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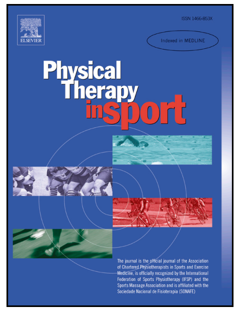

Is there association between cutting and jump-landing movement quality in semi-professional football players? Implications for ACL injury risk screening

Jesús Olivares-Jabalera, Alberto Fílter-Ruger, Thomas Dos´Santos, José Ortega-Domínguez, Rubén R. Sánchez-Martínez, Víctor M. Soto Hermoso, Bernardo Requena

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Title: Is there association between cutting and jump-landing movement quality in semi-professional football players? Implications for ACL injury risk screening.

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ABSTRACT

Objectives: To investigate the relationship between the Landing Error Scoring System (LESS) and Cutting Movement Assessment Score (CMAS) to evaluate movement quality, their intra- (INTRAob) and inter-observer (INTERob) reliability, and the comparison between the two drop vertical jump (DVJ) landings (1^{st} and 2^{nd}).

Design: Cross-sectional.

Participants: 42 male semi-professional soccer players performed three trials of DVJ and 70° change of direction with a ball located as an external focus.

Main Outcome Measures: Movement quality was evaluated through 2D video footage using the CMAS and LESS, screened by two observers. Relational, comparative and reliability analyses were conducted.

Results: Both tools showed moderate to substantial (ICC=0.58-0.71), and substantial to almost perfect (ICC=0.68-0.87) INTRAob and INTERob reliability, respectively. No significant associations were found among CMAS, LESS 1^{st} and 2^{nd} for either scores or risk profiles (r=-0.158-0.202, p>0.05). LESS 2^{nd} was moderately higher (ES=0.80-0.83, p=0.002-0.007) than 1^{st} scores.

Conclusions: CMAS and LESS are reliable tools to evaluate movement quality, although evaluations should be preferably performed by the same observer; ACL injury risk profile's is task-dependent; both landings of the DVJ should be assessed as they represent different biomechanical and neuromuscular control deficits.

Key words: field assessments, change of direction, landing, qualitative evaluation.

Highlights:

- CMAS and LESS are reliable tools to evaluate movement quality in soccer players.
- Ideally, CMAS and LESS evaluations should be performed by the same observer.
- Players' anterior cruciate ligament injury risk profile is task-dependent.
- Both landings in the drop vertical jump provide different yet useful information.

INTRODUCTION

Mitigating soccer injuries is of primary interest for sports medicine practitioners. Injuries have a meaningful impact on team performance, with lower injury rates associated with increased team performance, in both domestic (Hägglund et al., 2013) and European competitions (Hägglund et al., 2013), with important financial implications (Eliakim, Morgulev, Lidor, & Meckel, 2020). Of concern in soccer is anterior cruciate ligament (ACL) injuries, which results in extensive rehabilitation periods (>6 months) (Tabben et al., 2020), can be career threatening and can increase risk of developing knee osteoarthritis (Øiestad, Holm, Engebretsen, & Risberg, 2011). Additionally, post ACL injury, athletes are at risk of suffering a second ACL injury (Della Villa, Hägglund, Della Villa, Ekstrand, & Waldén, 2021; Webster, 2021), and not returning to the previous level of performance (Waldén, Hägglund, Magnusson, & Ekstrand, 2016). Consequently, maximising soccer players' availability and mitigating ACL injury risk (Olivares-Jabalera et al., 2021) is of great importance.

Eighty-eight percent of soccer ACL injuries occur during non-contact scenarios (i.e., cutting or landing) or involve indirect contact to the players' injured knee (i.e. resulting from an external force applied to the footballer, but not directly to the injured knee) (Della Villa et al., 2020). For example, 48% of these injuries occur during cutting actions while pressing or jump-landing (Della Villa et al., 2020; Grassi et al., 2020; Waldén et al., 2015). From a biomechanical perspective, during pressing ACL injury inciting events, dynamic knee valgus, ipsilateral trunk tilt and contralateral rotation, abducted hip and a flat and externally rotated foot are commonly observed (Della Villa et al., 2020). During jump-landing, extended knee and hip postures, lateral trunk flexion, hip internal rotations and knee valgus, are typical visual characteristics of non-contact ACL injuries (Padua et al., 2009). These aforementioned postures are associated with and can increase external knee abduction moments (KAM) during changes of direction (COD) (Dos'Santos, Thomas, McBurnie, Comfort, & Jones, 2021; Havens & Sigward, 2015) and landing (Hewett et al., 2005; Powers, 2010). Resultantly, these are considered high-risk postures (i.e., surrogates of ACL injury risk) which potentially increase ACL injury risk and thus, are specific deficits targeted in preventative training programmes (Dos'Santos, McBurnie, Comfort, & Jones, 2019).

