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Association between Functional Movement Screening™ scores and non-contact injuries in amateur rugby players

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Abstract – Objective: To examine the associations between the Functional Movement Screening (FMS™) scores and asymmetries between limbs in the different tasks with non-contact injuries in senior amateur rugby union players.
Method The design was a prospective cohort study. Sixty-eight ($n = 68$) male senior amateur rugby players completed the FMS™, which assesses seven functional movements on a scale of 0 to 3 and provides a total score of up to 21. Players were subsequently monitored for injuries during one competitive season. Likewise, match and training non-contact injuries with the associated variables were collected.
Results: Twenty-two (32.3%) players sustained one non-contact injury during the season. The median time lost was 24.5 days (IQR [15; 383]). Injured players showed a mean FMS™ composite of 14.50(SD 1.74), and non-injured showed a mean FMS™ composite of 14.57(SD 2.25). No statistically significant association was found between the presence of non-contact injuries and FMS™ composite score (OR = 0.98 [0.77; 1.27]) or FMS™ categorical score (≤ 14) (OR = 0.64 [0.23; 1.78]). The presence of an asymmetry between limbs in the active straight leg raise was associated with non-contact injuries (OR: 4.69 [1.35 - 17.9]) ($p = 0.02$).
Conclusion: FMS™ composite did not show differences between injured and non-injured players. Asymmetry in the active straight leg raise was strongly associated with non-contact injury occurrence.

Keywords: Rugby union, screening, injury risk, athletic performance

Résumé – Association entre les scores Functional Movement Screening™ et les blessures sans contact chez les joueurs de rugby amateur.
Objectif : Examiner les associations entre les scores Functional Movement Screening FMS™ et les asymétries entre les membres dans différentes tâches avec les blessures sans contact chez les joueurs seniors amateurs de rugby.
Méthode : Il s'agit d'une étude de cohorte prospective. Soixante-huit ($n = 68$) joueurs de rugby amateur seniors masculins ont complété le FMS™, qui évalue sept mouvements fonctionnels sur une échelle de 0 à 3 et fournit un score total de 21. Les joueurs ont ensuite été surveillés pour blessures au cours d'une saison de compétition. De même, les blessures sans contact lors des matchs et des entraînements, avec les variables associées, ont été recueillies.
Résultats : Vingt-deux (32.3%) joueurs ont subi une blessure sans contact au cours de la saison. Le temps médian perdu était de 24.5 jours (IQR [15; 383]). Les joueurs blessés ont montré un score FMS™ composite moyen de 14.50 (SD 1.74), tandis que les joueurs non blessés ont montré un score FMS™ composite moyen de 14.57(SD 2.25). Aucune association statistiquement significative n'a été trouvée entre la présence de blessures sans contact et le score FMS™ composite (OR = 0.98 [0.77 ; 1.27]) ou le score FMS™ catégorique (≤ 14) (OR = 0.64 [0.23 ; 1.78]). La présence d'une asymétrie entre les membres lors du relevé de jambe tendue active était associée aux blessures sans contact (OR : 4.69 [1.35–17.9]) ($p = 0.02$).
Conclusion : Le score FMS™ composite n'a pas montré de différences entre les joueurs blessés et non blessés. L'asymétrie dans le relevé de jambe tendue active était fortement associé à la survenue des blessures sans contact.

