วารสารวิทยาศาสตร์และเทคโนโลยีการกีฬา ปีที่ 15 ฉบับที่ 2, ธันวาคม 2558
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นิพนธ์ต้นฉบับ (Original articles)
ชีวกลศาสตร์ทางการกีฬา (Sports Biomechanics)

KNEE JOINT KINETICS DURING SINGLE-LEG JUMP LANDING IN FEMALE ATHLETES

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ABSTRACT:

Single-leg jump landing in various directions is a common task in sport activities. The aim of the present study was to investigate joint kinetics including knee net joint forces (KNJFs) and knee net joint moments (KNJMs) during single-leg jump landing. Material and method: Vicon™ motion analysis system and AMTI forceplate were used to collect the data. Nineteen female volleyball athletes were asked to perform the single-leg jump landing from a 30cm height platform in four directions including forward (0°), 30°diagonal, 60°diagonal, and lateral (90°) directions. The result exhibited that direction of single-leg jump landing significantly influenced ($p<0.05$) to peak KNJFs and KNJMs. A decreasing trend of peak anterior KNJF and an increasing trend of peak lateral KNJF were noted in forward, 30°diagonal, 60°diagonal and lateral jump landing, respectively. Significantly greater internal rotator and significantly less extensor of KNJMs were found during landing in lateral direction. Conclusion: Altered knee joint loading was observed in multi-directions jump landing. Jump landing in lateral direction might have a higher risk of knee injury because of a high lateral KNJF and internal rotator KNJM. Jump-landing training in multi-directions should be focused in order to prevent knee injuries. Athletes should perform landing carefully in diagonal and lateral jump-landing activities such as volleyball blocking and basketball lay-up.

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Key words : knee joint, single leg jump

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คิเนติกส์ที่ข้อเข่าขณะลงสู่พื้นจากการกระโดดด้วยขาข้างเดียวในนักกีฬาหญิง

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บทคัดย่อ

การลงสู่พื้นด้วยขาข้างเดียวจากการกระโดดในหลายทิศทางเป็นสิ่งที่พบได้บ่อยในกิจกรรมการเล่นกีฬา จุดประสงค์ของการศึกษานี้เพื่อทำการศึกษาตัวแปรทางคิเนติกส์ ซึ่งได้แก่แรงลัพธ์ข้อเข่าและโมเมนต์ลัพธ์ข้อเข่าขณะทำการกระโดดลงสู่เพื่อด้วยขาข้างเดียว โดยใช้เครื่องวิเคราะห์การเคลื่อนไหว Vicon และแผ่นวัดแรง AMTI ในการเก็บข้อมูลนักวอลเล่ย์บอลเพศหญิงจำนวน 19 คนเข้าร่วมการศึกษา โดยถูกบอกให้ทำการกระโดดลงสู่พื้นจากพื้นต่างระดับที่มีความสูง 30 เซนติเมตร ใน 4 ทิศทางดังนี้คือ ทิศด้านหน้า (0°) ทิศเฉียง 30° ทิศเฉียง 60° และทิศด้านข้าง (90°) ผลการศึกษาได้แสดงให้เห็นว่าทิศทางการกระโดดลงสู่พื้นมีผลต่อแรงลัพธ์ข้อเข่าและโมเมนต์ลัพธ์ข้อเข่าอย่างมีนัยสำคัญทางสถิติ ($p<0.05$) โดยมีแนวโน้มการลดลงของแรงลัพธ์ข้อเข่าทางด้านหน้าและมีแนวโน้มการเพิ่มขึ้นของแรงลัพธ์ข้อเข่าทางด้านข้างนอกจากการกระโดดลงสู่พื้นในทิศทางด้านหน้า ทิศเฉียงทำมุม 30° ทิศเฉียงทำมุม 60° และทิศด้านข้างตามลำดับ พบความแตกต่างอย่างมีนัยสำคัญในการเพิ่มของโมเมนต์ลัพธ์ข้อเข่าหมุนเข้าด้านในและการลดของโมเมนต์ลัพธ์ข้อเข่าเหยียดเข่าออก ขณะทำการกระโดดลงสู่พื้นด้วยขาข้างเดียวในทิศด้านข้าง บทสรุป การเปลี่ยนแปลงการรับแรงน้ำหนักข้อเข่าถูกพบได้ระหว่างการลงสู่พื้นจากการกระโดดในหลายทิศทาง โดยทิศทางการกระโดดลงสู่พื้นจากทิศด้านข้างอาจมีความเสี่ยงต่อการบาดเจ็บข้อเข่าได้มากกว่าเนื่องจากมีการเพิ่มขึ้นของแรงลัพธ์ข้อเข่าด้านนอกและมีการเพิ่มของโมเมนต์ลัพธ์ข้อเข่าหมุนเข้าด้านใน ฉะนั้นจึงควรให้ความสำคัญกับการฝึกฝนในเรื่องการลงสู่พื้นจากการกระโดดในหลายทิศทางเพื่อป้องกันการบาดเจ็บ โดยนักกีฬาควรมีการลงสู่พื้นอย่างระมัดระวังจากการเล่นกีฬาที่มีการกระโดดทิศมุมเฉียงและทิศด้านข้างเช่น การบล๊อคของวอลเล่ย์บอล การเลย์อัพของบาสเก็ตบอล

