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The associations between unilateral leg strength, asymmetry and injury in sub-elite Rugby League players

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ABSTRACT

Objectives: The aim of this study was to analyse the relationship between unilateral leg strength, associated asymmetries and the injuries suffered by sub-elite Rugby League (RL) players in one competitive season.

Design: A prospective cohort design was used.

Method: Unilateral leg strength was measured using the rear foot elevated split squat five repetition maximum test. Injuries were recorded using the Orchard classification system and were used to quantify relative risk (RR), mean severity, burden, player availability and survival time.

Results: No measures of leg strength were related to RR, relative leg strength was found to have a significant, but not meaningful correlation with total time lost to lower body injury, lower body injury burden and lower body injury survival time.

Conclusions: The data from the current study indicates a possible positive effect of increasing relative leg strength for injury outcomes in sub-elite RL players. This supports a heuristic that multi-joint lower body strength training for RL players has a potential dual effect of enhancing physical performance and reducing injury time loss, with minimal risk of harm.

1. Introduction

Rugby League (RL) is a locomotor-based, invasion, team game, requiring intermittent collisions with opposing players (Hausler et al., 2016; Johnston et al., 2019; Woods et al., 2018). Sirotic et al. (2009) reported the performance demands of sub-elite RL to be 103.0 ± 8.1 running metres per minute and 0.28 ± 0.16 tackles per minute (defensive collisions only). The combination of a high intensity and high volume running with frequent collisions creates a unique multifaceted performance and injury risk problem for RL multi-disciplinary support teams (MDST's). These challenges are further compounded by the constrained training time available time due to the part-time nature of sub-elite participation in RL.

The range of injury risk factors proposed by Bahr and Holme (2003) provides the MDST a menu of options from which they may choose to tackle injury time loss. Addressing all of them simultaneously is not possible in the time constrained sub-elite training schedule. Therefore, MDST's need to apply professional judgement decision making to identify those elements most critical to sub-elite RL players injury supported by robust evidence. The constraints of time placed on the part-time players and practitioners suggests that higher importance should be given to those modifiable factors which may also improve performance, increasing the efficiency of the physical preparation programme.

One such variable is lower body strength which has been extensively researched in RL players. The ability to execute successful tackles has been significantly ($r = 0.67$, $p = <0.05$) correlated to squat 1RM by Speranza et al. (2015) and increasing relative squat strength mitigated the loss of tackling performance from fatigue ($r = 0.71$, $p = <0.05$), (Gabbett, 2008). Squat strength has also been shown to be significantly ($r = >0.9$, $p = < 0.05$) correlated to total match running distance, high speed running distance and repeated high intensity efforts (Gabbett & Seibold, 2013). Such evidence supports the development of lower body maximal strength to increase RL match locomotor and collision performance.

Despite the wealth of data linking strength qualities to performance in RL, only one study, to date (Gabbett et al., 2012), has examined the risk of injury, in this sport, relative to lower-body

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strength. That study found that when absolute strength levels were discretised into stronger and weaker players (Back squat 1RM $\leq$ 165 kg vs $>$ 165 kg) there were no significant differences (p= $>$ 0.5) in match contact injury risks. However, Gabbett et al. (2012), only reported those injuries suffered during match collisions. Considering the current International Olympic Committee (IOC) definition of injury which state this is tissue damage resulting from rapid or repetitive transfer of kinetic energy (Bahr et al., 2020), such a narrow range of injury mechanism is not reflective of broader nature of possible injurious activities. As RL is a running-based invasion game other injury mechanisms and activities, such as non-contact strains or training injuries, may also generate these rapid or repetitive deformative events. Consequently, strength and strength training may positively effect injury incidence and severity through the resulting physiological adaptations. As a result of strength training tissues may have an enhanced capacity to tolerate greater volumes and frequency of energy transfer, thereby raising the bar of what may be a potentially injurious exposure to sporting demands.

The scope of this study, therefore, was to explore the association between leg strength and the injuries experienced by sub-elite RL players. The study of injury occurrence and consequence is a complex due to the multifaceted natured of injuries. Consequently, the term injury as a form of data is a nebulous one and can be related to different types of data. For example, an injury event refers to a participant suffering one injury, but does not reflect the timescale of that injury, when that injury occurred, nor the inflicting mechanism. Injury data as a dependent variable may then refer to an instance as discrete data or as a duration which is continuous, each necessitating different statistical approaches.

