

Altered Peak Knee Valgus during Jump-Landing among Various Directions in Basketball and Volleyball Athletes

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- A** Concept / Design
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Abstract

Purpose: Excessive knee valgus during landing tasks is a contributing factor to knee injuries. Most studies have examined lower extremity biomechanics during the forward direction of a jump-landing task. Athletes perform many movements in the air and land in multi-directions. Therefore, the purpose of this study was to assess the peak knee valgus angle (PKVA) during one leg jump-landing in various directions.

Methods: Eighteen male basketball and volleyball athletes participated in the study. Participants performed one leg jump-landing tests from a 30 cm height platform in four directions. Knee valgus motion was measured using Vicon™ motion system. The data were analyzed with repeated measures ANOVA.

Results: Direction significantly ($P<0.001$) influenced the PKVA during landing. Significantly higher PKVA was observed for the lateral ($8.8^{\circ}\pm 4.7^{\circ}$) direction as compared to forward ($5.8^{\circ}\pm 4.6^{\circ}$) direction ($P<0.05$). The PKVA in 30° diagonal ($7.5^{\circ}\pm 4.6^{\circ}$) and 60° diagonal ($7.7^{\circ}\pm 5.7^{\circ}$) directions was higher than in the forward direction ($P<0.05$).

Conclusion: One leg jump-landing in lateral and diagonal directions results in a higher PKVA compared to landing in a forward direction and could lead to a higher risk of knee injury.

Key Words: Jump-Landing; Knee Valgus Angle; Basketball and Volleyball; Risk of Knee Injury

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INTRODUCTION

Knee valgus or tibia abduction relative to the femur during the performance of sports has been reported as a risk of injury to ACL [1] and the patellofemoral joint [2]. Subjects with patellofemoral pain syndrome (PFPS) perform the single leg squat task with greater medial displacement of the knee, a greater knee valgus angle, compared to subjects without PFPS [2]. Moreover, knee valgus angle has been associated with patellar tendinosis. Lian et al investigated the performance of volleyball players with patellar tendinosis during take-off and reported that mal-alignment can cause abnormal loading patterns of the patellar tendon and develop into patellar tendinosis

[3]. Most non-contact knee injuries are reported to occur during one foot landing leading to poor balance and subsequent injury [4,5]. Therefore, one legged landing has been extensively assessed to evaluate the factors that contribute to the risk of lower extremity injury and to develop a preventative program.

Most studies have examined lower extremity biomechanics during the forward direction of the jump-landing task [1,7,8]. Herrington and Munro reported normative values of knee valgus angle during unilateral step landing in healthy males and females by using 2D method [9]. They suggested that knee valgus angle should be in the range of $5\text{-}12^{\circ}$ for females and $1\text{-}9^{\circ}$ for males. During practices and competitive games, such as basketball and volleyball, athletes perform many

tasks in the air requiring the athlete to jump and land in multi-directions. Wikstrom et al stated that assessing only the forward jump-landing maneuver did not fully evaluate the factors of lower extremity injury [10]. Investigating knee joint loading during various scenarios may better describe the risk of ACL injury [11]. Therefore, purpose of the study was to measure knee valgus angle during unilateral jump-landing in different directions. Peak knee valgus angle (PKVA) during the landing phase was compared among four directions [forward (0°), 30° diagonal, 60° diagonal, and lateral (90°)].

METHODS AND SUBJECTS

Subjects:

Eighteen male athletes (9 basketball and 9 volleyball athletes) (mean age = 20.2 ± 1.3 years, range 19 – 24 years, mean body mass index = 22.31 ± 1.42 kg/m², range 20.34 – 24.91 kg/m²) participated in the study. All participants were members of organized university teams and practiced at least 3 times per week for at least 3 months prior to testing. Participants had no reported musculoskeletal disorders within 3 months prior to data collection. Subjects were excluded if they had history of serious injury or operation of lower extremities (e.g. ACL injury, fracture, patellar dislocation). Participants were right leg dominant. The operational definition of dominant leg is the preferred leg to perform a single legged hop [12]. Each participant read and signed an informed consent which was approved by the Committee on Human Rights Related to Human Experimentation of Mahidol University.

Procedure:

Subjects wore sport clothes and shoes. All tests were collected in the motion analysis laboratory at the Faculty of Physical Therapy, Mahidol University equipped with a Vicon™ 612 workstation (Oxford Metrics, Oxford, UK). Kinematic data were captured by four video cameras at sampling frequency of 200 Hz. An AMTI forceplate was used to measure ground reaction forces (GRFs) in order to define initial contact.

The forceplate sampling frequency was 1,000 Hz [13,14]. The sixteen reflective markers based on lower body model of Plug in Gait were placed bilaterally on the subject's bony prominences at the anterior superior iliac spine (ASIS), posterior superior iliac spine (PSIS), thigh, lateral condyles of femur, shank, lateral malleolus, heel and 2nd metatarsals.

