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THE INFLUENCE A TYPE OF LANDING AFTER A BLOCK HAS ON VALGUS KNEE LOADING OF FEMALE VOLLEYBALL PLAYERS

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The aim of the study was to determine the association between stick, step-back, and run-back landings after a block and select risk factors of ACL injuries for female professional volleyball players. The research sample involved twenty female professional players of the Czech Extraleague. Two force plates were used to determine ground reaction forces. Eight infrared cameras were employed to collect the kinematic data. The one-factor repeated-measures analysis of variance, where the landing type is the factor, was used for comparing the internal adduction moment on the right lower limb. The highest internal adduction moment occurs during the run-back landing. This moment, however, did not have any effect within the first 100 ms after initial contact with the ground, but rather upon the subsequent motion carried out when stepping back off the net.

KEY WORDS: biomechanics, volleyball, landing, ACL injury, prevention

INTRODUCTION: Non-contact anterior cruciate ligament (ACL) injuries occur primarily in young, healthy individuals as a result of sudden changes in direction or speed during physical activities (Hewett, Shultz and Griffin, 2007). This type of injury is both serious and a very common problem in volleyball and requires medical intervention (Ferretti, Papandrea, Conteduca & Mariani, 1992). A much greater incidence of ACL injuries in volleyball occur in women (Ferretti, Papandrea & Conteduca, 1990). Hewett (2005) defined risk factor (the abduction angle in the knee joint and valgus moment) predicting the incidence of ACL injuries in women's volleyball through a prospective study of 205 women. In order to fulfill the meaning and objective of the game, players are forced to reduce the period of landing to a minimum. There are three types of landing after a blocking maneuver that provide the possibility to move immediately away off the net (stick landing, step-back landing and run-back landing). Both the stick landing and the step-back landing take place after a successful block and time pressure is not a factor here. Time pressure, on the other hand, is typical of the run-back landing, which occurs upon an unsuccessful attempt to block, after which the player has to continue the game, which means moving from the net immediately after the block. These movements can have an impact on biomechanical factors that present a risk for the occurrence of ACL injuries. The aim of this study is to determine the association between stick, step-back, and run-back landings after block maneuvers and selected risk factors of ACL injuries for female professional volleyball players.

METHODS:

Participants & Protocol: Fourteen elite female volleyball players (age 22.5 ± 4.6 years; height 180.9 ± 0.1 cm; weight 72.3 ± 8.3 kg) participated in this study. None of them had any previous history of hip, knee or ankle injuries. All procedures were orally explained to each player and informed consent was obtained in accordance with the guidelines of the University of Ostrava Ethics Committee. The research was conducted in the biomechanical lab of the Human Motion Diagnostic Centre. The subjects visited the laboratory on two different days, with an interval of 24 hours, and performed an identical protocol on each day. The upper edge of the net was at a height of 224 cm above the ground. To normalize the height of the jump, a static volleyball was suspended in the space above the net. The centre of the ball was located 15 cm above the edge of the net and 10 cm behind the edge of the net on the opponent’s side of the court. The data for both dynamic and kinematic analyses were collected from the following three types of landing: stick landing, step-back landing and run-back landing. A stick landing that is not followed by a subsequent movement is defined as a landing maneuver ending with both lower limbs on the ground with an intentional extension of the landing period achieved by a sufficient flexion in the knee joint. A step-back landing is characterized by a free step away from the net performed with the right foot immediately upon landing. A run-back landing is defined as an immediate stepping away from the net to a distance of 3 m that is initiated immediately upon landing by stepping back with the right foot. A warm-up was followed by five practice attempts. Then the subjects had to perform four successful attempts at a stick landing, step-back landing and run-back landing. All trials were performed with a maximal effort from a technical perspective, in random order and separated by a one minute rest period.

Experintal set-up: Two force platforms (Kistler, 9286 AA, Switzerland) embedded into the floor were used to determine ground reaction force data at a sampling rate of 1235 Hz. A motion-capture system (Qualisys Oqus, Sweden) consisting of eight infrared cameras were employed to collect the kinematic data at a sampling rate of 247 Hz. Retroreflective markers (diameter of 19 mm) were attached to the players' lower limbs and trunk according to a recommendation of the C-motion Company (C-motion, Rockville, MD, USA).