Assessing athletes' movement quality during activities that are similar to ACL injury mechanisms appears to be an effective way of identifying those athletes at potentially higher injury risk (Buckthorpe, 2021). Generally, laboratory-based measures (i.e. three-dimensional (3D) motion analysis), is considered the gold standard method, which can accurately evaluate full-body kinetics and kinematics related to potential injury risk during sporting movements (Fox, Bonacci, McLean, Spittle, & Saunders, 2016). However, the cost effectiveness and feasibility of this technology is prohibitive to most of the community-level for large mass screening of soccer players (Myer, Ford, Brent, & Hewett, 2007). Consequently, recent efforts have been directed to creating alternative field-based tests to identify athletes who display poor movement quality and thus potential high-risk of ACL injury (Fox et al., 2016). For example the Landing Error Scoring System (LESS) (Padua et al., 2009), is a valid and reliable 17-item to evaluate drop vertical jump (DVJ) movement quality (Padua et al., 2011, 2009), while the Cutting Movement Assessment Score (CMAS) is also a validated and cost-effective tool to identify athletes at higher risk of ACL injury (Dos'Santos, McBurnie, Donelon, et al., 2019; Dos'Santos, Thomas, McBurnie, Donelon, et al., 2021). However, the reliability and implementation of these tools in adult, semi-professional soccer players have yet to be established.

In soccer environments, time is often limited for testing, as a myriad of different factors (i.e. physical, technical-tactical, psychological) are trained during microcycle (Stolen, Chamari, Castagna, & Wisloff, 2005). To potentially save time when screening, further insight is required to establish which test provides most useful information with the least equipment and testing time requirements. In this sense, knowing if there exist some redundancy between landing and cutting tasks would be of interest. However, although relationships between biomechanics in both tasks has been explored using 3D objective kinetic and kinematic data (Cortes, Onate, & van Lunen, 2011; Jones, Herrington, Munro, & Graham-Smith, 2014; Kristianslund & Krosshaug, 2013; Krosshaug et al., 2016; Øiestad et al., 2010; Verhagen, Van Dyk, Clark, & Shrier, 2018), no study has investigated the relationship between cutting and landing movement quality using field-based qualitative screening tools which could be easily applied in soccer environments. Specifically, no study has analysed the potential differences and commonalities between two scientifically validated qualitative scales such as LESS and CMAS, as well as their ability to qualitatively categorise players into low and high risk of ACL injury. Additionally, whether some risky patterns (e.g. knee abduction and flexion angles, trunk control) reliant on the task has not been studied in manoeuvres predisposing to ACL injury in a soccer-specific environment. Furthermore, to our best knowledge, no study has compared LESS scores between the two DVJ landings. Therefore, it is unknown if similar movement quality is displayed between the two landings, and it is unclear if one could provide a better insight of the player's landing-injury profile.

The aims of the present study were threefold: (i) analyse intra- (INTRAob) and inter-observer (INTERob) reliability of jump-landing (LESS) and COD (CMAS) movement quality assessments in presence of a ball as an external stimulus, (ii) investigate the relationship between LESS and CMAS scores to identify athletes at high-risk of ACL injury, and (iii) compare injury risk profiles and LESS scores between the two DVJ landings assessments (LESS 1st and LESS 2nd).

MATERIALS AND METHODS

Experimental Approach to the Problem

A cross-sectional design was used for investigating the relationship between CMAS and LESS 1st, and LESS 2nd, and INTRAob and INTERob reliability of both tools. Participants were required to not vigorously exercise (i.e. no exposure to either high-load training sessions or games) 48h prior to testing. In a single session, participants performed, in a randomised order, three 70°COD (COD70) trials (three each direction), and three bilateral DVJ trials whereby 2D video footage were collected. Participants were instructed to execute the tests at maximal intensity, using a ball as a sports-specific external reference. Afterwards, CMAS and LESS tools were used to screen and evaluate movement quality of the COD70 and DVJ, respectively, by two raters. Relational, comparative and reliability analyses were carried out from these extracted data.

Subjects

Forty-two adult, male semi-professional (3RD and 4th division Spanish League) soccer players (age, 25.8±4.9 years; height, 1.80±0.07 m; mass, 76.0±8.9 kg; ≥15 years of soccer experience.) participated in this study. The following inclusion criteria was applied: train ≥ four times a week, not having suffered a severe knee injury in the two years before, and being free of injury at the time of data collection. Goalkeepers (n=6) were excluded, and their data were considered only for evaluating DVJ landings (aim 3). Only outfield players were considered for the rest of analyses (aims 1 & 2). A minimum sample size of

42 was calculated from an a priori power analysis using G*Power (Version 3.1, University of Dusseldorf, Düsseldorf, Germany), based upon a correlational value of 0.5 (large effect), power of 0.95, and type 1 error of 0.05. All subjects were informed of the risk and benefits of taking part in the study and signed an informed consent prior to data collection. The methodology used was approved by the Local Ethics Committee and conformed to the policy statement with respect to the Declaration of Helsinki.

Procedures

After completing a standardized warm-up (5' minutes self-selected jogging,5' dynamic warm-up drills and sub-maximal familiarization trials with the tests), subjects performed three trials of the COD70 and DVJ. The COD70 was performed following previous methodologies (Dos'Santos, McBurnie, Donelon, et al., 2019). Subjects were asked to sprint from the starting line at maximal velocity for 5 m, COD in the designated mark, and sprint for 5 m more towards a ball located at the end of the movement (fig. 1a).