Mots-clés : Rugby, dépistage, risque de blessure, performance athlétique

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1 Introduction

Rugby union is a collision sport characterized by multiple high-intensity physical (*i.e.*, sprints, jumps, changes of direction) and technical skills (*i.e.*, catching and passing, tackling) and other specific actions such as scrummaging and rucking (Edwards *et al.*, 2021; Flavell, Sayers, Gordon, & Lee, 2013; Kawasaki *et al.*, 2018). In this regard, match demands impose a high mechanical load to the lower limbs during changes of direction, linear sprints, horizontal and vertical jumps (Charalambous, Irwin, Bezodis, & Kerwin, 2012; Dos Santos, Mcburnie, Thomas, Comfort, & Jones, 2019). These physical demands, alongside the exposure to collisions and contact events, result in a high risk of sustaining rugby related injuries (Yeomans *et al.*, 2019). It has been recently reported that most injuries in rugby union occur through contact mechanisms and especially during tackling (Brooks & Kemp, 2011; Fuller, Taylor, Kemp, & Raftery, 2017; Williams, Trewartha, Kemp, & Stokes, 2013). Despite that a considerable number of injuries also occur during non-contact situations (Kemp *et al.*, 2020; Kenny & Comyns, 2020). In this sense, hamstrings strain injuries account for 34.3% of injuries overall and are the most common non-contact rugby injury diagnosis (Tondelli, Boerio, Andreu, & Antinori, 2021). More specifically, in amateur rugby, several risk factors for injury have been proposed, including playing position, body mass, injuries history, age, navicular drop, training pitch surface, and groin and hamstring strength deficits (Chavarro-Nieto, Beaven, Gill, & Hébert-Losier, 2021; Dolan *et al.*, 2022; Yeomans *et al.*, 2019). Nevertheless, it is currently unclear which are the most appropriate ways to assess injury risk factors in rugby players, which poses a challenge for sport physiotherapists and strength and conditioning coaches.

The Functional Movement Screen™ (FMS™) is an assessment tool that has been used in many sports (Hotta *et al.*, 2015; Kiesel, Butler, & Plisky, 2014) and has been suggested to be able to predict injury risk in senior male rugby union players (Attwood, Roberts, Trewartha, England, & Stokes, 2019; Tee, Klingbiel, Collins, Lambert, & Coopoo, 2016). Briefly the FMS™ is a simple and easy screening tool used to assess the functional movement competency of an individual (Cook, Burton, & Hoogenboom, 2006). The FMS™ involves performing seven functional movements including the stability push up (TSPU) and deep squat (DS), hurdle step (HS), in-line lunge (IIL), shoulder mobility (SM), active straight leg raise (ASLR), and rotary stability (RS) (Cook, Burton, Hoogenboom, & Voight, 2014; Cook *et al.*, 2006). The highest possible score for all these seven movements is 21, which is calculated by grading each movement on a scale from 0 to 3. Previous studies (Chorba, Chorba, Bouillon, Overmyer, & Landis, 2010; Lisman, O'Connor, Deuster, & Knapik, 2013) demonstrated that a cut-off of 14 points indicated significantly greater likelihood of injury in female collegiate athletes, American football players and male Marines. In addition, Kiesel *et al.*, (2014), reported

that a combination of scoring below 14 points (FMS™ score) and exhibiting asymmetries was highly specific for injury, with a specificity of 0.87 (confidence interval: 0.84–0.90). However, a recent review has questioned this association (Moran, Schneiders, Mason, & Sullivan, 2017), showing that level of association between FMS composite scores and injury is not sufficient to support the use of this screening as an injury prediction tool.

Regarding rugby, a study conducted in semi-professional, amateur and recreational players, reported that a one-point change in FMS™ score was associated with a 10% lower match-injury burden (*e.g.*, contact and non-contact injuries), resulting in a 50% lower match-injury burden when comparing players with low to high FMS™ scores (Attwood, Roberts, Trewartha, England, & Stokes, 2019). In another study (Armstrong & Greig, 2018) conducted with college rugby players, it was reported that FMS™ cut-off values of 11.5 could be used to identify players at higher risk of sustaining contact and non-contact injuries (*i.e.*, joint sprains, contusions, and muscle strains). Moreover, Duke, Martin, & Gaul, (2017) reported that a score of 14 could identify individuals at risk of injury, extending the generalizability of this FMS™ composite cut-off score to male rugby union players. Surprisingly, the abovementioned studies (Attwood *et al.*, 2019, Armstrong & Greig, 2018; Duke, 2017) included contact injuries in their analysis which is a limitation since the FMS™ was designed to evaluate the quality of movement patterns, exploring the neuromuscular control and muscular imbalance risk factors that contribute to non-contact injury, and not the tolerance to contact situations (Warren, Smith, & Chimera, 2015). Only one study (Tee *et al.*, 2016) conducted with professional rugby players, reported separately the associations between FMS™ scores with contact and non-contact injuries, showing that FMS™ cut-off score of 14/15 predicted non-contact injuries with an odds ratio of 4.3 (95%CI 0.9–21.0). However, the latter study (Tee *et al.*, 2016) failed to report which were the observed non-contact injuries.

