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ABSTRACT

Objectives:

To investigate factors associated with injury in amateur male and female rugby union players.

Design:

A prospective cohort study.

Setting:

Amateur rugby clubs in Ireland.

Participants:

Male (n=113) and female (n=24) amateur rugby union players from 5 of the top 58 amateur clubs in Ireland.

Main Outcome Measures:

Pre-season testing included physical tests assessing hamstring flexibility, dorsiflexion range of movement, adductor muscle strength and foot position. Wellness questionnaires assessed sleep quality (PSQI), coping skills (ACSI-28) and support levels (PASS-Q). Players were monitored throughout the season for injury.

Results:

The time-loss match injury incidence rate was 48.2/1,000 player hours for males and 45.2/1,000 player hours for females. Two risk profiles emerged involving; 'age + navicular drop + training pitch surface' (53%) and 'age + navicular drop + groin strength' (16%). An inverse relationship between groin strength and groin injury was found for the 'backs' players (-0.307, p<0.05). Using the PSQI, 61% of players had poor sleep quality, however no relationship between the wellness questionnaires and injury was found.

Conclusion:

Two injury risk profiles emerged, associated with subsequent injury occurrence. Using these risk profiles, individualized prevention strategies may be designed regarding deficits in groin muscle strength and identifying foot alignment.

KEY WORDS

Injury Surveillance; Rugby Union; Screening; Injury Risk

HIGHLIGHTS

- Poor adductor strength was associated with a higher incidence of injuries, particularly groin injuries.
- Injury risk profiles should investigate the relationship between modifiable and non-modifiable injury risk factors (e.g. age).
- Identifying foot posture type and its relationship with age and pitch surface may identify players at an increased risk of injury.

1. Introduction

Rugby Union, hereafter 'rugby', is a physically demanding field-based team sport, involving both high-intensity activities, such as sprinting, rucking, mauling and tackling, and low-intensity activities, such as walking and jogging (Roberts et al., 2008). These physical demands, alongside the exposure to collisions and contact events, result in a risk of rugby-related injury (Williams et al., 2013). Effective injury prevention strategies are reliant on high quality injury surveillance and the subsequent identification of the mechanism of injury (Gabbett et al., 2012). An understanding of the multifactorial influences regarding injury occurrence is required, particularly as injuries often result from interactions between various intrinsic and extrinsic risk factors (Nilstad et al., 2014). Intrinsic factors refer to factors within the athlete, such as demographics and psychosocial factors, while extrinsic factors are external to the athlete, such as training load, training surface and environment (von Rosen et al., 2017). Pre-season testing may help explain the cause and mechanism of a particular injury (Ljungqvist et al., 2009), however its predictive value regarding the risk of injury occurrence is unclear (Bahr, 2016). Injuries occur due to a particular mechanism of injury interacting with various intrinsic and extrinsic risk factors (Verhagen et al., 2018). Investigating a singular test in relation to injury occurrence provides little benefit to predict injury (Bahr, 2016) however interpreting a combination of tests, alongside playing exposure, may provide more meaningful information (Verhagen et al., 2018, Bittencourt et al., 2016).

Participation rates in rugby are rising, particularly in the female game where a 60% increase in player numbers was observed from 2013 to 2017, resulting in female players accounting for 26% of all rugby players worldwide (Rugby, 2017). Despite this increase in popularity, injury surveillance in female players is often limited to elite-level competitions, such as the Women's World Cup, with no long-term surveillance system in the amateur setting. In the 2010 Women's

World Cup, an incidence rate of 35.5/1,000 players hours was reported, with a higher rate found for 'backs' players than 'forwards' (40.9/1,000 player hours vs 30.7/1,000 player hours) (Taylor et al., 2011). Studies have established the epidemiology of rugby-related injuries for both amateur and professional male cohorts, with respective pooled incidence rates of 46.8/1,1000 player hours (Yeomans et al., 2018) and 81/1,000 player hours (Williams et al., 2013) reported, however little is known about the influence of both intrinsic and extrinsic risk factors.

The lower limb is commonly injured in rugby (Williams et al., 2013, Yeomans et al., 2018, Taylor et al., 2011) hence the identification of risk factors for lower limb injuries was a primary focus in the current paper. The following assessments have previously examined musculoskeletal pain and lower limb injury in various athletic populations and were therefore included; foot posture type (navicular drop test) (McManus et al., 2004), soleus muscle flexibility (knee to wall test) (Malliaras et al., 2006), hamstring muscle flexibility (straight leg raise test) (de la Motte et al., 2017) and groin muscle strength (adductor squeeze test) (Whittaker et al., 2015). The incidence of rugby-related injuries in relation to muscular strength (Evans et al., 2018) and pitch surface (Ranson et al., 2018) has been investigated in professional and semi-professional rugby and Rugby League however, these have been examined in isolation without consideration of the complex interactions of the other aforementioned factors.