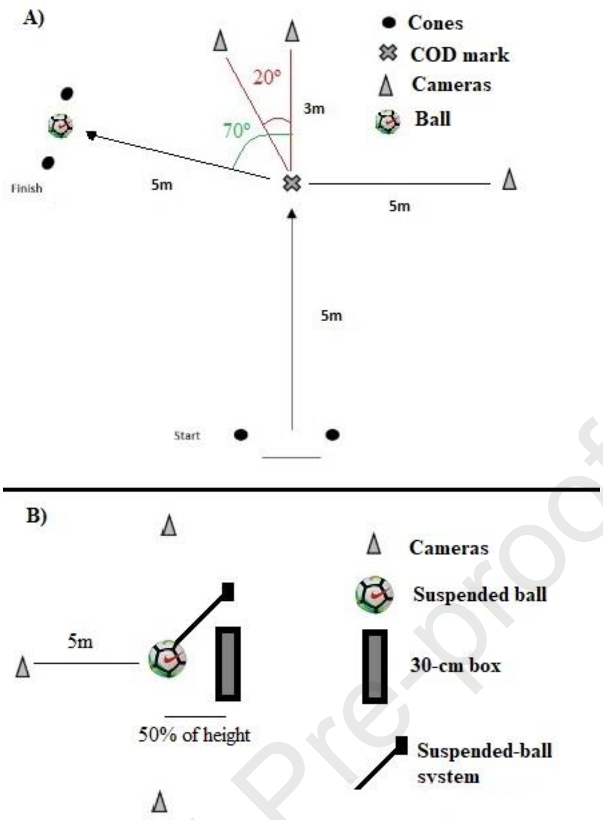

Fig 1. Experimental set-up for both the A) 70º change of direction, and B) drop vertical jump.

The DVJ was carried out in accordance with previous research (Padua et al., 2009), but with the inclusion of a suspended ball as an sport-specific external reference to reflect soccer-specific jumping biomechanics as it has shown to impact jump biomechanics (i.e. decrease ground contact times and braking impulse, increase rate of force development and maximum height reached) (Fílter et al., 2021)) (fig. 1b). For both tasks, participants were required to perform three successful trials, in the case of COD70 with both dominant (D): preferred limb to perform a penalty kick and nondominant (ND) limbs. All tasks were performed on an artificial grass field with their usual training footwear.

2D video footage for all tasks (240 Hz) were collected using three iPhone 11 (iOS 14.4.1, Apple. Inc., USA) smartphones, mounted upon 60-cm tripods at a distance of 3 m and 5 m perpendicular to the COD70 or DVJ. For the COD70, smartphones were placed at frontal, 20 degrees from frontal, and side views (fig. 1a) (Dos'Santos, Thomas, McBurnie, Donelon, et al., 2021). For the DVJ, one camera was placed at frontal, and two at side views (fig. 1b). All video footage was retrospectively viewed in Kinovea (0.8.15 for Windows, Bordeaux, France) for qualitative screening, and data analysed using the CMAS and LESS tools. Observers were two soccer strength and conditioning coaches and researchers with academic qualifications in Sports Sciences (Master's Degree). The week after the data were collected, the observers performed the screening independently, while their scores were collated by a third researcher (TDS) for the calculation of INTERob. The scores of the second and third trials from Observer 1 were used for INTRAob analyses.

CMAS and LESS screenings were performed in line with Dos'Santos et al. (Dos'Santos, Thomas, McBurnie, Donelon, et al., 2021) and Padua et al. (Padua et al., 2009), respectively. However, a 10th item was included in CMAS: rearfoot/forefoot contact, in line with recent CMAS recommendations (Dos'Santos, Thomas, McBurnie, Donelon, et al., 2021). The LESS screening was used to analyse both the first (the aim being jumping as high as possible to head the ball immediately after the landing) and second (the aim solely being landing after the maximum jump performed to head the ball) landings of the DVJ. A detailed description of the procedures and statistical analyses is provided as Supplementary Material.

Statistical analyses

All statistical analyses were performed in SPSS v 25 (SPSS Inc., Chicago, IL, USA) and Microsoft Excel (version 2019, Microsoft Corp., Redmond, WA, USA). Percentage agreements (sum of agreements / total of observations * 100) (Onate, Cortes, Welch, &

Van Lunen, 2010) and Kappa coefficients (Viera & Garret, 2005) were calculated for INTRAob and INTERob reliability of the CMAS and LESS individual items. For INTERob reliability, 101 and 94 trials were compared between the two observers for the CMAS and LESS tools, respectively, while 36 were compared for INTRAob reliability for both tasks for the reference observer. For INTERob reliability of CMAS and LESS scores, paired *t* tests and intraclass correlation coefficients (ICC) between scores from two observers were conducted after data were checked for normality. Mean differences and Hedges'*g* effect sizes (ES) with 95% confidence intervals (CI) were calculated. For the INTRAob reliability of CMAS and LESS scores, technical error of measurement (TEM), coefficient of variation (CV) (Baumgartner & Chung, 2009), ICC, and smallest detectable change (SDD) (Kropmans, Dijkstra, Stegenga, Stewart, & De Bont, 1999) were calculated.

