that represented the whole musculotendinous stiffness of the lower extremity (Farley *et al.*, 1993). The purpose of this study was to investigate the adjustment of leg stiffness and the relative electromyography (EMG) magnitude of different phases with shallow and deep drop jump (DJ) in order to understand the neuromuscular and contraction characteristics of different stretch amplitudes of SSC movement.

METHODS: There are 12 subjects in this experiment including jumpers and volleyball players whose ages are 20.5±1.93(y/o), heights are 181.01±6.23cm and weights are 71.95±4.93Kg. Kistler forceplatform (1200Hz), PEAK high speed video camera (120Hz) and EMG Biovision system (1200Hz) were used to record the ground reaction force, kinematics data and the

EMG-signals of gastrocnemius and rectus femoris. The intensity of external load was designed by 20cm, 40cm, 60cm and 80cm drop height and the angular displacement of knee joint with shallow drop jump (SDJ,<75rad) and deep drop jump (DDJ, >85rad) was asked to perform. The best performance out of three trials separated in two drops jump at every height-drop was used for analysing EMG, kinematics and leg stiffness. The EMG signal was full-wave rectified and then bandpass filtered at 10~400Hz. The stretch reflex and transmission phase was separately defined as the 30~120ms (Toft *et al.*, 1991) and 5% duration time of maximum angular displacement of knee joint (Gollhofer *et al.*, 1990) following the ground contact. Leg stiffness (K_{leg}) was calculated from the ratio of the ground reaction force to the displacement of the leg spring ($\triangle L$) during the contact phase. From the force-deformation relation (Figure1), we adopted the slope of ab curve to define the stiffness (K_{ecc}) of stretch reflex phase, slope of ac curve to define the stiffness (K_{tran}) of transmission phase, and the slope of cd curve to define the stiffness (K_{con}) of concentric phase.

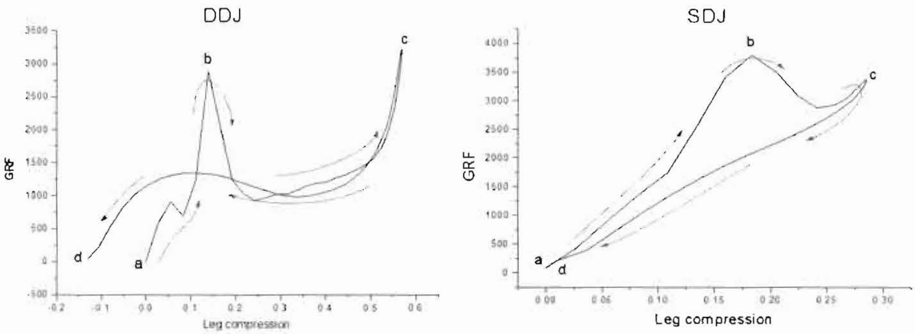

Figure 1. The force-deformation relation of leg spring with different two DJ.

