JOINT MOMENTS AND NEUROMUSCULAR FUNCTIONING IN DROP JUMP EXERCISES

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INTRODUCTION: In sport movements, such as sprinting and jumping, where the ability to produce explosive movements is extremely important, the elastic characteristics of the muscle-skeletal system are decisive (Alexander & Ker, 1990) (Anderson & Pandy, 1993). While the utilization of elastic energy was criticized for Counter Movement Jumps (CMJ) (van Ingen Schenau et al., 1997) during the performance of the drop jump (DJ), the imposed mechanical load formed the condition for elastic energy storage during the eccentric phase and its reutilization during the concentric phase. It is clear that the effectiveness of the stretch shortening cycle (SSC) requires three conditions: preactivation of the muscles preceding the eccentric phase, a short and fast eccentric phase and a short delay between eccentric and concentric actions. These conditions require a high level of muscular stiffness which has been found to be present with active reflex functions associated with muscle length variations, within the limits of short range elastic stiffness (SRES) (Gollhofer et al., 1992). The purpose of this study was to analyze the adaptation of the stretch reflex component of the activation of the neuromuscular system to the increase of the mechanical load, both in the stretching and push-off phases. This was studied through the analysis of the reflex activation phase of the electromyographyc (EMG) pattern. These changes were related to joint moments of force and to the relative length changes of some of the extensor muscles.

METHODS: Ten elite sprinters (height 182±5 cm, body mass 75.3±4.5 kg, 100 meters best 10.4±0.2secs) performed 6 DJ from 25, 40, 55 and 70 cm. EMG signals and ground reaction forces were A/D recorded at 1000Hz (Biopac MP100). EMG's from tibialis anterior (TA), Soleus (SOL), gastrocnemius (GAS), rectus femoris (RF), vastus medialis (VM), semi tendinosus (ST), biceps femoris (BF) and gluteus maximus muscles were recorded using bipolar active electrodes (30 mm inter-electrode distance) and a telemetric system (Glonner Biotel 88). The EMG signals were full wave rectified and integrated (IEMG) over different functional phases: pre-activation (PRE) (100 ms prior to contact), reflex induced activation phase (RIA) (from 30 ms to 110 ms after contact) and Late EMG Response phase (LER) (from 100 ms to the end). Vertical peak and vertical net impulses were calculated. Simultaneously, angular kinematic data of the ankle, knee and hip joints were calculated using a video analysis system (120 Hz). Each EMG signal was inspected for mechanical artifacts, and the vertical reaction force signals were inspected in order to detect Fz force peaks indicating a heel impact against the ground. If this was the case the trial was repeated.
Joint net moments from hip, knee and ankle were calculated using an inverse dynamics method. Visser model (Visser et al.,1990) was used to calculate the relative length changes (%L) of gastrocnemius (GAS), rectus femoris (RF) and biceps femoris (BF) muscles. After time normalization; force, position angle and the percentage of muscle length signals were averaged for each jumping condition. Statistical analysis of the differences between jumping heights were

tested for significance using Student's T-test for paired comparisons, and a 0.05 level of confidence was accepted.

RESULTS: The jumping performances did not show statistical differences among the four conditions, considering the net impulse and mechanical work variables. Nevertheless, the higher net impulse and total mechanical energy at the end of the push-off phase were obtained during the DJ55 trials and DJ70 trials.

Table 1 - Vertical net impulse and vertical force peak, contact time and height of rise of the CG.

	Downward Movement				
		DJ25	DJ40	DJ55	DJ70
$N.s.kg^{-1}$	Net Imp.	2.3 ±0.2	3.2 ±0.3	3.6 ±0.5 *	4.2 ±0.4 *†‡
	Push-off Phase				
$N.s.kg^{-1}$	Net Imp.	3.0 ±0.6	3.2 ±0.7	3.4 ±0.2	3.4 ±0.4
N	Fz max	3660±143	3800 ±125	4929 ±163	5570 ±148 †‡
Ms	Contact time	180.0±7	183.5±6	185±6	182.7±12
Cm	CG rise height	47.8±2	49.1±1	50.2±2	50.0±3

* The value of DJ70 and DJ55 differs from the value of DJ25.
† The value of DJ70 differs from the value of DJ40 and DJ25.
‡ The value of DJ70 differs from the value of DJ25.

Considering all three joints, the initial and final angular positions as well as total angular movement presented similar values in all jumping conditions. On the same line, no differences were detected in hip angular velocity among the four conditions. However, the negative peak values of the angular velocity increased for both ankle and knee joints as dropping height increased.

During the push-off phase ankle and knee angular velocities attained higher values at DJ55.

Gollhofer et al. (1992) discussed the elastic behavior of the muscle tendon complex as a function of short range elastic stiffness (SRES). The range of imposed muscle length changes play a major role determining the limits of these elastic properties, apparently when length changes attained values over 8% of the resting length of the muscle, the stretch load is excessive, and the muscle tendon complex tends to present a reverse energy balance. Our results showed that the total length changes of the gastrocnemius muscle increased slightly from 4.07% at DJ25 to 7.5% at DJ70 during the lengthening phase. A similar behavior was observed in the rectus femoris with average values increasing from 4.7% at DJ25 to 7.8% at DJ70. The values attained by the total length changes of the biceps femoris muscle were slightly higher when compared with the length changes obtained from GAS and RF. Total %L change in BF, during the lengthening phase, varied from 5.0% at DJ25 to 8% at DJ70. Nevertheless these values are inside the SRES.