For the study's second aim, Pearson product-moment correlations (Hopkins, 2002) between CMAS, LESS 1st and LESS 2nd scores were calculated. Percentage agreements and Kappa coefficients were calculated to establish agreements in low, moderate, and high injury risk classifications based on terciles (low, moderate, and high) between CMAS and LESS 1st, and CMAS and LESS 2nd. The χ^2 test was used to establish if there was any relationship in risk profile between CMAS and LESS 1st, and CMAS and LESS 2nd. For this analysis, the sample was split by the median value (high and low), so it was high enough to all expected cell counts in the χ^2 were greater than five. Additionally, χ^2 was also conducted to establish if there was relationship between the presence of knee valgus at initial contact in CMAS and LESS 1st and 2nd, and knee valgus at weight acceptance in CMAS and at peak knee flexion (PKF) in LESS 1st and LESS 2nd, as aberrant knee kinematics has been recurrently found in mechanisms of ACL injury (Della Villa et al., 2020; Grassi et al., 2020).

For the study's third aim, mean differences and Hedges' *g* ES, and Pearson's *r* were conducted to establish differences and relationships, respectively, between the LESS 1st and LESS 2nd scores. Percentage agreements and Kappa coefficients were additionally calculated for analysing agreement between low, moderate, and high injury risk profiles classifications between the two landings. Furthermore, percentages of appearance of the individual items were calculated for both scales. Statistical significance was defined $p \leq 0.05$ for all tests. As three trials were performed for each test, participants were considered to have displayed the deficits when it appeared in at least 2 of the 3 trials. For example, if participant scored 0, 0 and 1 in knee valgus at initial contact in CMAS, a '0' was selected as his representative value for knee valgus at initial contact.

RESULTS

Reliability of CMAS and LESS scales

Table 1 shows INTERob and INTRAob reliability of CMAS individual items. On average, agreement between the two observers were moderate (76%) and excellent (88%), with fair (k=0.35) and moderate (k=0.57) Kappa coefficients for INTERob and INTRAob reliability, respectively. Table 2 shows INTERob and INTRAob reliability of LESS individual items. On average, agreements were excellent for both INTERob and INTRAob (83 and 87%, respectively), while Kappa coefficients were moderate (k=0.50-0.59). There were no significant and trivial differences between observers in CMAS (ES= 0.09, p=0.280), yet a moderate significant difference in LESS 1st (ES=0.67, p<0.001) scores was observed. Additionally, moderate and substantial INTERob reliability was found for CMAS (ICC=0.58) and LESS 1st (ICC=0.71), respectively. INTRAob reliability data between scores for CMAS, LESS 1st and LESS 2nd is shown in Table 3.

LESS 2nd and CMAS showed a substantial reliability (ICC=0.68-0.70), while LESS 1st showed an almost perfect INTRAob reliability (ICC=0.87). Additionally, all tasks scores excluding LESS 2nd (CV=15.72) displayed values CV < 15% for intra-subject reliability.

Table 1
Inter- and intra-observer reliability of individual items for the CMAS tool. PFC = penultimate foot contact.

	Inter-observer reliability		**Intra-observer reliability**	
	% of agreement	*k*	% of agreement	*k*
Clear PFC braking	94	0.59	91	0.52
Wide lateral leg plant	97	0.24	94	0.32
Hip in an internally rotated position	80	0.48	88	0.64
Initial knee 'valgus' position	77	0.41	94	0.77
Inwardly rotated foot position	64	0.31	85	0.68
Frontal plane trunk position relative to intended direction	66	0.38	74	0.36
Trunk upright or leaning back throughout contact	57	0.16	79	0.59
Limited knee flexion during final contact	72	0.00	100	-
Excessive knee 'valgus' motion during contact	71	0.37	76	0.52
Foot contact	83	0.53	94	0.72
Average	76	0.35	88	0.57

Table 2
Inter- and intra-observer reliability of individual items for the LESS tool. IC = initial contact.

	Inter-observer reliability		Intra-observer reliability	
	% of agreement	*k*	% of agreement	*k*
Knee flexion at IC	73	0.25	88	0.72
Hip flexion at IC	100	-	100	-
Trunk flexion at IC	84	0.18	79	0.40
Ankle plantar flexion at IC	97	0.85	82	0.18
Medial knee position at IC	84	0.45	79	0.34
Lateral trunk flexion at IC	94	0.63	79	0.25
Stance width: wide	79	0.40	97	0.93
Stance width: narrow	90	0.81	88	0.76
Foot position: external rotation	77	0.56	85	0.69
Foot position: internal rotation	100	-	100	-
Symmetric initial foot contact at IC	73	0.47	71	0.41
Knee-flexion displacement	81	0.38	85	0.64
Hip-flexion displacement	100	-	100	-
Trunk-flexion displacement	91	0.79	88	0.75
Medial-knee displacement	87	0.73	88	0.76
Joint displacement	53	0.28	88	0.82
Overall impression	51	0.21	82	0.65
Average	83	0.50	87	0.59

Table 3

Intra-observer reliability of CMAS and LESS (1st and 2nd landing) scores (trial 2 vs trial 3). CMAS = cutting movement assessment score, LESS = landing error scoring system, 1st = first landing, 2nd = second landing, ICC = intraclass correlation coefficient, LL = lower limit, UL = upper limit, CV = coefficient of variation, TE = typical error, SDD = smallest detectable change.