Physiological and biomechanical factors are dominant in the area of sports-related injury occurrence and prevention, however the importance of non-physical risk factors has been highlighted in more recent years (Ivarsson et al., 2017). The Pittsburgh Sleep Quality Index (PSQI) (Biggins et al., 2018), the Athletic Coping Skills Inventory (ACSI-28) (Johnson and Ivarsson, 2011) and the Perceived Availability of Support in Sport Questionnaire (PASS-Q) (Gabana et al., 2017) questionnaires have been used to examine musculoskeletal pain, general wellness and injury in various sporting cohorts, including soccer, Gaelic Football and Australian Football (Ivarsson et al., 2017, Claudino et al., 2019), however the interaction of these variables, and other extrinsic risk factors, is yet to be examined in rugby. Due to the multifactorial nature of injury occurrence, highlighting the complex interactions and relationship between both intrinsic and extrinsic variables may result in novel insights into rugby-related injury incidence (Bittencourt et al., 2016). By creating an injury risk profile a better understanding of the cause and mechanism of injuries occurring may be observed and used to design individual injury prevention strategies. Therefore, the purpose of this study was to investigate intrinsic and extrinsic risk factors associated with injury in amateur male and female Rugby Union players.

2. Methods

This prospective cohort study was conducted during the 2016-2017 rugby season, which ran from July 2016 to May 2017. Five amateur rugby clubs (four male clubs, one female club) were recruited to the Irish Rugby Injury Surveillance (IRIS) project and invited to participate in pre-season physical and wellness testing. Clubs were contacted by the IRIS research team via email to the club secretary, club's primary medical professional and/or Senior 1XV rugby coach. One hundred and thirty-seven players participated in the pre-season testing and were subsequently monitored throughout the season for injury. Ethical approval for this study was granted by the institution's Research Ethics Committee in compliance with the Declaration of Helsinki.

2.1 Wellness assessments

Data regarding players' age; rugby playing position; rugby playing history; past medical and injury history; wellness and weight training information were collected using a specifically designed online questionnaire distributed via SurveyMonkey (SurveyMonkey, Palo Alto, CA, USA) cloud based software. Weight training information included average number of weight training sessions per week and self-reported measurements of the participant's one repetition maximum (1RM) during the previous 12 months, for the bench press, back-squat and deadlift. The web-based questionnaire also included standardized psychological questionnaires; the PSQI (Claudino et al., 2019) the ACSI-28 (Johnson and Ivarsson, 2011) and the PASS-Q (Gabana et al., 2017) (Table 1). An introductory email was sent to the club's primary medical professional and/or the Senior 1XV rugby coach to explain the survey, the time commitment and confidentiality of all collected information. The email also provided a web link to access the survey. The recipient was asked to send the email and survey web link to all members of the Senior 1XV squad. Participants were informed that they may exit the survey at any time without any implication. Participants were given 30 days to complete the survey from the date the email was distributed, with reminders sent 10 days and 20 days after the initial email. Participants were reminded to complete the questionnaire at the musculoskeletal testing day and were offered an electronic tablet to complete the questionnaire during the testing day if required. After 30 days, all complete responses were downloaded from the SurveyMonkey site and collated for statistical analysis.

2.2 Physical assessments

The IRIS research team attended one pre-season training session in each participating club to collect objective physical measurements including anthropometrics, navicular drop test (measure of foot posture type), knee-to-wall test (KTW), active straight leg raise test (ASLR) and adductor squeeze test (Table 1). The pre-season testing day took place mid-way through each clubs' pre-season training period, to allow for a standardized volume of training to have been completed. The research team included a qualified physiotherapist and students from the university's sports science and physiotherapy departments, who were trained to administer the assessments by the physiotherapist prior to attending the club. Each member of the research team performed the same physical assessment in each club. Participants gave written informed consent prior to testing. Participants completed a standardized 10 minute warm-up prior to testing, consisting of jogging and dynamic lower limb and upper limb stretching. The research team provided a demonstration of each test prior to the participant performing the test. There were four testing stations and four players were tested simultaneously in a random order to avoid the learning effect. Three measurements of each test were collected and the mean of the three measurements was used for data analysis.

