LANDING KINEMATICS AND MUSCLE ACTIVITY IN RUN-ON AND TWO-FOOT LANDINGS BETWEEN ATTACKING AND DEFENSIVE NETBALL PLAYERS

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The purpose of this study was to investigate landing kinematics and muscle activity differences in run-on and two-foot landings between attacking and defensive netball players. Eight British Universities and Colleges Sport (BUCS) level female players performed eight run-on and eight two-foot landing trials. In comparison to two-foot landings, run-on landings promote a smaller peak flexion at the hip and ankle, smaller range of motion at the hip and knee, and a more acute touchdown angle at the hip and knee. Furthermore, attacking players displayed a less flexed knee angle at touchdown compare to defensive players. This suggests run-on landings promote a stiffer, more upright landing mechanism resulting in increased anterior cruciate ligament (ACL) loading, with attacking players exhibiting a more ACL-damaging landing mechanism.

KEYWORDS: landing technique, injury, anterior cruciate ligament

INTRODUCTION: Netball is an extremely popular team sport, with over 20 million people participating in netball all over the world (World Netball, 2023). In netball, movement with the ball violates the rules, therefore players are required to perform repeated jumps coupled with sudden bursts of acceleration and deceleration to receive a pass (Mackay et al., 2023). The frequent rapid decelerations due to landing, are often associated with injuries such as, but not limited to, stress fractures, ankle sprains and anterior cruciate ligament (ACL) injury (Aerts et al., 2013). Sagittal plane factors have shown to contribute to the ACL injury mechanism and force dissipation during landings (Leppänen et al., 2017), highlighting the importance of investing kinematics in this plane. Landing techniques are influenced by both intrinsic factors, such as spatial orientation and proprioception during landing, and extrinsic factors, such as footfall patterns and the position of the team and opposition (Hopper et al., 1992), with the body being exposed to approximately 6.8 times its body mass during these motions (Hopper et al., 1999). Run-on landings involve the player landing on one foot, followed by the other when receiving a ball, while two-foot landings involve landing on both feet simultaneously when receiving a ball (International Netball Federation, 2020). Stuelcken et al. (2016) determined that in 13 cases, ACL injuries were a result of landing from a jump, with 53.8% occurring during one-foot landing (e.g., run-on) and 46.2% occurring during two-foot landing. The purpose of this study was to investigate kinematic and muscle activity differences in the dominant landing leg between run-on and two-foot landings, and whether player position, categorised into offensive and defensive players, influenced these variables.

METHODS: Eight female university netball players (mean ± standard deviation [SD]; age: 21 ± 1 years; mass: 64.8 ± 10.8 kg; stature: 1.67 ± 0.03 m) which included four offensive players (age: 21 ± 1 years; mass: 60.6 ± 3.5 kg; stature: 1.66 ± 0.01 m), and four defensive players (age: 20 ± 1 years; mass: 69.0 ± 14.6 kg; stature: 1.69 ± 0.03 m) who compete at a British Universities and Colleges Sport (BUCS) (national amateur league) level. After completing a self-led warm-up and familiarisation of the required movements, participants performed eight run-on and eight two-foot landings. Sixteen optoelectronic cameras (Arqus A26, Qualisys, Gothenburg, Sweden, 250 Hz) were used to record five reflective markers (Qualisys, Gothenburg, Sweden) that were attached superficially to the mid-glenohumeral joint, great trochanter, lateral femoral epicondyle, lateral malleolus, and fifth metatarsal phalangeal joint on the dominant leg. Following the SENIAM guidance on EMG (electromyography) electrode locations, four wireless EMG electrodes (Trigno Avanti, Delsys, Natick, USA, 2000 Hz) were attached superficially to the tibialis anterior (TA), medial gastrocnemius (MG), bicep femoris (BF) and rectus femoris (RF) on the dominant landing leg. Trials were rejected if markers fell, if participants performed an incorrect landing, if balance was lost, or if the electrodes detached or failed to record muscle activity. From the 16 trials collected per participant, three run-on and three two-foot trials were randomly selected for data analysis. Kinematic data were processed using Qualisys Track Manager (Qualisys v2.13, Gothenburg, Sweden), to calculate peak flexion (°), joint range of motion (°) and the angle at touchdown (°) at the hip, knee, and ankle, during the landing phase of the trials. Muscle activity data were processed using EMGworks Analysis, with raw data processed using root mean squared difference with a window size of 0.100s. Peak dynamic normalisation was then utilised to normalise trials against the maximum value for each muscle, sourced from the motion trials. This normalisation method was adopted as research has shown poor EMG reliability during isometric contraction due to fatigue, physiological factors and synergistic contributions (Ball & Scurr, 2010). EMG variables (muscle activation at touchdown (µV) and peak activation (µV) during the landing phase) were then expressed as percentages. A two-way ANOVA (IBM SPSS Statistics version 28, Chicago Illinois, USA) was utilised to analyse differences between positions (attack vs defence) and landing techniques (run-on vs two-foot) for both muscle activation and kinematic variables. Effect sizes were calculated using partial eta-squared, where 0.01 indicated a small effect, 0.06 indicated a medium effect, and 0.14 indicated a large effect (Cohen, 1988). Means and standard deviations (SD) were calculated using Microsoft Excel (Microsoft, New Mexico, USA).

