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Kinematic comparison between single and double-leg jump landings in sagittal plane for male handball players

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Abstract

Double and single leg jump (SL) landing activities are considered stressful tasks for handball players. Most of the previous researches focused on kinetic analysis of these activities rather than kinematic analysis. Also, there is a lack of comparative studies that were performed between the two types of activities. The main aim of this study is to perform lower extremity kinematic analysis to find the kinematic differences between single and double-leg jump (DL) landings in the sagittal plane (SP),in male handball players. The lower extremity kinematics were measured in 15elite male handball players(while performing SL and DL landings), by using three-dimensional motion analysis system (VICON). The results revealed statistically significant difference between the lower limb kinematics of SP_{SL} and SP_{DL}. During the $SP_{DL,}$ the hip and knee flexion angles increased more than those in SP_{SL}, while there was more knee adduction with internal rotation stress in SP_{SL} than in SP_{DL}(P< .05). The hip and knee flexion angles in the SP_{DL} showed moderate association with those during the SP_{SL}(R^2, 0.49 and 0.44 respectively). In addition, the hip abduction in the SP_{DL} showed moderate association with those during the SP_{SL} (R^2, 0.37). But, hip internal rotation, knee adduction, and knee internal rotation in the SP_{DL} showed weak association with those during the SP_{SL} (R^2 = 0.02-0.041; P > .05).The double-leg jump landing maybe considered as a less stressful task for the lower limb joints than the single-leg jump landing activity. As a clinical benefit, the double-leg jump landing activity may be used to screen the ACL injury risk in certain planes of joint motion.

Keywords: Handball players, high-risk movements, leg-jump landing.

INTRODUCTION

Handball is a vigorous multi-directional sport with a powerful emphasis on jumping, running and rapid changing of direction (4, 30, 36). To avoid any kind of sports injuries, structured approach is required for the players, as well as the study of risk factors and injury mechanisms should be performed (23). In handball sport, almost 70% of anterior cruciate ligament (ACL) injuries occur through non-contact mechanisms, which happen during sudden decelerating movement such as landing from jump activity (18, 22).

Landing mechanism is a frequently performed mechanism in multidirectional sports such as handball, basketball, volleyball, etc. The proper mechanism of landing is important not only to perform the task but also to protect the player from the risk of injury. The previous studies showed that landing with high impact force may be a risk factor for different lower extremity joints injuries, especially ACL injury. Increase of knee flexion angle with decrease of the ground reaction force (GRF) during landing activity can minimize the impact force and knee joint stress (39).

Particular lower extremity joint movements during the landing may increase the incidence of ACL injuries, including high knee abduction with internal rotation and low degrees of hip and knee flexion (less than 30°). Most of ACL injury was sustained at heel strike with the knee near from full extension(8, 12, 13). This movement patterns may place athletes at risk of ACL injury or to verify the effectiveness of ACL preventive programs (33). This movement pattern during the landing activity is different in male and female athletes. Chappell et al. (39) confirmed that female athletes had more shearing force on the proximal tibia with high knee extension moment and low knee flexion angle during landing in comparison to their male counterparts. Most previous studies focused on female athletes rather than male athletes, because females are more exposed to the risk of injuries than males due to several factors such as hormonal factor, biomechanics, neuromuscular adaptation, etc. Females exhibit less hip and knee flexion angle with high impact forces during landing mechanisms (3, 5, 27, 28, 31,35,37).

Different jump-landing techniques are used in multi-directional sports such as single and double-leg jump-landings (33). Also, these two landing techniques may be used to screen for high-risk movement mechanisms. Some studies stated that the biomechanical analyses of both jump–landing techniques are very useful to predict the risk of future lower extremity injuries (6,21,24). In addition, the jump-landing techniques are used to detect the biomechanical joint adaptations after the injury prevention protocols. These biomechanical adaptations with the prevention protocols tend to decrease the incidence of joints injury (15, 32).

Schmitz et al. (28) studied the biomechanics of lower extremity on recreational males and females. They showed that females exhibited less hip and knee flexion angles with high GRF compared to their male counterparts. This style of landing is so stiff in which females cannot absorb less amount of lower body energy and hence become more susceptible to injuries. Also, Yu et al.(38)found lesser knee flexion angle with greater abduction moment in women than in men during double-leg landing. This may make recreationally active female athletes more exposed to ACL injuries. Most of the previous studies have considered either single or double leg jump landing, and there is lack of attention on comparison between these two techniques.

