LANDING PATTERNS AFTER BLOCK IN VOLLEYBALL: APLICATION FOR ACL INJURY

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The aim of the present study was to describe landing patterns during initial phase (0-30° knee flexion) of “go” landing after block in volleyball. Nineteen elite female volleyball players served as participants in this study. Eight infrared cameras and two force platforms were employed to collect the kinematic and kinetic data. The players used four different landing patterns during initial phase of the “go” landing after block. The players landed with different knee angle positions at initial contact depending on landing pattern. Results of the current study generally suggest that players may protect the ACL during the initial phase of landing by decreasing knee frontal plane angle and moment in direction from valgus to varus position.

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

INTRODUCTION: The anterior cruciate ligament (ACL) is most often damaged during sports activities (de Loës, Dahlstedt & Thomée, 2000) and frequently occurs when landing from a jump on one or both legs. A much greater incidence of ACL injury in volleyball is found with female players (Boden, Dean, Feagin, & Garrett, 2000; Ferretti, Papandrea, Conteduca, & Mariani, 1992; Leporace et al., 2013; Lobietti, Coleman, Pizzichllo, & Merni, 2010). Frontal plane movements during landing may influence ACL strain (Quatman, Quatman-Yates & Hewett, 2010). Cadaver studies indicated that ACL strain occurred due to the application of valgus or varus knee moments (Markolf et al., 1995; Withrow, Huston, Wojtys, 2006). The peak ACL strain occurs shortly (approximately 40 ms) after initial contact with ground (Shin, Chaudhari & Andriacchi, 2007) and near full extension (0-30° knee flexion). Additionally, when the knee flexion increases the peak ACL strain decreases (DeMorat, Weinhold, Blackburn, Chudik, & Garrett, 2004). A previous study by Hewett (2005) suggested that the valgus angle in the knee joint and valgus moment predicts the incidence of ACL injuries in women's volleyball during jump-landing task. There are several landing techniques used by volleyball players after a block. One of the most frequent techniques is the “go” landing that occurs with a movement in the mediolateral direction along the net. This technique may have a significant influence on ACL loading in frontal plane. It is not clear how players chose their initial knee angle in “go” landing. The aim of the present study was to investigate landing patterns during initial phase (0-30° knee flexion) of “go” landing after block in volleyball. We hypothesized that players would use different strategies during initial landing phase from the perspective of the knee angle and the moment of force in frontal plane.

METHODS: Nineteen female volleyball players from the Czech Republic (age 21.3 ± 5.4 years; height 183.6 ± 3.7 cm; weight 71.3 ± 3.2 kg) participated in this study. The experimental setting was based on a real game situation.The upper edge of the net was at a height of 224 cm above the ground. To control 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. Each player performed 8 successful trials of “go” landing. The “go” landing is performed in a vertical direction with a medio-lateral movement along the net and include subsequent step by left leg in the original direction along the net immediately upon landing by right lower extremity (Figure 1).

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. Retro-reflective 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).
Raw 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 in 30° of knee flexion. All force platform data were filtered using a fourth-order low-pass Butterworth filter with a 50 Hz cut-off frequency. The motion capture coordinate data were low-pass filtered using the fourth-order Butterworth filter with a 12 Hz cut-off frequency. In order to determine the local coordinate system of the segment, all segments were modeled as a frustra of right circular cones, while the pelvis and trunk were modeled as cylinders (C-motion, Rockville, MD, USA). The local coordinate systems were defined using the standing calibration trial for each participant. The analysis in this study includes data related to the right lower limb only. The internal varus-valgus moment on the right knee was calculated using a Newton-Euler inverse dynamics technique (Hamill & Selbie, 2004). The proximal local coordinate system of the knee was oriented such that the valgus moment in the frontal plane of the thigh provided positive numbers and initiated a tendency towards the movement of the calf toward the middle plane. The varus-valgus knee joint angle was determined as the angle between the local coordinate systems of the thigh and shank in the frontal plane (positive values indicate varus angle, negative values indicate valgus angle).The landing patterns were classified based on a valgus angle and moment data.

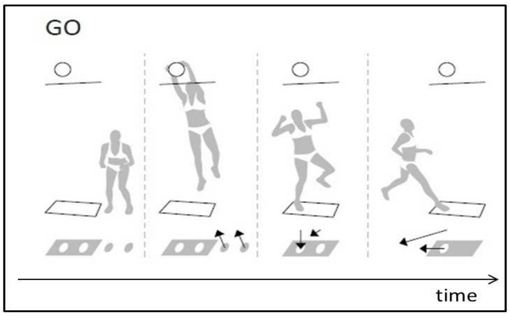

Figure 1: "go" landing after volleyball block

RESULTS: The frequencies of landing patterns was: pattern 1 (n=2), pattern 2 (n=8), pattern 3 (n=6) and pattern 4 (n=3). Mean, standard deviation for all dependent measures are shown in Table 1.

Table 1: Summary of the frontal knee angle and internal moment of typical landing pattern (M ± SD) on the right lower limb in four landing patterns (n=4).