	ICC	LL	UL	CV	LL	UL	TE	LL	UL	SDD
CMAS	0.70	0.58	0.80	14.17	12.29	15.67	0.78	0.68	0.92	2.13
LESS 1st	0.87	0.81	0.92	13.51	11.72	15.97	0.83	0.72	0.99	2.30
LESS 2nd	0.68	0.52	0.79	15.72	13.39	19.03	1.24	1.06	1.50	2.45

Relationship between CMAS and LESS tools

Table 4 shows the relationship between CMAS, LESS 1st and LESS 2nd scores for ND, D and mean of both limbs, with all relationships being nonsignificant and trivial to small. The χ^2 test revealed no significant relationship between risk categories (high, low) for any of the possible combinations between CMAS and LESS (ND, D and mean between limbs) tools, either for the first and second landing (p=0.182-1.000). Additionally, when comparing the presence/absence of knee valgus at initial contact in CMAS and LESS 1st, and CMAS and LESS 2nd, all were nonsignificant, except for the relationship of knee valgus at initial contact between CMAS and LESS 1st for the ND limb that were moderately associated (C=0.376, p=0.016). Out of the 36 players observed in both tests, 30 (83%) shared the same kinematics, in which 27 (75% showed no knee valgus), and 3 (8%) showed knee valgus at initial contact. For the knee valgus at WA (for CMAS) and at PKF (for LESS) items, there were no significant relationship for any comparison. Percentage agreements and Kappa coefficients between risk categories for CMAS, LESS 1st and LESS 2nd are shown in Table 5. Agreements in risk classifications were poor (23-50%), with poor or slight Kappa coefficients for all comparisons, except for the relationship between CMAS and LESS 2nd in ND, which was fair (k = 0.25). Figure 2 depicts a scatter plot showing CMAS and LESS 1st risk profiles (high and low) illustrating the poor relationship and agreements between tasks.

Table 4

Relationship between CMAS and LESS (1st and 2nd landing) scores. CMAS = cutting movement assessment score, LESS = landing error scoring system, ND = nondominant, D = dominant. * = significant ($p < 0.05$) relationship between variables using Pearson product-moment correlations.

r	LESS 1st ND	LESS 1st D	LESS 1st mean	LESS 2nd ND	LESS 2nd D	LESS 2nd mean
CMAS ND	0.041	-0.158	-0.059	0.202	0.062	0.176
CMAS D	0.078	-0.009	0.036	0.076	0.016	0.078
CMAS mean	0.066	-0.119	-0.026	0.182	0.053	0.165
LESS 1st ND	-	-	-	-0.268	-0.234	-0.298
LESS 1st D	-	-	-	-0.266	-0.168	-0.275
LESS 1st mean	-	-	-	-0.280	-0.214	-0.301

Table 5

Percentage of agreements and Kappa coefficients between risk categories (high, moderate, low) for the CMAS and LESS screening tools. CMAS = Cutting movement assessment score, LESS landing error scoring system, 1st = first landing, 2nd = second landing, ND = nondominant, D = dominant.

	% of agreement	*k*
CMAS vs LESS 1st (ND)	36	0.04
CMAS vs LESS 1st (D)	39	0.08
CMAS vs LESS 1st (mean)	42	0.13
CMAS vs LESS 2nd (ND)	50	0.25
CMAS vs LESS 2nd (D)	32	-0.02
CMAS vs LESS 2nd (mean)	44	0.16
LESS 1st vs LESS 2nd (ND)	23	-0.16
LESS 1st vs LESS 2nd (D)	35	0.03
LESS 1st vs LESS 2nd (mean)	25	-0.13

