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Original Article

The effect of seasonal performance variations on anterior cruciate ligament injury risk factors in young female volleyball players

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ABSTRACT

Purpose: This study aimed to examine how key anterior cruciate ligament (ACL) injury risk indicators, including knee flexion angle, single-leg jump performance, landing forces, and jump-landing mechanics, change across three distinct seasonal phases (pre-season, beginning of the season, mid-season) in young female volleyball players.

Methods: Twelve adolescent female volleyball players completed performance assessments at three time points. Single-leg countermovement jump (SLCMJ) height, peak landing force, knee flexion angle during landing, and Landing Error Scoring System (*LESS*) scores were recorded. Repeated measures comparisons were used to assess temporal changes.

Results: The pre-season period demonstrated the poorest performance profile: the lowest jump heights, the highest landing forces, reduced knee flexion angles, and the highest *LESS* scores. From pre-season to the beginning of the season, jump height increased significantly, while landing forces and *LESS* scores decreased. Knee flexion angles increased progressively across the season for both extremities, indicating improved neuromuscular control and safer landing mechanics. The high F_{land}/h_{jump} ratio observed in the pre-season suggests an unfavorable combination of high landing loads and low performance, reflecting a high ACL injury risk.

Conclusions: Findings highlight the pre-season period as the most critical phase for ACL injury risk in young female volleyball players. Reduced neuromuscular performance, insufficient knee flexion, and higher landing loads converge during this time, increasing injury susceptibility. Coaches and practitioners should prioritize neuromuscular control, landing technique, and lower-limb strength balance in pre-season training. Future research with larger, multi-sport cohorts should further investigate the direct relationship between seasonal performance changes and injury incidence.

Introduction

Non-contact anterior cruciate ligament (ACL) injuries remain a significant concern among female team athletes.[1,2] Women are three times more likely than men to suffer ACL injuries.[3] The incidence of ACL tears in female adolescents has increased dramatically, with half of all tears occurring between the ages of 15 and 25.[4] In team sports, non-contact ACL injuries typically occur during sudden decelerations, changes of direction, and single-leg landings.[5,6,7] Volleyball is a sport with a notably high risk of ACL injuries, making awareness and preventive measures crucial for athletes. The need to identify modifiable risk factors for ACL injuries and develop injury prevention programs has led to increased research on this topic.[8]

Improved athletic performance is considered a vital component of injury prevention strategies.[9,10] Enhanced lower-extremity strength and velocity are associated with greater tolerance to higher workloads and a

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lower risk of injury in team-sport athletes.[11] Recent studies indicate that improved neuromuscular capacity may protect athletes from greater joint loading and therefore help reduce non-contact lower extremity injuries.[12] During landing after jumping, decreased knee flexion angles have been shown to produce greater ACL strain.[13] Therefore, hip and knee joint flexion is crucial in controlling the forces and momentum generated in the knee joint during landing.[14] Furthermore, this force and moment may sometimes be greater at an extremity during dynamic movement, another significant finding regarding injury risk. The symmetry index, characterized by asymmetries between the right and left lower extremities, is considered a strong predictor of injury in various sports.[15] It has been suggested that bilateral leg asymmetries preferentially load the stronger leg and, in recurrent cases, may exceed the force tolerance capacity of this leg, causing injury.[16]

Various screening methods are used as effective tools for identifying injury-related risk factors during movements that commonly lead to injuries. Previous research has primarily assessed ACL injuries, particularly during landing tasks, using movement analysis methods (2D or 3D).[17] However, the impracticality of these assessments for the sports environment has highlighted the need for field-based, cost-effective, and easily applicable screening tools. For this purpose, field-based screening tools such as the Landing Error Scoring System (*LESS*)[18] and the Single-Leg Landing Error Scoring System (SL-*LESS*)[19] have been developed as alternatives for identifying movement patterns associated with lower extremity injury risk.[20]

The *LESS* is a field assessment tool used to identify potentially high-risk jump-landing movement patterns.[21] Although a high *LESS* score alone does not indicate that an athlete will definitely experience an ACL injury, it can be used to separate athletes into high- and low-risk subgroups based on landing mechanics.[22] Therefore, variables such as the *LESS* score and knee flexion angle during landing can be considered target metrics reflecting ACL injury risk. However, athlete performance and associated injury risk are not static; they change over time in response to factors such as training load, fatigue, and in-season breaks.