Table 1: Physical and wellness screening measures

Screening	Measurement	Methods	Results	Research
PSQI	Sleep quality	Questionnaire Scale 0-21	≥5 Poor sleep quality <5 Good sleep quality	Sensitivity 89.6% Specificity 86.5% (Claudino et al., 2019)
ACSI-28	Coping skills	Questionnaire Scale 0-84	Higher score – higher coping skills	Test-retest reliability 0.87 Internal consistency coefficient 0.86 (Smith et al., 1995)
PASS-Q	Perceived support	Questionnaire Scale 0-20	Higher score – higher levels of support	Test-retest reliability 0.73-0.84 Internal validity 0.69-0.87 (Freeman et al., 2011)
ASLR	Hamstring flexibility	Hamstring board	Higher score – more flexibility	Intra-rater reliability 0.94-0.99 (Askling et al., 2010)

KTW	Soleus flexibility Dorsiflexion ROM	WB* lunge test Distance from wall to foot	Higher score – more flexibility	Intra-rater reliability 0.97-0.98 Inter-rater reliability 0.97-0.99 (Malliaras et al., 2006)
Adductor squeeze	Groin muscle strength	Blood pressure cuff	Higher score – higher isometric strength	Intra-rater reliability 0.89-0.92 (Delahunt et al., 2011)
Navicular drop	Static foot position	Distance from navicular process to floor – WB & NWB+	Drop >10 mm indicative of pronated foot type	Intra-rater reliability 0.94 Inter-rater reliability 0.91 (Spörndly-Nees et al., 2011)

*WB: Weight-bearing

+NWB: Non weight-bearing

2.3 Injury monitoring.

During the playing season match injury data were collected using a bespoke rugby-specific web-based injury surveillance system (IRISweb), which has been previously described in detail (Yeomans et al., 2019). All match injuries and the number of matches per team were recorded during the season so that injury incidence rates could be collected (Fuller et al., 2007). An injury was defined following the World Rugby consensus guidelines injury definition, with any injury resulting in a player being unable to take a full part in rugby match or training activities further categorized as a 'time-loss' injury (Fuller et al., 2007). Injury data included the body location and nature of injury, the timing of injury during the match and the event surrounding the injury. Provisional diagnoses, final diagnoses and total days absence from rugby match and/or training activities were also recorded.

2.4 Statistical analysis

Initially, descriptive statistics such as mean, standard deviation (±SD), median (interquartile range) and percentages for participant demographics, number of injuries (injury count) and location of injury were analyzed using SPSS (IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY: IBM Corp). Shapiro-Wilk test indicate data were normally distributed. Rugby players are identified as either 'forwards' (positions 1-8) or 'backs' (positions 9-15) due to the physical differences and positional demands observed (Roberts et al., 2008), therefore descriptive analyses were categorised according to playing position (Table 2). Rugby requires participants to pass and kick from both sides of the body therefore both the left and right sided measurements for calf muscle and hamstring muscle flexibility were reconfigured to the average of the two measurements and the absolute difference between measurements, before proceeding to the regression modelling phase of analysis (Pavely et al., 2009). The latter derived variable captures side-to-side imbalances whilst the former describes an aggregate measure of flexibility, rather than analyzing data in relation to limb dominance. With regard to weight training practices, self-reported measurements of the participant's one repetition maximum (1RM) during the previous 12 months, for the bench press, back-squat and deadlift were scaled (normalized) by dividing the 1RM by the participant's body mass for use in the Poisson regressions.

All subsequent statistical analyses were conducted using the statistical programming language R (R Core team, 2018). Exploratory variables were initially screened to identify a subset of variables to include in the starting model to be supplied to the stepwise forward-backward model search algorithm. This was achieved by fitting separate single-variable Poisson response linear models of 'injury occurrence' on each of the explanatory variables and selecting variables producing values of the likelihood-ratio test statistic showing or approaching statistical significance at a nominal level, (p-value < 0.10). Any missing-ness in the data was addressed by applying multiple imputation by chain equations using the R package 'Mice' (van Buuren and Groothuis-Oudshoorn, 2011). In the analyses reported here, 100 complete data sets were generated using 'Mice', each of which was submitted to the following forward-backward stepwise model-selection routine. The same starting-model, based on the variables selected in the variable screening step, was specified for each of the 100 imputed data sets. At each iteration in each model search, variables were either deselected or recruited to the current model based on the change they produced in the Bayesian Information Criterion (Venables, 2002). The predictor variables included in final 100 fitted models were tabulated for the purposes of determining the relative importance of each variable and accounting for model uncertainty.

3. Results

One hundred and thirty-seven rugby players [male n=113 (mean age=22.7±3.9), female n=24 (mean age=25.6±4.9)] from the highest levels of the amateur league in Ireland (All Ireland League) participated in the screening and were subsequently monitored for injury throughout the rugby season. Only 47% of these participants completed the questionnaires, despite rigorous follow-up.