Understanding injury risk factors in rugby players is crucial for sports professionals to determine athletes' movement risk factors and implement targeted interventions for injury prevention. The FMS™ has shown potential in predicting injuries in various sports, but its applicability and accuracy as an injury risk predictor in rugby players, particularly at the amateur senior level, remain to be fully established. Moreover, no studies to date have investigated the association between FMS™ scores and non-contact injury risk in senior amateur rugby players. Therefore, the present study aimed to examine the associations between FMS™ scores and asymmetries between limbs in the different tasks with non-contact injuries in senior amateur rugby players. It was further hypothesized that lower FMS™ scores and asymmetries would be positively associated with the occurrence of non-contact injuries in this population (Tee *et al.*, 2016; Armstrong & Greig, 2018).

2 Method

2.1 Experimental approach to the problem

In this study a descriptive, prospective, and longitudinal design was adopted. Assessments were conducted during the 2019 preseason over three consecutive weeks on Tuesdays and Thursdays, with ten players completing the assessments on each day. FMS^{TM} assessments were completed at the end of the pre-season in February. Injury and exposure data were collected during the competitive season between March and October, recording non-contact time loss injuries.

2.2 Participants

Sixty-eight senior amateur male rugby players ($n = 68$; age: 25.5 years interquartile range(IQR) [IQR: 22.00; 28.00]; height: 178.96 ± 6.52 cm; body mass: 87.00 kg [IQR: 79.00; 96.25] who were members of one rugby club that regularly competes in the first division A of the Buenos Aires Rugby Union (URBA) competition volunteered to participate in this study. The inclusion criteria were as follows: players had to, i) be healthy and active rugby players; ii) no injuries or medical conditions (*i.e.*, vestibular, visual or balance impairment or any neurological disease) sustained in the last six months prior to the assessment. The study met the ethical standards and was approved by the Research Ethics Committee of the University of Flores conformed to the recommendations of the Declaration of Helsinki. After being informed of the purpose and experimental procedures, participants signed an informed consent form prior to participation.

2.3 Procedures

All participants were assessed by the same examiner, a sports physiotherapist (FMS^{TM} certified) with more than 5 years of experience conducting FMS^{TM} screenings, at the same location during the evening (7 p.m. to 9 p.m.) in an indoor club facility. Regarding anthropometric traits, body mass (BM) was measured using an electronic scale (HD-366, Tanita Corporation, Japan), and height using a height rod and a vertex (Rosscraft Innovations, Vancouver, Canada), following the protocol recommended by the International Society for the Advancement of Kinanthropometry (ISAK). Additionally, body mass index (BMI), expressed in kg/m^2, was calculated by dividing the player's BM by the player's height squared.

2.4 Functional movement screening data

The FMS^{TM} is comprised of seven fundamental movement patterns (screenings) that require a balance of mobility and stability (including neuromuscular/motor control). These fundamental movement patterns were designed to provide observable performance of basic locomotor, manipulative, and stabilizing movements (Cook *et al.*, 2014). The screenings were completed in the following order: DS, HS, ILL, SM, ASLR, RS and finally TSPU. Each of the seven movements was scored from 0 to 3 allowing a maximum score of 21 (Cook *et al.*, 2014). To begin the evaluation process, we prioritized the review of mobility patterns (SM and ASLR) in a sequential manner. Afterwards, attention was directed towards motor control or stability patterns (RS and TSPU) in the designated order. Lastly, the functional patterns (ILL, HS and DS) were addressed in their respective order. For this reason, we also divided the scores in three sub-groups: functional, stability, and mobility (Cook, 2011). An asymmetry between the right and left sides was considered if the scores between each side were different. The lowest score of each screening was used to obtain the 'composite score'. The FMS^{TM} has been shown to be a reliable tool among clinicians demonstrating acceptable inter-rater and intra-rater reliability in rugby players when scored in real time, regardless of the experience of participants (Armstrong & Greig, 2018).

