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EFFECTS OF SUPPLEMENTARY MATS ON GROUND REACTION FORCES AND NEUROMUSCULAR PRE-ACTIVATION IN GYMNASTICS LANDINGS

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The purpose of this study was to analyse the effects of supplementary mats on ground reaction forces (GRF) and neuromuscular activation of selected leg muscles during gymnastics landings. Participants (n=10) performed landings from 1 m and 2 m height onto a landing mat and landing mat plus a soft supplementary mat. EMG of lower extremity muscles and ground reaction forces were measured. Results showed a decrease between 15% and 40% of the peak GRF and the peak rate of force development (RFD), respectively, when using supplementary mats. While the duration of pre-activation remained unchanged, the amount of pre-activation was reduced when landing on supplementary mats. From a biomechanical point of view supplementary mats can be recommended in gymnastics landings.

KEY WORDS: jump landing, EMG, pre-activation, landing mats.

INTRODUCTION: Training loads in gymnastics include 10.000 – 20.000 impacts per year and up to 50 impacts per hour (Brüggemann, Assheuer, & Eckhardt, 2000). Approx. 70% of all injuries result from either landings in floor exercises or dismounts (Marshall, Covassin, Dick, Nassar, & Agel, 2007), whereas uncontrolled and unsuccessful landings are a main cause of injury (Schmidtbleicher, 1981). Therefore improving landing mechanics by e.g. reducing the impact forces or the muscle-activation strategies has been the focus of several studies. It has been shown that the landing movement is influenced by the landing surface (e.g. Brüggemann, 2000), but also by the way the movement is performed: Devita and Skelly (1992) distinguished between soft and hard landings, having an active flexion in the ankle, knee and hip joints during the soft landing and therefore reducing the impact forces by 23 % and the landing movement. Schmidtbleicher (1982) reported about pre-activations of the leg muscle before landing. Muscle activity reached 87% of the maximum voluntary contraction (MVC) 100-120 ms before landing. Janshen (2000) showed that pre-activation duration of m. vastus lateralis and m. biceps femoris was significantly higher in well-trained compared to untrained athletes leading to an increased stabilization of the knee joint. This leads to an increased knee joint stiffness and decreased knee flexion of trained gymnasts while landing. Consequently, this causes “harder” landings with higher impact forces (Devita & Skelly, 1992; Janshen & Brüggemann, 2001; Marinsek, 2010). Janshen (2000) also showed a significant longer pre-activation duration of m. gastrocnemius lateralis and m. peroneus longus at landing heights of 1m and higher for well-trained athletes.

In practice additional soft landing mats, called supplementary mats or ‘happy landing mats’, were introduced and used in competitions according to the FIG (Federation internationale de Gymnastique) to reduce impact loads. What has yet not been discussed for the supplementary mats is the aspect, that sensory information plays an important role in movement control strategies. It seems that visual information is used during a jump to predict the time of landing. It is assumed that this information is used to anticipate the forces while landing as jumpers adjust the onset time of the muscle pre-activation (Liebermann & Goodman, 2007). As the supplementary mat itself (10 cm) should not have a high cushioning effect, the actual landing would occur 10 cm after the first contact with the supplementary mat. Based on the visual information it therefore was assumed that for the same jump height the muscle pre-activation would start earlier. This would lead to an extended pre-activation of the muscle, giving more time to stiffen the lower limb.

Hence, the aim of this study was to analyse the influence of supplementary mats on ground reaction forces (GRF) and neuromuscular pre-activation of selected leg muscles during gymnastics landings. It was hypothesized that the use of supplementary mats leads to a reduction of the peak vertical GRF, the peak rate of force development (RFD) and the amount of muscle pre-activation and to an extended pre-activation duration of the measured muscles.

METHODS: Ten male participants (24.7 ± 2.7 yrs, 177.5 ± 3.2 cm, 72.0 ± 7.4 kg) with different sports background were recruited for this study. Subjects performed landings from 1 m and 2 m height onto a landing mat and landing mat plus a supplementary mat. The landing mat and the supplementary mat had a thickness of 10 cm and the supplementary mat had a foam density of 25 kg/m³ (± 2 kg/m³), tenacity of ≥ 115 kPa and a compression hardness of 40% (4 kPa ± 0.5 kPa), which is in accordance to the FIG standards. Ten jumps were performed from a platform for each height including five landings with and five landings without the supplementary mat. Figure 1 shows a schematic illustration of the experimental setup. As the landing mats had larger dimensions than the force plate, the mats were additionally placed on a distance plate (2 cm) mounted on the force plate to ensure that all forces acting during landing were captured (Figure 1).

