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Original Article

Comparative analysis of lower extremity kinematics: Effects of different single-leg rotational landings on dominant and non-dominant legs

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Abstract:
Problem statement: Single-leg landings increase the likelihood of lower extremity injuries. Although previous studies have highlighted kinematic differences in lower limb movements during landings in different directions, sports such as basketball and volleyball often involve rotational movements before landings, potentially increasing injury susceptibility**. Objective:** This study aimed to evaluate the influence of single-leg rotational landings on lower extremity kinematic parameters and explore differences between dominant and non-dominant legs. **Materials and methods:** Fifteen male collegiate basketball players performed single-leg rotational landings with the testing leg extended and hands on their hips. They jumped from a 30-cm-high box, minimizing knee flexion, and landed on the testing leg in three directions: forward (FL), clockwise (CL), and counter-clockwise (CCL), using both their dominant (DL) and non-dominant limbs (NDL), landing on the center of a force plate. Lower limb kinematics (including hip, knee, and ankle angles) from three trials were averaged and analyzed. **Results:** A 3 (direction) × 2 (leg) repeated measures ANOVA, complemented by post-hoc Tukey tests, was employed to identify discrepancies in lower extremity joint angles at initial contact (IC) and maximum knee flexion (MKF). No significant differences were observed in the main effect of direction**.** However, significant disparities in knee abduction, ankle inversion, and internal rotation were identified between DL and NDL. **Conclusion:** Basketball players may exhibit a predisposition towards rotational movement on their dominant side. Consequently, this study provides valuable insights for coaches and sports scientists, aiding in understanding kinematic differences during single-leg rotations, enhancing training protocols and mitigating injury risks.
Keywords*:* **Landing, Male, Rotation landing, Kinematics, Lower extremity**

Introduction

Jump-landing is a fundamental movement in numerous sports (Harringe et al., 2007), notably in basketball and volleyball, where athletes engage in frequent jumping activities (Vander Does et al., 2015). Studies indicate that volleyball and basketball players perform approximately 60 and 70 jumps, respectively, during a 60-min game (McClay et al., 1994; Lian et al., 1996). Effective jump-landing requires coordination of physique, muscle cocontraction, and flexibility. Thus, establishing a well-coordinated landing strategy is imperative for efficiently absorbing the impact forces (Aerts et al., 2013). Ground reaction forces (GRF) generated during jump landings require a synchronized interaction of the lower body's kinematic and kinetic chain, adapting to increasing force and dynamic movement. Variations in movement patterns and knee motion within this chain significantly influence the resultant forces. For instance, different jump-landing techniques, such as drop jumps and step landing tasks, may increase GRF and valgus strain on the knee joint during landing, compromising the mechanical absorption of generated forces (Ford et al., 2003; Herrington, 2011).

Several studies have underscored the unpredictability of landings in sports, whether executed with the dominant or non-dominant leg, often resulting in moderate strain forces on lower extremity structures (Nasseri A. et al., 2020; Agel et al., 2007; Dick et al., 2007; Fong et al., 2007). This dynamic nature of landings contributes significantly to ankle and knee injuries, which are prevalent in various sporting activities. An analysis of ankle injury causation emphasizes the critical role of landing stability as a defining factor in injury risk. Increased variation in postural sway while standing on one leg correlates with increased susceptibility to ankle injuries (McKay G.D. et al., 2001). Lateral ankle sprains, for instance, frequently occur upon foot–ground contact, characterized by sudden inversion of the ankle joint with limited plantar flexion and insufficient internal rotation, typically during landing and sideward movements (Panagiotakis et al., 2017). Regarding knee injuries, anterior cruciate ligament (ACL) injuries are prevalent, especially during landings (Hootman et al., 2007). Factors such as knee loading, encompassing valgus–varus movement, internal–external rotation, extension, and proximal anterior tibial shear force, exert significant strain on the ACL, thus contributing to ACL injuries (Krosshaug T. et al., 2007).