ACL injuries are particularly important due to both the high cost of treatment and the lengthy return-to-play period. The literature generally agrees that performance tends to decline after midseason breaks, suggesting that athletes may experience deterioration in neuromuscular control and landing mechanics at the start of a new season. While there are studies examining seasonal performance changes, to our knowledge, no study has tracked landing knee flexion angle and *LESS* scores, which are specific risk indicators for ACL injuries, throughout the season. Therefore, the purpose of this study was to examine changes in performance indicators in female volleyball players throughout the season, including landing knee flexion angle and *LESS* scores. It was hypothesized that performance indicators and knee flexion angles would be lower at the beginning of the season, while *LESS* scores would be higher.

Methods

Participants

A total of twelve participants from the Akdeniz Bilgi Sports Club 2nd league young women's volleyball team participated in the study (Table 1). The athletes trained 5 days/week, 3 hours/day. These trainings included technical and tactical volleyball drills, as well as resistance training, once a week. The weekly schedule was planned according to the match day. A priori power analysis using G*Power (version 3.1, University of Düsseldorf, Germany) identified that when using a within-factors repeated-measures analysis of variance (ANOVA), a sample of 12 was required to fulfil a statistical power of 0.81, a type 1 alpha level of 0.05, and an ES of 0.3.[23] Participants had at least 4 years of training experience. The study was conducted at the Biomechanics Laboratory of the Faculty of Sports Sciences, Akdeniz University. Participants were informed about the study and included after completing voluntary consent.

Table 1
Mean and SD values for the participants' characteristics.

Parameters (N=12)	S_{pre}	S_{begin}	S_{mid}
Age (year)	16.25 ± 0.92	16.25 ± 0.92	16.25 ± 0.92
Height (cm)	173.75 ± 7.42	173.58 ± 7.34	173.58 ± 7.34
Weight (kg)	61.06 ± 7.20	62.48 ± 7.46	61.83 ± 7.21
BMI	20.31 ± 2.51	20.77 ± 2.50	20.36 ± 2.17
BF (%)	24.50 ± 4.57	23.27 ± 3.82	24.52 ± 4.44
SMM (kg)	43.52 ± 3.22	45.31 ± 3.81	44.10 ± 3.65

S_{pre}: pre-measurement; S_{begin}: the beginning of the season; S_{mid}: the mid-season; SMM: skeletal muscle mass; BMI: body mass index; BF: body fat.

Methods

Study design

The study included female athletes playing in the second league. In this category, the first half of the league started in September and ended at the end of December. The second half was completed between January and June. Performance tests were conducted a total of three times: before the new season (S_{pre}) (August), at the beginning of the season (S_{begin}) (September), and during the mid-season (S_{mid}) (December) (Fig. 1). After determining the anthropometric characteristics, single-leg countermovement jumps (SLCMJ) were performed, along with a jump for *LESS*. Prior to each test measurement, a warm-up protocol consisting of 10 minutes of light running, stretching, and sport-specific warm-up exercises, followed by 10 minutes of plyometric training drills, was implemented, totaling 20 minutes. A 1-minute rest period was given between jumps, and a 3-minute rest period between tests. The study was evaluated for ethical considerations and approved by the Akdeniz University, Ethical Committee of Clinical Research (approval number: 11.05.2022/355). Consent forms were signed by all participants prior to the study. The study was conducted in accordance with the Declaration of Helsinki.