3.1 Player Demographics

The male players had more rugby playing experience than the female players (13.6±4.5 years versus 6.3±4.2 years), however there was no significant difference between the experience of male and female players at their current division (2.9±2.2 and 2.9±1.9 years respectively). All of the female participants trained regularly on grass pitches, however 88% of the male players trained on grass pitches with 12% training on artificial pitches. Using the navicular drop test, 84% of female players and 32% of male players demonstrated a 0-10 mm drop bilaterally. Forty-two percent of male players exhibited a bilateral drop of >10 mm, while a rise in navicular position was observed in 2% of males. Side-to-side differences were also recorded, with 16% of females and 24% of males demonstrating a 0-10 mm drop on one foot and a drop >10 mm on the other. Table 2 shows the results of the musculoskeletal assessments for all 137 participants.

Forty-seven percent of the 137 players completed the questionnaires (n=64). Of these respondents, 59% of males and 83% of females had poor sleep quality, with 41% of males and 17% reporting good sleep quality (males = 5.2±2.7, females = 7.3±3.1 (Claudino et al., 2019). Male players were found to have higher levels of coping skills than female players using the ACSI-28 (52.6±9.8 vs 44.9±10.5 respectively), similar to previous research to validate the ACSI-28 (Smith et al., 1995). Results of the PASS-Q indicated similar levels of perceived support for males (11.1±2.5) and females (11.2±1.9) (Freeman et al., 2011).

Table 2: Player anthropometric and baseline musculoskeletal data (mean±standard deviation)

	Male *n=113*		**Female** *n=24*	
	Forwards	*Backs*	*Forwards*	*Backs*
Total (number of participants)	59	54	11	13
Height (cm*)	180.5±23.6	179.5±4.8	169.8±3.8	165.9±7.1
Mass (kg+)	102.8±10.9	85.4±7.9	87.3±14.1	69.5±11.3
Waist:Hip ratio	0.85±0.05	0.85±0.05	0.82±0.05	0.78±0.04
Right KTW [a] (cm)	10.9±2.8	9.9±2.9	6.7±2.7	8.4±1.9
Left KTW (cm)	10.4±2.6	10.6±2.7	7.4±1.3	8.5±1.4

Average KTW (cm)	10.6±2.5	10.3±2.7	7.1±1.3	8.5±1.6
Side-to-side difference KTW (cm)	1.4±1.5	1.6±1.4	2.1±2.6	0.9±0.5
Adductor squeeze @0° [b] (mmHg [c])	184.9±18.9	175.2±30.8	139.2±26.6	146.7±35.5
Adductor squeeze @45° (mmHg)	152.5±42.3	161.9±31.8	152.8±19.2	150.1±50.9
Adductor squeeze @90° (mmHg)	128.9±40.6	137.9±32.9	139.9±15.9	135.8±31.4
Right SLR [d] (°)	79.9±8.4	82.9±6.4	74.8±13.1	78.6±10.1
Left SLR (°)	77.3±8.3	78.9±5.6	71.8±10.2	79.2±11.6
Average SLR (°)	78.6±8.1	80.9±5.3	73.3±11.3	78.9±10.1
Side-to-side difference SLR (°)	4.4±3.2	5.4±4.6	4.9±3.9	6.2±4.7

*cm: centimeters
[+] Kg: kilograms
[a] KTW: Knee to wall test, a measure of calf muscle flexibility
[b] °: degrees of range of movement
[c] mmHg: pressure in millimeters of mercury
[d] SLR: Straight leg raise test, a measure of hamstring muscle flexibility

3.2 Injury Count

Of the 137 players monitored throughout the season, 84 sustained one or more injuries (66 male players, 18 female), with a total of 150 injuries recorded (104 match injuries, 41 training injuries, five warm-up injuries) in a total of 105 matches. The time-loss match injury incidence rate was 48.2/1,000 player hours for males and 45.2/1,000 player hours for females. Injuries that resulted in no absence from rugby match and/or training activities were considered slight injuries and not included in the calculation of time-loss injuries, as shown in Table 3. Of the players that sustained an in-season injury, 61% of males and 56% of females had reported a previous injury within the last 12 months, however this was not associated with subsequent injuries in-season. Table 4 shows the most common injuries by location, injury type and diagnosis.