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Previous research indicates that a substantial portion of ankle and knee injuries in basketball and volleyball—ranging from 45% to 86%—occur following landings from jumps (Bahr and Bahr, 1997; McKay et al., 2001; Vander Does et al., 2015). Factors such as inadequate knee flexion, excessive knee abduction, and internal rotation increase the risk of knee injuries among athletes during landing tasks (Dai et al., 2012; Everard et al., 2021). While earlier studies predominantly focused on knee biomechanics with forward-directed landing tasks (Ford et al., 2003; Herrington, 2011), the real-world sporting environment often requires landings on a single leg from various directions. Consequently, few studies have explored the relationship between lower extremity injuries and landing direction (Sinsurin et al., 2013 & 2017). For instance, Kunugi et al. (2017) investigated male collegiate soccer players performing single-leg landings in forward, lateral, and medial directions. Their analysis of lower limb kinematics, particularly ankle dynamics during impact phases, revealed significant differences among the three landing directions. Specifically, lateral landings exhibited smaller eversion and pronation positions of the ankle and rearfoot, requiring more time to stabilize in the mediolateral plane (TTS-ML) compared to forward and medial landings. Additionally, mediolateral GRFs were higher in lateral and medial landings than in forward landings. Sinsurin et al. (2017) examined nineteen female volleyball athletes performing single-leg landings in four directions: forward, diagonal at 30° and 60°, and lateral at 90° angles. Their investigation revealed various knee and hip strategies across different landing directions, potentially attributed to variations in landing techniques. They attributed differences to a stiff landing strategy. Worse knee synchronization was observed during sideways landings compared to forward and diagonal landings, indicating that the non-dominant limb exhibited superior coordination during multidirectional jump landings. Consequently, the dominant limb appeared to have a higher injury risk owing to the different stresses imposed by diagonal, lateral, and rotational landings. The results underscore the significance of whole-body posture during landings, wherein lower limb extension and inward rotation, accompanied by hip adduction, potentially increase the risk of lower extremity injuries (Dempsey et al., 2012).

Basketball and volleyball players frequently perform jumps with rotational movements before landing. While the biomechanics of lower extremities during multi-directional jump landings have been extensively studied, there is a lack of research on single-leg rotational landings and the differences between landing on dominant and non-dominant limbs (Limroongreungrat et al., 2023; Jamkrajang et al., 2022). Thus, the objectives of this study were twofold: 1) to investigate the impact of single-leg rotational landings on lower extremity kinematic variables, and 2) to examine differences between dominant and non-dominant legs during these landings. We hypothesized that lower extremity kinematics associated with rotational landings would exhibit significant variations between directions and between dominant and non-dominant legs.

Materials and methods

Participants

The sample size was determined using G* Power (Faul et al., 2009) conducting an a priori power analysis for repeated measures analysis of variance with an effect size (f) = 0.25 (significance level: 0.05; power: 0.95; repeated measures = 3). The power analysis indicated that 15 subjects would be required to attain sufficient statistical power. Therefore, 15 male basketball players were recruited for this study. Their mean age was 19.87 ± 1.96 years, height 177.62 ± 6.06 cm, weight 71.20 ± 7.78 kg, and body mass index (BMI) 22.27 ± 1.14 kg/m^2. On average, participants engaged in basketball training for 4.73 ± 0.59 hours/week. Inclusion criteria stipulated that participants must exercise at least 3 sessions/week (≥1 hour/session) and have no history of musculoskeletal issues in either leg within the past three months before testing. Exclusion criteria encompassed severe lower extremity injuries or surgeries. All participants received detailed explanations of the testing procedures, and they provided informed consent by signing the consent form approved by the Mahidol University Committee on Human Rights Related to Human Experimentation (MU-CIRB 2020/161.1410).