Jump performances

Single-leg countermovement jump (SLCMJ) and analysis

All jumps were performed on a portable dual force plate (ForceDecks Lite, Vald Performance Pty Ltd., Brisbane, Australia) at a sampling rate of 1000 Hz. During the SLCMJ tests, participants were instructed to stand on one leg, actively initiate a downward movement, then rapidly jump vertically with the supporting leg as high as possible, and land on the same leg. Hands were to remain on the hips throughout the movement, and participants were required to maintain balance for at least three seconds after landing. To avoid affecting performance, participants were not permitted to swing their inactive lower extremity before take-off during SLCMJ trials. If any contribution from the inactive extremity was suspected, the trial was repeated. A one-minute rest period was provided between jumps to minimize muscle fatigue. Before each jump test was performed, the force plates were zeroed using the manufacturer's software. Body weight was measured using dual force plates over at least one second, during which the participant was asked to stand upright and remain as still as possible (McMahon et al., 2018). Peak landing force (F_{land}) and jump height (h_{jump}) data were recorded for jumps for evaluation purposes. F_{land} was defined as the highest force recorded during the post-landing phase after jumping. The average values of three jumps for each SLCMJ variable were used for analysis.

Jump-landing performance

To determine the error score for *LESS*, jump-landing performance was performed. The participant began the task standing on a 30-cm-high box, placed at a distance equal to half the body height from a landing area marked by a line on the ground. Participants were instructed to jump forward, land just beyond the line, and jump to maximum height

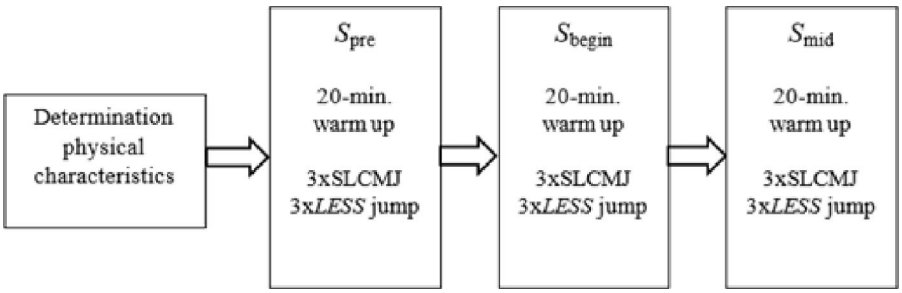

Fig. 1. Study procedure.

immediately after landing. A 1-minute rest period was provided between jumps to minimize muscle fatigue. Participants' performances were recorded with two video cameras (iPhone X, Apple, California, USA). It was mounted perpendicular to the plane(s) of motion (sagittal and frontal) on a tripod focused on movement (Figs. 2,3).

Recorded jump performances were evaluated according to the titles and descriptions accepted in the *LESS* analysis. The *LESS* is a valid and reliable clinical movement analysis tool that evaluates specific jump-landing characteristics.[23] Movements were evaluated at the frame of initial contact, defined as the moment just before the foot was completely flat on the ground, and during the phase from initial contact to peak knee flexion (Table 2). The *LESS* primarily employs a binary scoring system to detect clear movement faults, such as insufficient knee flexion or excessive medial knee displacement. As a result, even a one-point difference in the overall *LESS* score may correspond to moderate or substantial variations in certain biomechanical measures.[19] A higher *LESS* score reflects a greater number of landing errors and, therefore, poorer jump-landing mechanics. For analysis, the mean *LESS* score from the three trials within each testing session was used. The same person made the analysis and evaluations.

Kinematic analysis

Knee flexion angle ($\theta_{knee\text{-}flex}$)

To determine the knee flexion angle, all jump-landing trials were recorded using two cameras (sagittal plane). The cameras were placed on a tripod at approximately the participant's center of mass. Knee flexion angles were calculated as the angle at which maximum flexion occurred in the knee during the landing phase after the jump. The knee flexion angle was defined as the angle connecting the greater trochanter and the lateral femoral condyle, and the lateral femoral condyle and the lateral malleolus. Knee angle values were analysed using Kinovea Software (Version 0.8.27, France). The average knee flexion angle values obtained from three trials were considered.

