NEUROMUSCULAR CONTROL DURING GYMNASTIC LANDINGS

Lars Janshen
German Sport University Cologne
Institute for Athletics and Gymnastics

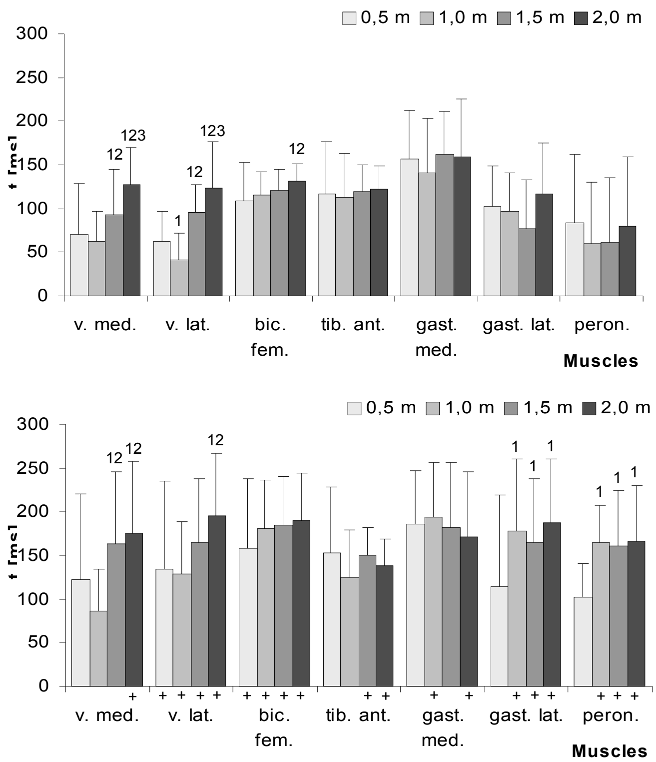
The purpose of this study was to analyze muscular activity of the lower extremity during gymnastic landings from four different heights. Twelve female gymnasts at two training levels performed landings from heights of 0.5 m, 1.0 m, 1.5 m and 2.0 m. Myoelectric activity of specific muscles of the left leg, pressure distribution under the left foot and kinematics of the landings were recorded. All muscles showed pre-activation prior to touchdown. Pre-activation time and intensity escalated with increasing falling heights. Compared to the less trained subjects, the longer muscular pre-activation in highly trained athletes led to increased stiffness of the knee and ankle joint. This caused greater maximum forces under the leading foot and lower maximum forces under the rear foot of the high-level athletes during landings from greater heights compared to the less trained gymnasts.

KEYWORDS: gymnastics, landings, neuromuscular control, EMG, foot stability

INTRODUCTION: In gymnastics, injuries to the lower extremities, especially to the foot, ankle, and knee joints are mainly attributed to floor exercise and landings from apparatus (Lowry & Leveau, 1982; Mc Auley et. al., 1987; Kolt & Kirkby, 1999). Previous studies have investigated the kinematics displayed during landings from different heights (Mc Nitt-Gray, 1993) or on different surfaces and their effect on landing strategies (Mc Nitt-Gray et al., 1994). The purpose of this study was to analyze the activity of specific muscles of the lower leg during gymnastic landings from four heights. Furthermore, the effect of training level on muscular coordination patterns during landings was investigated.

METHODS: Twelve female gymnasts performed vertical landings from heights of 0.5 m, 1.0 m, 1.5 m and 2.0 m, respectively, onto a 20 cm landing mat. Each subject performed five landings from each height in a randomized order. Eight gymnasts (age 25±2 years, height 165±7 cm, mass 63±4 kg) were recruited from the national university league and four were from international levels of performance (age 16±3, height 155±4 cm, mass 45±9 kg). During the landings, myoelectric activity of the muscles vastus medialis and vastus lateralis, biceps femoris, tibialis anterior, peroneus longus, gastrocnemius medialis and lateralis 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) as well as the integrals (iEMG) of pre- and post-activation. The EMG-Signals were filtered by moving average (window length 50 ms, step 1 ms). The onset of EMG was defined by using the description by Di Fabio (1987). RMS and iEMG were described as relative to the maximum values of the respective subjects (%-max). To compare muscles of one subject, RMS and iEMG were described as 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-system). The area under the foot was divided in four sections including the medial and lateral (ball and heel) areas of the foot. Peak force, instant of peak force, force rate from touchdown to peak force and force-time-integral were analyzed for all four sections. The force 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. In the statistical analysis a multivariate ANOVA was performed with the factors ”training level” (group factor), ”muscle” and ”drop height”.