Procedure

Laboratory preparation

Ten optoelectronic cameras (BTS bioengineering, Italy) recorded kinematics at a sampling rate of 200 Hz. Forty-four reflective markers were attached to the participants' bodies, adhering to the trunk and lower limb model developed by Vanrenterghem et al. (2010), encompassing markers on the thorax, pelvis, thighs, shanks, and feet. Static and dynamic trials were captured. Smart tracker and Smart analyzer software (BTS bioengineering, Italy) were used to track, digitize, and interpolate any missing data for all movement phases. Subsequently, the marker data were filtered using a 20 Hz low-pass Butterworth filter (Roewer B. D. et al., 2014) in Visual 3D software (C-motion, Germantown, USA). Joint kinematics were calculated from initial contact (IC) to maximum knee flexion (MKF), with the data normalized to encompass 100% of the landing phase spanning from IC to MKF.

Testing and Landing Protocol

Participants' weight and height were initially measured. Then, participants engaged in a 10-min warm-up session comprising cycling at a consistent intensity of 60 W on a model 828 E cycle ergometer (Monark, Inc., Stockholm, Sweden) and 5 min of dynamic lower limb stretching exercises, including rotational lunges, side lunges, body-weight squats, and hamstring walks. Subsequently, participants were instructed to stand on the testing leg with the knee extended and hands on the iliac crest. They were then prompted to jump from a 30-cm high box, aiming for minimal knee bending, and land on the testing leg in three directions: forward landing (FL), clockwise landing (CL), and counter-clockwise landing (CCL), utilizing both their dominant (DL) and non-dominant limbs (NDL), with the landing target being the center of the force plate positioned 20 cm from the box (Fig. 1). For all conditions, participants maintained open eyes, fixed their gaze forward, endeavored to balance quickly, and held the single-limb stance for 5 s. No specific landing technique instructions were provided. The researcher randomized the order of DL and NDL and landing directions using a ballot method. A 30-s rest was allocated between trials, with each subject performing three successful landings in each direction. A 5-min rest was provided between each landing direction. Trials were stopped and repeated if the subject's opposite foot made contact with the floor or box, if the test limb's toe failed to point forward, if post-landing foot movement was detected, or if hands were used to regain balance.

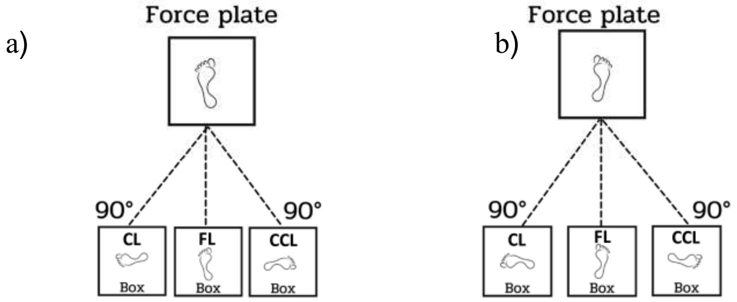

Fig. 1 Landing tasks a) Landing on NDL doing CL (left), FL (middle), and CCL (right) and b) Landing on DL, doing CL (left), FL (middle), and CCL (right)