Figure 1 presents averaged signals of force (Fz) and rectified EMG’s (REMG) of gluteus maximus (GM), biceps femoris (BF), rectus femoris (RF), vastus lateralis (VL), gastrocnemius (GAS) and soleus (SOL), with the three functional phases defined by the dashed vertical lines. The RIA phase was defined from 30 ms to 110 ms after contact, in agreement with the short and medium latency stretch reflexes for VL, and RF (Horita et al., 1996) and a compromise with the quasi-isometric phase period for the triceps surae (Gollhofer et al., 1992).

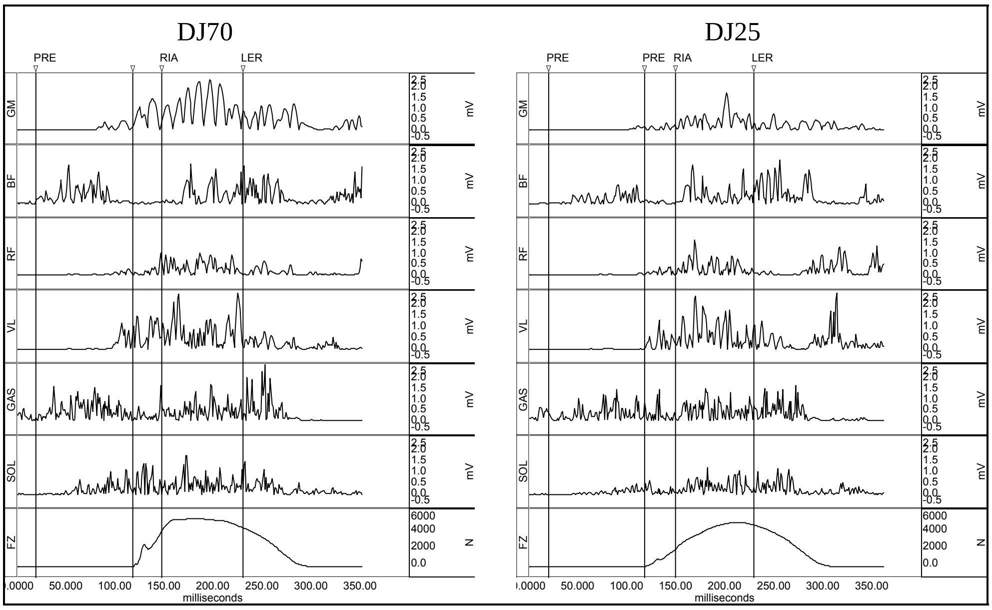

Figure 1 - Averaged signals of force (Fz) and rectified EMG's (REMG) of gluteus maximus (GM), biceps femoris (BF), rectus femoris (RF), vastus lateralis (VL), gastrocnemius (GAS) and soleus (SOL), On the left panel DJ70 on the right pane DJ25. Note the increase of REMG on the RIA phase muscles during DJ70.

Table 2 - Results for the integrated EMGs (IEMG) for the three functional phases, pre-activation, 100 ms prior to contact, reflex induced activation for 30 ms to 110 ms after contact, late EMG response, more than 110 ms after contact. For gluteus maximus (GM), biceps femoris (BF), rectus femoris (RF), vastus lateralis (VL), gastrocnemius (GAS) and soleus (SOL), SD values were omitted for clearance. IEMG units: mV*ms.

DJ		GM			BF			RF			VI			GAS			SOL	
	PRE	RIA	LER	PRE	RIA	LER	PRE	RIA	LER	PRE	RIA	LER	PRE	RIA	LER	PRE	RIA	LER
25	5.4	40	22	20	28	21	3.1	30	23	7.6	63	40	44	40	25	12	42	25
40	6.2	42	25	22	29	20	5.2	36	23	8.5	64	37	44	39	25	15	37	37
55	6.8	47	24	23	31	27	5.6	31	17	10	59	27	45	37	26	19	37	27
70	7.8	52	21	24	34	26	6.7	38	21	14	73	31	43	37	25	21	37	29

The IEMG of the three functional phases studied are shown in Table 2. Semi-tendinosus (ST) and tibialis anterior (TA) were omitted because they present a clearly antagonistic pattern with the extensor muscles. ST was slightly active only during PRE. TA probably plays a role on the control of pronation in the earlier part of contact (Veloso et al.1994).

The IEMG value of the PRE phase was high for BF, GAS and SOL and did not increase with stretch load. The IEMG of the RIA phase increased with the increase in dropping height for GM, BF, RF and VL. Statistical significance ($p<0.05$) was observed when DJ25 and DJ40 were compared with DJ55 and DJ70. For GAS and SOL the subjects maintained the same IEMG values for the increased stretching loads. For all these muscles the RIA phase presented higher IEMG values when compared with LER.

The peak values for hip, knee and ankle joint moments were similar for the four jumping heights. Nevertheless, a different joint moment/time curve pattern was obtained. On DJ70 the peak values of joint moments of the three joints were obtained earlier, coinciding with the stretching phase of the studied muscles. For DJ70 a slight decrease in the value of moments of force was observed during the ascending phase in the three joints.

CONCLUSIONS: The studied athletes were able to resist increasing stretching speeds and forces during the braking phase presenting the mentioned conditions for efficient SSC. This ability is related to the increased capability of maintaining high levels of stretch reflex during the RIA phase, revealing the importance of the stretch reflex effect on increasing muscle stiffness. The increased muscular stiffness probably allowed the athletes to maintain the range of imposed stretch inside the short range elastic stiffness.

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