Table 3: Injury incidence rates for males and females

	No. Clubs	No. matches	Exposure hours	No. timeloss injuries	IR*	No. slight injuries	IR*
Male	4	84	1680	81	48.2	1	0.6
Female	1	21	420	19	45.2	3	7.1

*IR: incidence rate per 1,000 player hours

Table 4: Top three most common body location of injury, type of injury and injury diagnosis

Body location	Shoulder 19% Ankle 13% Posterior thigh 10%
Injury type	Muscle/tendon strains 33% Ligament sprains 27% Haematoma/contusions 13%
Diagnosis	Ankle ligament sprains 12% Acromioclavicular joint sprains 10% Hamstring muscle strains 9%

3.3 Risk Profiles

To create injury risk profiles, the physical and wellness exploratory variables were screened. Following this, the initial model specified in the deployment of the stepwise forward-backward model search algorithm on the imputed data sets was a generalized linear model Poisson regression of 'injury incidence' on; 'age' + 'navicular drop' + 'adductor squeeze test' @45° of hip flexion' + 'usual training pitch surface'. These variables were categorized as follows; age: 'under 25 years' and 'over 25 years', navicular drop test: '>10 mm drop, '0-10 mm drop' or 'navicular rise' and usual training pitch surface: 'grass' or 'artificial'.

The most influential variables, for males, were age, navicular drop and usual training pitch surface, and occurred in 100%, 70% and 53% of fitted models, respectively. The dominant model (53% of models) related injury incidence to these influential variables, and for this model complete information was available on these dimensions having 0% missing-ness. This indicated that male players over the age of 25 (injury rate = 1.5, 95% CI 1.21-1.84), with a navicular drop >10mm (injury rate = 1.3, 95% CI 1.06-1.58) and regularly training on an artificial pitch (injury rate = 1.85, 95% CI 1.18-2.75) had a higher injury incidence. The next most influential model (16%), for both males and females, incorporated the influence of the variables 'adductor squeeze test (@45° of hip flexion)' in place of the variable 'usual training pitch surface'. This indicated that, alongside age and navicular drop as mentioned above, male and female players with weaker adductor muscle strength had a higher injury incidence (injury rate = 1.57, 95%CI 1.15-2.08). When analyzed according to rugby playing position, an inverse relationship between adductor strength at 0° of hip flexion and groin injury was found for the 'backs' players (-0.307, $p<0.05$). No such relationship was found for the 'forwards' players.

4. Discussion

This baseline cross-sectional study aimed to investigate the relationship between both intrinsic and extrinsic factors and injuries in male and female senior amateur rugby. The most influential variables were subsequently isolated to create an injury risk profile. The most influential injury risk profile for males, included age, navicular drop and pitch surface. Age has often been associated with injury risk, particularly for muscle strains (Murphy et al., 2003). Muscle strains accounted for one third of all injuries reported in this cohort and age featured as an influential variable in each of the risk profiles. Therefore, as age is a non-modifiable risk factor, it is worthy of note during the pre-season rugby period but should be viewed in relation to its interactions with the other variables in the risk profile (navicular drop and pitch surface). A navicular drop >10mm also featured in each of the injury risk profiles. The navicular drop test has been found to be a reliable measure of bony position and loading indicating an over-pronated foot type, however, it should be interpreted with caution as a static measure of dynamic foot function (Langley et al., 2016). A large drop in navicular height may be associated with an increased injury risk, particularly for lower extremity injuries (McManus et al., 2004, Murphy et al., 2003). Foot position and playing surface are closely related due to the relation between foot position and ground reaction force (Murphy et al., 2003). Rugby is played on both grass and artificial surfaces and this may affect injury occurrence. It has previously been shown that pitch surface did not affect the overall incidence of injuries but did affect the nature of injuries with more thigh haematoma and foot injuries observed on artificial surfaces (Ranson et al., 2018). An artificial pitch surface was found to be an influential variable alongside foot-posture for the male cohort, therefore with previous research indicating a higher incidence of foot injuries on artificial pitch surfaces, the interaction of these variables should be noted in an effort to reduce injury risk.

The second-most influential model, for both males and females, replaced pitch surface with adductor strength (@45° hip flexion). Decreased groin strength has been associated with subsequent groin injury in many sports, including Gaelic Football, soccer and Australian Football (Whittaker et al., 2015). The current study found an association between groin strength (@0° hip/knee flexion) and subsequent groin injury (-0.307, $p<0.05$), for the ‘backs’, indicating that weaker adductor muscle strength may result in a higher groin injury risk. Groin strength (@45° hip/knee flexion) was also found to be an influential variable in the injury risk profile, alongside age and navicular drop measurements. Tailored prevention strategies have been shown to reduce the severity of lumbo-pelvic hip injuries in professional rugby (Evans et al., 2018), and while hip and groin injuries only accounted for 5% of all injuries sustained during the season, two thirds of these injuries were severe and resulted in more than 28 days absence from rugby (Fuller et al., 2007). The adductor squeeze test is performed clinically in three different ranges of hip and knee flexion; 0°, 45° and 90° to elicit groin pain and maximal adductor muscle activity however it has been reported that performing the adductor squeeze test at 45° of hip and knee flexion is the optimal position to elicit maximal groin muscle activity (Delahunt et al., 2011). The current study demonstrates the importance of testing in the three different ranges of hip and knee flexion as adductor strength at 45° of hip and knee flexion influenced the incidence of injury, and adductor strength at 0° of hip and knee flexion was also associated with groin injuries for the 'backs'. Therefore, pre-season screening of groin strength in three different positions, may aid the development of a tailored prevention strategy to decrease the severity of these injuries.

