NET KNEE JOINT PEAK POWER OUTPUT IN FOUR LANDING STRATEGIES AFTER BLOCK IN VOLLEYBALL

David Zahradnik, [1] Daniel Jandacka,[1] Roman Farana,[1] Jaroslav Uchytil[1] and Martin Zvonar[2]

Human Motion Diagnostic Center, University of Ostrava, Ostrava, Czech Republic[1]
Faculty of Sports Studies, Masaryk University, Brno, Czech Republic[2]

The maximal rate of energy absorption of the knee joint represents a risk factor in non-contact knee injuries. The aim of the study is to compare the absorbed net knee peak power during a bilateral landing after a block in a stick, balance, step back and run back landing strategies. Twelve male professional volleyball players of the highest caliber in the Czech Republic (aged 24.5 ± 4.6 years; height 196.8 ± 0.1 cm; mass 90.1 ± 8.3 kg) participated in this study. From the aspect of the absorbed net knee joint peak power, the landing strategy step back and stick landing appears to be the best option. The balance landing may be in greater risk of non-contact knee injuries.

KEY WORDS: volleyball, knee, injury prevention, net joint knee power, kinematic analysis.

INTRODUCTION: Non-contact knee joint injuries are the most common injuries in volleyball (Decker, Torry, Wyland, Sterett, & Steadman, 2003). During the landing, the ankle, knee and hip joints are exposed to load due to the effects of the ground reaction force. Many authors have examined the effects of ground reaction forces on the joints of lower extremities (Decker et al., 2003; Chockley, 2008; Podraza & White, 2010). The toe-heel landing is the most common type of landing in those studies. The knee joint flexion plays an important role in the absorption of energy during the landing (Cortes, Onate, Abrantes, Gagen, Dowling, & Van Lunen, 2007). It has been proven that the knee joint together with the hip joint absorb the most energy during bilateral landing (Yeow, Lee, & Goh, 2011). In volleyball, there are four basic landing strategies after a block (stick, balance, step and run back). When the block is successful, it is followed by a stick, balance and step landing. A stick landing represents a landing on the ground with both lower extremities with a conscious expansion of the landing period by a sufficient flexion in the knee joint. A balance landing is characterized by an out-of-balance position of the player after landing on both lower extremities and the simultaneous effort to keep balance. A step back landing is characterized by stepping back from the net immediately following the landing. In a game situation when the guarding continues in one's own field, for instance after an unsuccessful block, the player is forced to move from the net to the following game position as soon as possible immediately after the landing (run back landing). The maximal rate of energy absorption of the knee joint represents a risk factor of a non-contact knee injury. The aim of the study is to compare the absorbed net knee peak power during a bilateral landing after a block in a stick, balance, step back and run back landing strategies.

METHODS: Participants: Twelve male professional volleyball players of the highest caliber in the Czech Republic (aged 24.5 ± 4.6 years; height 196.8 ± 0.1 cm; mass 90.1 ± 8.3 kg) participated in this study. At the time of testing, they had no injury that would prevent their participation in physical activity for more than two weeks over the previous six months (Dai, Sorensen, & Gillette, 2010). All procedures used in this study were approved by the Research Ethics Committee of the Diagnostic Center.

Protocol: The participants visited the center on one day. The experimental settings were based on a real situation of a volleyball block in a match. There was a male volleyball net installed in the laboratory. To normalize the height of the jump, a static volleyball ball was suspended in the space above the net. The centre of the ball was located 35 cm above the edge of the net and 20 cm behind the edge of the net on the opponent's side of the court. The data needed for the dynamic and kinematic analyses were obtained in four landing strategies (stick, balance, step and run back). Stick landing is defined as landing on the spot with both lower extremities, and with a conscious expansion of the landing period by a sufficient flexion in the knee joint. Balance landing is defined by an out-of-balance position of the player after landing on both lower extremities and the simultaneous effort to keep balance. Step back landing is defined as stepping back from the net immediately following the landing. Run back landing is defined as landing and moving as fast as possible 3m away from the net. The participants received information about the success of the block (successful x unsuccessful) by an acoustic signal at the moment of the contact with the ball above the net. If a block is performed successfully, stick, balance and step back landing might occur. Run back landing occurred always in case of an unsuccessful block. The participants had to block the static ball in every executed attempt. In both situations, the participants were motivated to execute the landing so that it reflected the situation in a match as close as possible. Before the beginning of the testing, the subjects had time for a complete warm-up including flexing and dynamic warm-up. After the warm-up, five practice attempts followed. Subsequently, the participants had to perform two successful attempts in the situation with stick, balance, step back and run back landing in a random order. The randomness of the selection of the individual experimental situations was monitored by the examiner as per the chart prepared in advance. The participants executed two successful attempts in each examined landing strategies. The participants were asked after each attempt whether the executed block corresponded with a real situation in a match. If the player's feedback was negative, the attempt was repeated. The attempt was also repeated when the participants failed to land on the force plate with the correct foot. To record eight successful attempts, the participants executed 18 attempts on average.

Experimental Set-up: Two force plates (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 infra-red cameras was employed to collect the kinematic data at a sampling rate of 247 Hz. Before the testing session, a right handed global coordinate system was employed and defined using an L-frame with four markers of the known location. A two-marker wand of the known length was used to calibrate the global coordinate system. The global coordination system was oriented so that the z-axis was vertical, y-axis was in anteroposterior and the x-axis was in the mediolateral direction. The data from the force plates and the cameras were collected simultaneously. The calibrations markers were placed bilaterally on the lateral and medial malleolus, medial and lateral femoral condyles, greater trochanter of femur, on the shoe over the first and fifth metatarsal heads. The tracking markers were securely positioned to define the trunk (acromion), pelvis (iliac crests, posterior superior iliac spines), thighs and shanks (four light-weight rigid plates holding a quaternion of markers) and feet (triad of markers on the heel over the calcaneus). The study was carried out at the Biomechanics Laboratory.