However, recent research has questioned the value of statistical modelling in the prediction of injury (Bullock et al., 2022). Additionally, Bahr (2016) has stated that prior screening of risk “probably never will” predict injury, leading to the proposition that injury severity is more meaningful than injury incidence (Bahr et al., 2018). Recognising the limitations and values of injury statistical modelling Jovanovic (2017) proposed the use of heuristics, which intertwine research evidence and the personal experiences and values of the practitioner. Tversky and Kahneman (1974) describe heuristics as a method of making decisions amid complexity and uncertainty in such a way that minimizes practitioner time and cognitive load. As alluded to previously, sub-elite RL is a part-time competition, resulting in player information relating to both injury in performance being available at short notice and near the time for action. Based on these constraints, the development of simple heuristic indicators would appear to be highly beneficial to those working in this environment. Consequently, this paper's aim is not one to propose a clinical model of injury prediction based on the analysis of data presented, but to translate this information to guide the formation of injury reduction heuristics in RL related practitioners.

There is a clear gap in this field of research relating to the relationship between time-loss injuries in sub-elite RL and lower body strength. Such a shortfall of evidence has a limiting effect on the decision-making processes of MDST's, working with sub-elite RL players. Therefore, the purpose of this study was two-fold, firstly to report the injuries suffered in this population, to establish the possible scope for an association between lower-body strength and injury. Secondly, to investigate the association between these injuries and lower-body strength to explore a simple heuristic that increasing strength training in sub-elite RL players would reduce time lost to lower-body injuries. This study hypothesized that there would be an inverse relationship between leg strength and injury time loss injuries, but no association with inter-limb asymmetry.

2. Methods

The study employed a prospective cohort design, utilising an observational approach to injury data collection. Following institutional ethical approval and consent from both gatekeepers and individuals, participants from three RL teams were recruited. Anthropometric data and unilateral leg strength measurements were collected at the commencement of each teams' pre-season training. Following initial data collection, a qualified an injury surveillance officer (ISO) was nominated by each team. ISO's were required to meet the Rugby Football League (RFL) operational standards for medical personal. This person recorded all injuries experienced by their respective group for the duration of one competitive year.

2.1. Participants

The participants were recruited from one adult semi-professional group (Senior), competing League One of the Rugby Football League (RFL), and two Super League academy groups (Emerging), competing in the Super League academy championship (Under 19's). All teams were engaged in a minimum of three training sessions per week including both strength and conditioning (S&C) and RL specific activities. All participants completed an individual consent form and medical screening questionnaire prior to testing. Players were excluded from the study if they had not received a minimum of two years prior S&C training experience, were currently injured, rehabilitating a prior injury or the clubs' medical staff deemed the testing protocol unsuitable for the player or left their clubs before the end of the season.

A total of 53 participants were included in the study (age = 19.9 ± 4.7 years, mass = 89.3 ± 10.6 kg, height = 1.81 ± 0.1 m), of these 34 were emerging players (age = 17.0 ± 0.9 years, mass = 86.4 ± 11.1 kg, height = 1.82 ± 0.1 m) and 19 were senior players (age = 25.1 ± 4.0 years, mass = 94.4 ± 7.7 kg, height = 1.80 ± 0.4 m).

2.2. Strength measurement

Strength testing took place during the first week of pre-season training at the training facilities of each of the respective participating clubs. Leg strength was measured using the rear foot elevated split squat five repetition maximum test (RFESS 5RM), which has been previously demonstrated as a reliable measure of load (ICC = 0.93, CI 0.88–0.96) and asymmetry (ICC = 0.73, CI 0.39, 0.89, Kappa = 0.60) (Helme et al., 2019). The percentage difference method (PDM) (Bishop et al., 2018) was applied to the measurement of asymmetry in the RFESS 5RM, for both the magnitude only and the magnitude plus direction of asymmetry. To ascertain the magnitude of asymmetry which exceeded the noise of test the minimum detectable asymmetry (MDA) was calculated, adopting the symmetry threshold calculation applied by Helme et al. (2019).

$$\begin{aligned}\text{MDA} = {} & \text{Mean load asymmetry} \\ & + (1.64 \text{ x Standard error of the mean (SE)})\end{aligned}$$

Each participant's left and right leg scores were converted to mean value and reported as absolute strength (ABS), relative strength (REL) and the asymmetry (ASY) between each limb.

2.3. Injury data

The International Olympic Committee's definition of injury (Bahr et al., 2020) was adopted for this study, which is:

> "Injury is tissue damage or other derangement of normal physical function due to participation in sports, resulting from rapid or repetitive transfer of kinetic energy".