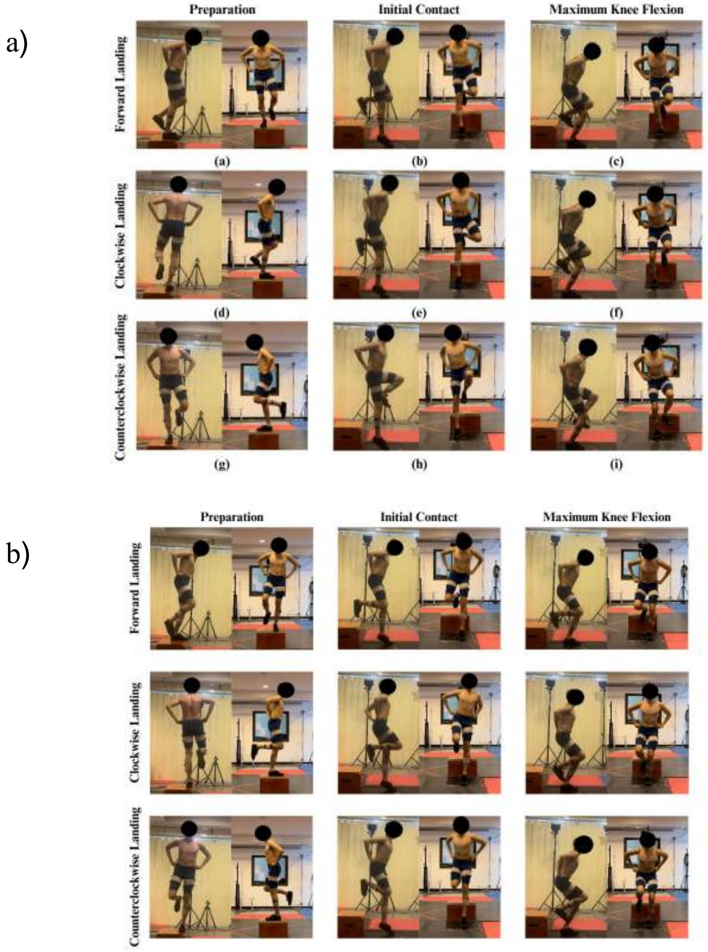

Fig. 2 a) Landing on DL and b) Landing on NDL
(top, middle, and bottom panels represent forward, clockwise, and counterclockwise landings, respectively)

Statistical analysis

The data distribution was evaluated using Shapiro–Wilk tests. A 3 (directions) × 2 (leg) repeated measures ANOVA with post-hoc Tukey tests were utilized to identify disparities in lower extremity joint angles at initial contact (IC) and maximum knee flexion (MKF). All data are reported as mean ± standard deviation (SD). Statistical analyses were performed using SPSS software (version 25), and the α level was set at p < 0.05.

Results

The findings indicated that, at initial contact, the knee abduction angle of the DL was greater than that of the NDL, demonstrating a significant main effect between legs (p = 0.038, ηp2 = 0.061). Additionally, significant differences in ankle angle at initial contact were observed, with the DL exhibiting inversion (p < 0.001, ηp2 = 0.733) and internal rotation (p < 0.001, ηp2 = 0.799), whereas the NDL displayed eversion and external rotation. At maximum knee flexion, a significant difference was detected in hip flexion between legs (p = 0.013, ηp2 = 0.077).

Furthermore, significant disparities in ankle angle were noted, with the dominant leg demonstrating inversion (p < 0.001, ηp2 = 0.89) and internal rotation (p < 0.001, ηp2 = 0.657), while the non-dominant leg exhibited eversion and external rotation.

Table 1 Mean ± standard deviation (SD) of peak joint angles of lower extremities in three planes between the dominant and non-dominant legs and three landing tasks (directions) at initial contact