The current study found that 61% of players had poor sleep quality. This is higher than what has previously been reported in elite Gaelic football (52.2%) (Biggins et al., 2018) or elite rugby and cricket (50%) (Swinbourne et al., 2016). Poor sleep has been associated with decreased general health and wellness and also decreased physical performance (Biggins et al., 2018). No relationship between injury incidence and sleep quality was found in the current study, however the PSQI was only assessed at pre-season training and had poor compliance. Future research should assess sleep quality longitudinally to investigate the influence of sleep in the injury risk profiles in amateur rugby players. High levels of perceived support has previously been associated with higher self-confidence and lower levels of athlete burnout (Freeman et al., 2011). Rugby injuries have previously been associated with athlete burnout (Cresswell and Eklund, 2006), however in the current study the PASS-Q was not found to be influential in the injury risk profiles. It has been reported in the literature, that injury risk and recovery are influenced by negative coping skills (Ivarsson et al., 2017) however no association between the ACSI-28 and injury was found in the current study. Results from the wellness questionnaires were included in the analyses to generate injury risk profiles, however they were not found to be influential in the models and this may be due to poor compliance in completing the questionnaires.

The time-loss match injury incidence rate was 48.2/1,000 player hours for males and 45.2/1,000 player hours for females, similar to pooled rates in senior amateur male rugby players (46.8/1,000 player hours) (Yeomans et al., 2018) and higher than rates reported in elite female competition (35.5/1,000 player hours) (Taylor et al., 2011). History of previous injury has been found to be a risk factor for future injury (Murphy et al., 2003) and while 61% of male and 56% of female players who sustained an in-season injury reported a history of previous injury, no associations were found in this study.

5. Study limitations

The pre-season testing day took place mid-way through each clubs pre-season training, however the type and volume of training completed in the weeks prior to testing differed in each club, and therefore results may not be reflective of the players' physical state during the whole season. Repeated measures, particularly for sleep quality, may have demonstrated variation in results throughout the season. Risk factors and injuries are temporal in nature and the fluctuation in test results over the season may have added to the risk profiles identified in the current study. The results of the questionnaires were included in the risk models but were not found to be influential in the injury risk profiles. This may be due to poor compliance in completing the questionnaires and therefore may have impacted the injury risk profiles. The current study represents a small sample size reporting the initial results of risk profiling in amateur male and female rugby, however further research is now required with larger cohorts. Only one team (male team) trained regularly on artificial pitch surfaces and therefore the risk profile of age, navicular drop and pitch surface pertained only to the male teams. Future recruitment of both male and female teams that train regularly on artificial surfaces may be beneficial to analyze the interaction of pitch surface and specific injury incidence. The subjective and retrospective nature of the background history questionnaire may have influenced the accurate reporting of the previous incidence of injury and the 1RM data. The average number of weight training sessions per week was reported during pre-season and the frequency of weight training may have varied throughout the playing season. Future research should monitor the frequency, intensity and volume of training throughout the season to see any possible relation to injury incidence.

6. Conclusion

This study was conducted as part of the Irish Rugby Football Union IRIS Project, a prospective injury surveillance strategy in Irish amateur male and female rugby. The purpose of this study was to analyze the complex interactions of both intrinsic and extrinsic factors on injuries. Investigating a combination of tests in relation to the injury event, may provide meaningful information around the occurrence of an injury. By testing players during pre-season and subsequently monitoring injury occurrence in-season, two influential risk profiles emerged, involving; 'age + navicular drop + training pitch surface' (53%) and 'age + navicular drop + groin strength' (16%). These risk profiles may be used to highlight players at an increased risk of injury and might also aid the development of targeted injury prevention strategies, particularly with regards groin muscle strength. The current study demonstrates the importance of testing groin strength in various ranges of hip and knee flexion and the inclusion of adductor strength testing in pre-season may aid the development of a tailored prevention strategy to decrease the severity of these injuries. Future recruitment and monitoring of female players is needed to provide meaningful analysis regarding the intricacies of the women's game.