Each team's injuries were recorded according to the Orchard classification system (Rae & Orchard, 2007) by the ISO using an online data collection form created specifically for that team. Time-loss injuries only were recorded and was defined as the date of onset of absence from sports participation to when the medical staff deemed the participant was able to return fully to all RL activities. Due to the turn-over players and staff at the participating clubs, post-season follow-ups were not possible on those players who were currently injured on the last day of surveillance. The duration of these injuries was recorded from the date of onset to the date of their team's last fixture. The nature of the activity being completed (match or training) was recorded and all time-loss injuries were included but due to the operational demands faced by the ISO's the inciting mechanisms were not recorded.

The specific duration for all injuries were reported in days lost and their severity classification according to the following values (Fuller et al., 2007): Slight (0–1 days), Minimal (2–3 days), Mild (4–7 days), Moderate (8–28 days) and Severe (>28 days). Where participants incurred multiple injuries, total time loss and mean time loss were reported, which were further categorised into all injuries and lower-body only. Player availability was calculated as the total number of days a player was able to fully participate in RL activities, as a proportion of their team's season duration and was calculated using the following equation:

(((Season length - upper body injury time loss) − lower body injury time loss)/(Season length-upper body injury time loss))) *100.

To the author's knowledge, this is the first study to adopt such an approach and represents a novel and innovative method of reporting injury data. In adopting this method, an accurate value can be placed on the availability of a player, resulting from only lower-body injuries.

Mean weekly exposures, based on a sample of indicative sessions, were calculated for each team (inclusive of all training forms, such as strength and conditioning), differentiating between pre-season and in season phases. A standardised approach to match play duration was adopted where a player was were considered to have been involved in the whole game (80mins = 1.33 h).

2.4. Statistical analysis

To reflect the multifaceted nature of injury, this study translated the epidemiological data into: incidence, severity, burden, player availability and survival time. This data range required a differentiated inferential analysis approach. For all tests an A priori analysis of the sample size was performed. Contingency table analysis, as used for risk ratio, required an α of 0.95 and a β of 0.8 for an effect size of 0.3 (moderate) in 108 participants. For the same level of statistical power to be achieved in correlational analysis 83 participants were required. Post-hoc analysis of the sample size ($n = 53$) indicated an ES of ≥ 0.43 was required for contingency table analysis and ≥ 0.37 was required for correlational analysis to achieve the required statistical power (Power = 0.8, $\alpha = 0.05$, $\beta = 0.2$). This ES was implemented to make inferences about the meaningfulness of analysis and avoid type 1 errors. All tests were performed applying and reporting 95% confidence intervals (CI).

A receiver operating characteristic (ROC) curve was performed to determine the threshold level of ABS, REL and ASY which maximises the true positive rate (sensitivity (Sn)) and true negative rate (specificity (Sp)) of predicting those who became injured. Area under the curve (AUC) data were generated, where 50% is equated to the prediction capabilities of random chance.

Using ROC curve derived threshold values for ABS, REL and ASY participants were divided into those above and below the cut-off and 2 × 2 contingency tables were produced for lower lower-body injuries only. From the contingency tables relative risk (RR), Sn, Sp, positive likelihood (LR+) and negative likelihood (LR-) ratios were calculated. In this study the magnitude of RR was be classified as follows: trivial (<1.22), small (1.22 < 1.86), moderate (1.86 < 3), large (≥3), according to the guidelines by Olivier et al. (2017). Fishers' exact tests were then performed to determine the significance of the RR. Using the information relating to the sample size in this study an odds ratio of ≥2.47 is required to achieve a β value of greater than 0.8. The size of the likelihood ratios were interpreted using the following criteria; small, (<2) moderate (2 < 5) and large (5 < 10) (Dauty et al., 2016). Likelihood ratios were converted into probability odds, using the estimations reported by McGee (2002).

2.5. Severity, burden and availability

Multiple linear regression (MLR) analysis was performed to examine the capacity of the variables collected (ABS, REL ASYM, age and body mass) to predict mean injury severity, player burden and player availability. A backwards stepwise approach was adopted until the minimal adequate model (MAM) was achieved. MAM was determined when all components of the model were either significant (<0.05) or tending to be significant (0.05 ≥ 0.1). For each variable up to four model iterations were created, eliminating the variable with the highest p value on each occasion. For all models analysed, comparison of Aikake information criterion (AIC) values was conducted to determine the probability of information loss between the model with the lowest AIC value (AIC_{MIN}) and subsequent iterations. This was achieved through determining the relative likelihood ratio, using the following equation:

$$\mathrm{Exp}((\mathrm{AIC}_{\mathrm{MIN}} - \mathrm{AIC}_i) / 2)$$

In the case of AIC_{MIN} and MAM being achieved in different models, the author's judgement as to which model represented best overall fit was applied.