Statistical analysis

All statistical analyses were conducted using SPSS Statistics Ver. 25 (Chicago, IL, USA). Changes over time in variables (F_{land}, h_{jump}, and $\theta_{knee\text{-}flex}$ for both the dominant and non-dominant extremities) recorded at different times (S_{pre}, S_{begin}, and S_{mid}) were analyzed using the related-samples test, a nonparametric test. When significant main effects or interactions were found, post hoc Bonferroni tests were performed. The Wilcoxon Paired Two-Sample T-Test was used to determine the differences in pairwise comparisons. The results were evaluated within a 95 % confidence interval, and the level of significance was set at $\alpha<0.05$. Test-retest reliability was determined by calculating interclass correlation coefficients (ICCs), and a 2-tailed t-test was used to assess whether a significant difference existed between the two tests for a variable. The ICCs and their confidence interval (CI95 %) for knee flexion angles were 0.85 (CI95 %: 0.59–0.95) and 0.95 (CI95 %: 0.87–0.98) for the right and left extremity in S_{pre}, respectively. The ICC for the LESS score in S_{pre} was 0.89 (CI95 %: 0.72–0.96).

Results

SLCMJ performance data

Our findings indicated that the lowest values of the *D* and *ND* extremity F_{land} parameters were observed in S_{pre}, and the highest in S_{mid}. The value obtained in S_{pre} was statistically different from both S_{begin} and S_{mid} values for both extremities. h_{jump} values were statistically different for S_{begin} and S_{mid} in the *D* and *ND* extremities compared to S_{pre}. It was determined that h_{jump} increased towards the middle of the season (13.44 cm for *D* and 14.12 cm for *ND*). When the peak landing force index (F_{land}/h_{jump}) was evaluated among the extremities, it was observed to be the highest value in the S_{pre}. The index was determined as 2.60 in the *D* extremity and 2.65 in the *ND* extremity. In the S_{begin}, it was determined that this value improved statistically by 4.23 % in the *D* extremity and 9.43 % in the *ND* extremity (Table 3).

The *D* and *ND* limbs S_{mid}(for *D*: 65.99°, for *ND:* 58.47°) maximum

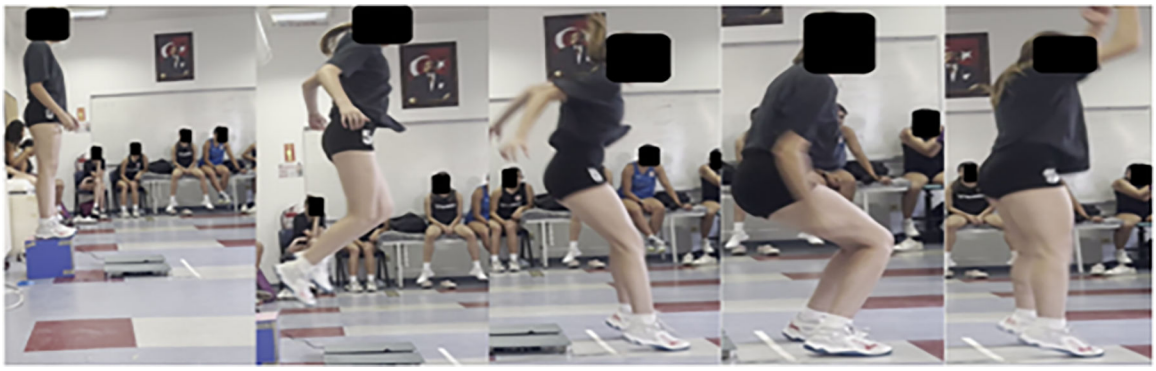

Fig. 2. *LESS* jump-landing sagittal view.