References:

Askling, C. M., Nilsson, J. & Thorstensson, A. 2010. A new hamstring test to complement the common clinical examination before return to sport after injury. *Knee Surg Sports Traumatol Arthrosc*, 18**,** 1798-1803.

Bahr, R. 2016. Why screening tests to predict injury do not work—and probably never will…: a critical review. *Br J Sports Med,* 50**,** 776-780.

Biggins, M., Cahalan, R., Comyns, T., Purtill, H. & O'Sullivan, K. 2018. Poor sleep is related to lower general health, increased stress and increased confusion in elite Gaelic athletes. *Phys Sportsmed,* 46**,** 14-20.

Bittencourt, N. F. N., Meeuwisse, W. H., Mendonça, L. D., Nettle-Aguirre, A., Ocaino, J. M. & Fonseca, S. T. 2016. Complex systems approach for sports injuries: moving from risk factor identification to injury pattern recognition—narrative review and new concept. *Br J Sports Med,* 50**,** 1309-1314.

Claudino, J. G., Gabbet, T. J., De Sá Souza, H., Simim, M., Fowler, P., De Alcantara Borba, D., Melo, M., Bottino, A., Loturco, I., D'Almeida, V., Carlos Amadio, A., Cerca Serrao, J. & P Nassis, G. 2019. Which parameters to use for sleep quality monitoring in team sport athletes? A systematic review and meta-analysis. *BMJ Open Sport Exerc Med,* 5**,** e000475.

Cresswell, S. L. & Eklund, R. C. 2006. Changes in athlete burnout over a thirty-week "rugby year". *J Sci Med Sport,* 9**,** 125-134.

De La Motte, S. J., Lisman, P., Gribbin, T. C., Murphy, K. & Deuster, P. A. 2017. A systematic review of the association between physical fitness and musculoskeletal injury risk: Part 3 - flexibility, power, speed, balance, and agility. *J Strength Cond Res*, 33(6):1723-1735..

Delahunt, E., McEntee, B. L., Kennelly, C., Coughlan, G. F. & Green, B. S. 2011. The adductor squeeze test: which is the optimal test position for eliciting maximum squeeze values and adductor muscle activity? *Br J Sports Med,* 45**,** 345-345.

Evans, K. L., Hughes, J. & Williams, M. D. 2018. Reduced severity of lumbo-pelvic-hip injuries in professional Rugby Union players following tailored preventative programmes. *J Sci Med Sport,* 21**,** 274-279.

Freeman, P., Coffee, P. & Rees, T. 2011. The PASS-Q: the perceived available support in sport questionnaire. *J Sport Exerc Psychol,* 33**,** 54-74.

Fuller, C. W., Molloy, M. G., Bagate, C., Bahr, R., Brooks, J. H., Donson, H., Kemp, S. P., McCrory, P., McIntosh, A. S., Meeuwisse, W. H., Quarrie, K. L., Raftery, M. & Wiley, P. 2007. Consensus statement on injury definitions and data collection procedures for studies of injuries in rugby union. *Br J Sports Med,* 41**,** 328-31.

Gabana, N. T., Steinfeldt, J. A., Wong, Y. J. & Chung, Y. B. 2017. Gratitude, burnout, and sport satisfaction among college student-athletes: The mediating role of perceived social support. *J Clin Sport Psych,* 11**,** 14-33.

Gabbett, T. J., Ullah, S. & Finch, C. F. 2012. Identifying risk factors for contact injury in professional rugby league players – Application of a frailty model for recurrent injury. *J Sci Med Sport,* 15**,** 496-504.

Ivarsson, A., Johnson, U., Andersen, M. B., Tranaeus, U., Stenling, A. & Lindwall, M. 2017. Psychosocial factors and sport injuries: Meta-analyses for prediction and prevention. *Sports Med,* 47**,** 353-365.

Johnson, U. & Ivarsson, A. 2011. Psychological predictors of sport injuries among junior soccer players. *Scand J Med Sci Sports,* 21**,** 129-36.

Langley, B., Cramp, M. & Morrison, S. C. 2016. Clinical measures of static foot posture do not agree. *J Foot Ankle Res,* 9**,** 45-45.

Ljungqvist, A., Jenoure, P., Engebretsen, L., Alonso, J. M., Bahr, R., Clough, A., De Bondt, G., Dvorak, J., Maloley, R., Matheson, G., Meeuwisse, W., Meijboom, E., Mountjoy, M., Pelliccia, A., Schwellnus, M., Sprumont, D., Schamasch, P., Gauthier, J.B., Dubi, C., Stupp, H. & Thill, C. 2009. The International Olympic Committee (IOC) Consensus Statement on periodic health evaluation of elite athletes March 2009. *Br J Sports Med,* 43**,** 631-643.

