Muscular control and stability of the lower extremity during expected and unexpected landings

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Introduction

In sports, especially in gymnastics, the majority of injuries occur in the lower extremity. The highest injury rates are located at the ankle joint (Kolt & Kirkby, 1999; Lowry & Leveau, 1982; McAuley et al., 1987). Concerning foot stability during landing, there is an ongoing discussion about the influence of muscular pre-activation. In a previous study from Janshen (2000) effects of training level and drop height on muscular pre-activation could be demonstrated. In other studies, like those from Duncan & McDonagh (2000) and Dyhre-Poulsen et al. (1991), the component of stretch reflex during landing has been investigated. However, the influence of pre-activation on foot stability during landing is mostly unsolved. The purpose of this study was to analyze the muscular control of the lower extremity with respect to the pre-activation and the effect on foot stability during expected and unexpected landings.

Method

Twelve female gymnasts performed expected and unexpected landings from a height of 0.1 m onto two parallel mounted force plates (KISTLER). Eight subjects (height 165±7 cm, mass 63±4 kg) were recruited from the national university league (L1) and four (height 155±4 cm, mass 45±9 kg) from international level of performance (L2). To standardize the vertical landings a special harness was used. During the landings myoelectric activity of the muscles vastus medialis (VM) and lateralis (VL), biceps femoris (BF), tibialis anterior (TA), peroneus longus (PR), gastrocnemius medialis (GM) and lateralis (GL) of the left lower extremity were recorded using surface electrodes (Blue-Sensor). The signals were pre-amplified and stored on a PC. The sampling rate was 1000 Hz. The instant of touchdown of the left foot was recorded by an accelerometer (1000 Hz). The analyzed EMG parameters included time and mean amplitude (RMS = route mean square) of pre-activation (prior to touchdown) and RMS of post-activation (after touchdown). The EMG-Signals were filtered by moving average (window length 50 ms, step 1 ms). The EMG onset was defined as the first value, when RMS exceeded three times standard deviation of the respective resting EMG for more than 20 ms. RMS was described relative to the maximum values of the respective subjects (%-max). To compare muscles of one subject, RMS was described relative to the maximum voluntary contraction (MVC) of that subject. Pressure distribution under the left foot was recorded at 180 Hz using capacitive insoles (Pedar-expert, Novel). The area under the foot was divided in four sections including the medial and lateral ball and heel. Peak pressure, instant of peak pressure, pressure rate from touchdown to peak pressure and pressure-time-integral were analyzed for all four sections. To eliminate differences in body weight of the two subject groups the pressure parameters were related to body mass. To analyze the movements of the knee and ankle joints, kinematic data were collected using a side view video (50 Hz) (Panasonic AG-DP800). The analyzed parameters were angle amplitude and angular velocity of the left knee and ankle joint. For the statistical analysis a multivariate ANOVA was performed.

Results & Discussion

During all landings the range of ankle dorsiflexion was less than that of the knee joint flexion. In expected and unexpected landing conditions the highly trained athletes (L2) demonstrated significantly (p<0.05) lower maximum knee flexion (11±6° and 15±8° respectively) compared to L1 gymnasts (25±15° and 27±11°). Between landing conditions, no differences in maximum joint flexion within groups were found. However, during unexpected landings L1 athletes reached maximum ankle joint dorsiflexion significantly earlier (22±8 ms) than during expected landings (85±15 ms). For the gymnasts of L2 maximum knee
flexion occurred significantly earlier during unexpected landings (149±31 ms to 227±92 ms). The muscles of all subjects were activated prior to touchdown in both landing conditions. The pre-activation time and RMS were shorter for the unexpected landings independent of training level (s. Fig. 1).

In the group of less trained subjects (L1) this difference was significant for the biceps Femoris (54±35 ms / 106±52 ms) and all shank muscles except lateral gastrocnemius. The recorded pre-activation times were 48±44 ms / 110±45 ms (TA), 52±34 ms / 106±44 ms (GM) and 34±31 ms / 99±54 ms for the peroneus muscle. Further the intensity of pre-activation of these shank muscles, represented by RMS values of the EMG signal, were significantly lower than during the expected landings. The highest difference was observed for TA (11.7±7.3 %-max / 22.2±12.4 %-max) followed by GM (10.1±8.1 %-max / 20.3±12.9 %-max) and PR (10.2±4.6 %-max / 17.9±10.6 %-max). The faster dorsiflexion of the ankle joint together with the reduced time and intensity of pre-activation of the shank muscles seems to hint at lower ankle joint stiffness during the unexpected landings. This is supported by several authors, who assumed a coherence of joint stiffness and the activity of the muscles, that act on the specific joint (Caster & Bates, 1995; Evens et al., 1983; McNitt-Gray, 1993; Zhang et al., 1998; Zhang et al., 2000). Hagood et al. (1990) have described an increased knee joint stiffness at higher muscular activity of the knee extensors and flexors when acting as antagonists. In L2 subjects no significant differences of muscular pre-activation time and RMS were found. During the unexpected landings the pre-activation of all muscles was slightly longer compared to L1 gymnasts.

However, an insufficient stabilization of the ankle joint during unexpected landings can be assumed for both groups of athletes. This is supported by significantly higher peak pressure under the medial and lateral heel during unexpected landings (s. Fig. 2). In general this effect was slightly higher for the less trained subjects compared to the highly trained athletes. The recorded values of medial and lateral heel during expected and unexpected landings were 4.2±3.4 kPa/kg and 2.8±2.7 kPa/kg to 7.8±3.6 kPa/kg and 6.0±3.1 kPa/kg respectively for L1 and 2.0±1.9 kPa/kg and 2.0±1.6 kPa/kg to 4.1±3.2 kPa/kg and 3.6±2.9 kPa/kg respectively for L2. Corresponding to the lower ankle joint stiffness in the group of less trained athletes (L1), peak pressure of medial and lateral heel occurred significantly earlier during unexpected (41±28 ms and 33±25 ms) than during expected landings (73±22 ms and 75±31 ms). In contrast no differences in time or amplitude were found under the ball. As mentioned before, the increased peak pressure under the medial and lateral heel probably resulted from the reduced muscular pre-activation of the shank which provided less stability to the ankle joint at touchdown. This may result from the absence of preparation during the unexpected landings.
Muscular pre-activation seems to be important for stabilizing the lower extremity during landing at touchdown. The pre-activation of the shank muscles may provide more controlled dorsiflexion of the ankle joint and in turn to reduce peak loads under the heel. The slight difference between training levels seems hint at an increased foot stability during unexpected landings, when landing strategy is improved. Therefore, correct landing technique should be stressed during training in order to prevent injuries.

**Conclusion**

Muscular pre-activation seems to be important for stabilizing the lower extremity during landing at touchdown. The pre-activation of the shank muscles may provide more controlled dorsiflexion of the ankle joint and in turn to reduce peak loads under the heel. The slight difference between training levels seems hint at an increased foot stability during unexpected landings, when landing strategy is improved. Therefore, correct landing technique should be stressed during training in order to prevent injuries.

**References**