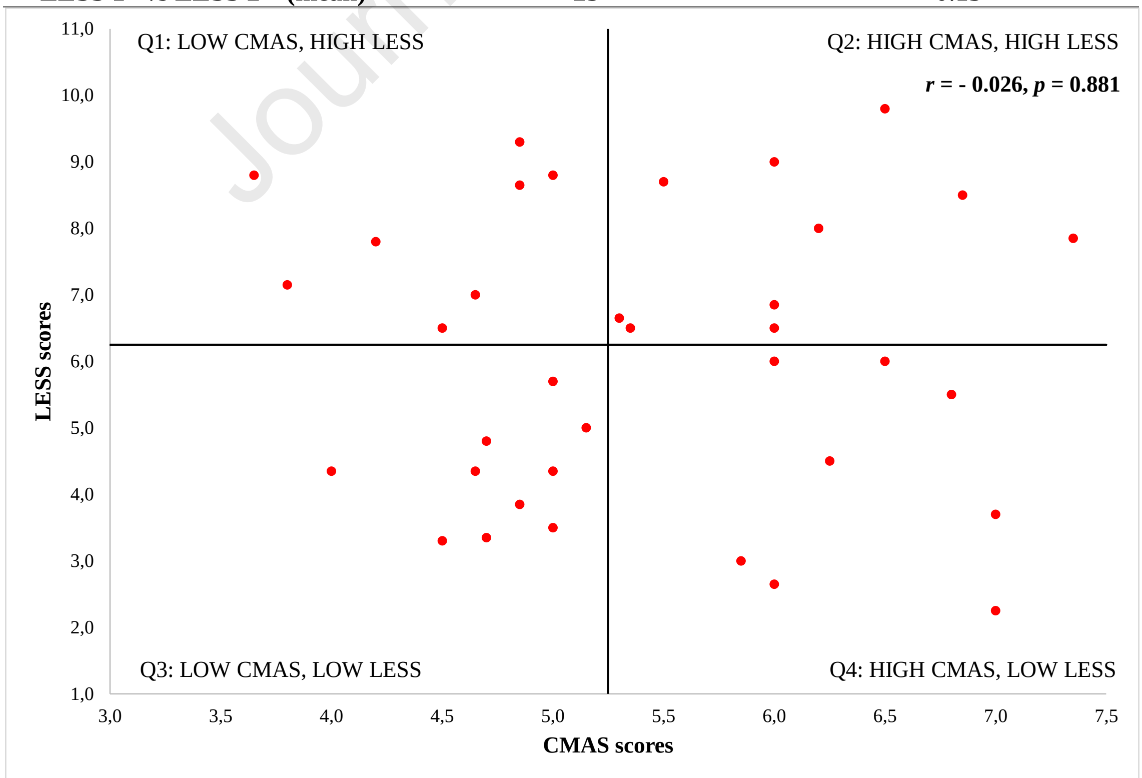

Fig 2. Scatter plot showing CMAS and LESS mean 1st scores relationship, divided into four quadrants (two risk profiles: high and low). Q1 = Quadrant 1: players that showed low risk in CMAS and high risk in LESS; Q2 = Quadrant 2: players that showed high risk in CMAS and high risk in LESS; Q3 = Quadrant 3: players that showed low risk in CMAS and low risk in LESS; Q4 = Quadrant 4: players that showed high risk in CMAS and low risk in LESS. CMAS: cutting movement assessment score; LESS: landing error scoring system.

Comparison between LESS 1st and LESS 2nd scales

In LESS 2nd, participants showed a moderately higher score for both ND (6.0 vs. 7.8, ES = 0.80-0.83, $p = 0.002$) and D (6.2 vs. 7.9, ES = 0.80-0.83, $p = 0.007$) compared to LESS 1st. Table 5 shows the risk profile distribution for each individual item for both LESS 1st and LESS 2nd, with a poor agreement in all combinations. There was no significant trivial to small relationships between scores for ND, D or mean between LESS 1st and LESS 2nd (Table 4); however, LESS 1st and LESS 2nd means were inversely, although nonsignificant, moderately correlated ($r = -0.30$, $p = 0.059$). Table S1 (Supplementary Material) shows the percentage of subjects that scored a high-risk deficit (1 or 1 and 2) in each of the individual items of first and second landings. In Figure 3, a scatter plot illustrates the moderate relationship between LESS 1st and LESS 2nd scores but poor agreements.

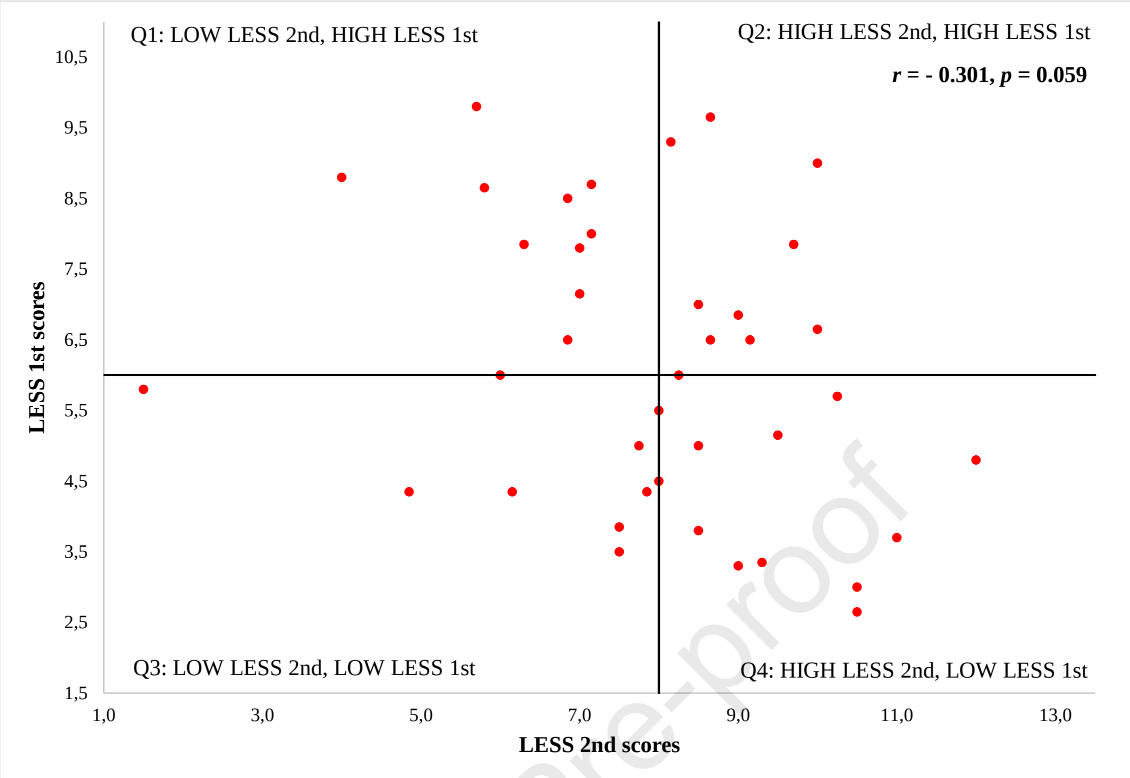

Fig 3. Scatter plot showing LESS 1st and LESS 2nd mean scores relationship, divided into four quadrants (two risk profiles: high and low). Q1 = Quadrant 1: players that showed low risk in LESS 2nd and high risk in LESS 1st; Q2 = Quadrant 2: players that showed high risk in LESS 2nd and high risk in LESS 1st; Q3 = Quadrant 3: players that showed low risk in LESS 2nd and low risk in LESS 1st; Q4 = Quadrant 4: players that showed high risk in LESS 2nd and low risk in LESS 1st. CMAS: cutting movement assessment score; LESS: landing error scoring system; 1st: first landing; 2nd: second landing.