Subjects practiced jump-landing 3 - 5 times in each direction to become familiar with the testing movements. Subjects performed the one leg jump-landing test in four directions; forward (0°), 30° diagonal, 60° diagonal, and lateral (90°) directions (Figure 1). The order of jump direction was selected randomly. A 30 cm height platform was placed 70 cm from the center of the forceplate. The participants stood on the dominant leg on a wooden platform, and flexed the other knee approximately 90° with a neutral hip rotation. Both hands were placed on the waist to eliminate variability in jumping mechanics due to arm-swing. Each subject was instructed to carefully jump-off the wooden platform without an upward jump action. Subjects jumped and landed while always facing and looking forward during jump-landing tests. If a subject did not maintain unilateral balance, land on the center of forceplate, or maintain hands on the waist, it was considered as an unsuccessful trial and reperformed. Three successful trials in each direction of jump-landing were analyzed. Participants rested five minutes between directions and at least thirty seconds between trials. Only the dominant leg of subjects was assessed.

Data acquisition and analysis:

Sixteen marker coordinates were filtered by a fourth order zero-lag Butterworth digital filter at a cut-off frequency of 8 Hz residual analysis technique [15]. A three dimensional model of the lower extremity was constructed by Plug in Gait software. The data of knee valgus angle was digitized between 100 ms prior and 300 ms after landing. These time intervals selected in this testing protocol have not been investigated in other studies. The angular displacement of each trial was therefore plotted to determine the pattern of knee motion. The PKVA during the landing phase from three trials was averaged and analyzed. The statistical comparisons were performed with SPSS statistics 17.

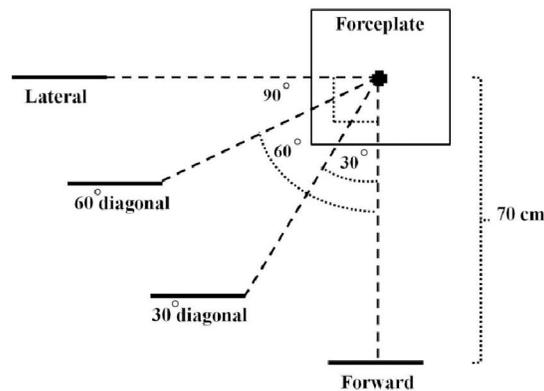


Fig. 1: Research setting of jump-landing directions. Subjects jumped from starting position in each direction and landed on the center of force platform

Repeated measures ANOVA was used to compare the effect of jump-landing directions. Pairwise comparisons were performed with Bonferroni correction to determine differences between jump-landing directions. The level of statistical significance was set at p-value less than 0.05.

9.731, $P < 0.001$]. Fig. 3 shows the values of PKVA for the four jump-landing directions. Significantly higher PKVA during landing was found in 30° diagonal ($P = 0.02$), 60° diagonal ($P = 0.003$), and lateral ($P = 0.001$) directions as compared to forward direction. There was no significant difference for the other comparisons.

RESULTS

The angular displacement of the knee joint in the frontal plane is shown in Fig. 2. The pattern of knee motion across four directions was similar. Knee valgus typically reached the peak angle during the first 200 ms after the foot contacted the forceplate. The landing direction significantly influenced the PKVA [$F(3,51) =$

DISCUSSION

This investigation evaluated the effect of jump-landing direction on knee valgus angle in basketball and volleyball athletes. In each direction, the maximum knee valgus angle occurred 100 – 200 ms after landing for all trials.

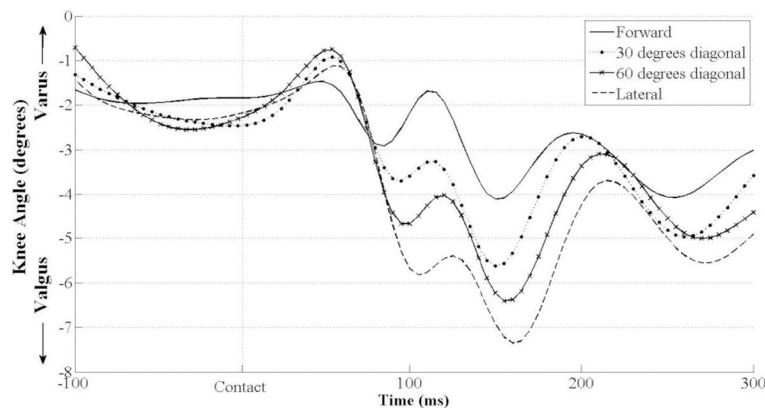


Fig. 2: Average angular displacement of knee joint in the frontal plane. In Y-axis, positive value represents varus and negative value represents valgus. X-axis exhibits the time period from 100 ms prior to landing to 300 ms after foot contact