2.5 Injury data

Data were collected prospectively according to the Consensus Statement on injury definitions and procedures for studies of injuries in rugby union (Fuller *et al.*, 2007), and performed by an experienced physiotherapist with more than 5 yr working in rugby. Data was digitalized through Google Forms (Google Form-Google, Mountain View, CA, USA), and exported to a sheet matrix, with match and training times recorded. Injury was defined as a functional physical disorder caused by energy transfer exceeding the body capacity to preserve its functional or structural integrity sustained during a rugby match or training and preventing the player from taking a full part in all training activities for more than one day (Fuller *et al.*, 2007). Only the initial non-contact injury experienced by the players was considered for the analysis. Subsequent injuries to the same body segment or muscle were excluded from the analysis. Injury severity was classified based on the days the player was not fully available to participate in training and competition: 1–7 days lost, 8–28 days lost or > 28 days lost (Bahr *et al.*, 2020).

2.6 Statistical analysis

The distribution of the sample was determined using Shapiro-Wilk statistical test and graphical evaluation using histograms and box-and-whisker plots. Normally distributed continuous variables are reported as mean and standard deviation (SD). Otherwise, the median and interquartile range (IQR) was used. Categorical variables were reported as presentation number and percentage (%). Chi-square test or Fisher's exact test were used to compare categorical variables, whereas the remaining variables were compared *via* Student's t test or U-Mann-Whitney as appropriate. The FMS^{TM} composite was analyzed continuously (with values from 0 to 21) and categorically (with values ≤ 14 or > 14). To determine the association between injury and the rest of the variables, simple regression analyzes were performed with injury as

Table 1. Player's demographic data, mean FMS^{TM} composite scores, and mean FMS^{TM} sub-groups scores of injured and non-injured players.

	Overall, $N = 68$	Non Injured, $N = 46$	Injured, $N = 22$	p-value
Age, years (median [IQR])	25.50 [22.00; 28.00]	25.00 [22.00; 27.75]	26.50 [23.00; 28.75]	0.269
Height, cm (mean (SD))	178.96 (6.52)	179.33 (6.27)	178.18 (7.10)	0.502
Body mass, kg (median [IQR])	87.00 [79.00; 96.25]	86.50 [78.25; 95.00]	88.50 [80.50;101.50]	0.416
BMI, kg/m^2 (median [IQR])	27.10 [25.20; 28.95]	26.44 [24.81; 28.61]	27.61 [26.80; 29.59]	0.107
FMS^{TM} composite (mean (SD))	14.54 (2.08)	14.57 (2.25)	14.50 (1.74)	0.905
FMS^{TM} <= 14 (%)	32 (47.1)	20 (43.5)	12 (54.5)	0.551
FMS^{TM} > 14 (%)	36 (52.9)	26 (56.5)	10 (45.5)	0.405
FMS^{TM} functional score (mean (SD))	6.24 (1.33)	6.24 (1.42)	6.23 (1.15)	0.973
FMS^{TM} mobility score (mean (SD))	4.06 (0.99)	4.13 (0.91)	3.91 (1.15)	0.393
FMS^{TM} stability score (mean (SD))	4.32 (0.74)	4.26 (0.77)	4.45 (0.67)	0.318

References: FMS^{TM} = Functional Movement Screen; cm: centimeters; Kg: kilogram; BMI: Body Mass Index; m^2: meter squared; IQR: interquartile range; SD: standard deviation.

Table 2. Mean (SD) of injured and non-injured players in FMS^{TM} for individual component screening.