Data Analysis: The marker data were processed using the Visual 3D 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 the end was defined as a time of 100 ms after the start (Decker et al., 2003). All lower extremity segments were modeled as frusta of right circular cones while the pelvis and trunk were modeled as a cylinder. The local coordinate systems were defined using a standing calibration trial. The coordinate data were low-pass filtered using the fourth-order Butterworth filter with a 12Hz cutoff frequency. All force plate data were low-pass filtered using the fourth-order Butterworth filter with a 50Hz cutoff frequency. The net joint moment for the right knee was calculated according to Hamill and Selbie (2004). The right net knee joint power was calculated as a cross product of the instantenous net joint moment and joint angular velocity. The positive power for the right knee indicated energy absorbtion trough net excentric muscular concractions.

Statistical Analysis: The means and between-subjects standard error (SE) were determined for the net knee joint peak power for each type of landing strategies (stick, balance, step back and run back). Typical errors (TE) and intra-class correlations (ICC) for the repeated power output measurement were computed for each type of landing. A repeated measures analysis of variance (type of landing X subjects) with a criterion alpha level of 0.05 was performed to determine the possible net knee joint peak power differences during different type of landing. Mauchly's sphericity tests were not found to be significant.

RESULTS: This study identified the highest mean values (± SE) of the net knee joint peak power at the right knee during the balance landing (2019±56) while comparing it with the step back (1323±184), stick (1394±119) and run back (1721±289) landings (Figure 1).

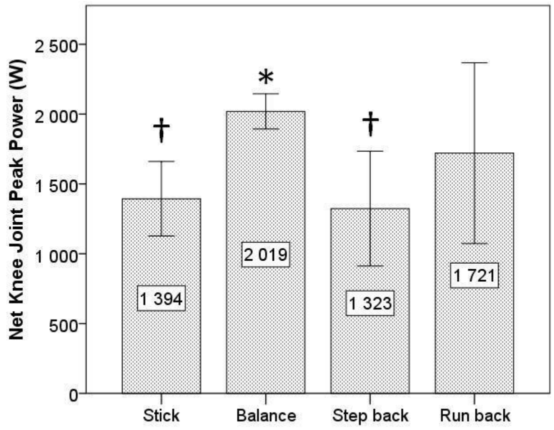

Figure 1: Mean and (SE) net knee joint peak power at the right knee according to type of landing. * signify significant differences in comparison with the stick landing. † signify significant differences in comparison with the balance landing.

Statistically significant differences were determined between the stick landing and balance landing (p=0.012) and furthermore between the balance landing and step back landing (p=0.017). The stick landing had ICC=0.81 and TE=193 W, the balance landing had ICC=0.76 and TE=208 W, the step back landing had ICC=0.90 and TE=153 W and the landing and run back had ICC=0.46 and TE=546 W.

DISCUSSION: The aim of the study was to compare the absorbed net knee joint peak power during a bilateral landing after a block in stick, balance, step back and run back landing strategies. The landing posture consistent with reduced ACL injury risk and limiting the forces must be absorbed by the lower extremity (Fong, Blackburn, Norcross, McGrath, & Padua, 2011). In the presented study the players are forced to utilize various landing strategies which differ by the position of the body in the moment of the contact with the ground. In the event of the step back and run back landings, the body tends to lean backward as opposed to the stick and balance landings where the body tends to lean forward. In the study we focused on the double-leg landing as it is apparent that, in the sagittal plane, the hip and knee showed major contributions to energy dissipation during double-leg landing; the hip and ankle are the dominant energy dissipaters during the single-leg landing (Yeow et al., 2011). The greatest value of the net joint knee peak power was found in the balance landing. We believe that the reason for that is the effort of the subject to maintain a dynamic balance immediately after the contact with the ground. This type of landing happens in a situation when the player is forced to divert arms from the body axis above the net in order to block the ball more efficiently. When the player lands, he tries to keep a dynamic balance in order to avoid threatening his partners or breaking the rules, for instance by touching the net. This effort leads to a production of high values in the net knee joint peak power. The lowest values of the net knee joint peak power were recorded in the step back landing. The step back landing is considered to be a more considerate version of landing. This type of landing is in accordance with the conclusions of Zahradnik and Jandacka (2011). During the subsequent move back, a part of the energy is not absorbed until the step-back from the net. Players use this type of landing in a situation when they have a space to execute the subsequent move and when they do not have to maintain a dynamic balance. While performing the stick landing, the players can consciously prolong the time of landing by flexing the knee joint successfully. This landing strategy seems to be beneficial due to decreasing the load on the knee joint as the vertical powers are reduced. This conclusion is in accordance with the conclusion of the study (Yu, Lin, & Garrett, 2006). The volleyball players cannot use a more significant forward-bend of the entire body when performing the stick landing due to the net in their way. It has been also found out that leaning the entire body forward during landing may produce more plantar-flexor moment and less knee-extensor moment (Shimokoki, Lee, Shultz, & Schmitz, 2009). We think that when performing the step back landing, the players naturally compensate the lack of the ability to lean forward by leaning backward and stepping back. The landing and run back represents the most difficult landing strategy for the subjects, represented by low ICC values and large TE.

CONCLUSION: This study presents novel scientific information in volleyball. From the aspect of the absorbed net knee joint peak power, the step back and stick landing strategies appear to be the best. When landing with a balance effort, the knee joint must produce a significantly higher net knee joint peak power. The balance landing may be in greater risk of non-contact knee injuries.

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