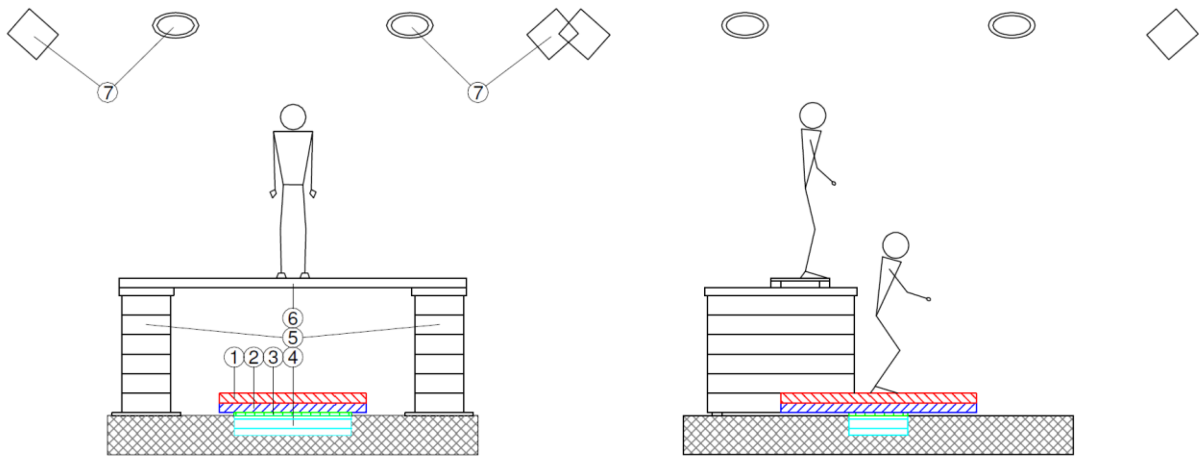

Figure 1: Schematic illustration of the experimental setup. (1) supplementary mat, (2) landing mat, (3) distance plate, (4) AMTI force plate, (5) scaffold, (6) jump platform, (7) VICON® IR-cameras

Subjects had to land with both legs at the same time and the landings should end in a standing position without any additional movement. Jumps were performed barefoot and in randomized order. Subjects were given a 3 min break between the jumps to avoid fatiguing effects. GRF were recorded using an AMTI force plate (Advanced Mechanical Technology, USA, 1000 Hz). As variables peak vertical GRF (Fz_{max}) and peak rate of force development (RFD_{max}) were analyzed. All data was normalized to body weight (BW).
Using surface EMG muscle activity of m. gastrocnemius lateralis (GL), m. tibialis anterior (TA), m. rectus femoris (RF) and m. biceps femoris (BF) was measured. Muscle pre-activation duration was computed as the time of the muscle onset until landing. Landing was defined as the time when the GRF exceeded 5% BW. Integrated EMG over a time-window of 200 ms and normalized to a standard drop jump from 40 cm was used to quantify the level of pre-activation of each muscle before landing.
For statistical analysis the mean values, tested for normal distribution, were compared using the paired sampled t-test with SPSS. The level of significance was set as $\alpha = 0.05$

RESULTS: The comparison of the mean values for the different landing conditions showed a significant decrease of the Fz_{max} by 15% ($p < 0.001$) when using a supplementary mat landing from a height of 1m, and by 18% when landing from a height of 2 m (Figure 2, left). The

RFD_{max} equals the steepest increase in the force-time relationship during landing. Using supplementary mats lead to a significant decrease in the RFD_{max} by 43% (1 m) and 41% (2m) (Figure 2, right).

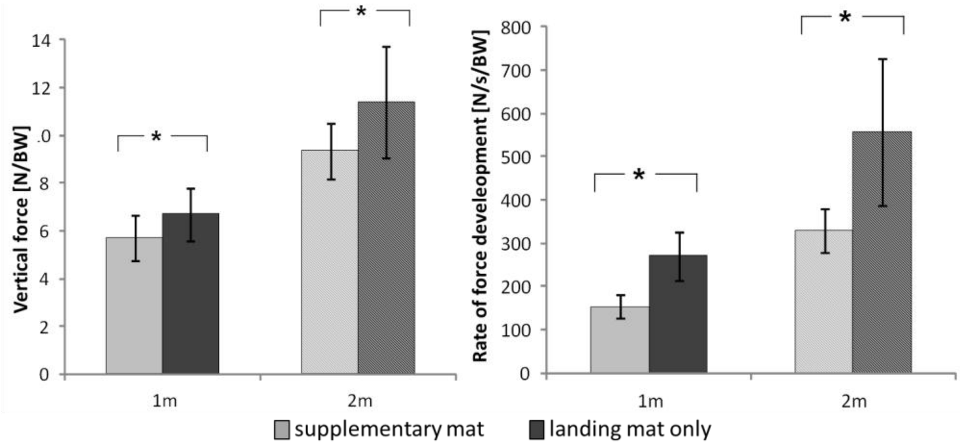

Figure 2: Maximum GRF (left) and RFD (right) landing from 1 m or 2 m height on a landing mat or an additional supplementary mat (means ± SD).