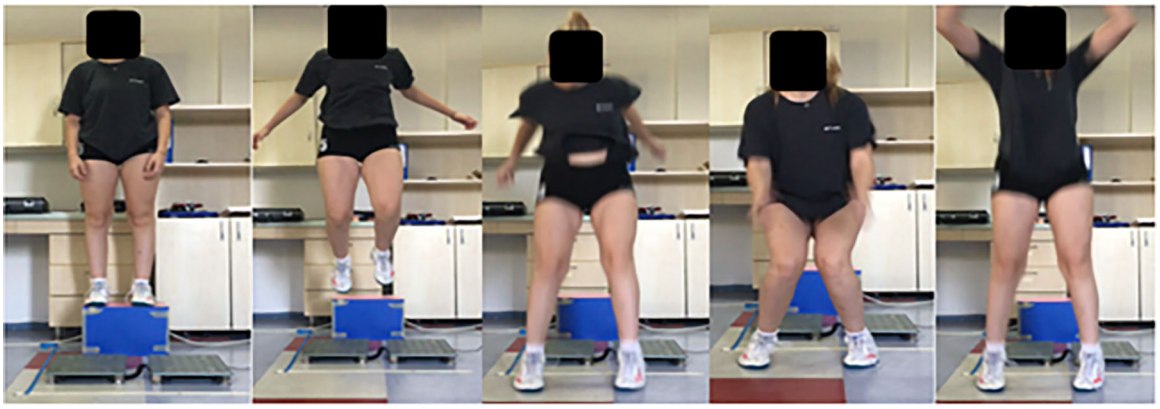

Fig. 3. *LESS* jump-landing frontal view.

knee flexion is statistically significantly higher than the S_{begin}(for *D*: 62.19°, for *ND*: 58.47°)(Z=-2.80, p<0.05; Z=-2.19, p < 0.05, respectively). It was observed that the $\theta_{knee\text{-}flex}$ increased for both extremities as the season progressed. In S_{pre}, the lowest angle was found in the *ND* extremity (Table 4).

Landing error scoring system (LESS) after the jump

Participants' *LESS* scores are presented inTable 5. S_{begin} (4.47) *LESS* score was statistically significantly lower than S_{pre} (4.81) (Z=-2.04, p<0.05). It was determined that the *LESS* score decreased throughout the season.

Discussion

This study evaluated performance measures used to assess ACL injury risk factors (SL landing force, knee flexion angle, and post-jump *LESS*) at three different time points: pre-season (S_{pre}), beginning of the season (S_{begin}), and mid-season (S_{mid}).

Findings show that the lowest jump performance values were recorded in the pre-season (S_{pre}). As the season progressed, there were significant increases, especially in dominant and non-dominant extremity jump height (SL-h_{jump}), post-jump landing force (SL-F_{land}), and knee flexion angles. This suggests that the lack of training that occurs during the inter-season break leads to a decline in performance and, consequently, an increased risk of injury. The findings are consistent with studies on semi-professional soccer players[24] and young female volleyball players.[25] These studies also reported that jump performance was significantly lower in the preseason compared to the end of the previous season, but improved as the season progressed. Similarly, Bishop et al. (2023) conducted a season-long study with male soccer players and found that their performance was lowest during the preseason. These results emphasize that the decline in performance during the preseason preparation phase is a critical period for athletes in terms of injury risk.[16]