RESULTS AND DISCUSSION: During all landings, the rear foot showed a later ground contact than the leading foot and the range of ankle dorsiflexion was less than that of the knee joint flexion. With increasing drop height, knee flexion and ankle dorsiflexion increased significantly. The maximum knee flexion of the highly trained athletes (78±10°) was significantly lower than that of the less trained subjects (97±16°).
All muscles were activated prior to touchdown (Lees, 1981). During all landings the pre-activation levels (RMS) of the shank muscles, with the exception of tibialis anterior, were higher than the thigh muscles. At increasing drop heights the athletes of both training levels showed increasing duration, RMS and iEMGs values of the pre-activation phase of the knee extensor muscles (Figure 1).



1-4 = significant differences between landing heights ($p<0.05$)
\+ = significant differences between training levels ($p<0.05$)

Figure 2 - Pre-activation time (averages + standard deviations), in milliseconds during landings of the highly trained (above) and less trained (below) athletes.

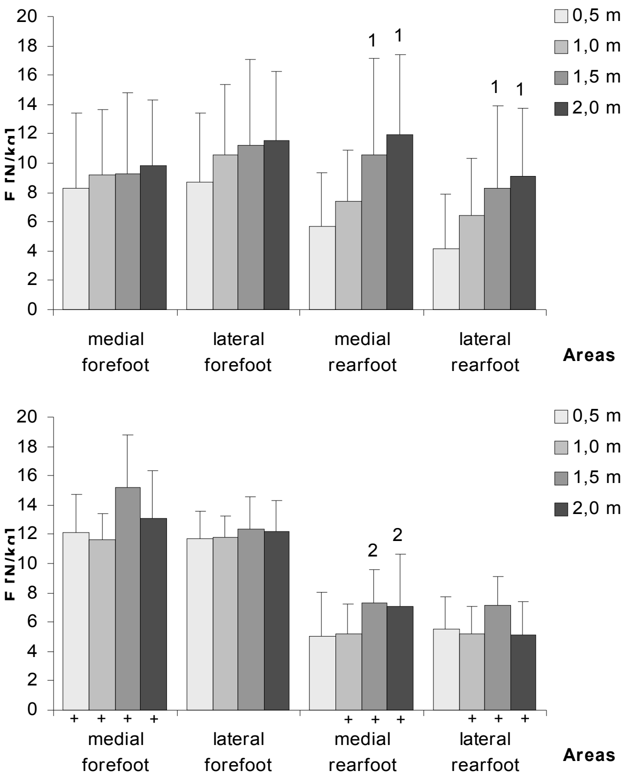
Significant differences in the dependent variables were observed, between the landings, from the drop heights of 0.5 m. and 1.0 m., when compared to 1.5 m and 2.0 m. In the pre-activation phase, the medial and lateral vastii of the less trained subjects, showed RMS values of 3.3±3.4 and 3.6±3.8% Max (0.5 m), 3.7±2.4 and 3.1±3.0 %-Max (1.0 m), These were significantly lower than the values of 6.2±2,4 / 7.4±6.0 %-Max (1.5 m) and 10.0±4,1 / 11.2±8,0 %-Max (2.0 m). For the highly trained athletes, similar significant differences in the pre-activation RMS of the muscles were observed. Compared to the less trained subjects, the highly trained athletes showed significantly longer pre-activation for the medial and lateral vastii for all drop heights. The same results were seen for the medial gastrocnemius and peroneus muscle at landings from heights above 0.5m.