Malliaras, P., Cook, J. L. & Kent, P. 2006. Reduced ankle dorsiflexion range may increase the risk of patellar tendon injury among volleyball players. *J Sci Med Sport,* 9**,** 304-309.

McManus, A., Stevenson, M., Finch, C. F., Elliott, B., Hamer, P., Lower, A. & Bulsara, M. 2004. Incidence and risk factors for injury in non-elite Australian Football. *J Sci Med Sport,* 7**,** 384-391.

Murphy, D. F., Connolly, D. A. J. & Beynnon, B. D. 2003. Risk factors for lower extremity injury: a review of the literature. *BrJ Sports Med,* 37**,** 13-29.

Nistand, A., Andersen, T. E., Bahr, R., Holme, I. & Steffen, K. 2014. Risk factors for lower extremity injuries in elite female soccer players. *Am J Sports Med,* 42**,** 940-948.

Pavely, S., Adams, R. D., Di Francesco, T., Larkham, S. & Maher, C. G. 2009. Execution and outcome differences between passes to the left and right made by first-grade rugby union players. *Phys Ther Sport,* 10**,** 136-41.

Ranson, C., George, J., Rafferty, J., Miles, J. & Moore, I. 2018. Playing surface and UK professional rugby union injury risk. *J Sports Sci,* 36**,** 2393-2398.

Roberts, S. P., Trewartha, G., Higgitt, R. J., El-Abd, J. & Stokes, K. A. 2008. The physical demands of elite English rugby union. *J Sports Sci,* 26**,** 825-833.

Rugby, W. 2017. *World Rankings* [Online]. Available: https://www.worldrugby.org/rankings/wru [Accessed 19 May 2019].

Smith, R. E., Schutz, R. W., Smoll, F. L. & Ptacek, J. T. 1995. Development and validation of a multidimensional measure of sport-specific psychological skills: The athletic coping skills inventory-28. *J Sport Exerc Psych,* 17**,** 379-398.

Spörndly-nees, S., Dåsberg, B., Nielsen, R. O., Boesen, M. I. & Langberg, H. 2011. The navicular position test - a reliable measure of the navicular bone position during rest and loading. *Int J Sports Phys Ther,* 6**,** 199-205.

Swinbourne, R., Gill, N., Vaile, J. & Smart, D. 2016. Prevalence of poor sleep quality, sleepiness and obstructive sleep apnoea risk factors in athletes. *Eur J Sport Sci,* 16**,** 850-858.

Taylor, A. E., Fuller, C. W. & Molloy, M. G. 2011. Injury surveillance during the 2010 IRB Women's Rugby World Cup. *Br J Sports Med,* 45**,** 1243-1245.

Van Buuren, S. & Groothuis-Oudshoorn, K. 2011. MICE: Multivariate Imputation by Chained Equations in R. 45(3):67.

Venables, W. N., Ripley, B. D. 2002. Modern Applied Statistics with S, New York.

Verhagen, E., Van Dyk, N., Clark, N. & Shrier, I. 2018. Do not throw the baby out with the bathwater; screening can identify meaningful risk factors for sports injuries. *Br J Sports Med,* 52**,** 1223-1224.

Von Rosen, P., Frohm, A., Kottorp, A., Fridén, C. & Heijne, A. 2017. Multiple factors explain injury risk in adolescent elite athletes: Applying a biopsychosocial perspective. *Scand J Med Sci Sports,* 27**,** 2059-2069.

Whittaker, J. L., Small, C., Maffey, L. & Emery, C. A. 2015. Risk factors for groin injury in sport: an updated systematic review. *Br J Sports Med*, 49**,** 803-809.

Williams, S., Trewartha, G., Kemp, S. & Stokes, K. 2013. A meta-analysis of injuries in senior men's professional Rugby Union. *Sports Med*, 43**,** 1043-55.

Yeomans, C., Kenny, I. C., Cahalan, R., Warrington, G. D., Harrison, A. J., Hayes, K., Lyons, M., Campbell, M. J. & Comyns, T. M. 2018. The incidence of injury in amateur male Rugby Union: A systematic review and meta-analysis. *Sports Medicine*. 48(4):837-848.

Yeomans, C., Kenny, I. C., Cahalan, R., Warrington, G. D., Harrison, A. J., Hayes, K., Lyons, M., Campbell, M. J., Glynn, L. G. & Comyns, T. M. 2019. The design, development, implementation and evaluation of IRISweb; A rugby-specific web-based injury surveillance system. *Phys Ther Sport*, 35**,** 79-88.