It has been reported that non-contact lower extremity injuries are associated with jump performance and that improved neuromuscular capacity can protect athletes from greater joint loads.[12] In performances where vertical stiffness is crucial, such as drop jumping,[26] it is also important to consider that post-jump landing stiffness can increase the risk of injury.[27] In the context of injury risk, this issue represents a multifactorial complex phenomenon. Both a stiff landing and poor performance can increase the risk of injury. This may be particularly true during SLCMJ. To reduce this complex effect, Cohen et al. (2020)[28] suggested considering the peak landing force index (F_{land}/h_{jump}), which also accounts for the passive impact load associated with jump height. This index, used in our study, has been integrated into seasonal performance assessments for the first time as a parameter that relatively assesses landing stiffness in athletes. This result, which was significantly higher in the preseason, supports the notion that high landing loads and poor performance may combine to increase the risk of ACL injury. Studies examining the seasonal distribution of injuries in the literature have indicated that injury incidence is higher in both women and men during the off-season[29] or that ACL injuries are more frequent in the first part of the season.[30] Studies with soccer players have shown that ACL injuries peak in the first part of the season (September-October) and towards the end of the season (March-May).[30,31] In basketball, the total number of injuries was significantly higher than average for both men and women after the off-season (September-October) and at the beginning of the year (January-March), whereas it was lower before the off-season (April-July) and in December. Furthermore, the fact that a quarter of ACL injuries occurred in the first 15 minutes of the game may also indicate players' limited neuromuscular capacity at that point.[30] These injury periods can result from athletes not training enough during the offseason or from excessive preseason training volume. Therefore, identifying at-risk athletes can help coaches and sports medicine specialists intervene with an individualized injury prevention training program.[32]

It is known that less knee flexion during landing results in greater load on static joint stabilizers.[33] Training programs focusing on landing with greater knee flexion have been shown to improve knee flexion and anterior shear strength.[34] The increase in knee flexion angles throughout the season indicates that athletes' neuromuscular control and joint stability during landing have improved. Recent studies indicate that lower knee flexion angles increase ACL stress and the risk of ACL injury.[33,35] Therefore, increasing knee flexion angles as the season progresses reduces the risk of ACL injury. This study, which evaluated post-jump landing performance, determined that participants' maximum knee flexion angles during landing increased by 10.81 % in the *D* limb and 18.39 % in the *ND* limb at the end of the season. This was recorded as an increase in the F_{land}/BW value of the *ND* limb and, consequently, in the SLCMJ jump height. The change in the greater knee flexion angle in the *ND* limb also positively decreased the F_{land}/h_{Jump} ratio.

Another method used to assess injury risk is examining changes in the *LESS* score. To our knowledge, this is the first study to assess seasonal injury risk using this method. *LESS* is a reliable clinical screening tool that identifies individuals at increased risk of non-contact ACL injury by assessing their landing biomechanics. A higher *LESS* score reflects poorer landing technique, whereas lower scores indicate more optimal landing mechanics. Athletes with a poor landing score have been reported to have a higher risk of ACL injury compared to others.

In addition to studies indicating that participants with a LESS score ≥ 5 have a poor landing score,[22] there are also studies that categorize LESS scores into subcategories (excellent (LESS score <4), good (LESS score >4 to ≤5), moderate (LESS score >5 to ≤6), and poor (LESS score >6).[19] Although some studies have suggested that *LESS* is insufficient for

Table 2
Definitions for individual landing error scoring system items.