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คำสำคัญ : ข้อเข่า, การกระโดด

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INTRODUCTION

Single-leg jump landing in various directions is a common task in sport activities such as basketball and volleyball [1-3]. In 2013, Sinsurin et al [4] examined the effect of jump-landing directions including forward, diagonal, and lateral directions on peak knee valgus angle and lower extremity moments. They found that, in male athletes, different lower extremity mechanics were observed during landing in various directions. Besides, lateral jump landing showed high peak knee valgus angle which might increase the risk of knee injury such as ACL injury. High rate of ACL injury has been reported in female athletes, which was 4-6 times greater than male athletes [2]. It was interesting to study whether how female athletes responded to multi-directions jump landing. Therefore, purpose of this study was to investigate the joint kinetics including knee net joint forces (KNJFs) and knee net joint moments (KNJMs) during single-leg jump landing in female athletes.

METHOD

Nineteen-female volleyball athletes participated in the present study. All participants were members of organized university team and had practiced at least 3 times per week for at least 3 months prior to testing. Participants had no musculoskeletal problems within 3 months prior to collecting data. Each participant read and signed an informed consent form, which was approved by the Committee on Human Rights Related to Human Experimentation of Mahidol University.

Procedure

Jump-landing tests were collected in the motion analysis laboratory at the Faculty of Physical Therapy, Mahidol University, equipped with a Vicon™ Motion Analysis system (series number 1.8.4, Oxford Metrics Ltd., Oxford, UK). Prior to testing, participants were asked to wear sport clothes and shoes providing from researcher. Kinematic data was captured by ten video cameras at sampling frequency of 100 Hz. An AMTI forceplate at sampling frequency of 1,000 Hz was used to detect ground reaction forces (GRFs). The positions of 35 markers placement were follow the Plug-in-gait marker placement. Before testing, the calibration of motion analysis system was performed with static and dynamic calibrations.

The participants were instructed how to perform jumping from starting position and landing on the center of forceplate with the dominant leg correctly. Participants were asked to perform the single-leg jump-landing tests from a 30cm height wooden platform in four directions including forward (0°), 30°diagonal, 60°diagonal, and lateral (90°) directions (Figure 1) [7]. The participant stood with the tested leg on a wooden platform and bent knee 90° approximately on the non-tested leg with both hands on the waist in order to eliminate variation of arm swing. Each participant was introduced to carefully jump off the wooden platform without an upward jump action and to look forward through jump-landing test. If participant was not able to maintain balance, land on the center of force platform, maintain the hands on the waist, or move out of the force platform. It was considered as an unsuccessful trial. An unsuccessful trial was excluded and recollected.

Picture:

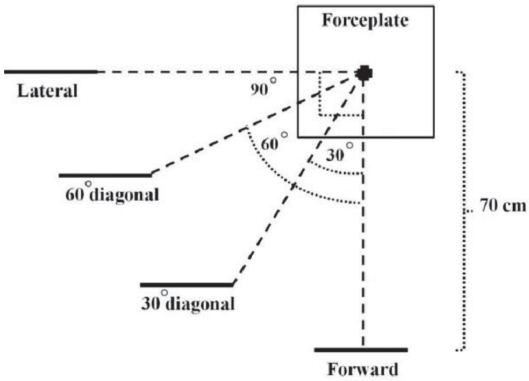

Figure 1 Research setting of jump-landing tests [7]

Before data collection, participants were allowed to practice jump landing three to five trials in order to accustom the testing. The session of jump-landing tests was ordered randomly. Each direction performed 3 trials. Participants were allowed to rest five minutes between sessions and to rest at least thirty seconds between jump-landing trials. The data of tested leg was processed. Thirty-five reflective markers coordinates and GRFs were filtered at the cut-off frequencies of 6 Hz and 40 Hz, respectively. The cut-off frequencies were determined with the residual analysis technique [5]. Average peak KNJFs and KNJMs from three trials of each jump-landing direction was analyzed and reported. Normal distribution of the data was observed which was tested by the Kolmogorov – Smirnov Goodness of Fit test. Repeated measures ANOVA was used to compare for the main effects of direction. Post hoc paired t-test was performed with Bonferroni correction. The level of statistical significance was set at p – value less than 0.05.