DISCUSSION

The primary findings of this study were (1) CMAS and LESS scores in presence of a ball as an external focus showed substantial and almost perfect INTRAob reliability, respectively, and individual items, on average, excellent percentages of agreement, while moderate to excellent INTERob reliability of CMAS and LESS was observed, respectively; (2) there was no meaningful relationship between CMAS and LESS 1st and 2nd for either scores, individual items (except for knee valgus at IC), or injury risk profiles; and (3) LESS 2nd scores were moderately higher than LESS 1st. Therefore, both tools are generally reliable, but cannot be used interchangeably to evaluate potential ACL injury risk in soccer players.

For the CMAS, our data showed slightly lower INTRAob and INTERob reliability for CMAS individual items and scores compared to previous research (Dos'Santos, McBurnie, Donelon, et al., 2019), although intra-subject variability was similar in comparison to a previous research in a similar cohort of athletes (CV = 14.2 vs. 11.4-22.2%) (Dos'Santos, McBurnie, Comfort, et al., 2019). The items with the lowest agreements were the 'inwarly rotated foot position' and those related to the trunk (in frontal and sagittal planes) (57-66%, Table 1). For the LESS score, slightly lower INTRAob (Padua et al., 2009) and INTERob reliability was observed compared to previous research (Onate et al., 2010). However, similar INTERob reliability for LESS 1st (ICC = 0.83 vs. 0.72-0.84) were obtained compared to previous research (Padua et al., 2011, 2009). The individual items with the lower agreements in LESS were 'joint displacement' and 'overall impression' (51-53%, Table 2), probably due to the multiple options to score them (3 vs. 2 in the rest of items). The slightly lower reliability measures could be attributed to the following reasons: (i) the different cohorts of athletes participating in the previous studies (none male, adult, semi-professional players) (Dos'Santos, McBurnie, Donelon, et al., 2019; Onate et al., 2010; Padua et al., 2011, 2009); and (ii) the inclusion of a ball as an external focus, which can induce changes in jump-landing mechanics and may also affect the reproducibility of the movement (Fílter et al., 2021; Mok, Bahr, & Krosshaug, 2017). For INTERob differences, our slightly lower reliability may have been influenced by the lack of expertise of observer 2 (~ 10 hours of training before extracting the data), apart from the fact that previous reliability analyses have been performed by the creators of the tools (Dos'Santos, McBurnie, Comfort, et al., 2019; Dos'Santos, McBurnie, Donelon, et al., 2019; Padua et al., 2015, 2009), with presumably more experience in the screening tools. However, our data suggest that both CMAS and LESS assessment with the inclusion of a ball as an external focus can provide reliable data and while improving the sports-specificity (Fílter et al., 2021), although they should be preferably performed by the same observer to improve reliability of the measurements.

CMAS scores were not significantly correlated to either LESS 1st or 2nd (Table 4). Additionally, there were poor relationships between risk profiles when divided by high/low (χ^2: p=0.182-1.000), and poor agreement when divided by terciles (i.e. low, moderate and high) (Table 5, Figure 2). We additionally found no meaningful relationship between the presence/absence of knee valgus between the tasks. Collectively, corroborating previous 3D biomechanical investigations (Chinnasee, Weir, Sasimontonkul, Alderson, & Donnelly, 2018; Cortes et al., 2011; Jones et al., 2014; Kristianslund & Krosshaug, 2013; Nedergaard, Dalbø, Petersen, Zebis, & Bencke, 2020), these findings highlight that injury risk profiles are task dependent. Furthermore, differently to previous studies conducted in more controlled, objective 3D-laboratory assessments, our results is the first to demonstrate that the independence in movement quality between tasks is still present in a soccer-specific environment with an external focus, which is known to better simulate the real situations in which ACL injuries occur. For instance, even though important elements such us the footwear (Bennett, Brock, Brosnan, Sorochan, & Zhang, 2015), the turf (Zhou, Li, & Bai, 2019) or the presence of a ball as an external focus (Fílter et al., 2021) has shown the potential to influence body biomechanics and increase knee loads, they have not been included before to conduct such analyses.

DVJ and CODs have major differences that could explain these results. COD is a higher-velocity action, which consist of a unilateral, multi-planar movement, as opposed to the predominantly single-planar, bilateral DVJ (Kristianslund & Krosshaug, 2013).

Consequently, practitioners should not assume poor cutting movement quality will equate to poor jump-landing movement quality, and vice versa. Therefore, it would be prudent to include both landing and cutting tasks for a holistic overview of potential ACL injury risk when screening soccer players. As the two tasks reflect soccer ACL injury mechanisms (Della Villa et al., 2020; Waldén et al., 2016), screening landing and cutting will lead to better individualized preventative programs which can be tailored to address movement quality deficits.

