LOWER LIMB LANDING RESPONSES BY YOUNG FEMALE GYMNASTS ON DIFFERENT TYPES OF MATS: A PRELIMINARY STUDY

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Landing is a fundamental skill in artistic gymnastics, practiced continually throughout all levels and using various types of landing mats. The aim of the current study was to investigate how the vertical ground reaction forces (VGRF), knee and ankle joint kinematics changes during gymnasts landing on different types of landing mats with FIG certification. Four young active female gymnasts performed 10 trials of landing to two type of mats. Synchronized kinematic and kinetic data were collected for each trial. Effect size statistics determined individual and group mean differences between landing conditions. The preliminary results of the current study suggested that the PROTOTYPE of landing mat reduces the VGRF and thus may decrease the impact forces acting on the lower limbs in gymnastics.

KEY WORDS: landing, kinematics, lower limbs, testing, mats, FIG.

INTRODUCTION:

Landing is a fundamental skill in artistic gymnastics and practised continually throughout all levels (Straker et al., 2021). Previous studies show that during a single training week female gymnast performed more than 200 landings (Gittoes & Irwin, 2012). The results of epidemiological studies show that in sport gymnastics, the lower limbs are identified as the most common site of injury (e.g. Edouard et al., 2018) and usually occur as a result of uncontrolled or repetitive landings (Bradshaw & Hume, 2012). Specifically, the knee and ankle joint represent the most commonly affected part of the body (e.g. Edouard et al., 2018). These injuries most commonly happen in the landing phase, during which the knee and ankle joint is subjected to high mechanical loads (Gittoes & Irwin, 2012). Gymnasts repeatedly land after multiple rotations, leading to a high frequency of ankle injuries (Marshall et al., 2007). Factors such as the position of the body's center of gravity, the technique of the landing and the surface of the landing area contribute to this frequency and severity of injury. In landing research, a variety of surfaces have been developed which are commonly assigned to one of two groups: point-elastic surfaces that distribute forces over a small area, and area-elastic surfaces that react to a local force by deforming over a relatively large area (Mills, Yeadon, & Pain, 2006). In recent years there have been changes in the rules for the construction of impact surfaces, which must comply with the requirements of the international governing body (FIG). For this reason, landing mats are made from different materials and are constantly being developed to increase safety of athletes. Testing of landing surfaces according to Fédération Internationale de Gymnastique (FIG) rules and standardization procedure is carried out using a predefined impactor (20 kg ± 0.2 kg; Ø 10 cm ± 0.5 cm) that impacts with an impact velocity of 3.96 m/s (corresponding to a height of 0.8 m). Findings of previous studies state that the issue of testing different types of mats does not consider the biomechanical loading of the athletes' musculoskeletal system and the repetitive mechanical loading of the lower limbs (Mills, Yeadon, & Pain, 2010; McNitt-Gray et al., 1993). Thus, more research is needed to investigate biomechanical responses of athlete musculoskeletal system during landing on different types of surfaces to make landing mats safer. Therefore, the aim of the current study was to investigate changes in VGRF, knee and ankle joint kinematics during gymnasts landing on different types of landing mats with FIG certification.

METHODS:

Participant & Protocol: Four young active female gymnasts from Czech Republic, with more than 5 years' experience with systematic training and competitive gymnastics, participated in this study (age: 12.1±1.6 years; height: 147.5±12.8 cm; mass: 35.4±9.0 kg). In accordance with the guidelines of the University of Ostrava Ethics and Research committee and according to Helsinki declaration, an informed consent and parental consent were obtained from each gymnast and her parents. During their career, they had no lower limbs injuries, which could affect the measurement results. After self-preferred warm up and practice trials of landings, the gymnasts performed 10 trials of drop landings to each type of mats. Participants were instructed to perform a competition landing style in barefoot conditions. The drop landings were performed stepping off from a platform of an approximately 0.80m high to replicate typical landing velocities experienced by gymnasts on apparatus such as the floor and balance beam (McNitt-Gray, 1991) onto force plate covered with gymnastics mats. All trials were performed in a random order and separated by a one-minute rest period. Only successful trials were included in this analysis, due to the nature and low difficulty of drop jump landing task minimum errors occurred as such very few trials were excluded. Two different types of mats that both met FIG regulation were used in the current study. Both mats are of different structure and are covered by different material (Figure 1). “REGULAR” mat was covered by carpet and is widely used in training and competition, “PROTOTYPE” mat was covered by synthetic leather and in time of testing was under development.