Data analysis: Both kinetic and kinematic data were processed using Visual3D software (C-motion, Rockville, MD, USA). The range of the analyzed motion started with the first occurrence of the ground reaction force above 20N and finished either when a step-back landing had a final positive value from the ground reaction force or when a stick landing finished with the return of the subject to the default upright position, i.e. standing up. The local coordinate systems were defined using a standing trial operation. The coordinate data were low-pass filtered using a 4th order Butterworth filter with a 12Hz cutoff frequency. All data collected from the force plates were low-pass filtered using a 4th order Butterworth filter with a cutoff frequency of 50 Hz. Six degrees of freedom were collected for each segment from motion reflexive markers for the corresponding segment. This was followed by calculating the three dimensional angles in the ankle, knee and hip joints using the Cardan sequence xyz (Hamill & Selbie, 2004). The analysis in this study includes data related to the right lower limb only. Net moments of force in the joints were calculated using the inverse dynamics technique (Hamill & Selbie, 2004b), normalized according to body weight and formulated within the local coordination system of the proximal segment (Grood & Suntay, 1983). The internal adduction moment of force (valgus moment) on the right lower limb was calculated using the technique by Hamill and Selbie (2004). The proximal local coordinate system of the knee was oriented so that the valgus moment in the frontal plane of the thigh provided positive numbers and initiated a tendency towards adduction (the movement of the calf toward the middle plane).

Statistical analysis: The one-factor repeated-measures ANOVA (factor: a type of landing) was used for comparing the internal adduction moment on the right lower limb. If Mauchly's test was significant, Greenhouse-Geisser corrections were used. This was followed by carrying out Bonferroni pairwise comparisons. The effect size that the types of landing had on the dependent variables was evaluated with the use of the Eta squared index (Cohen, 1973). Since the one-factor analysis of variance was used, we consider that the partial value η^2 <0.009 represents a trivial effect, partial η^2 = 0.009-0.0588 a small effect, partial η^2 = 0.0588-0.1379 a medium effect and partial $\eta^2 > 0.1379$ a large effect (Cohen, 1988). The statistical power of the test (SP) was formulated in accordance with Cohen's study (1962). A statistical significance was set for all of the tests at a significance level of $p < 0.05$.

RESULTS: The one-factor analysis of variance showed a major influence of a type of landing on the internal adduction moment on the right lower limb (F =5.96, p =0.019, df =1.18, partial η^2 =0.239 and SP =0.693). The subsequent pairwise comparison using Bonferroni corrections showed that there is a significantly higher internal adduction moment on the right lower limb during a run-back landing than during a step-back landing ($p < 0.042$).

Table 1
Mean values and standard deviation of the internal adduction moment on the right lower limb generated during the execution of three types of landing (n=20).

Variable	Stick landing		Step-back landing		Run-back landing	
	M	*SD*	*M*	*SD*	*M*	*SD*
Internal adduction moment ($Nm.kg^{-1}$)	0.25	0.14	0.27	0.19 [a]	0.37	0.31[a]

Note: The same lettering located on the right following both mean and standard deviation values shows a statistically significant difference (p<0.05)

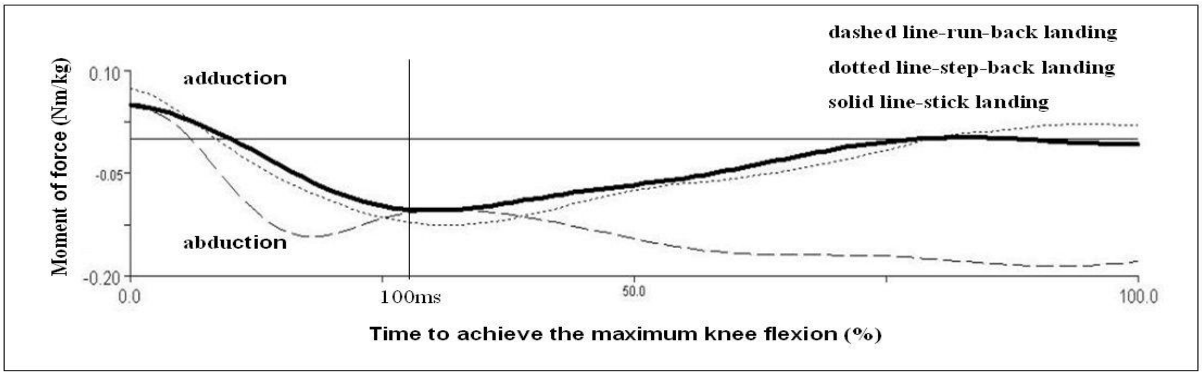

Figure 1: Internal adduction-abduction moment in the right knee joint (n=20)