Thus, the main purpose of this study was to examine the kinematic effects of single and double leg jump-landing on the joints of the lower limbs, and to compare the single and double leg jump landing kinematics in order to detect the most stressful technique on the lower limb joints. It was hypothesized that there would be significant differences between single and double leg jump landing kinematics. Also, the single leg jump landing is more stressful than the double leg jump landing technique.

MATERIALS & METHODS

Participants

Fifteen elite male handball players, who were active in regular sports, were recruited to participate in this study. The participants' demographic data are presented in Table 1. It was ensured that the participants had identical experience in terms of participation in competitions and activity levels. Participants with history of any type of lower extremity joint injuries or any balance disorder were excluded. The subjects were investigated for fitness and asked to sign a consent form approved by the institutional (University of Dammam, Saudi Arabia) review board. The biomechanical data was filtered and used to analyze the performance of each jump-landing task, and also to compare the performance of both tasks.

Table 1. Mean (SD) of participants' demographic Data (n=15).

Parameters	Mean ±SD
Age(y)	19.6 (3.5)
Height (m)	185 (3.7)
Weight (kg)	83.5 (5.2)
BMI	24.4 (0.6)

SD: Standard deviation

Study Design

Randomized controlled laboratory study was applied to detect the kinematic differences between the single and double legjump landing activities in the sagittal plane for male handball players. Data were collected from the dominant lower extremity during single-leg jump landing and from both the lower extremity during double-leg jump landing. Both the jump-landing tasks have the same demand in which the player transits the body from horizontal translation to vertical one. Each participant performed the jump-landing activity after running a fixed distance. Three successful trials were performed by each participant, and the mean of these trials was taken in the same session.

Instrumentation

A three-dimensional motion analysis system (VICON; Oxford, UK; Bonita cameras, 250frames/s) was used to measure the knee kinematics (knee peak flexion angle with adduction or abduction, and internal or external rotation) and hip kinematics (hip peak flexion with adduction or abduction, and internal or external rotation). The system was calibrated for each session before data collection and the lab volume origin was set by using the T-shaped Active Wand Marker. The kinematic model of lower limb(plugin gait model) for 16 markers was used in a certain arrangement on the participants' both lower extremities. The reflective markers were put on the bony landmarks by double adhesive strips (adhesive tape, QTY5).

Procedures

The study was performed in the biomechanics labof University of Dammam, Saudi Arabia and was conducted by one examiner under the same conditions. The aim of study was explained to each participant in details and all queries of the participants were answered. Each participant started with warming up in the form of running in place for about3-5 minutes. They wore suitable (tight) clothing as required for motion capturing.

The16 reflective markers were put bilaterally on anterior superior iliac spine, posterior superior iliac spine, mid-thigh, lateral knee joint line, mid-tibia, lateral malleolus, heels and finally the head of second metatarsals. The starting position for calibrations was T-shape position(Figure 1) for determining the neutral anatomical alignment of each body segments and measuring the static reference trial for subsequent biomechanical measurements. After the warming up period, each participant ran a fixed distance of about 450 cm and performed single-leg-jump landing by the dominant leg (Figure 2) and double-leg- jump landing (Figure 3). The dominant limb was detected as the preferred limb when kicking the ball. The order of both tasks was random (between single and double leg jumping). The participants maintained the position of landing with maximum knee and hip flexion for 3 sec. They were instructed to keep hands as close as possible to the body during the landing phase, to prevent moment variability around lower extremity joints. Each player performed three successful trials for each task with barefeet to prevent any data variability due to different shoetypes. The mean of these three trials for each task was calculated.

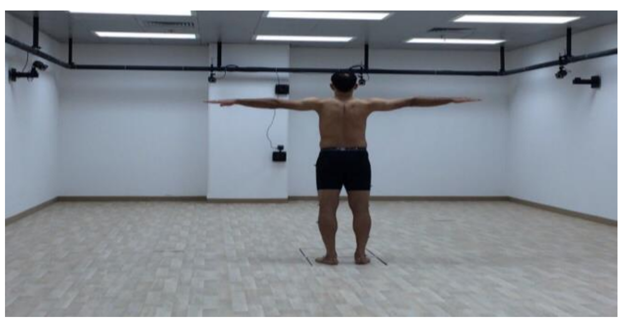

Figure 1. Starting T- shape position

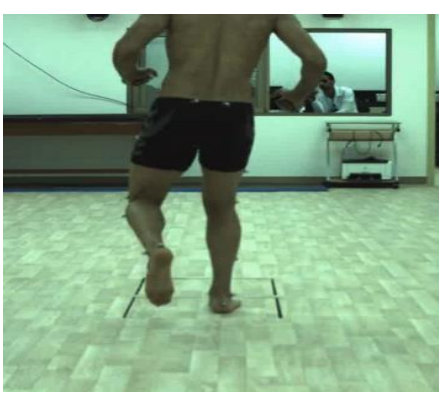

Figure 2. Single leg jump- landing task.