Joint angle (degree)		**Legs and directions**						**p-value**					
		Dominant leg (right leg)			**Non-dominant leg (left leg)**			**Between legs**		**Between directions**		**Interaction**	
		FL	**CCL**	**CL**	**FL**	**CCL**	**CL**	***p***	**Effect size**	***p***	**Effect size**	***p***	**Effect size**
Hip	Flexion (+) / Extension (−)	41.95 ± 12.52	40.34 ± 11.58	40.49 ± 13.14	39.58 ± 12.61	39.50 ± 12.09	47.55 ± 7.34	0.620	0.003	0.391	0.024	0.273	0.033
	Abduction (−) / Adduction (+)	12.60 ± 3.52	14.66 ± 3.44	12.32 ± 4.21	12.47 ± 3.19	11.35 ± 3.13	13.74 ± 4.46	0.409	0.009	0.856	0.004	0.059	0.071
	Internal (−) / External rotation (+)	−9.79 ± 5.91	−10.12 ± 5.96	−9.91 ± 6.47	−10.03 ± 6.93	−12.98 ± 5.15	−11.87 ± 7.69	0.294	0.018	0.689	0. 012	0.782	0.008
Knee	Flexion (+) / Extension (−)	19.48 ± 6.29	21.70 ± 6.07	17.90 ± 7.85	18.37 ± 7.60	17.23 ± 6.86	17.15 ± 7.75	0.188	0.023	0.591	0.014	0.587	0.014
	Abduction (−) / Adduction (+)	−5.69 ± 2.64	−5.94 ± 2.98	−5.16 ± 3.15	−4.26 ± 2.47	−4.43 ± 2.36	−4.07 ± 2.79	0.038*	0.061	0.765	0.008	0.961	0.001
	Internal (−) / External rotation (+)	−18.95 ± 11.55	−19.70 ± 10.42	−18.50 ± 11.06	−20.43 ± 9.36	−19.65 ± 9.83	−19.00 ± 8.75	0.493	0.007	0.872	0.004	0.919	0.002
Ankle	Flexion (+) / Extension (−)	−35.88 ± 6.79	−37.23 ± 7.08	−37.62 ± 7.08	−34.66 ± 7.14	−33.82 ± 8.86	−35.52 ± 8.46	0.166	0.023	0.784	0.006	0.855	0.004
	Inversion (−) / Eversion (+)	−9.34 ± 5.45	−7.06 ± 4.41	−6.50 ± 4.88	7.92 ± 4.98	7.54 ± 3.66	7.13 ± 5.11	<0.001*	0.733	0.717	0.011	0.414	0.028
	Internal (−) / External rotation (+)	−16.46 ± 6.67	−17.24 ± 8.64	−16.08 ± 7.73	20.00 ± 10.06	18.74 ± 11.19	21.43 ± 12.10	<0.001 *	0.799	0.788	0.007	0.962	0.001

*Statistically significant difference (*p* < 0.05). FL = forward landing, CL = clockwise landing, CCL = counter-clockwise landing

Table 2 Mean ± standard deviation (SD) of peak joint angles of lower extremities in three planes between the dominant and non-dominant legs and three landing tasks (directions) at maximum knee flexion

Joint angle (degree)		**Legs and directions**						**p-value**					
		Dominant leg (right leg)			**Non-dominant leg (left leg)**			**Between legs**		**Between directions**		**Interaction**	
		FL	**CCL**	**CL**	**FL**	**CCL**	**CL**	***p***	**Effect size**	***p***	**Effect size**	***p***	**Effect size**
Hip	Flexion (+) / Extension (−)	39.23 ± 8.81	38.08 ± 10.22	36.06 ± 8.42	41.01 ± 10.45	40.83 ± 10.62	47.17 ± 7.18	**0.013**	0.077	0.683	0.010	0.132	0.051
	Abduction (−) / Adduction (+)	2.49 ± 1.91	3.13 ± 2.12	3.54 ± 2.65	4.46 ± 2.75	2.87 ± 1.98	4.85 ± 3.14	0.069	0.043	0.216	0.040	0.231	0.038
	Internal (−) / External rotation (+)	−8.94 ± 5.25	−11.16 ± 9.21	−7.83 ± 1.98	−9.43 ± 5.02	−8.64 ± 6.51	−12.43 ± 9.40	0.609	0.004	0.883	0.004	0.227	0.046
Knee	Flexion (+) / Extension (−)	59.84 ± 8.27	61.75 ± 6.93	61.25 ± 8.08	57.55 ± 11.52	60.00 ± 9.19	57.77 ± 9.10	0.211	0.021	0.666	0.011	0.938	0.002
	Abduction (−) / Adduction (+)	−8.42 ± 4.52	−7.67 ± 5.11	−7.65 ± 5.14	−7.39 ± 4.64	−7.22 ± 4.34	−6.74 ± 4.27	0.450	0.008	0.859	0.004	0.972	0.001
	Internal (−) / External rotation (+)	−9.73 ± 6.18	−9.62 ± 6.27	−8.72 ± 6.44	−8.85 ± 6.90	−9.30 ± 6.58	−10.37 ± 8.34	0.924	0.000	0.991	0.000	0.786	0.007
Ankle	Flexion (+) / Extension (−)	−29.04 ± 8.08	−28.89 ± 7.96	−29.95 ± 8.96	−29.69 ± 11.39	−27.73 ± 11.87	−28.47 ± 10.39	0.750	0.001	0.906	0.002	0.904	0.002
	Inversion (−) / Eversion (+)	−14.77 ± 6.27	−14.69 ± 6.86	−15.05 ± 4.91	12.63 ± 4.02	13.06 ± 3.91	13.91 ± 4.08	<0.001 *	0.890	0.946	0.002	0.863	0.005
	Internal (−) / External rotation (+)	−10.54 ± 5.81	−6.92 ± 5.54	−7.25 ± 5.99	13.41 ± 9.71	10.79 ± 8.01	12.91 ± 10.01	<0.001 *	0.657	0.828	0.006	0.393	0.029