Landing Error Scoring System Item Operational Definition of Error	Evaluation direction	Error Scoring
Knee flexion: initial contact The knee is flexed less than 30° at initial contact.	Sagittal	Absent = 1 Present = 0
Hip flexion: initial contact The thigh is in line with the trunk at initial contact	Sagittal	Absent = 1 Present = 0
Trunk flexion: initial contact The trunk is vertical or extended on the hips at initial contact.	Sagittal	Absent = 1 Present = 0
Ankle plantar flexion: initial contact The foot lands heel to toe or with a flat foot at initial contact.	Sagittal	Absent = 1 Present = 0
Medial knee position: initial contact The center of the patella is medial to the midfoot at initial contact.	Frontal	Absent = 0 Present = 1
Lateral trunk flexion: initial contact The midline of the trunk is flexed to the left or the right side of the body at initial contact.	Frontal	Absent = 0 Present = 1
Stance width: wide The feet are positioned greater than shoulder width apart (acromion processes) at initial contact.	Frontal	Absent = 0 Present = 1
Stance width: narrow The feet are positioned less than shoulder width apart (acromion processes) at initial contact.	Frontal	Absent = 0 Present = 1
Foot position: external rotation The foot is externally rotated more than 30° between initial contact and maximum knee flexion.	Frontal	Absent = 0 Present = 1
Foot position: internal rotation The foot is internally rotated more than 30° between initial contact and maximum knee flexion.	Frontal	Absent = 0 Present = 1
Symmetric initial foot contact: initial contact One foot lands before the other foot, or 1 foot lands heel to toe, and the other foot lands toe to heel.	Frontal	Absent = 1 Present = 0
Knee-flexion displacement The knee flexes less than 45° between initial contact and maximum knee flexion.	Sagittal	Absent = 1 Present = 0
Hip-flexion displacement The thigh does not flex more on the trunk between initial contact and maximum knee flexion.	Sagittal	Absent = 1 Present = 0
Trunk-flexion displacement The trunk does not flex more between initial contact and maximum knee flexion.	Sagittal	Absent = 1 Present = 0
Medial-knee displacement At the point of maximum medial knee position, the center of the patella is medial to the midfoot.	Frontal	Absent = 0 Present =1
Joint displacement **Soft:** the participant demonstrates a large amount of trunk, hip, and knee displacement. **Average**: the participant has some, but not a large amount of, trunk, hip, and knee displacement. **Stiff:** the participant goes through very little, if any, trunk, hip, and knee displacement.	Sagittal	Soft = 0 Average = 1 Stiff = 2
Overall impression **Excellent:** the participant displays a soft landing with no frontal-plane or transverse-plane motion. **Average:** all other landings. **Poor:** The participant exhibits large frontal-plane or transverse-plane motion, or a stiff landing with some frontal-plane or transverse-plane motion.	Sagittal, Frontal	Excellent = 0 Average =1 Poor = 2

predicting injury risk,[30] others have reported that it remains useful for classifying athletes by risk level.[22] Furthermore, a correlation has also been identified between LESS scores and 3D kinematic analysis assessments of the lower extremity.[24] In this sense, it was determined that participants' *LESS* scores were high before the preseason (S_{pre}) and decreased towards the end of the season. The *LESS* results were consistent with those from other ACL injury risk factors. The results also indicate a high risk of injury during the pre-season, which aligns with the peak landing force index. One of the strengths of this study is its holistic assessment of different performance parameters throughout the season. However, the study also has some limitations. The limited sample size, the examination of athletes in only one specific sport, and the lack of a direct relationship to injury frequency limit the generalizability of the findings.

Conclusion

In conclusion, our findings suggest that the preseason period is a critical period for ACL injuries. Poorer performance, increased landing force, and inadequate knee flexion angle were observed in athletes during the preseason, and these factors have been identified as potential risk factors for ACL injury. Coaches and sports scientists should place special emphasis on neuromuscular control, landing techniques, and exercises aimed at strength imbalances in their preseason preparation programs.

In addition, Coaches should:

- Create training programs for the off-season to minimize performance loss in athletes,
- Evaluate athletes' performance at the end of the season and prepare individualized training programs for the mid-season break,
- Re-evaluate athletes' performance after the break and revise individual training programs.

It should also be considered that intense pre-season training programs may increase the risk of injury in athletes due to neuromuscular losses during this period.

Future studies should investigate the direct relationships between performance parameters and injury incidence by conducting seasonal follow-ups across various sports and larger sample sizes.

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Ethical approval and consent to participate

The study was evaluated for ethical considerations and approved by the Akdeniz University, Ethical Committee of Clinical Research (approval number: 11.05.2022/355). Consent forms were signed by all participants prior to the study. The study was conducted in accordance with the Declaration of Helsinki.

Consent for publication

Not applicable.

CRediT authorship contribution statement

Mustafa Demirel: Writing – original draft, Methodology, Data curation, Conceptualization. **Serkan Uslu:** Writing – review & editing. **Eren Akdağ:** Investigation, Validation. **Emel Çetin Özdoğan:** Supervision, Project administration, Formal analysis.

Table 3
Dominant and non-dominant extremity SLCMJ performance metrics.

