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Neuromuscular functioning of athletes and non-athletes in the drop jump

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Abstract In many sports vertical jumping is important. This study compared neuromuscular functioning of the lower extremity muscles together with some kinetic and kinematic parameters before and during ground contact in drop jumps from two heights [0.4 m (DJ40) and 0.8 m (DJ80)] in 7 highly trained triple-jumpers and 11 physically active controls. The triple-jumpers jumped 32% higher in DJ40 and 34% higher in DJ80, had shorter braking and total contact times, and greater average and peak vertical ground reaction forces than the controls. In both drop jumps in the electromyogram pre-activity of the vastus lateralis and gastrocnemius muscles started earlier in the jumpers than in the controls. For the control group the increase in dropping height was associated with a decrease in the propulsion force, and resulted in more extended knee and ankle angles at touch down and more flexed angles at the deepest position than for the jumpers. All angular displacements for DJ80 were larger than for DJ40 in the control group. The triple jumpers and control subjects differed with respect to their neuromuscular functioning in the drop jump exercise and they responded in a different way to the increase in dropping height.

Key words Jumping · Stretch load · Stretch speed · Specificity · training history

Introduction

In many sports, including ball games, track and field and ski jumping, vertical jumps, especially plyometric drills have been shown to play an essential role in increasing the explosive power of the lower extremities (Verhoshanski 1966). Among plyometric drills, which have also been known as stretch-shortening cycle drills (Steben and Steben 1981), drop jumping or depth jumping have been widely used (Wilt 1978). Executing a drop jump involves jumping down from a height and, upon landing, performing a maximal vertical jump. The lower extremity muscles perform a stretch-shortening cycle (SSC), during which it has been found the eccentric stretching phase influences the subsequent concentric shortening phase (Cavagna et al. 1965). During SSC, use of elastic energy and reflex activation of the neuromuscular system have been shown to be important for the production of power in the propulsive phase of the following jump (Bosco et al. 1982b).

The capability of muscle to store and use elastic energy has been found to depend on the muscle length and stretching speed (Cavagna et al. 1965), the force at the end of the stretching phase and the coupling time between the eccentric and concentric phases (Bosco et al. 1981). It has been reported that a rapid and short stretch (Cavagna et al. 1968), a high force at the end of the stretch and a short coupling time favour the use of tendomuscular elasticity (Bosco et al. 1982a, 1982c). Komi and Bosco (1978) have demonstrated that after the vertical dropping height reaches a certain level, the rebound jumping height declines. Viitasalo and Bosco (1982), however, have not reported any significant effects of dropping height on the following rebound jumping height among male students. The optimal dropping height has been found to be 0.66 m (Komi and Bosco 1978) and 0.4 m (Viitasalo 1982) for volleyball players, 0.63 m for male physical education students and 0.48 m for female students (Komi and Bosco 1978). Dropping heights as high as 1.1 m have also been reported (Bobbert 1990; Schmidtbleicher and Gollhofer 1982), being employed to create higher than optimal (in respect of jumping height) dropping heights and to produce an overload stimulus.

Myoelectrical activity (EMG) before and during the eccentric phase of contact has been found to be highly
correlated with the contact time, contact force and angular parameters in trained athletes (Aura and Viitasalo 1989; Viitasalo and Aura 1987). This has been suggested to be due to pre-programmed patterns, dispatched from higher centres in the nervous system (Melvill-Jones and Watt 1971). It has been found that the human locomotor system is taught to fit the muscle status of external demands (Dietz et al. 1979). Pre-activation has been shown to be important both for the enhancement of the EMG during the eccentric phase of the take-off and for the timing of muscle action with respect to ground contact (Moritani et al. 1991). The activation of the muscles regulates muscle stiffness. Stretching of an active, stiff muscle during the eccentric phase of take-off stores elastic energy in the cross-bridges and tendons. It has been shown that this elastic energy can be used during the concentric phase of muscle contraction (Cavagna et al. 1971). Thus, the effects of training on neuronal control mechanisms and on muscular spring characteristics are important.