*Statistically significant difference ($p < 0.05$). FL = forward landing, CL = clockwise landing, CCL = counter-clockwise landing

Discussion

The primary objective of this study was to examine the impact of various rotational landing directions on lower extremity kinematics, specifically focusing on a single-leg rotation (90-degree rotation) before landing—an action prevalent in sports such as basketball and volleyball. Our results did not reveal significant differences in lower extremity kinematics across different rotational directions. This outcome may be attributed to the participants executing drop landings with a 90-degree rotation from a 30-cm box, a task familiar to male basketball players.

Furthermore, our study aimed to investigate differences between the dominant and non-dominant legs during single-leg landings. We hypothesized that significant differences in lower extremity kinematics related to rotational landings between these limbs would be observed. Our findings partially supported this hypothesis, demonstrating statistically significant differences between dominant and non-dominant legs during single-leg landings concerning hip flexion at maximum knee flexion, knee abduction at initial contact, and ankle inversion with internal rotation during both landing events. However, no statistically significant differences were observed in the effects of directional variations or the interaction between limb dominance and directional effects on lower extremity joint angles.

Mercado-Palomino et al. (2021) examined kinetic and kinematic data of hip, knee, and ankle joints during block jump-landings in dominant and non-dominant directions among female volleyball players. Their findings revealed significant differences in movement strategies between the dominant and non-dominant limbs. The researchers elucidated that players aiming for optimal spike performance typically employ a three-step sequence dictated by their dominant hand for hitting, leading them to land predominantly on their non-dominant limb. Consequently, the non-dominant limb, serving as the lead limb, experiences variations in jump-landing direction during game situations, disrupting the usual three-step sequence and changing the jump-landing movement strategy. This difference in limb movement strategies during jump-landing underscores potential asymmetries in strength and balance (Mercado-Palomino et al., 2021).

This study showed that the hip flexion angle during landing at the maximum knee flexion phase was greater in the non-dominant leg compared to the dominant leg. Typically, during maximum knee flexion, the hip joint exhibits passive flexion. Consequently, the increased hip flexion in the non-dominant leg may indicate compensation for lesser knee flexion or other asymmetries in lower extremity muscle strength (Hunter et al., 2000). Sinsurin et al. (2017) reported significant differences between dominant and non-dominant limbs, particularly regarding volleyball players' peak vertical ground reaction force. In 30° diagonal jump landings, the non-dominant leg displayed greater hip flexion, whereas in 60° diagonal and lateral jump landings, the dominant leg exhibited more hip flexion. The researchers recommended emphasizing lower extremity flexion, particularly at the hip and knee joints, when landing in lateral and diagonal directions, advocating for a soft-style landing technique associated with injury prevention and reduced injury risk (Laughlin et al., 2011). In contrast, Wang and Fu (2019) investigated the impact of asymmetry on kinematics during single-leg landings in female soccer players. They found that hip flexion was greater in the dominant leg compared to the non-dominant leg. Additionally, Mokhtarzadeh et al. (2017) studied side-to-side lower limb differences in movement patterns during a single-leg drop-landing task in athletic females. They reported no significant difference in hip angle between dominant and non-dominant legs.