Figure 3. Double leg jump- landing task.

Data Reduction and Statistical Analysis

The landing phase of both tasks (SL and DL) was imported to the visual 3D analysis system, from initial contact to maximum descend. The kinematic data were filtered and processed using the Nexus software (version 2.1.1). The kinematic variables of interest included: a) hip abduction or adduction and internal or external rotation at peak hip flexion angle and b) knee abduction or adduction and internal or external rotation at the peak knee flexion angle, during the landing phases of SL and DL. These variables were selected to compare the kinematic characteristics (of both landings) to find the most stressful activity on the knee joint, and also to study the effect of each task on the incidence of ACL injuries due to rigid- leg jump landing.

The kinematic data from the hip and knee joint during the SL and DL jump landings were analyzed by using SPSS version 20. The data were checked for the consistency of measurements between sessions, by using interclass correlation coefficient. Descriptive analysis was performed to estimate mean and standard deviation for all the variables of interest. The Paired sample t-test was used to test the lower limb kinematic differences between the SL and DL. In addition, linear regression detected the representation of lower limb kinematics during DL to the kinematics during SL. The level of significance was set at 0.05 as obtained from SPSS.

RESULTS

Descriptive Analysis

The summary of the descriptive analysis is presented in Table2.Preliminary checks were conducted to ensure that there was no violation of the assumptions of normality and linearity. The normality of distributions were verified by the Kolmogorov-Smirnov test ($P>0.05$).

Data Consistency/Reliability (between sessions)

All the values of Intra-class correlation coefficient (ICC) for the kinematic variables show consistency between sessions in both SL and DL tasks; all the values are excellent (> 0.75; Table 3).

Kinematics Comparison (Paired t-test results)

Kinematic differences between single and double leg landings are summarized in Figure 4. Significant differences are observed between all the variables of interests (P < 0.05) except the hip internal rotation where there is no significant difference between hip internal rotations in both tasks (P > 0.05).

Table 2. Means (±SD) for each variable of interest.

Variables	SL (n=15)	DL (n= 15)
Hip flexion	50.97 (± 5.89)	55.73 (± 5.43)
Hip abduction	-5.28 (± 1.53)	-10.33 (± 2.30)
Hip internal rotation	28.61 (± 3.71)	27.33 (±4.59)
Knee flexion	56.73 (± 5.45)	63.12 (± 4.91)
Knee adduction	23.54 (± 5.35)	13.06 (± 3.41)
Knee internal rotation	25.99 (± 4.15)	20.55 (± 5.04)

SD: Standard deviation, SL: Single landing, DL: Double landing

Table 3. Between-session consistency for kinematic data at the peak hip and knee flexion angles for both tasks.

Variables	SL	DL
Hip flexion	0.85	0.88
Hip abduction	0.84	0.86
Hip internal rotation	0.82	0.82
Knee flexion	0.94	0.87
Knee adduction	0.90	0.93
Knee internal rotation	0.86	0.92

Data is tabulated in the inter-class correlation coefficient (ICC).
SL, Single leg; DL, double leg.

In comparison between SL and DL tasks, the results show significant difference in the peak hip flexion angle between both tasks (P = .001, t = -4.21) with greater hip flexion angle in DL than in SL. There is a significant difference in peak knee flexion angles(P = .000, t = -5.81) with greater flexion angle in DL than in SL. Significant difference is also found between hip abduction angles (P = .000, t = 10.61) with shallow hip abduction in SL than in DL. Moreover, there is significant difference in the knee adduction (P = 0.000, t = 6.89) with greater knee adduction in SL than in DL. Finally, significant difference is found in knee internal rotation angles (P = .010, t = 2.91) with greater knee internal rotation angle in SL than in DL.