Figure 1: Types of landing mats (right – REGULAR, left - PROTOTYPE)

Data Collection: Synchronized kinematic (10 QUALISYS cameras; 240 Hz) and kinetic (1 KISTLER force plate; 1200 Hz) data were collected for each trial. Based on C-motion Company (C-motion, Rockville, MD, USA) recommendation, retroreflective markers and clusters were attached to the gymnasts' lower limbs. Since the dimension of mats covering force plate could affect kinetic calculations, depth of the transducer was set as the sum of the manufacturer depth for the force plate and depth of mat (0.2 m), this corrected the center of pressure (COP) location.

Data analysis: Raw data were processed using the Visual 3D software (C-motion, Rockville, MD, USA). All analyses focused on dependent variables such as VGRF, knee and ankle kinematics during landing phase. The coordinate data were low-pass filtered using a fourth-order Butterworth filter with a 12 Hz cut off frequency. All force plate data were low-pass filtered using a fourth-order Butterworth filter with a 50 Hz cut off frequency. Statistical analyses were performed using Microsoft Excel (2007, Microsoft Inc., New Mexico, USA). Due to small sample size an individual-orientated analysis strategy was employed where differences within each gymnast were quantified using a repeated trials approach. The mean and standard deviation (SD) of 10 trials were calculated for the right leg of each condition and grouped together to assess differences between the two groups. Cohen´s d effect sizes (ES) incorporating the pooled standard deviation were used and ES interpreted as <0.2 trivial, 0.21-0.5 small, 0.51-0.8 medium and >0.8 large (Cohen, 1992).

RESULTS: Descriptive statistics with means and standard deviations for two conditions are presented in Table 1.

Table 1: Mean±SD group and individual VGRF, knee and ankle kinematics of the right leg when performing landing on different types of mats.

	VGRF (BW)		Knee Ab/Adduction (°)		Knee Flexion (°)		Ankle Inv/Eversion (°)		Ankle Dorsiflexion (°)	
Gymnast	PROTO	REGUL	PROTO	REGUL	PROTO	REGUL	PROTO	REGUL	PROTO	REGUL
G1	1.79±0.21	1.90±0.19	9.1±1.6	8.1±1.7	-82.8±9.1	-77.5±8.5	-14.4±2.1*	-15.8±1.6	86.5±3.8	84.9±3.8
G2	1.56±0.10	1.71±0.10*	0.1±2.6	0.1±2.4	-78.1±5.6	-76.1±6.2	-10.2±3.0	-9.8±2.1	90.1±2.3	88.4±4.5
G3	1.53±0.15	1.63±0.10*	-2.2±1.2*	-1.2±1.6	-88.5±4.0	-87.7±4.5	-11.0±2.3	-11.5±2.6	90.5±2.8	90.6±1.6
G4	1.65±0.15	1.80±0.32*	1.2±1.4	1.2±1.0	-76.9±10.3	-74.9±5.4	-15.1±2.8	-16.0±3.6	81.8±3.5	81.4±2.9
Group	1.63±0.11	1.76±0.12*	2.1±4.9	2.1±4.2	-81.6±5.3	-79.0±5.8	-12.7±2.4	-13.3±3.1	87.2±4.0	86.3±4.0

Notes: VGRF, vertical ground reaction force; BW, Bodyweight; °, degree; „PROTO“, Prototype mat; „REGUL“, Regular mat; ***** large ES <0.8

The vertical landing forces (VGRF) were typically ~7% higher on the REGULAR mat for this group of gymnasts (ES=1.1 [large]) as illustrated in Figure 2. This result was also present individually for three of the four gymnasts (G2: ES = 1.5 [large]; G3: ES = 0.9 [large]; G4: ES = 1.0 [large]). Limited technical differences in lower body kinematics were identified in the drop landings between the two mats, and only within individual gymnasts. G1 had greater ankle inversion on the REGULAR mat (ES=0.9 [large]). G3 displayed greater knee joint adduction on the PROTYPE mat (ES=0.8 [medium]).