Post-hoc univariate analysis was performed for each of the predictor and outcome variables, on all components included in a statistically significant multivariate injury model. This was performed using a Pearson product moment correlation (PPMC) or Spearman rank order correlation (SROC) dependent on the normality of the data.

2.6. Survival time

The duration of time preceding an injury was calculated from the date of strength testing to the date the first injury was recorded, for each player. However, this study was specifically focused on lower-body injuries so survival time was recorded in two ways. Firstly, time to the first injury of any kind and secondly to the first instance of a lower-body injury. Where a participant suffered an excluded injury (not to the lower limbs), prior to a lower-body injury, this time-loss period was subtracted from the time between the onset of surveillance to the occurrence of the lower-limb injury. Where a player did not suffer any injury, the survival period was recorded as the full length of the data collection period, for that team. Any participant suffering only an excluded injury had this duration subtracted from their respective team's total surveillance duration. Analysis was performed using Cox's multivariate proportional hazard ratio (Cox_{PH}), to create a frailty model, refined using backwards stepwise approach to achieve statistical significance. From within the generated model, hazard ratio's (HR) for each component were determined. The ES of the HR reported were interpreted using the same values and descriptors as stated for interpretation of RR (Olivier et al., 2017).

3. Results

Mean ABS for all participants was 93.3 ± 13.7 kg (SE = 1.90 kg), (Senior = 93.3 ± 15 kg, Emerging = 90.3 ± 12 kg) REL was 1.04 ± 0.17 kg/kg the (SE = 0.79 kg). The mean magnitude of asymmetry was 3.79 ± 5.45% (SE = 0.76%) and the MDA was calculated as 6.22% (moderate = 4.88% and large = 9.2% which was only exceeded by 10 participants (senior n = 3, emerging = 7).

The results of the ROC analysis are provided in Table 1, from which the AUC for ABS, REL and ASY indicated a 0.64%, 7.2% and 2.69%, better than chance ability to predict a lower body injury, respectively. The RR for all strength values found to be not significant (p = >0.05), with trivial to small effect sizes, suggesting no benefit or harm from strength levels above or below the threshold values.

The mean values (±1SD) for mean injury severity, player availability, total lower body time loss, lower body injury burden and survival time to a lower body injury are presented in Table 2. Multivariate and univariate analysis of these outcome variables are presented in Table 3 and Fig. 1. For all outcome measures, the initial multivariate analysis models (Table 2) were found to have the greatest significance. In all cases the outcomes were found to be trivial (ES < 0.3) and were not improved by any backwards steps.

Univariate analysis did not identify any significant correlations between either ABS or ASY with any of the outcome variables. REL did demonstrate significant most likely moderate correlations for player availability, total lower body time loss and lower body injury burden Application of a clinical MBD approach found that this was moderately beneficial, consider using (95.7% probability of a positive effect). However, this ES (r = 0.33) fell short of the threshold level of ≥0.36 determined for acceptable statistical power, resulting in a β of 0.3.

Although the Cox_{PH} analysis did not yield a significant finding (p = 0.2), further inspection of included variables indicated that relative strength was associated with a 70% hazard reduction (HR = 0.30) and age with a 10% increase (HR = 1.1), no other variable indicated any change in survival time.

4. Discussion

The aim of this study was to explore the prevalence of lower-body injuries, in sub-elite RL players and if unilateral leg strength may contribute to a heuristic that may reduce their resulting time-loss. No measures of leg strength (ABS, REL, ASY) were associated with increased RR (p > 0.05 and RR < 1.86)) of injury occurrence, nor were they any better than chance at predicting players who may suffer a lower body injury (AUC <58%). This information does not support the notion that leg strength would prevent any injury from occurring. The data from this study indicate that 77% of the sample at least one injury and 68% suffered a lower-body injury. Considering this data it is highly probably that participation in RL will result in an injury of some kind and this is most likely to be to the lower-body. Consequently, the more pertinent question is not whether or not leg strength may prevent injury occurrence, but if it can reduce the time lost as a result of said injury.

