Muscle coordination in loaded squat jump

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Computer Methods in Biomechanics and Biomedical Engineering

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1. Introduction

Power-generating capacity is essential in explosive-oriented physical tasks (Newton et al. 1999). Its assessment could help us to understand the basic properties of the neuromuscular system (Cronin et al. 2005). Vertical jump is one of the most common and simple means used to evaluate maximal power (Vandewalle et al. 1987). However, the loading condition that maximises the resulting power output in squat jump exercise is still a matter of debate in the literature (Cormie et al. 2011). Although previous investigations have reported that the mean electromyographical (EMG) activity remains relatively stable as load increases during the concentric phase (i.e. push-off) of a vertical jump (Eloranta 1996; Nuzzo and McBride 2013), the activation timing could be affected differently by external load. Therefore, this study aimed to investigate the neuromuscular coordination of the lower limb muscles involved during squat jumps performed under different isoinertial loading conditions.

2. Methods

A total of 20 (7 females, 13 males) trained athletes (age: 25.1 ± 4.5 years; height: 177.8 ± 7.4 cm; body mass: 74.1 ± 11.9 kg) participated in this study. They performed squat jumps in seven loading conditions: 0%, 10%, 20%, 30%, 40%, 50% and 60% of the maximal additional load the participants were able to lift concentrically once (1RM). Mechanical parameters were recorded using a force platform in time with EMG activity, recorded wirelessly from seven muscles (soleus (SOL), gastrocnemius lateralis (GL), tibialis anterior (TA), vastus lateralis (VL), rectus femoris (RF), semitendinosus (ST) and gluteus maximus (GMax)) of both legs. From the vertical ground reaction force, instantaneous force, acceleration, velocity, position and power were determined over the entire push-off phase duration. All EMG data were analysed as the root mean square (RMS) and normalised to the RMS obtained during maximal voluntary isometric contractions performed for each joint on a Con-Trex MJ (CMV AG, Duebendorf, Switzerland) isokinetic dynamometer. Analyses of variance were performed to compare mechanical and EMG patterns obtained during the jump push-off phase between loading conditions.

3. Results

3.1 Mechanical patterns

While peak force signifi increased (from 1962 ± 397 to 2559 ± 525 N; $p = 0.0001$), peak velocity (from 2.5 ± 0.2 to 1.6 ± 0.1 m.s$^{(1}$; $p = 0.0001$), peak acceleration (16.2 ± 2.0 to 6.6 ± 1.4 m.s$^{(2}$; $p = 0.0001$) and peak power (3770 ± 899 to 3491 ± 935 W; $p = 0.006$) decreased as external load increased. Peak force and peak acceleration occurred significantly later as load increased (from 54% to 69% of the push-off phase duration; $p = 0.0001$), whereas peak velocity and peak power occurred significantly earlier for heavy loads compared to light loads ($p = 0.0001$).

3.2 EMG patterns

Although a significant main effect of muscle (mean activity: $p = 0.004$; peak activity: $p = 0.58$) was observed on muscle timing and amplitude, these parameters were not affected by the load.

4. Conclusions

This study showed that in a ballistic movement carried out maximally, the changes in mechanical outputs with increasing load do not result from a reorganisation of the underlying neuromuscular activity. These results are in accordance with those reported in the previous studies (Eloranta 1996; Nuzzo and McBride 2013) but provide

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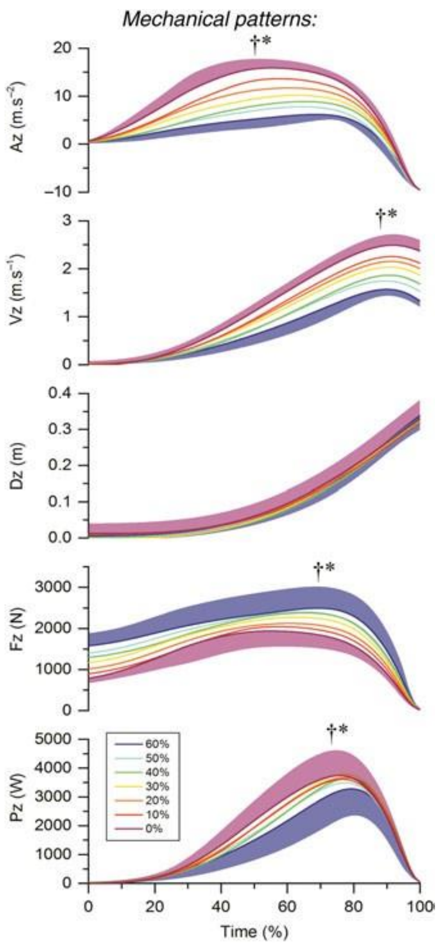

Figure 1. Time-course of vertical acceleration, velocity, position, force and power of the centre of mass during the push-off phase of squat jumps performed at 0% (red), 10% (orange), 20% (yellow), 30% (green), 40% (light blue), 50% (dark blue) and 60% (purple) of the 1RM. For the sake of clarity, SDs are presented for 0% and 60% of 1RM. †, significant main effect of load on peak value. *, significant main effect of load on peak time occurrence (Colour online).

supplemental information on EMG patterns of more muscles. This lack of load effect on the EMG patterns could originate from the fact that within the central nervous system, template motor programmes exist for specific classes of movements whose output are determined by the setting of specific parameters (i.e. timing, amplitude). A specific neuromuscular command would then be dedicated to maximal explosive ballistic efforts (Rodacki et al. 2002; Van Zandwijk et al. 2003). The present findings yield a new insight into the design of optimal isoinertial muscle training for power-oriented activities and in performance or rehabilitation settings.

Acknowledgements

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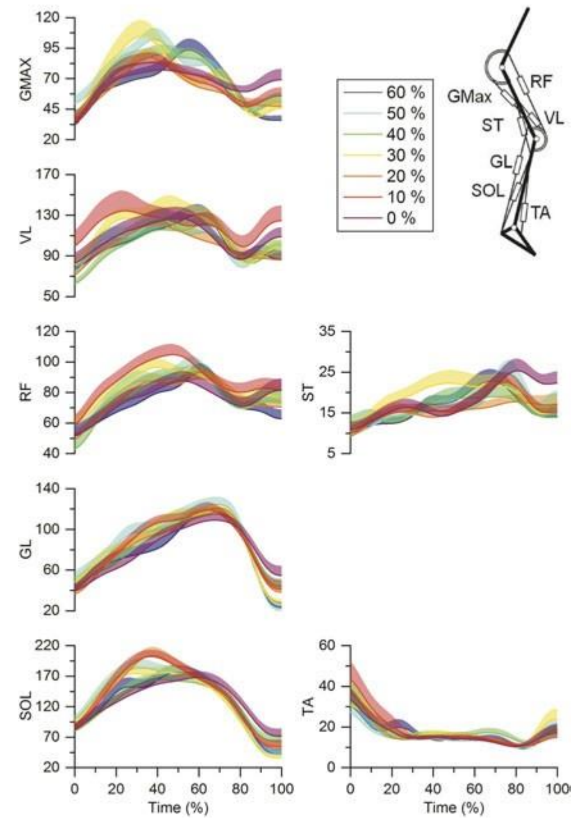

Figure 2. The EMG activity patterns during the push-off phase of squat jumps performed at 0% (red), 10% (orange), 20% (yellow), 30% (green), 40% (light blue), 50% (dark blue) and 60% (black) of 1RM. Data are pooled for both limbs and normalised to the maximal isometric root mean square value (RMS_{max}) for GMax, VL, RF, ST, GL, SOL and TA muscles and presented as mean þ SE (Colour online).

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