RESULT

Main direction effect significantly influenced to lateral KNJF ($F(1,18) = 163.67$, $p < 0.001$) and anterior KNJF ($F(1,18) = 41.83$, $p < 0.001$). Pairwise comparisons are shown in the Table 1.

Main direction effect significantly influenced to extensor (NJM $F(1,18) = 34.54$, $p < 0.001$) and internal rotator KNJM ($F(3,54) = 17.59$, $p < 0.001$). Pairwise comparisons are shown in the Table 2.

DISCUSSION

The finding of the present study showed that the direction of jump landing significantly influenced to horizontal KNJFs but did not influence to vertical KNJF. The higher magnitude of anterior KNJF was observed in forward (6.51 N/Kg) direction than 30º diagonal (6.29 N/Kg), 60º diagonal (4.86 N/Kg), and lateral

(4.14 N/Kg) directions, respectively. Lateral KNJF, on the other hand, showed an increasing trend from lateral (4.63 N/Kg), 60º diagonal (3.65 N/Kg), 30º diagonal (3.14 N/Kg), and forward (0.94 N/Kg) direction, respectively. Directional change of jump-landing protocol in horizontal plane was observed. The horizontal GRFs, which are the required parameters for estimating KNJFs, also changed. This could be the reason why there was the difference of horizontal KNJFs. Cortes et al [6] showed that an increase of posterior GRF had been theorized to increase the strain on the knee ligamentous structures by enhancing the proximal anterior tibia shear force, which creates an anterior displacement of the tibia thus increasing the strain on the ACL. In case of knee muscle control, we hypothesized that muscles around knee joint might not function well to stabilize the knee and to diminish the lateral KNJF. Knee muscles mostly place in antero-posterior part of the knee. Then, anterior KNJF might be controlled well even show a higher peak value. However, EMG should be included in the further study in order to understand knee muscle function.

Table 1. Peak knee NJFs during multi-directions landing (Mean (S.D.)) (N/kg)

Directions	Anterior (+) / Posterior (-)	Medial (+) / Lateral (-)	Superior (+) / Inferior (-)
Forward (0°)	6.51 (0.50)$^{z\,a}$	-0.94 (0.22)	-36.19 (3.36)
30°	6.29 (0.56)$^{z\,a}$	-3.14 (0.36)^{x}	-36.47 (3.41)
60°	4.86 (0.73)	-3.65(0.63)$^{x\,y}$	-36.79 (3.92)
Lateral (90°)	4.14 (1.47)	-4.63 (1.00)$^{x\,y\,z}$	-36.78 (4.04)

^{x} Statistically significant difference compared with forward direction ($p<0.05$)

^{y} Statistically significant difference compared with 30° diagonal direction ($p<0.05$)

^{z} Statistically significant difference compared with 60° diagonal direction ($p<0.05$)

^{a} Statistically significant difference compared with lateral direction($p<0.05$)

Table 2. Peak internal KNJMs during multi-directions landing (Mean (S.D.)) (Nm/kg)

Direction	Extensor (+) / Flexor (-)	Varus (+) / Valgus (-)	Internal rotator (+) / External rotator (-)
Forward (0°)	3.21 (0.67)	1.01 (0.32)	0.09 (0.04)
30° diagonal	3.16 (0.73)	0.99 (0.28)	0.13 (0.05)
60° diagonal	2.05 (0.52)$^{x\,y}$	0.92 (0.43)	0.14 (0.04)
Lateral (90°)	2.03 (0.65)$^{x\,y}$	0.91 (0.36)	0.18 (0.05)$^{x\,y\,z}$

^{x} Statistically significant difference compared with forward direction ($p<0.05$)

^{y} Statistically significant difference compared with 30° diagonal direction ($p<0.05$)

^{z} Statistically significant difference compared with 60° diagonal direction ($p<0.05$)