Relationships between single and double leg jump landing tasks (regression analysis)

The results of linear regression to show the relation between SL and DL jump landings are summarized in the Table 4. All kinematic variables in DL jump landing are moderately representative to those in SL (R^2 = 0.44-0.49; P <.05) except hip internal rotation, knee adduction and internal rotation (R^2 = 0.02-0.041; P >.05) where they are not representative to each other.

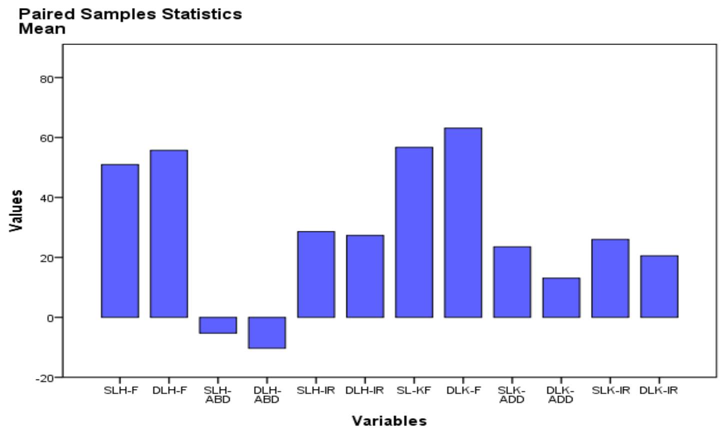

Figure 4. Mean of hip and knee kinematics during SL and DL. SLH-F(single leg hip-flexion), DLH-F (double leg hip- flexion), SLH-ABD (single leg hip-abduction), DLH-ABD (double leg hip-abduction), SLH-IR (single leg hip- internal rotation) DLH-IR (double leg hip-internal rotation), SLK-F (single leg knee flexion), DLK-F (double leg knee –flexion), SLK-ADD (single leg knee-adduction), DLK-ADD (double leg knee-adduction), SLK-IR (single leg knee- internal rotation), DLK-IR (double leg knee-internal rotation).

Table 4. Linear regression (R^2) of kinematic data between SL and DL jump landings.

Variables	DL-SL	Adjusted R^2	Beta coefficient	P	F
Hip flexion	.523*	.455	.703	.003	12.68
Hip abduction	.365*	.316	.604	.017	7.46
Hip internal rotation	.041	-.033	.202	.469	.555
Knee flexion	.443*	.400	.665	.007	10.3
Knee adduction	.024	-.051	.154	.584	.315
Knee internal rotation	.027	-.047	-.166	.555	.367

* $P < 0.05$

DISCUSSION

The main aim from this study was to detect the less strenuous jump- landing activity for male handball players to reduce the occurrence of lower limb injuries, especially ACL injuries. This could be detected by comparing the two most common activities (such as single-leg and double-leg jump landings) in multidirectional sports like handball. The results show significant differences between the two jump landing techniques in the SP, with SL jump landing being more strenuous than DL jump landing due to the increased kinematics of hip and knee joints. In addition, the hip and knee kinematics in DL show moderate association with those in SL. This moderate associationin a certain plane of motion may allow the use of DL jumping as a screening test for the lower limb joint pathology like ACL injuries. Although the DL jump is less stressful than SL jump, it does not represent all joint movements in different planes of motion. So, it could be used only as a screening test for certain plane of joint movements such as hip flexion, hip abduction and knee flexion.

Knee joint is the most stressful joint especially in multidirectional sports like handball, owing to its location between the longest lever arms in the body (femur and tibia). The kinematic of this joint would be affected by the different mechanisms of jump-landing (16, 17, 20). In this study, the SL jump landing is considered stiff compared to DL jump landing for male handball players due to the relatively lesser hip and knee flexion angles. However, in comparison with female athletes, the SL landing is considered less stiff. Yu and Garrett, (38) showed the importance of active hip and knee flexion motion in reducing the impact force during the landing from drop-jump and this reflected the ACL loading during the landing activity. This proved that increase in the hip and knee flexion angle during DL jump landing relieves most of the stresses from the lower limb joints and performs the landing as spring-like action to absorb most of the impact forces. In addition, Zhang et al. (2000)(40)observed that the eccentric work of hip and knee joints during landing decreased with change of landing technique from soft to stiff. This could happen when the angle of hip and knee flexion decreases from DL to SL landing techniques.