Significant (p = <0.05) most likely moderate correlations were found between mean REL and total time lost to lower body injury (r = −0.3, CI -0.04, −0.54, p = 0.03), player availability (r = −0.3, CI -0.04, −0.54, p = 0.03) and burden (r = -0.33, CI -0.06, −0.55, p = 0.03). Conversely neither ABS nor ASYM were found to have any significant associations with the duration of injury, nor were they indicated to be of greater than trivial to small effect. An MBD analytical approach indicated moderate evidence of potential benefit from increasing relative leg strength (>95%) with little probability of harm (≥5%). Initially this would indicate that the data would support the application of strength development, relative to body mass, as injury time-loss strategy. However, these correlation ES did not generate sufficient statistical power for the sample, which required a threshold level of r = ≥ ±0.37. Such observations are challenging to the practitioner and requires an understanding of statistical analysis to interpret. Whilst the analysis does support a significant effect, the magnitude of this did not meet the threshold level to be meaningful in this sample size. Practitioners are therefore noted to take caution when adopting these findings on the statistical significance alone as low ES and wide CI's increases the possibility that a type I error may be evident. Nevertheless, these findings do suggest that of all the metrics measured, increasing levels of leg strength in sub-elite RL players, warrants further examination in reducing injury time-loss.

Examination of the injury rates reported in this study are lower than in other RL studies. Across the whole sample there were 45.68 injuries were recorded, per 1000 match play hours and 5.36 per 1000 training hours, which was below the range (115−825 injuries/1000 h) reported by (King et al., 2010). Age has been identified by Bahr and Holme (2003) as a risk factor for injury, so the inclusion of two emerging teams and only one senior team may have influenced the injury frequency and duration of the injuries observed. However, Tee et al. (2019) observed 85 injuries per 1000 h match hours in three emerging teams during one season which exceeds the incidence of the comparable emerging players in this study (21.65 per 1000 h). Consideration of the data above, indicates that injuries were much less frequent, in the current study, resulting in fewer incidents recorded for analysis. The reduction in injury events may increase the possibility of a type II error in the analysis of associating leg strength measures, with injury costs. Without further research it is unclear if the injury frequency observed in this study is an atypical anomaly or the product of improved injury reduction strategies adopted by the teams studied.

A further limitation to this study was the in-situ nature of data collection that placed additional demands on the ISO's above and beyond their normal duties. As a consequence of this the ISO's were not able to record the mechanism of injury. This meant that the data presented could not be identified as those caused by contact with other players or not. As described in the introduction RL is a collision sport which is characterised by intentional, high intensity collisions with opposing players (and accidental collisions with those on the same team). Collision based injuries have been reported as those

Table 1
Summary of ROC analysis predicting lower body injuries using strength variables as independent variables.

Variable	Threshold	Area under the curve (AUC)	Specificity	Sensitivity	Relative risk (RR)	Positive likelihood rate
Absolute Strength	112.75 Kg	50.64% (CI 47.37, 58.22)	17.65	91.67	1.21	−0.21
Relative Strength	1.28 kg/Kg	57.2% (CI 49.6%, 66.2%)	23.53	94.44	1.06	0.22
Asymmetry	12.49%	52.69% (CI 47.6, 61.6%)	11.77	97.22	0.13	−0.03

Table 2
Summary of injury duration measures (±1sd), comparing the whole sample with each sub-group of participants.

	Whole sample	Senior	Emerging
Mean lower limb injury severity (days)	30.90 ± 36.11	35.05 ± 41.34	25.45 ± 28.19
Total lower limb time loss (days)	32.49 ± 48.62	25.76 ± 39.83	44.53 ± 60.68
player availability (%)	89.14 ± 15.90	91.17 ± 13.34	85.49 ± 19.55
Burden (Lower Limb injury only) (days/1000 exposure hours)	170.62 ± 214.02	135.61 ± 165.83	233.28 ± 274.66
Survival time to a lower limb injury (days)	152.02 ± 112.49	123.21 ± 104.78	168.12 ± 114.92