KNJMs represent which muscle group works dominantly during movement by summation between agonist and antagonist muscle groups. The current study reported the KNJMs in term of internal moment. The finding of current study exhibited that there was a significant difference in peak extensor NJM during landing. A decreasing trend of peak extensor NJM was observed from forward (3.21 Nm/kg), 30º diagonal (3.16 Nm/Kg), 60º diagonal (2.05 Nm/Kg), and lateral (2.03 Nm/Kg) directions, respectively. This could be that mechanical demand of knee extensor decreased during landing from forward to lateral directions. In 2013, Sinsurin et al [7] investigated the effect of jump-landing direction on peak knee moment in male athletes and exhibited that knee moment in sagittal plane showed the similar pattern during 100 ms before and 300 ms after foot contact in various jump landing directions. Flexor NJM work dominantly before foot contact and, then, changed immediately to be extensor NJM after foot contact. However, there was difference in peak value of extensor NJM (range, 3.12 – 3.43 Nm/kg) during landing in multidirectional directions. Frontal KNJM influences to the knee valgus motion which is the risk of knee injuries [4]. The finding of the present study exhibited a decreasing trend of varus NJM from forward (1.01 Nm/kg), 30° diagonal (0.99 Nm/kg), 60° diagonal (0.92 Nm/kg), and lateral (0.91 Nm/kg) directions. This might increase the risk of knee injuries cause of increasing knee valgus NJM. In 2011, Yeow et al [8] suggested that increased of knee valgus moment would trend to increase the risk of knee injury. Excessive external knee valgus moment was thought to place females at greater risk for ACL injury [9]. However, there was no a significant difference of peak varus NJM between jump-landing directions. Yeow's study supported Hewett's study. Hewett et al studied a prospective of 205 female athletes and found that those who tore their ACL over the course of a season demonstrated greater (2.5 times) knee valgus moments during a landing than those who did not tear their ACL [10]. Besides, Sigward and Powers stated that an excessive knee valgus moment and high lateral GRF increased hip abduction, hip internal rotation, and a more internally rotated foot progression angle. These were a high risk of ACL injury in female athletes [10]. Moreover, lateral jump landing exhibited the greater internal rotator KNJM than other directions. It might increase the knee instability as well. Therefore, athletes should perform landing carefully in diagonal and lateral jump-landing activities such as volleyball blocking and basketball lay-up. Jump-landing training in multi-directions should be focused in order to prevent knee injuries.

Conclusion

Knee biomechanics responded differently to various single-leg jump landing in female athletes. The current study exhibited that altered knee joint loading was observed in multi-directions jump landing. Jump landing in lateral direction might have a higher risk of knee injury because of a high lateral KNJF and internal rotator KNJM. Athletes should perform landing carefully in diagonal and lateral jump-landing activities.

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REFERENCES

1. McKay GD, Goldie PA, Payne WR, Oakes BW. Ankle injuries in basketball: Injury rate and risk factors. Br Jl Sports Med. 2001;35:103–108.
2. Ferretti A, Papandrea P, Conteduca F, Mariani PP. Knee ligament injuries in volleyball players. Am J Sports Med. 1992;20:203–207.
3. Nihat O, Margareta N. Fundamentals of biomechanics equilibrium motion and deformation. New York: Van Norstrand Reinhold; 1956.
4. Sinsurin K, Vachalathiti R, Jalayondeja W, Limroongreungrat W. Altered peak knee valgus during jump-landing among various directions in basketball and volleyball athletes. Asian J Sport Med. 2013;4:195-200.
5. Winter DA. Biomechanics and motor control of human movement. Third edition ed. Waterloo: John Wiley & Sons, Inc; 2005:45-80.
6. Cortes N, Morrison S, Van Lunen BL, Onate JA. Landing technique affects knee loading and position during athletic tasks. J Sci Med Sports. 2012;15:175-181.
7. Sinsurin K, Vachalathiti R, Jalayondeja W, Limroongreungrat W. Different sagittal angle and moment of lower extremity joints during single-leg jump landing among various directions in basketball and volleyball athletes. J Phys Ther Sci. 2013; 25:1109-1113.
8. Yeow CH, Lee PV, Goh JC. An investigation of lower extremity energy dissipation strategies during single-leg and double-leg landing based on sagittal and frontal plane biomechanics. Hum Mov Sci. 2011; (30) :624–635.
9. Sigward SM, Powers CM. Loading characteristics of females exhibiting excessive valgus moments during cutting. J Clin Biom. 2007 Apr;22:827-833.

10. Hewett TE, Myer GD, Ford KR. Biomechanical measures of neuromuscular control and valgus loading of the knee predict anterior cruciate ligament injury risk in female athletes: a prospective study. Am J Sports Med. 2005;33:492-501.