From the muscles measured only the muscles BF and GL showed mentionable pre-activation, so the results of TA and RF are not presented. There is no clear difference or tendency regarding the duration of pre-activation neither with respect to landing surface nor concerning landing height. The pre-activation of the GL, however, is substantially longer than the pre-activation of the BF (Figure 3, left). The amount of muscle pre-activation of the BF and GL was higher when landing from 2 m height compared to 1 m landings. For both landing heights and both muscles the IEMG in the pre-landing phase is lower when landing on the supplementary mat. The differences, however, are only significant for the muscle GL (Figure 3, right).

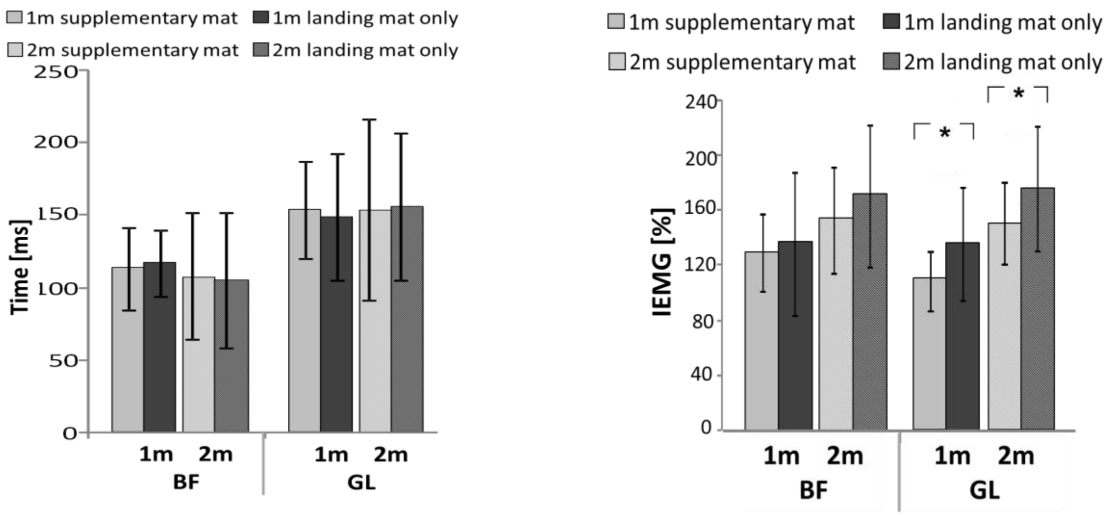

Figure 3: Time (left) and amount of pre-activation (IEMG, right) of m. biceps femoris (BF) and m. gastrocnemius lateralis (GL) (means ± SD).

DISCUSSION: Results showed a significant decrease in the Fz_{max} when using supplementary mats. It was shown in the literature that using supplementary mats can decrease the loads in the spine of about 20% (Brüggemann, 2000). Assuming that the loads in the spine correlate with the GRF, this results support the findings of Brüggemann (2000). In addition to a reduction of the Fz_{max}, there is an increase in the duration between landing and reaching the

peak GRF. This is expressed as a decrease of about 40% in the RFD_{max}. Therefore, it can be assumed that the landing movement gets slowed down with the first contact of the supplementary mat. This effect occurs, although the supplementary mat is designed with low compression hardness and therefore should not contribute to cushioning. Results, however, suggest an additional damping due to the supplementary mat in the first landing phase leading to decreased Fz_{max} and RFD_{max}.
It was hypothesized that the use of supplementary mats would lead to an extended pre-activation of the muscle. This could not be found in this study showing similar durations of pre-activation in all investigated conditions. In addition to observations of Schmidtbleicher (1982), who showed that muscle pre-activations are largely automatic movement patterns, which are not influence by the composition of the landing area, this study suggests that the delayed actual landing – delayed by the thickness of the supplementary mat- does also not influence the movement pattern. However, results of the current study showed lower amounts of muscle pre-activation when using supplementary mats. The jumpers might expect softer landings on the combination of standard landings mats and supplemental mats which might lead to lower pre-activation of the 'landing cushioning muscle', primarily the m. gastrocnemius lateralis.

CONCLUSION: Due to high impact forces gymnastics is related with a high injury risk. A reduction of impact forces seems to be beneficial. One way to decrease impact forces during landing is the use of supplementary mats. This study showed a decrease of about 15% of the peak GRF and of about 40% of the rate of force development, respectively, when supplementary mats were used. The use of supplementary mats, however, does not lead to a prolonged, but to a reduced amount of muscle pre-activation. From a biomechanical point of view supplementary mats can be recommended in gymnastics landings.

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