RESULT AND DISCUSSION: The result found is that SDJ had higher leg stiffness during SSC movement. Especially, during the transmission and concentric phases, K_{tran} and K_{con} had significant higher values of SDJs than that of DDJs (p<.05). This result supported the suggestion of Canvana considered that increased muscle stiffness during the transmission phase will favor a better transmission of force and reduce the transmission time. In this study, we also found that the average transmission time of SDJ (5.42±0.35ms) was much shorter than that of DDJ(12.89±0.22ms). We monitored the stretch reflex by EMG patterns to explain the adjustment of leg spring stiffness during different stretch amplitudes of SSC movement. In order to generate more power to react to perturbations, the muscle needs to be spring-like, In order to react appropriately;the stretch reflex helps the muscle achieve this capability(Enoka, 1994). The timing of stretch reflex intervened had been reported by many authors (Bergui *et al.*, 1992;Dietz *et al.*, 1979, 1981;Fellow *et al.*, 1993;Lee & Tatton, 1978;Matthew, 1991), however, the 30~120ms latency of stretch reflex phase of this study included the short-latency of M1, medium-latency of M2 and fewer part of M3 (Toft *et al.*, 1991). In the figure 3, the average EMG magnitudes of SDJ at the stretch reflex and transmission phase were higher than that of DDJ;it was reasonable that stretch reflex stimulated the muscular activities because of the higher load intensities with SDJ. Furtheremore, the modulation of leg stiffness at the eccentric and transmission phase was mainly determined by the stretch reflex. During the concentric phase, the SDJ seems to have lower average EMG magnitudes, which was because of the help of larger stored elastic energy; the muscle did not have to be forced to contract vigorously, so the EMG activity of concentric phase was reduced. Therefore, the smaller relative EMG magnitude demonstrated SDJ could utilize elastic energy more efficiently than that of DDJ. From the facts above, it is recommended to adopt the method of SDJ to induce a stronger SSC mechanism with stretch reflex. The result also implied that autogenetic inhibition of the tonic stretch reflex occurred at the 80cm of drop height, because of the over-lengthening of the muscles, this may cause the detaches of the cross-bridges and inhibition reflex. It was recommended to avoid the high load intensity which had the disadvantages for the enhancement of plyometric training.

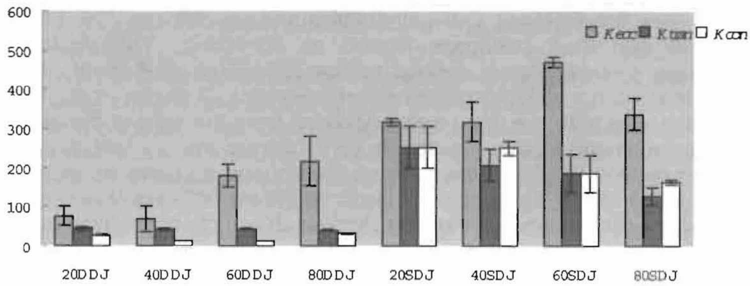

Figure 2. The leg stiffness of two different drop jump during the phases.

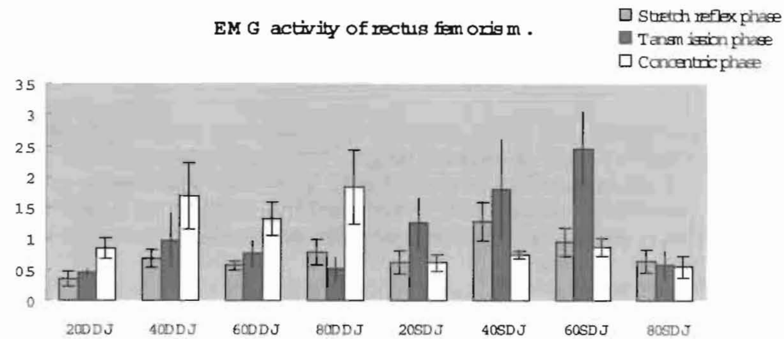

Figure 3. The comparison of EMG amplitude of rectus femoris m. between DDJ and SDJ.

CONCLUSION: Despite the fact that many experts argue that SSC plays an important role in enhancing muscle force and power output in explosive movement, the measurements of the reuse of stored elastic energy and efficiency in SSC are still difficult. The benefits of stretch reflex recruited the muscles fibers to adjust the musculotendinous stiffness were identified. In the two different drop jump, the shallow drop jump showed the benefits of induced SSC mechanism. It is recommended to adopt the method of SDJ to induce a stronger SSC mechanism with stretch reflex.

REFERENCES:

Latash ML, Zatsiorsky VM (1993). Joint stiffness. Myth or reality? *Hum Move Sci*, **12**, 653-692.

C. Bosco and Paavo V. Komi (1979). Petentiation of the mechanical behavior of the human skeletal muscle through prestretching. *Acta Physiol Scand*, **106**, 467-472.