	Overall ($N = 68$)	Non-Injured ($N =46$)	Injured ($N = 22$)	p-value
Deep squat	2.01 (0.50)	2.02 (0.54)	2.00 (0.44)	0.8595
Hurdle step	2.10 (0.65)	2.11 (0.67)	2.09 (0.61)	0.914
In line lunge	2.11 (0.70)	2.11 (0.74)	2.13 (0.64)	0.8746
Shoulder mobility	1.93 (0.63)	1.96 (0.63)	1.86 (0.64)	0.5767
Active straight leg raise	2.13 (0.64)	2.17 (0.57)	2.05 (0.79)	0.4979
Trunk stability push-up	2.34 (0.68)	2.28 (0.69)	2.45 (0.67)	0.3325
Rotary stability	1.99 (0.21)	1.98 (0.26)	2.00 (0.00)	0.5694

References: FMS^{TM} = Functional Movement Screen; SD: standard deviation.

the dependent variable and each covariate (FMS^{TM}) as continuous variable (0 to 21), FMS^{TM} categorically (with values ≤ 14 or > 14) and with each FMS^{TM} sub-groups as independent variables. From this analysis, those variables considered clinically relevant by the authors and/or presenting a p-value < 0.2 in the simple regression analysis and demonstrating clinical relevance were selected for multiple regression analysis to build an explanatory model for this association (Chorba *et al.*, 2010; Kiesel *et al.*, 2014; Lisman *et al.*, 2013). The results of this selection were compared using the BestGLM methods ("exhaustive" method). Were considered statistically significant p values lower than 0.05. All analyzes were performed using the statistical program R version 4.1.2.

3 Results

Table 1 provides demographic characteristics and descriptive statistics for injured and non-injured players. Twenty-two players (32.3%) sustained one non-contact injury during the season, all the injuries occurred in the lower limbs. Sixteen injuries (72.7%) occurred in matches, whilst twelve (54.5%) were soft tissue injuries (muscle strains). There were not subsequent injuries to the same body segment or muscle in the injured group. Regarding body locations, ten injuries (45.5%) involved the thighs. According to game situations, sixteen injuries (72.7%) occurred during running actions. The number of median days lost was 24.5 days (IQR [15; 383]). The mean score for each FMS^{TM} screening for non-injured and non-contact injured players are reported in Table 2.