Interestingly, moderately greater LESS scores were observed during the second landing of the DVJ compared to the first (ES=0.80-0.83, $p<0.01$) and, thus, appears to be a task which will identify more high-risk deficits and potential injury risk in these players. This increase is mainly due to a more rigid landing (less knee, hip and trunk flexion) and a poorer trunk control in the frontal plane (Table S1). Furthermore, players' risk profile between LESS 1st and 2nd were not related (Table 4, Table 5, Figure 2). Although knee valgus motion and load in a DVJ has been proposed as a predictor of ACL injuries in female athletes (Hewett et al., 2005), some criticism has arisen in recent years against injury prediction (Bahr, 2016) and the external validity and utility of the DVJ in ACL injury screening (Cronström, Creaby, & Ageberg, 2020; Fältström, Hägglund, Hedevik, & Kvist, 2021; Krosshaug et al., 2016; Mørtvedt, Krosshaug, Bahr, & Petushek, 2020; Romero-Franco, Ortego-Mate, & Molina-Mula, 2020). If it could be argued that the DVJ simulate loading patterns of motion where ACL injuries occur, then it may be necessary to develop screening test which include movements that are more comparable to what is seen in competition (Krosshaug et al., 2016). With the inclusion of a suspended ball, our study increased sports-specificity, as an overhead target has shown to alter the jump performance and biomechanics (Fílter et al., 2021). Another advantage of using a DVJ is that two landings can be analysed. From our data, the second landing seems to display a different, more aberrant pattern (4 out of 36 players landed with one leg, or one leg was more loaded than the other – i.e., asymmetrical), and represent different risk profiles, where movement quality may be more highly compromised (Table 5). This observation is in line with previous studies that show a different neuromuscular and biomechanical characteristics between the two DVJ landings (Bates, Ford, Myer, & Hewett, 2013b, 2013c; Whyte et al., 2017), and an increase in aberrant movement during the second (Bates, Ford, Myer, & Hewett, 2013a). Therefore, our results show that both DVJ landings should be screened in athletes for more insight into aberrant movement quality (Bates et al., 2013a) when a deeper analysis is required. However, as the second landing seem to share more commonalities with common mechanisms of ACL injury in landings (Waldén et al., 2016) and may predispose to a higher risk of injury (Bates et al., 2013a, 2013b, 2013c), it is suggested to provide more useful information when screening football players.

CONCLUSION

In conclusion, our data suggests that CMAS and LESS with a ball as an external focus are reliable tools to evaluate the movement quality related to ACL injury risk profiling in cutting and landing actions in adult semi-professional soccer players. Indeed, injury risk profiles are task-dependent, and the evaluation of landing movement quality cannot be generalised to cutting movement quality, and vice versa. Additionally, both the first and second landing in the DVJ could provide useful information in injury risk identification, as they show differentiated neuromuscular control discrepancies. More research is needed in larger samples, and with more ecological movements such as unanticipated cuts, single-leg landings or presence of opponents, that better simulate the mechanisms in which ACL injuries in soccer frequently occur. Table 6 provides a summary of the practical applications of the study.

Table 6
Summary of the practical applications from the present study. ACL = anterior cruciate ligament, CMAS = Cutting Movement Assessment Score, COD = change of direction, DVJ = drop vertical jump, LESS = Landing Error Scoring System.

Inter- and intra-observer reliability of CMAS and LESS	CMAS and LESS are reliable tools to evaluate movement quality during COD and DVJ, respectively, with the ball as an external focus in semi-professional soccer players. However, when being used by different members of the staff, care must be taken as the reliability is reduced when two observers perform the same assessment, especially for the CMAS. Therefore, it is suggested that, when possible, the same person conducts the qualitative screening to establish meaningful changes in performance.
ACL risk profile	As there is no meaningful relationship in the risk profiles between both tasks and given that cutting and landings are mechanisms of ACL injuries, COD and a jump-landing tests should be included in soccer teams ACL injury screening batteries. Practitioners are encouraged to include a ball as external focus to improve the external validity of the tests.
Landings of the DVJ	When using the valid and reliable CMAS and LESS tools to establish the ACL risk profile of the soccer player, both landings in the DVJ must be considered, as they have different objectives and represent different biomechanical and neuromuscular control deficiencies patterns.
Utility of CMAS and LESS evaluations	By performing these evaluations, practitioners could: (i) identify the individual movement quality and neuromuscular control deficits which may predispose their athletes to greater non-contact ACL injury risk, and (ii) design tailored preventative programs in order to mitigate their individual risk factors of non-contact ACL injury.

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Title: Is there association between cutting and jump-landing movement quality in semi-professional football players? Implications for ACL injury risk screening.

Highlights:

- CMAS and LESS are reliable tools to evaluate movement quality in soccer players.
- Ideally, CMAS and LESS evaluations should be performed by the same observer.
- Players' anterior cruciate ligament injury risk profile is task-dependent.
- Both landings in the drop vertical jump provide different yet useful information.

Conflict of interest: none declared.

Ethical Approval: All subjects were informed of the risk and benefits of taking part in the study and signed an informed consent prior to the data collection. The methodology used was approved by the Local Ethics Committee and conformed to the policy statement with respect to the Declaration of Helsinki.

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