RESULTS: The results of this study showed differences in peak flexion at the hip ($\eta^2 = 0.751$) and ankle ($\eta^2 = 0.563$), ROM at the hip ($\eta^2 = 0.807$) and knee ($\eta^2 = 0.864$) and angle at touchdown at the hip ($\eta^2 = 0.738$) and knee ($\eta^2 = 0.578$), between landing conditions (Table 1). Furthermore, differences in angle at touchdown at the knee ($\eta^2 = 0.578$) was observed between playing positions (Table 2). No significant differences were observed for activation at touchdown (η^2 = TA: 0.202; MG: 0.015; BF: 0.181; RF: 0.004) or peak activation during the landing phase (η^2 = TA: 0.105; MG: 0.006; BF: 0.213; RF: 0.008) (Figure 1).

Table 1. Mean ± SD for peak flexion, range of motion and angle at touchdown at the hip, knee, and ankle for run-on (RO) and two-foot (TF) landings.

	Peak flexion		Range of motion		Angle at touchdown	
	RO	TF	RO	TF	RO	TF
Hip (°)	29.5 ± 10.1**	50.6 ± 8.7	25.2 ± 9.4**	44.2 ± 8.1	14.2 ± 6.4**	26.7 ± 7.8
Knee (°)	73.8 ± 15.1	74.7 ± 8.5	57.6 ± 15.3***	63.0 ± 12.6	21.3 ± 5.8*	28.5 ± 8.2
Ankle (°)	-2.5 ± 6.0*	3.0 ± 7.0	38.3 ± 12.4	33.7 ± 13.6	29.2 ± 10.5	33.8 ± 12.5

***Significant difference between run-on and two foot (p ≤ 0.05). **Significant difference between run-on and two-foot (p ≤ 0.01). ***Significant difference between run-on and two-foot (p ≤ 0.001).**

Table 2. Mean ± SD for peak flexion, range of motion and angle at touchdown at the hip, knee, and ankle for attackers (A) and defenders (D).

	Peak flexion		Range of motion		Angle at touchdown	
	A	D	A	D	A	D
Hip (°)	42.3 ± 14.4	37.9 ± 14.7	37.8 ± 13.6	31.6 ± 12.3	18.9 ± 8.2	22.0 ± 11.0
Knee (°)	79.4 ± 8.4	69.2 ± 13.0	66.8 ± 8.7	53.8 ± 15.4	20.7 ± 3.7*	29.0 ± 8.8
Ankle (°)	1.6 ± 6.6	-1.1 ± 7.4	34.6 ± 8.9	37.4 ± 16.3	35.0 ± 11.8	28.1 ± 10.7

