Muscle activation patterns and efficiency of high jump take-off

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Introduction
The high jump is a demanding field event in which a jumper must tolerate extremely high impact forces during the take-off. The two main factors that determine highest position of the CM during flight path are CM height at the instant of toe-off and the vertical velocity of CM. Dapena (1990) has shown that the Vv of CM increases when the horizontal approach velocity (Vh) increases (r=0.79). However, there is an optimal Vh for every jumper that is not the same as the jumpers maximal Vh. If the velocity (impact force) is too high the spinal inhibition (golgi tendon organ) will occur. The purpose of the present study was the investigate how the increasing of the Vh changes the muscle activation patterns during the high jump take-off and how the EMG variables and neuromuscular control are related to the Vv production.

Methods
Ten male (age 24.3 ± 2.6 years, height 188.49 ± 4.5 cm, weight 76.56 ± 7.72 kg; mean ±s) high jumpers volunteered to participate in this study. The jumpers performed 5 jumps with a 4 step approach (short) and 5 jumps with full (8 steps, long) approach. Ground reaction forces were measured using a 13 m long force plate (Kistler and TR-test, sampling frequency 1 kHz). 3D –movement analysis (200 fps) was done with Peak Motus system. The EMG signals were recorded (sampling frequency 1000 Hz) with surface electrodes from gluteus maximus (GM), vastus lateralis (VL), rectus femoris (RF) and gastrocnemius (GA) muscles. The EMG signals were full-wave rectified and averaged. The averaged EMGs were computed for 15 phases (25 ms time interval windows) during the pre-activation and take-off phases. The EMG amplitudes were then normalized to the average activities of two consecutive contacts that were recorded during maximal sprinting. Stepwise multiple regression analysis was used to examine the relationships between variables. The paired samples T-test for the repeated measurements was used for the comparison between the approaches.

Results
Horizontal velocity increased from 5.33 ± 0.39 m·s⁻¹ to the 6.08 ± 0.86 m·s⁻¹ when length of approach increased from the short to the long. The Vh was significantly correlated (r=0.76, p<0.001) with Vv. CM peak heights were 1.91 ± 0.12m (short) and 1.97 ± 0.17 m (long) respectively. The muscle activation patterns were similar (fig 1.) in both cases (short vs. long) when comparison was done subject by subject. The regression analysis showed that the jumpers’ CM vertical velocity (toe-off) correlated (r=0.52, p<0.001) with GA pre-activation and VL activity (r=0.56, p<0.001) during the short latency reflex phase (25-50 ms after contact). At the instant of the lowest knee angle (50-75 ms) the GA activation correlated negatively (r=-0.56, p<0.001) to the Vv.

Conclusions
The results of the present study confirm that the muscle activation models of the take-off are pre-programmed but not the approach velocity dependent. However the regression analysis shows clearly that jumpers with highest vertical velocity are using muscle activation models that contain high pre-activation and high activity during the short latency reflex phase (25-50ms). Thus the short range stiffness is very high during the impact / eccentric phase and this creates good possibilities to store elastic energy to the muscle-tendon complex and recoil it during concentric phase. This would favour increase of the Vv. This study supports the idea that pre-programmed muscle activation patterns includes also the regulation model (via γ –activation) to increase muscle spindle sensitivity to the stretch.

References
Dapena J., McDonald C, Cappaert J. International Journal of Sport Biomechanics, 1990, 6, 246-261