Based on the specificity of training (e.g. Hortobagyi 1982) the functioning of the neuromuscular system and the biomechanical characteristics of jumping have been shown to differ among subjects with different training backgrounds (Komi and Bosco 1978; Kyröläinen and Komi 1995a, 1995b). The present study compared neuromuscular functioning of the lower extremity muscles together with some kinetic and kinematic parameters before and during ground contact in drop jumps from two heights. Comparisons were made between highly trained triple-jumpers, and physically active controls. Two dropping heights were used to produce two eccentric stretching speeds for the leg extensor muscles of the dominant leg. The pre-amplified EMG signals (60 dB, 10–500 Hz) were telemetrically (Glommer, Biomes 2000, cut-off frequency 360 Hz, 3 dB) transmitted to a magnetic tape recorder (Racal, V-store, Southampton, UK; cut-off frequency 2.5 kHz) simultaneously with three dimensional ground reaction force signals from the force platform. An electrical goniometer (58 g) was attached to the lateral side of the right knee joint.

The EMG, goniometer and force signals were off-line A-D converted (1 kHz) to a computer for further analysis. One drop jump per subject from both heights was filmed with a Canon Scoopic 16-mm camera operating at 69 frames s⁻¹. Due to film failure it was not possible to analyse one subject in the control group. The camera was located perpendicular to the sagittal plane at a distance of 29.2 m. When the subject touched the force platform a marker signal was turned on to synchronise the filmed data with the force and EMG signals. A light flashed in front of the jumper gave the marker on the film.

The EMG was averaged (aEMG) for two successive 50-ms periods prior to the ground contact, and for the first and second halves of the braking and the propulsion phases of contact:

\[ x_{aEMG}(T) = \frac{1}{T} \int_0^T |x(t)| dt \]

where \( T \) is the observation time, and \( x(t) \) the EMG signal.

The braking and propulsion phases were determined by the contact time and minimal angle position of the knee as proposed by Aura and Viitasalo (1989). Both absolute (arbitrary units) and relative aEMG values were used. The EMG values were normalised to, e.g. maximal isometric (see Voigt et al. 1991) or concentric (see Voigt et al. 1995) values. Drop jump EMG has been shown to be also related to squatting jump EMG activity (Viitasalo and Bosco 1982) and the relationships among maximal isometric, concentric, squatting jump, countermovement jumps (eccentric and concentric) and drop jumps (eccentric and concentric) EMG activity to depend on the muscle (Viitasalo 1984). Thus, there is no standard for presentation of relative EMG values. We selected the second part of the propulsion phase as 100% because it has been supposed to be the one where untrained subjects also had enough time to produce their voluntary maximal activation level.

Duration of the pre-contact EMG activity was from the moment when the rectified EMG reached a level of 0.04 mV to touchdown on the force platform (threshold 5 N). The thresholds were selected on the bases of maximal amplitude and baseline noise. The flight times of the jumps were used to calculate the height of rise of the body centre of gravity as has been suggested by Asmussen and Bonde-Petersen (1974). Average and peak vertical forces as well as braking and propulsion times were calculated from the force-time curves (Bosco and Komi 1979). For the EMG and force analyses the two best jumps (on the basis of the jumping height) from both dropping heights were selected and averaged.

During the dropping and contact phases hip, knee and ankle angles as well as vertical location of the body centre of mass (CM) were analysed from the film using a NAC (MC-OF) analyser connected to an Ariel performance analysis system. The manually digitised raw data were smoothed with the quintic spline algorithm (smoothing factor 0.002 m). Based on Dempster (1955), the mechanical model of the jumper was assumed to consist of eight rigid body segments. The relative segmental masses and locations of segmental mass centres were used to obtain the location of the whole body CM. Values were calculated at the touch down and

**Methods**

**Subjects**

A group of 18 subjects were divided into jumpers (7 triple-jumpers of Finnish national caliber) and controls (11 students with physically active life styles but no specific jumping training). The jumpers of Finnish national caliber) and controls (11 students with physically active life styles but no specific jumping training). The subjects performed various jumping drills with warming-up the subjects performed various jumping drills with warming-up the subjects performed various jumping drills with warming-up the subjects performed various jumping drills with warming-up the subjects performed various jumping drills with warming-up the subjects performed various jumping drills with