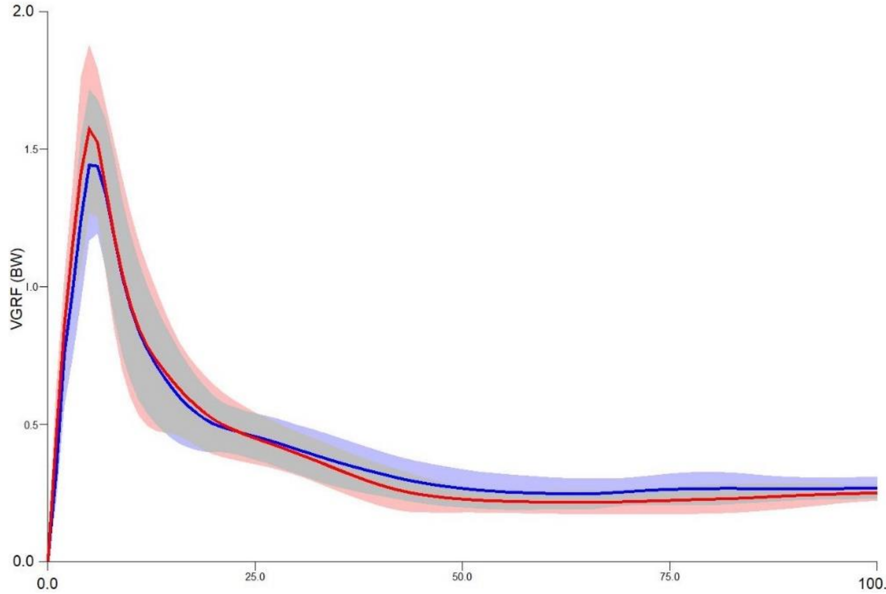

Figure 2: Group VGRF profile during landing (red – REGULAR mat, blue – PROTOTYPE mat)

DISCUSSION: The main goal of sports gymnastics is to increase safety of athletes, especially through the use of landing surfaces. Therefore, the aim of the current study was to investigate how the VGRF, knee and ankle joint kinematics changes when young gymnasts landing on different types of landing mats with FIG certification. The results of this preliminary study suggest that the new type of mat reduces the VGRF and thus may decrease the impact forces acting on the lower limbs. In general, group analysis (Table 1 and Figure 2) showed a general trend in the reduction of peak VGRF during landing on PROTOTYPE mat which may indicate to lower mechanical strain across knee and ankle joints, decreasing the risk injury in female gymnasts (Seegmiller & McCaw, 2003). These differences could be explained by knee joint flexion action, when during PROTOTYPE mat landing all gymnasts landed in more flexed knee position (Table 1). This finding supports conclusions by Slater et al. (2015), who highlighted that the greater lower limb flexion in gymnastic landings is associated with reduced landing force. However, it should be notice that in the current study these differences were not significant and further research needs to be done in this area. Furthermore, based on study by McNitt-Gray et al. (1991) who observed lower peak VGRF and greater knee flexion between the no mat condition and the mat conditions we speculated that PROTOTYPE mat could have better damping properties and reduce mechanical demands placed on gymnast when landing. Differences in knee joint abduction and ankle inversion (Table 1) suggested individual responses of gymnasts when landing and are in favor with previous study by Straker et al. (2021). Despite all the limitations of this preliminary study such as small sample size, possible bias in forces parameters caused by the stiffness and height of the mats, limited kinematic parameters to the right limb and a simple drop landing task we strongly believe that further research in the area of landing mats represents an important area of research and may have significant impact to make this sport safer for athletes.

CONCLUSION: The preliminary results of the current study suggested that different structure of FIG certificated mats may change biomechanical responses during landing skills performed by young female gymnasts. Specifically, our findings suggest that the new PROTOTYPE of landing mat reduces the VGRF and thus may decrease the impact forces acting on the lower limbs in gymnastics.

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