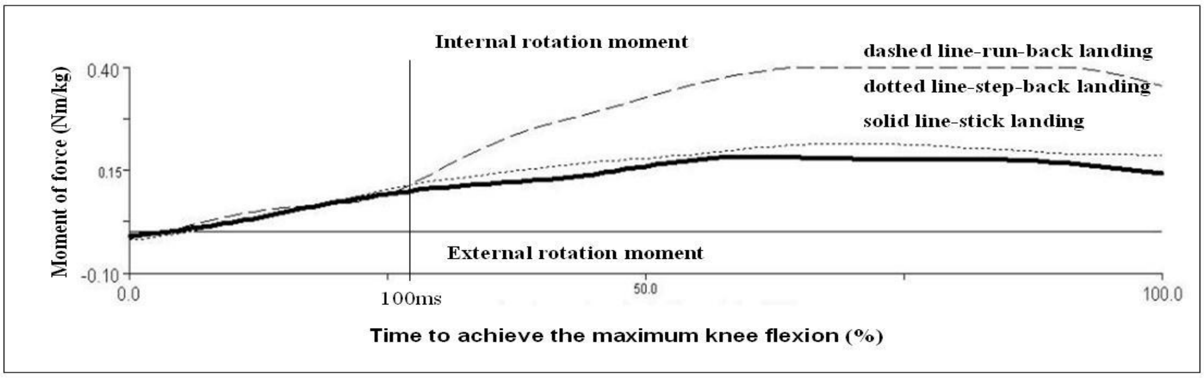

Figure 2: Internal-external moment in the right knee joint (n=20)

DISCUSSION: The aim of this study was to determine the influence of stick, step-back and run-back types of landing after a block maneuver on the selected risk factors of ACL injuries of professional female volleyball players. Landing following a take-off is a primary non-contact mechanism causing ACL injuries in women's volleyball and basketball (Ferretti et al., 1992; Kirkendall and Garett, 2000). The main finding of the study is that when a run-back landing maneuver is followed by immediately stepping away from the net, as opposed to a step-back landing, there is a significantly higher internal adduction moment in the knee of the right lower limb (Table 1). During the stance phase (starting from the initial contact with the ground and ending with maximum flexion in the knee joint) it is common for internal adduction moment to occur first in all types of landing. This is then followed by internal abduction moment, which smoothly transforms into internal adduction moment in the case of the stick landing and step-back landing (Figure 1). Markolf et al. (1995) demonstrates that combination of the knee varus and internal rotation moment loads ACL (Figure 1,2). It is surprising that the internal adduction moment (Table 1), in the case of the run-back landing, is at its maximum when actively moving away from the net. This phase, however, is not shown in the graphs. In addition, it was proven that at the point when the athletes made contact with the ground while executing the run-back landing, they put their right lower limbs into internal rotation in the knee joint, which gradually transforms into external rotation. This is in contrast to stick landings and step-back landings, during which only external rotation in the knee joint on the right lower limb was observed. McLean et al. (2005) assumed that the increased abduction in women's knee joints, when combined with an increased variability of tibia rotation, can contribute to an increased risk of ACL injuries. Myer et al. (2004) describes lower extremity motion pattern that is associated with risk, such as ligament dominance in landing. The findings also showed that there was a tendency during the execution of a run-back landing for internal rotation caused by the internal moment (Figure 2). Furthermore, the knee joint in the case of the run-back landing creates external rotation of the knee while simultaneously experiencing net moment of internal rotation by the action of passive structures of the knee joint. Such a combination of acting forces may expose the anterior cruciate ligament to undergo greater stress during the landing maneuver.

CONCLUSION: The highest internal adduction moment, which is considered to be a risk factor for ACL injuries, occurs during the run-back type of landing. This moment, however, did not have any effect during the first 100 ms after the first contact with the ground, which accounts for the highest risk for ruptures, but rather during the subsequent movement carried out when getting away from the net. Coaches should apply and teach the players a modified method of getting away from the net after a block that will not increase risk factors for anterior cruciate ligament ruptures.

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