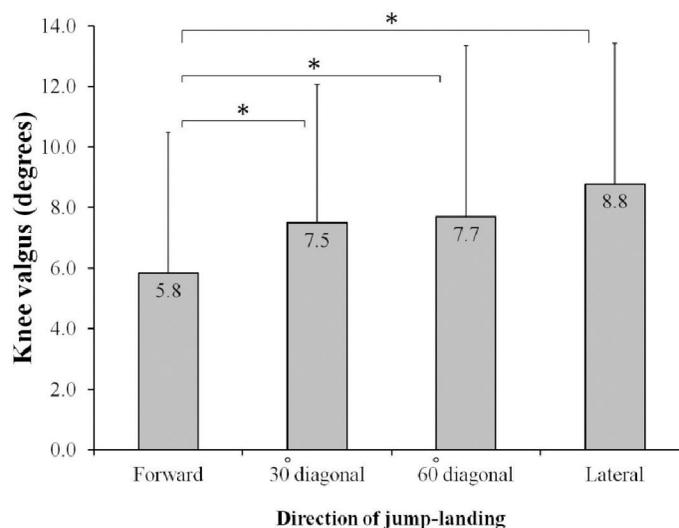


Fig. 3: Comparison of peak knee valgus angle during landing between four directions. Asterisks indicate statistical significance between jump-landing directions ($P < 0.05$)

Harrington found that the knee valgus angle in 50 healthy males during unilateral forward landing was 4.9 degrees [9]. The present study demonstrated 5.8 degrees of knee valgus angle in basketball and volleyball athletes during forward jump-landing and 8.8 degrees in the lateral direction of landing. The amount of PKVA during landing showed an increasing trend from the forward to the lateral direction (Figure 3). Ford et al stated that poor knee joint control in the frontal plane might be observed in landing with increased knee valgus motion [16] which can contribute to ligamentous injury.

In the mechanism of ACL injury, Andrews and Axe presented the concept of ligamentous dominance [17]. The ACL prevents excessive anterior tibial translation and knee valgus. An excessive loading of the ACL would occur if the lower extremity musculature could not sufficiently absorb the forces during landing. Normal knee alignment during dynamic weight bearing movement is important for injury prevention. Landing with neutral knee alignment helps to distribute forces during load acceptance [18,19]. Normally, muscle and cartilage absorb the loading impact during landing. If a jumper lands with abnormal alignment of lower limb, the impact load cannot be absorbed completely by muscle and cartilage tissue. Then, ligaments have to absorb the load and are susceptible to risk of injury.

On average subjects showed an increase of 3 degrees of peak knee valgus during lateral jump-landing compared to forward jump-landing. Knee valgus is considered the main mechanism of non-contact ACL injury [20] and predictor of possible injury [1,21]. The large knee valgus movement may lead to ACL overstretching and injury [22,23]. Knee valgus or Knee-in and Toe-out was reported as the predominant action at the time of non-contact ACL injury [24]. When observing the raw data, five subjects in the present study consistently showed high knee valgus in every direction of jump-landing. They had PKVA higher than the average of 8.9° valgus angle of lateral jump-landing. In conditions of muscle fatigue or unexpected loading angle, they may be at greater risk of injury compared to the other subjects.

McLean compared anticipated and unanticipated landing finding that peak knee abduction moment was substantially larger in unanticipated landing [25]. In the present study, subjects anticipated the direction of landing. Potentially the angle would have been greater with an unexpected direction of landing. McLean et al demonstrated the association between knee motion change and valgus loading [26]. Knee valgus loading can be increased 100% by an increase of 2° knee valgus motion during a cutting task. This may imply that lateral jump-landing included in this investigation

could induce more knee valgus loading than occurred in the other directions and increase the risk of knee injury. This finding supported Wikstrom who found that the direction of jump-landing influenced the lower extremity joint control [10]. They indicated that lateral and diagonal jump-landings showed more instability in the frontal plane than forward jump-landing. They suggested that in addition to testing jump-landing in forward direction, landing should be assessed in various directions.

The finding of the present study indicated an increase of PKVA during landing from forward to lateral jump-landings in male basketball and volleyball athletes. The athlete should be made aware that landing laterally may increase knee valgus angle and could lead to the risk of knee injury. For further study, female athletes should be tested to investigate the gender effect during jump-landing in various directions. Moreover, it is interesting to study the effect of jump-landing directions in athletes with ACL deficiency.

CONCLUSION

Significant difference of PKVA was found between directions during one leg jump-landing. Jump-landing in lateral and diagonal directions induced greater knee valgus angle than landing in the forward direction and could possibly lead to an increased risk of knee injury.

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Conflict of interests: None

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