3.1 Functional movement screen score and injury risk

No baseline measures were statistically significantly associated with the presence of injury after simple regression analysis. No statistically significant association was found between the presence of non-contact injury and FMS^{TM} composite score (OR = 0.98 [0.77; 1.27]) or FMS^{TM} categorical score ($\leq$ 14) (OR = 0.64 [0.23; 1.78]). Similarly, no statistically significant association was found between the presence of non-contact injury and FMS^{TM} functional sub-group (OR = 0.99 [0.68; 1.46]), FMS^{TM} mobility sub-group (OR = 0.79 [0.47; 1.34]) or FMS^{TM} stability sub-group (OR = 1.45 [0.70; 3.01]). After the multiple analysis regression, none of the variables included in the final model was independently associated with the presence of non-contact injuries. The difference in distribution of FMS^{TM} scores for injured and non-injured groups is depicted in Figure 1.
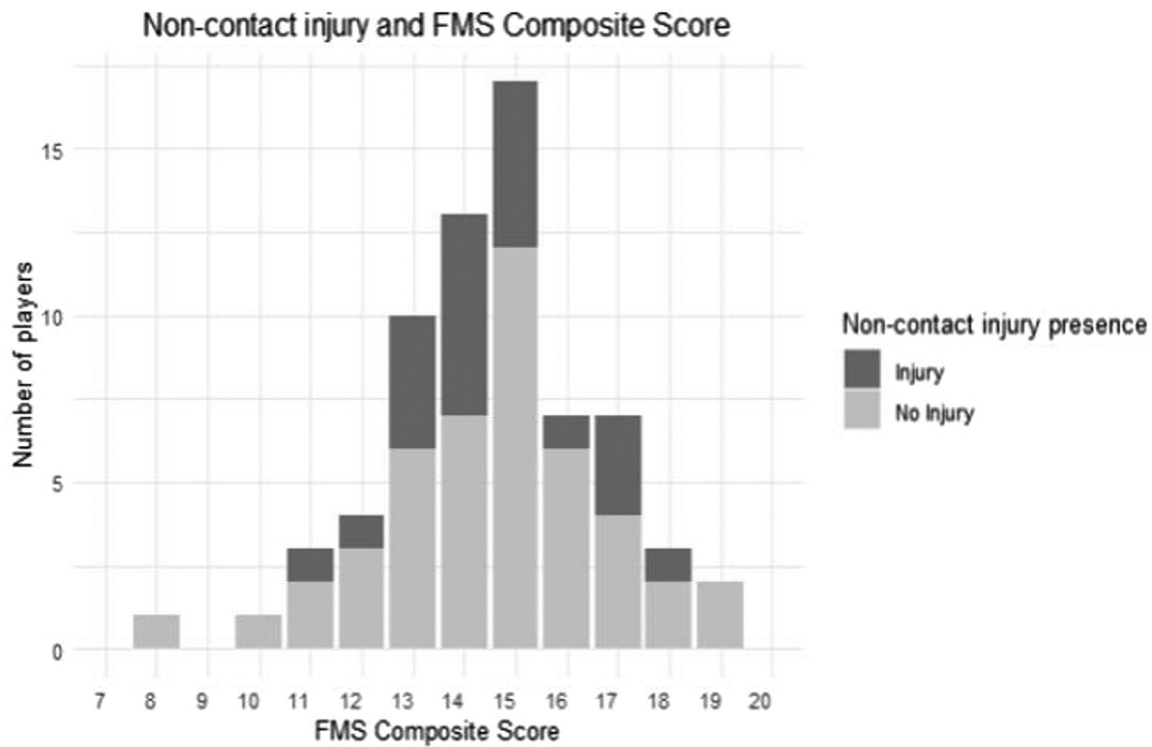
Fig. 1. The difference in distribution of FMS^TM scores for injured and non-injured groups.

3.2 Asymmetries and injury risk

Thirteen players (19.12%) exhibited asymmetry in the ASLR screening, and 8 players (61.54%) sustained non-contact lower limb injuries. Among the 55 players without asymmetries, only 14 (25.45%) sustained injuries. The association between the presence of injury and the presence of asymmetries in the ASLR (OR: 4.69 [1.35–17.9]), as determined by Fisher's Exact Test, was statistically significant ($p = 0.02$). The injuries observed in this subgroup included three hamstring strains (37.5%), one meniscal tear, and one ACL tear. No other asymmetry was found to be associated with the presence of injury.

4 Discussion

The aim of this study was to determine whether the results of FMS^TM may be associated with the risk of non-contact injury in amateur rugby players. FMS^TM screenings results were compared with records of injuries that occurred during a complete competitive season. Present findings showed that the mean composite FMS^TM scores of players who suffered non-contact injuries were not significantly different than the scores of those players who did not (injured 14.50 *vs.* non-injured 14.57). Regarding the associations between FMS^TM scores and non-contact injury risk, no associations were observed between the presence of non-contact injury and FMS^TM composite score (OR = 0.98 [0.77; 1.27]) or FMS^TM categorical score (≤ 14) (OR = 0.64 [0.23; 1.78]). According

to symmetry and injury risk, asymmetries revealed in the active straight leg raise (ASLR) were associated (OR: 4.69 [1.35 − 17.9]) with the presence of non-contact injury ($p = 0.02$).