Regarding knee joint angles at initial contact, it was noted that the knee abduction (valgus) angle of the dominant leg exceeded that of the non-dominant leg—a pattern associated with an increased risk of knee injury (Koga et al., 2010). Our findings align with Ford et al. (2003), who observed significantly greater valgus knee angles in the dominant leg during a drop vertical jump. Knee injuries often result from landing with insufficient knee flexion, excessive knee abduction, and knee internal rotation (Dai et al., 2012; Everard et al., 2021), particularly because knee abduction or valgus angle can impose stress on the ACL through anterior tibial translation, potentially leading to injury. Several studies have reported a higher incidence of knee injuries in the dominant leg (DeLang et al., 2021; Svensson K. et al., 2018; Brophy R. et al., 2010; Zebis MK. et al., 2009), suggesting a predisposition to knee injuries during landing in the dominant leg. Additionally, hip position, stiffness, and hip joint abduction strength have been implicated in knee valgus (Lohmander et al., 2004; Chaudhari et al., 2006; Geiser et al., 2010). Neuromuscular fatigue of the hip abductor muscle can increase knee valgus angle, albeit the clinical significance of this change may vary. Effective hip joint control is crucial for maintaining favorable knee alignment and preventing ACL injuries during jump landing (Geiser et al., 2010). The gluteus medius muscle also plays a vital role in reducing knee valgus moment during single-leg landing (Lohmander et al., 2004). Reduced gluteus medius muscle activity can increase knee valgus moments during landing and single-leg squatting (Lohmander et al., 2004). Hewett et al. (2010) proposed four neuromuscular imbalances contributing to ACL injury in athletes: ligament dominance, quadriceps dominance, leg dominance, and trunk dominance. Ligament dominance entails neuromuscular imbalance leading to valgus collapse, while quadriceps dominance involves primarily stabilizing the knee joint using the quadriceps. Inadequate knee flexion during jump landing increases the risk of sustaining an ACL injury. Leg dominance refers to side-to-side asymmetry in the lower extremities, including muscle recruitment, strength, and flexibility, while trunk dominance signifies difficulty controlling the trunk in three-dimensional space. Unlike anatomical factors, these neuromuscular imbalances can theoretically be modified through appropriate interventions, emphasizing the importance of ACL injury prevention programs and the efficacy of such interventions. Consequently, incorporating a training regimen targeting hip and knee muscle strength may be a valuable addition to ACL injury prevention programs.

The ankle angle during landing, both at initial contact and maximum knee flexion, revealed inversion and internal rotation in the dominant leg, while the non-dominant leg exhibited eversion and external rotation. These findings are consistent with the study by Komsak et al. (2017), which demonstrated greater ankle adduction and inversion in the dominant leg during single-leg landings at 60° diagonal and lateral (90°) jump landings. The combination of internal rotation and inversion of the ankle joint is a characteristic feature of the mechanism of lateral ankle sprains. The most prevalent ankle injuries involve the lateral ligaments (Garrick JG., 1997; Panagiotakis et al., 2017), with the dominant limb being a contributing factor (Fong et al., 2009). Both knee and ankle injuries are frequently reported in the dominant leg (DeLang et al., 2021; Svensson et al., 2018; Brophy et al., 2010; Zebis et al., 2009). Beynnon et al. (2002) emphasized that the dominant limb is implicated as a risk factor for lower extremity injuries owing to the increased demand placed on it by most athletes. Consequently, athletes often exhibit increased frequency and magnitude of movement about the ankle, particularly during high-demand activities, which may predispose them to ankle injuries.