During the landings, from 1.0 m up to 2.0, the lateral gastrocnemius and peroneus muscle of the high-level athletes showed a significantly longer duration and higher RMS values in the pre-activation phase compared to the drop height of 0.5 m. The recorded values of gastrocnemius lateralis, were 178±82 ms and 16.6±10.2 %-Max (1.0 m) up to 188±73 ms and 20.2±10.7 %-Max (2.0 m) compared to 115±104 ms, 10.3±9.6 %-Max (0.5 m). The peroneal muscle showed values of 164±43 ms and 13.1±6.6 %-Max (1.0 m) up to 166±38 ms and 17.4±10.5 %-Max (2.0 m) compared to 101±39 ms, 7.0±3.9 %-Max (0.5 m). The RMS of the post-activation phase significantly increased with greater drop heights for all muscles except medial and lateral gastrocnemius. Both components of gastrocnemius displayed high activation levels during landings from 0.5 m, when compared to the other muscles.
The higher activation levels of the shank muscles relative to the thigh muscles during all landings, can provide increased stiffness at the ankle when compared to the knee joint. The increase in the pre-activation phase, especially of the thigh muscles, may result form the anti-

cipation of higher loads that occur during landings from greater heights. The athletes from both training levels required a higher level of thigh muscle activation to provide controlled knee flexion during landing. Only the highly trained athletes showed an adaptation of the shank muscle activation to the increasing loads. Furthermore, the longer pre-activation phase of the knee extensor muscles of the highly trained subjects may result in a greater degree of knee joint stiffness, which in turn may lead to less knee flexion compared to the less trained athletes. It is assumed that the higher activation may lead to higher muscle force (Metral & Cassar, 1981). Therefore, the muscular control during landings of the highly trained athletes might be more suitable for supplying an active absorption of energy, which is not appropriate for the less trained subjects.

Corresponding to these findings, the analysis of pressure distribution parameters showed significant differences between subjects of both training levels. In the group of highly trained athletes, a significant reduction of maximum force under the rear foot as compared to the leading foot was registered for all drop heights (Figure 2).

The less trained athletes showed a reduction only during the landings from 0.5 m. In the group of highly trained athletes, a significant delay was observed in the instant of maximum force during the landings from 0.5 m compared to the values of all other drop heights, at the medial (ball) area of the foot. This was recorded as (191±72 ms to 61±53, 85±85, and 116±85 ms). Data on the lateral or leading foot were (188±46 ms, 81±44, 93±93, 38±28 ms) and the lateral rear foot (175±93 ms to 104±62, 101±60, 96±73 ms). For the less trained subjects, the instant of maximum force during the landings was very similar to those described above. In comparison to the less trained athletes the highly trained subjects showed significantly higher maximum forces under the medial (ball) area of the foot and significantly lower forces under the rear(heel) of the foot during the all landings except from the drop height of 0.5 m.



1-4 = significant differences between landing heights ($p<0.05$)

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Figure 2 - Maximum force (averages + standard deviations), in N/kg during landings of the highly trained (above) and less trained (below) athletes.

The muscular activation of the shank, probably allows an active absorption of energy that reduced the impact force of the rear of the foot (or heel area) at landing (Nigg & Herzog, 1994). In comparison to the less trained subjects, the higher muscular activation during landing from heights above 0.5 m might allow the highly trained athletes more controlled dorsiflexion at the ankle joint. The higher forces under the ball of the foot and lower forces under the rear or heel of the foot support this.

CONCLUSIONS: Landings from greater heights led to increased mechanical and muscular loads of the lower extremity, especially of the knee extensors. A longer and higher pre-activation of the shank muscles, probably enabled more controlled ankle dorsiflexion. This, in turn, resulted in a reduction in the maximum forces under the rear or heel of the foot. In this study, muscle activation was affected by the training level of the athletes. Therefore, correct landing technique should be stressed during training in order to prevent injuries.

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