Variable	valgus/varus angle (°)		varus/valgus moment ($Nm.kg^{-1}$)	
	IC	*30°*	*IC*	*30°*
Pattern 1	-4,35 ± 1,36	-4,30 ± 0,96	0,19 ± 0,06	0,19 ± 0,12
Pattern 2	-4,73 ± 1,44	-1,59 ± 1,92	0,20 ± 0,08	0,06 ± 0,19
Pattern 3	-3,71 ± 3,23	0,25 ± 3,90	0,17 ± 0,06	-0,33 ± 0,17
Pattern 4	1,31 ± 0,81	5,25 ± 1,67	0,08 ± 0,05	-0,41 ± 0,17

Note: (+) varus angle, valgus moment; (-) valgus angle, varus moment; IC initial contact; 30° knee flexion

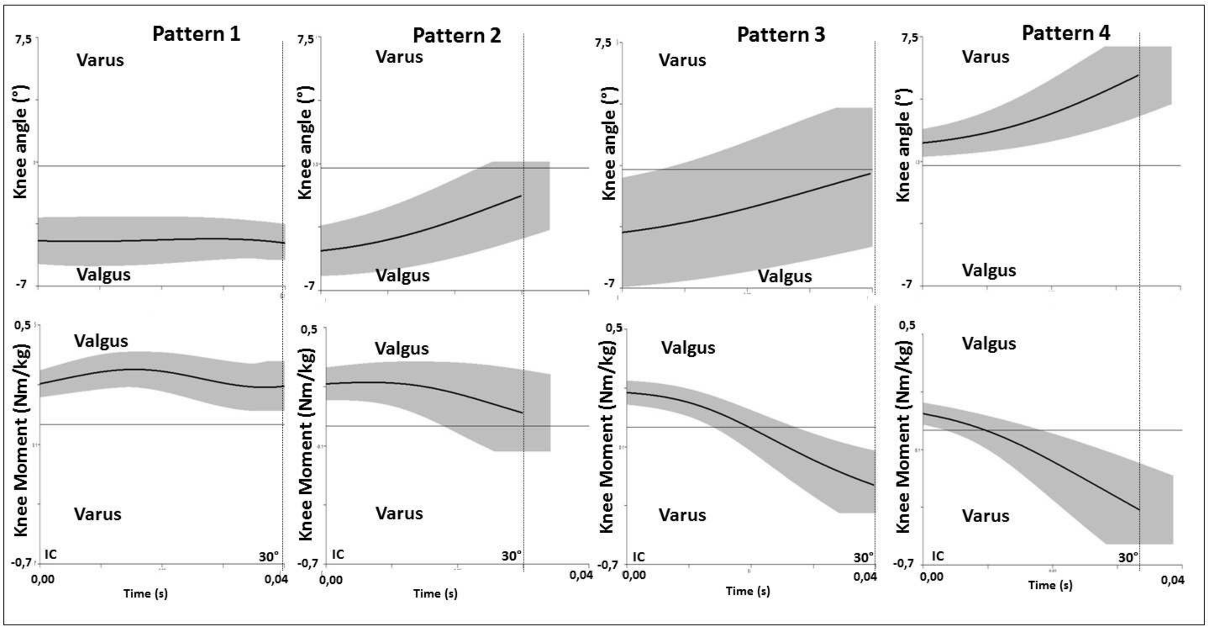

Figure 2: Typical knee angle and moment of force-time traces of the four landing patterns of a representative subject after a block (from initial contact to 30° knee flexion) (n=4).

DISCUSSION: The aim of the present study was to describe landing patterns during initial phase (0-30° knee flexion) of “go” landing after block in volleyball. We hypothesized that players would use different strategies during initial landing phase from the perspective of knee angle and moment of force in frontal plane. The results of the current study supported this hypothesis. The main finding of this study confirmed that the players used four different landing patterns during initial phase of the landing after block. We found that players have general tendency choose landing with a valgus angle at initial contact to varus angle at instant of 30°knee flexion except landing pattern 1. Similarly, we found a general tendency to decrease valgus knee moment and subsequently increase varus knee moment from initial contact to 30°knee flexion (Figure 2). Results of the current study are not in accordance with previous findings by Hughes et al. (2010). These authors found the opposite tendency for frontal knee angle and moment during bilateral straight block landing. These differences may be caused by lack of lateral movement during landing investigated in Hughes et al. (2010) study. Moreover, “go” landing presents single leg landing. The landing pattern 1 is characterized by almost the same valgus angle and moment at initial contact and at instant of 30°of knee flexion. The landing pattern 1 shows the greatest valgus moment at instant of 30° knee flexion than patterns 2-4. This valgus moment presents predictive risk factor of ACL injury (Hewett et al., 2005). The landing pattern 2 shows continuous decrease valgus angle and moment from initial contact to 30°knee flexion. The landing pattern 3 is characterized by smooth transition valgus angle and moment at initial contact to varus angle and moment at instant of 30° knee flexion. The landing pattern 4 shows continuous increase varus angle from initial contact to 30°knee flexion and a smooth transition from the valgus moment at initial contact to varus moment at instant of 30° knee flexion. Peak ACL load usually occurs near full extension (0-30° knee flexion) and when the knee flexion increases the peak ACL strain decreases (DeMorat et al., 2004). Results of the current study generally suggest that players with patterns 2, 3 and 4 may protect the ACL during the initial phase of landing (from initial contact to 30° knee flexion) by decreasing knee frontal plane angle and moment in direction from valgus to varus position (Figure 2).

CONCLUSION: Players used four different landing patterns during initial phase of the “go” landing after block. The players landed using different knee angle positions at initial contact depending on landing pattern. All landing patterns showed a valgus moment at initial contact and continuous decrease of the valgus moment and subsequently increased the varus moment from initial contact to 30°knee flexion. The highest valgus moment, which is considered to be a risk factor for ACL injuries, is evident in landing pattern 1 at the instant of 30°knee flexion only.

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