Various factors influence the joint angles and movements of the lower extremities during single-leg landing, including neuromuscular control, compensatory movements, and task variations. Neuromuscular control mechanisms are crucial for preparing, maintaining, and restoring functional joint stability during jump landing (Allet et al., 2017). Single-leg landing poses a challenge to neuromuscular control by altering muscle force and length feedback during the abrupt deceleration upon landing. Effective muscle function is vital during jump landing to counteract potentially harmful alignment and excessive joint stress (Nyland et al., 2011). Consequently, inadequate neuromuscular control during athletic movements can lead to detrimental alignment and increased joint forces in the lower extremities (Pollard et al., 2010). Maniar et al. (2022) investigated lower extremity muscle function during single-leg landing and highlighted the significant role of muscles in joint contact and movement. Therefore, understanding muscle function during dynamic tasks is crucial for informing athletic training interventions aimed at improving landing performance. Many studies have outlined training programs to prepare individuals for single-leg landing situations or prevent injuries (Mandelbaum et al., 2005; Myer et al., 2005; Sasaki et al., 2019). Neuromuscular training programs for ACL injury prevention encompass various components, such as plyometrics, balance, agility, flexibility, and strengthening, to address different aspects of neuromuscular control (Mandelbaum et al., 2005; Myer et al., 2005). Core stability exercises are frequently included in lower extremity injury prevention programs, especially for ACL injury prevention. The dynamic movements of the trunk and hip joints influence knee joint biomechanics during physical activities, and deficits in neuromuscular control of the trunk and hip joints may increase the risk of injury (Zazulak et al., 2007; Hewett et al., 2009; Frank et al., 2013; Khayambashi et al., 2017).

This study has several limitations. First, this study only evaluated male participants. This could potentially restrict the generalizability of our findings to other populations because exploring different genders may yield varied results. Furthermore, our study solely focused on joint angle variables, neglecting additional kinetic variables and electromyography (EMG) data. Future investigations should encompass a broader range of variables, including kinetic variables and EMG, to understand single-leg landing tasks comprehensively. Additionally, incorporating movement variability and utilizing a time series approach, such as statistical parametric mapping, would enable a more detailed analysis of single-leg landing dynamics.

Conclusions

This study examined the impact of single-leg rotational landings on dominant and non-dominant legs, focusing on their effects on lower extremity joint angles at initial contact and maximum knee flexion. The observed differences in joint angles between the dominant and non-dominant legs may contribute to varying injury rates for each limb. Specifically, during the maximum knee flexion phase of landing, the non-dominant leg exhibited a greater hip flexion angle, suggesting its potentially superior ability to absorb forces and potentially reducing the incidence of hip joint injuries compared to the dominant leg. Conversely, the dominant leg demonstrated a higher angle of knee abduction (valgus) at initial contact, indicating a greater susceptibility to knee injuries. Furthermore, the ankle angle of the dominant leg displayed inversion and internal rotation at both initial contact and maximum knee flexion, while the non-dominant leg exhibited eversion and external rotation. These differences in joint angles may predispose the dominant leg to more frequent knee and ankle injuries, given that their landing positions resemble injury mechanisms.

These findings underscore the asymmetrical characteristics of single-leg rotational landings and emphasize the importance of implementing targeted strengthening exercises and comprehensive injury prevention programs tailored to individual athletes. Addressing the asymmetries and specific movement patterns identified in this study is critical for injury prevention. Incorporating skill-specific training drills replicating game-like scenarios involving single-leg rotational landings can also mitigate the risks of landing tasks on both legs. This highlights the importance of athletes being more cognizant of their landing mechanics and injury prevention strategies.

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