***Significant difference between attackers and defenders (p ≤ 0.05).**

DISCUSSION: The findings that a smaller ROM and touchdown angles were observed during run-on landings indicate that a stiffer, more upright landing mechanism was adopted to perform this landing technique and may increase stress to the ACL (Schmitz et al., 2007). Di Paolo et al. (2022) indicated that a lower sagittal range of motion is linked to ACL injury mechanisms and that efforts should be made to employ a higher knee range of motion to dissipate these forces. Furthermore, attacking players may be at a higher risk of developing ACL injuries due to their reduced knee angle at touchdown, however, both attacking and defensive players displayed a knee touchdown angle of <30º, which can increase the risk of a knee injury developing (Belcher et al., 2022). Consequently, this means both landing types may exhibit low knee flexion at the point of touchdown, providing one potential cause for the mechanism of injury observed by Stuelcken et al. (2016), where all injury cases occurred during one of these landing types. Greater dorsiflexion has also been displayed in single-leg landings of individuals with chronic ankle instability suggesting that this is present in run-on landings and making them potentially hazardous for netballers (Brown et al., 2008). A peak hip flexion angle of 45° has been highlighted as the approximate suggested hip flexion at peak resultant force to minimise stress on the musculoskeletal system (Steele et al., 1990), which is similar to the two-foot result in this study of 50.6°. Following the conclusion of Fong et al. (2011) that greater ROM at the ankle is associated with greater knee flexion, the absence of peak flexion difference at the knee could be due to the lack of difference in the ROM at the ankle.

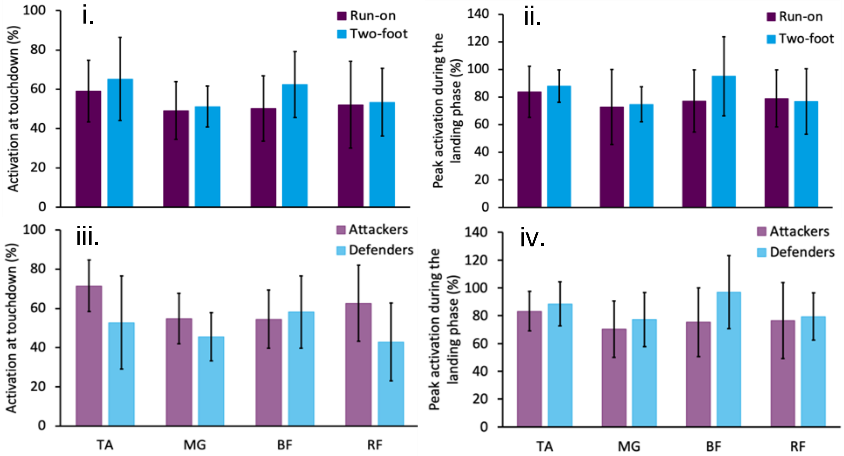

Figure 1. Mean (error bars for SD) activation at touchdown (i) and peak activation during the landing phase (ii) between landing conditions, and activation at touchdown (iii) and peak activation during the landing phase (iv) between player position for the TA, MG, BF and RF.

No significant differences were observed across the EMG variables for all muscles, possibly due to the study not recreating game intensity and action-reaction scenarios, therefore the landing motions may not have been game-realistic. However, differences have been recorded between landing conditions as seen by Pappas et al. (2007), where they observed a 45% increase in muscle activation during unilateral landings compared with bilateral landings, which can increase ACL tensile forces. This increase in tensile force when paired with a knee flexion of less than 40°, as seen in the angle of touchdown results, have been associated with ACL tears (DeMorat et al., 2004). Therefore, future research should consider incorporating ground reaction force measurements to gain a better understanding of EMG results and allow better comparisons between landing kinematics and the forces being applied to the body.

CONCLUSION: This study suggests run-on landings promote a reduced peak flexion at the hip and ankle, which is associated with increased ACL loading and ankle injuries. Additionally, reduced ROM of the hip and knee during run-on landings results in a stiffer landing mechanism, associated with higher stress on the ACL. Furthermore, attacking players exhibit a less flexed knee angle at touchdown when compared to defensive players, suggesting a higher injury rate in attacking players. Moreover, both knee and hip angle at touchdown were less flexed during run-on landing, resulting in a more upright position being adopted which can lead to less force being absorbed by the muscles. The impact of this study on players suggests that greater flexion and ROM should be considered by coaches and practitioners when performing run-on and two-foot landings, to ensure force dissipation occurs through the muscles, minimising the risk of ACL injuries.

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