The common source of injuries in handball is the jump-land sequences and the most common type of injuries is the ACL injury. Nevertheless, most of the previous studies confirmed that the incidence rate of this injury was higher in female athletes than in male counterparts. This was attributed to the difference in kinematics of the knee and hip joints during the landing phase of jumping activities. The effect of kinematic on the amount of ACL loading is also proved by the results of our study. In this study, the male athletes performed landing with hip abduction with internal rotation (broad landing base) and knee adduction with internal rotation; this could relive part of the stresses in comparison with the female athletes in the previous studies, who performed the landing with hip adduction, knee abduction with external or internal rotation. This female dynamic valgus stress or stiff landing, is theorized as a common mechanism of ACL injury (2,26,29).

When studying the differences between the SL and DL jump landing activities, the differences in hip kinematics are very important, as the hip kinematics are related to knee kinematics during closed chain tasks. In this study, the knee valgus stress during the landing activity is highly related to the hip abduction and internal rotation for male handball players. In contrast, the female athletes exhibit knee valgus stress during jumping which is highly associated with the hip adduction and internal rotation. So the male athletes are less vulnerable to ACL injuries than their female counterparts due to female dynamic valgus stress during landing (9, 19). Jacobs et al.(10) indicated that women exhibited more hip adduction with knee valgus stress during landing from jump. Increase in the women’s knee motion at these planes might put greater stress on the ACL (1). Also, Tsai & Powers (34) confirmed that the encouragement of increased hip and knee flexion angle during landing activities might decrease the tibiofemoral compression loads and delay the knee osteoarthritis after ACL injuries.

The present results show that DL jump-landing technique can be used as a clinical screening test for ACL injury. However, a study by Krosshaug et al. (14) confirmed that the double limb vertical drop jump had poor screening for ACL injuries. Also, Taylor et al. (33)found that sagittal DL jump task could be used as a prediction for knee kinematics but not representative for hip kinematics and hip and knee kinetics, especially when comparing DL and SL jump landings. As the SL activity is more strenuous in joint kinematics than DL activity, some studies confirmed that the SL activity is more representative than DL to the position of injury during the sports video analysis (8,12). In addition, the advanced injury screening systems (2D and 3D video analysis) became more valid and precise than the traditional methods like DL screening tests. Also, the DL screening test is unable to give a detailed representation of risk of injury during multidirectional sports like handball (11).

Moreover, the amount of joint movements during the DL activity does not represent that during the SL task; it is obvious in our results that the joint movements in SL activity are greater than those in DL activity. The results of this study highlight the demand of greater joint movements during SL activity, which may put a high challenge on hip and knee joints in exerting more muscle moments to dissipate more energy during this strenuous task. Harty et al. (7) stated that 70% of ACL injuries occurred through non-contact mechanisms and more force generated during SL activity. The greater movement and force during SL task may create high-risk pattern of movement that affects mainly the highly stressed joint between the longest lever arms in the body (Knee joint).

However, there is lack of studies that confirm that training of athletes on SL task may decrease injury risk during SL and DL tasks. Also no study has confirmed so far that high-risk movements during DL task are considered as high-risk movements during SL task. Therefore, further studies are recommended on these types of activities in different planes of motion (frontal and transverse) to study their effect on athletic players in multidirectional sports. The findings of this study confirm that the SL activity is more strenuous than the DL activity due to high joint kinematics in SL than in DL. Although the DL activity has not representedsome of the joint kinematics of SL, it could be used as screening for certain activities such as hip abduction and knee and hip flexion movements. In addition, the study can be repeated on both males and females to assess the effect of gender.

This study was performed on real handball players but in virtual environment which differs from the real one where the factors such as surface, humidity, multidirectional motion in different planes, etc. may affect the joint performance and mechanics. Also, the measurements of kinetic data might confirm and strengthen the present findings. Finally, this research was focused on only on male handball players.

The results of this study confirm the significant difference between lower extremity kinematics during single-leg and double-leg landing techniques, and it are concluded that the DL activity is less strenuous for male handball players than the SL activity. These findings can direct handball players to use DL rather than SL during the movement in the sagittal plane to relieve part of the joint stresses and decrease the incidence of ACL injuries.

It is also found that there is moderate association between DL and SL movements at certain motion planes. However, the DL does not provide a comprehensive representation of all movements of SL, and hence DL can be used as a screening test only for certain Joint kinematics (not all lower extremity kinematics) in strenuous multidirectional sports like handball.

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Conflict of interest

The author declares that there are no financial interests involved with the contents of this paper.

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