Performance	Session	*D*			*ND*		
		Mean (SD)	Comparisons		Mean (SD)	Comparisons	
F_{land} /BW (N.kg^{-1})	S_{pre}	27.76(3.03)	$S_{pre} - S_{begin}$	Z=-2.299 p=0.02*	28.39(3.66)	$S_{pre} - S_{begin}$	Z=-2.296 p=0.02*
	S_{begin}	31.42(3.93)	$S_{pre} - S_{mid}$	Z=-2.255 p=0.02*	31.67(4.23)	$S_{pre} - S_{mid}$	Z=-2.255 p=0.02*
	S_{mid}	32.50(3.45)	$S_{begin} - S_{mid}$	Z=-0.712 p=0.48	32.97(3.17)	$S_{begin} - S_{mid}$	Z=-0.210 p=0.83
h_{jump} (cm)	S_{pre}	11.04(2.03)	$S_{pre} - S_{begin}$	Z=-2.803 p=0.01*	10.79(1.49)	$S_{pre} - S_{begin}$	Z=-2.805 p=0.01*
	S_{begin}	13.00(2.16)	$S_{pre} - S_{mid}$	Z=-2.666 p=0.01*	13.53(2.15)	$S_{pre} - S_{mid}$	Z=-2.666 p=0.01*
	S_{mid}	13.44(2.61)	$S_{begin} - S_{mid}$	Z=-0.889 p=0.37	14.12(2.06)	$S_{begin} - S_{mid}$	Z=-1.007 p=0.31
(F_{land}/BW)/h_{jump} (N.kg^{-1}/cm)	S_{pre}	2.60(0.57)	$S_{pre} - S_{begin}$	Z=-2.497 p=0.01*	2.65(0.54)	$S_{pre} - S_{begin}$	Z=-2.090 p=0.04*
	S_{begin}	2.49(0.54)	$S_{pre} - S_{mid}$	Z=-2.192 p=0.03*	2.40(0.53)	$S_{pre} - S_{mid}$	Z=-2.073 p=0.04*
	S_{mid}	2.52(0.63)	$S_{begin} - S_{mid}$	Z=-0.178 p=0.86	2.41(0.54)	$S_{begin} - S_{mid}$	Z=-0.889 p=0.37

S_{pre}: pre-measurement; S_{begin}: the beginning of the season; S_{mid}: the mid-season; F_{land}: Peak landing force; h_{jump}: Jump height; BW: body weight; *D*: dominant extremity; *ND*: non-dominant extremity.
* $p < 0.05$

Table 4
Maximum knee flexion angles of the *D* and *ND* limbs in SLCMJ.

$\theta_{knee\text{-}flex}$ (°)	Session	Mean(SD)	Comparisons	
D	S_{pre}	58.86(10.48)	S_{pre} - S_{begin}	Z=-1.844 p=0.07
	S_{begin}	62.19(10.55)	S_{pre} - S_{mid}	Z=-2.599 p=0.01*
	S_{mid}	65.99(11.16)	S_{begin}- S_{mid}	Z=-2.803 p=0.01*
ND	S_{pre}	50.68(9.64)	$S_{pre} - S_{begin}$	Z=-2.803 p=0.01*
	S_{begin}	58.47(8.39)	$S_{pre} - S_{mid}$	Z=-2.803 p=0.01*
	S_{mid}	62.10(11.92)	S_{begin}- S_{mid}	Z=-2.192 p=0.03*

Table 5
LESS scores.

	Session	Mean(SD)	Comparisons	Z	p
LESS score	S_{pre}	4.81(1.35)	S_{pre}-S_{begin}	-2.043	0.04*
	S_{begin}	4.47(1.42)	S_{pre}-S_{mid}	-1.245	0.21
	S_{mid}	4.221(.37)	S_{begin}-S_{mid}	-1.866	0.06

S_{pre}: pre-season; S_{begin}: the beginning of the season; S_{mid}: mid-season; *LESS*: Landing error scoring system after jump
* $p < 0.05$.

Conflicts of interest

We wish to confirm that there are no known conflicts of interest associated with this publication.

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