The lack of associations between FMS^TM composite scores and the presence of non-contact injuries indicates that composite FMS^TM scores may not be appropriate to be used as an indicator of injury risk as has been reported in a previous study (Duke *et al.*, 2017). Consistent with this supposition Cook *et al.* (2014) suggested that the FMS^TM was designed to challenge the interactions of kinetic chain mobility and stability necessary for performance of fundamental, functional movement patterns (Cook *et al.*, 2006), but the movement asymmetry in those patterns could be related to a biomechanical or neuromuscular deficit. Hence, the FMS^TM may not be able to determine the cause of that alteration, which would indicate that an in-depth examination could be useful. Consequently, understanding what occurs during each exercise and which movement alteration may be associated to the injury risk factor would likely be more significant for coaches and physical therapists in terms of injury risk analysis than correlating risk with a specific movement quality composite score. The latter may help to develop more effective and realistic training interventions.

To the best of our knowledge, this study is the first to analyze only non-contact injuries and the possible association with FMS^TM total scores. Present results showed no statistically significant association between the presence of non-contact injury and FMS^TM composite

score or FMS^{TM} categorical score ($\leq$ 14). Conversely, previous studies (Armstrong & Greig, 2018; Attwood *et al.*, 2019) reported positive associations between the FMS^{TM} scores with injuries, however with different outcomes than the ones reported herein. Typically, the FMS^{TM} indicates that the composite score is what should be used to consider an athlete at risk of injury (Cook *et al.*, 2014). However, as indicated by present findings, the score obtained in an individual FMS^{TM} screening should be considered when choosing the strategies for correcting the movement quality to ultimately reduce the risk of sustaining non-contact injuries. In this study, no statistically significant differences were observed between the injured and non-injured limbs in each individual task (Tab. 2).

One interesting finding in the present study is that the asymmetries in the ASLR screening were associated (OR: 4.69 [1.35–17.9]) with the presence of non-contact injuries ($p = 0.02$). Another study in professional rugby reported an association between scores of ASLR, DS, ILL and severe injuries, indicating that ASLR would detect 96% of the players who suffered a severe injury (Tee *et al.*, 2016), but contrary with our study these associations included contact injuries. In addition, authors (Tee *et al.*, 2016) proposed the identification of ASLR score < 2 as a risk factor for severe injuries in professional rugby union players, highlighting that may be a valuable step toward reducing the risk of injury. Another study (Hotta *et al.*, 2015) conducted in competitive male runners showed that a combination of DS and ASLR scores ($\leq$3) during preseason is a more useful approach for predicting (OR: 9.7, [2.1–44.4]) running injuries during season, but the FMS^{TM} composite score was not. It is well established that the active knee extension test (AKE test) and ASLR can determine with high reliability hamstrings with low flexibility, which can cause a posterior pelvic rotation that increases the risk of sustaining a hamstring injury (Neto, Jacobsohn, Carita, & Oliveira, 2015). Considering the high incidence rate of lower extremity injuries across all levels of rugby (Kenny & Comyns, 2020; Schwellnus *et al.*, 2019), the ability to detect ASLR asymmetries or suboptimal outcomes in this task may significantly influence the susceptibility to hamstring injuries in rugby players. Employing a specialized assessment tool for this purpose holds promise for enhancing injury prevention strategies, thus warranting diligent attention and further investigation.

The current study is subject to several limitations that should be considered. First, the relatively small number of participants and injuries may lead to reduced statistical power; however, it is important to note that a robust regression methodology was employed to mitigate this issue. Furthermore, the inclusion of various types of non-contact injuries in the analysis may introduce some ambiguity, and a more focused approach targeting a specific injury, such as hamstring strain may provide greater precision. Lastly, it is worth noting that the study was conducted within a single club, and caution should be exercised when extrapolating the findings to broader populations or different rugby settings.

5 Conclusions

In summary, present findings indicate that FMS^{TM} composite score should not be used to detect injury risk for time-loss non-contact injuries in senior male amateur rugby players. The asymmetry between legs in the ASLR screening was associated with non-contact injury occurrence, most of which (37.5%) were hamstring injuries. This screening should be considered as a possibly meaningful preseason player assessment. The FMS^{TM} would be most effectively used in combination with other tools of injury-risk assessment, as injury in rugby union and other sports is determined by many factors other than fundamental movement quality.

Conflict of interest

The authors declare that they have no competing interest.

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