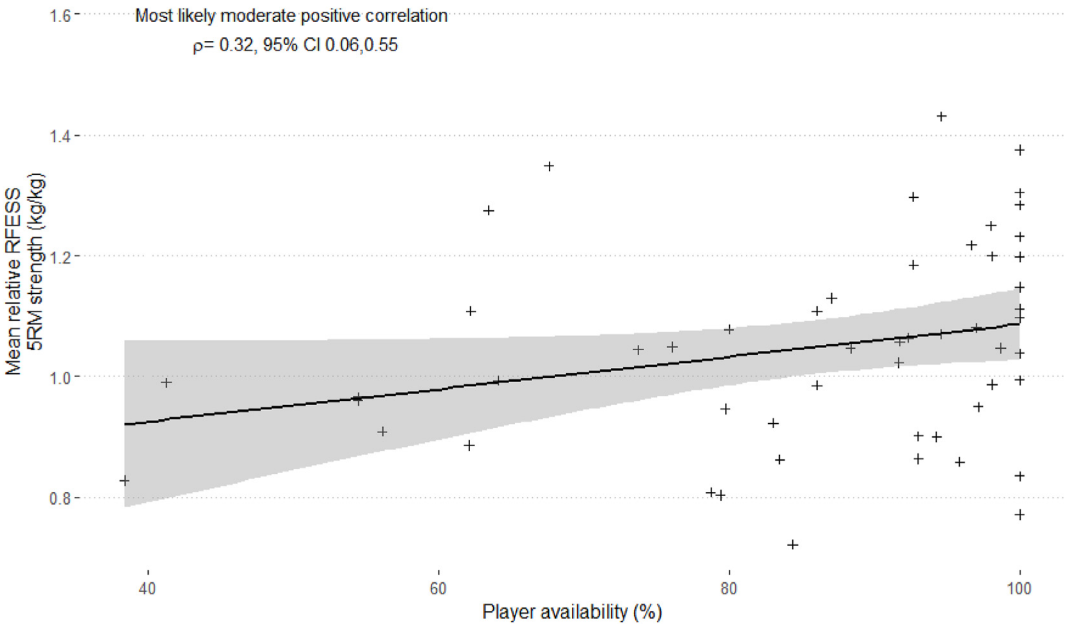

Fig. 1. An illustration of the Spearman's rank order correlation between a player's availability, based on lower body injuries only, across the playing season in relation to mean relative leg strength in the rear foot elevated squat 5RM test.

Table 3
Multivariate and univariate analysis of lower-body injury outcome variables.

	Multiple linear regression		Univariate Spearman's Rank order correlations					
			Absolute Strength		Relative strength		Asymmetry magnitude	
	Adjusted R^2	P value	r (95% CI)	P value	r (95% CI)	P value	r (95% CI)	P value
Mean lower limb injury severity (days)	−0.02	0.55	−0.28 (−0.56, 0.05)	0.1	−0.27 (−0.55, 0.07)	0.12	0.06 (−0.27, 0.38)	0.07
Total lower limb time loss (days)	−0.14	**0.03**[a]	−0.21 (−0.45, 0.07)	0.14	−0.3 (−0.53, 0.04)	**0.03**[a]	0.11 (−.037, 0.17)	0.45
player availability (%)	−0.13	**0.04**[a]	0.21 (0.06, 0.45)	0.13	0.3 (0.03, 0.53)	**0.03**[a]	0.10 (−0.18, 0.36)	0.48
Burden (Lower Limb injury only) (days/1000 exposure hours)	0.2	**0.01**[a]	0.21 (−0.46, 0.06)	0.13	−0.33 (−0.55, −0.06)	**0.02**[a]	0.03 (−0.3, 0.24)	0.81
	COX'S PROPORTIONAL HAZARD RATIO							
Survival time to a lower limb injury (DAYS)		**0.2**	0.2 (−0.07, 0.45)	0.15	0.2 (−0.07, 0.45)	0.15	0.04 (−0.23, 0.31)	0.75

[a] Significant at the α level.

that are the most frequently occurring in the sport (Fitzpatrick et al., 2018; Tee et al., 2019) and due to the demands of the sport considered non-preventable. However, incidence of injury has already been established as a poor metric for analysing injury (Bahr et al., 2018), instead the duration should examined, especially relative to exposure. The limitation of this paper, therefore, is not the ability to determine if increasing strength reduces injury contact derived incidence, but instead the time lost to such injuries. It is has been observed that strength training has positive effects on muscle, tendon and bone qualities (Andersen, 2011; Magaranis et al., 2011) which may potentially dampen the injurious effects of some contact events thereby reducing their severity. Further research is required to explore this hypothesis.

5. Conclusion

This study sought to explore the heuristic that increasing lower body strength had a positive effect on injuries in sub-elite RL players. The data observed that lower body injuries accounted for 74.13% of the days lost, further establishing the importance of understanding how such injuries interact with modifiable internal risk factors, such as strength. Analysis of ABS, REL and ASYM did not find any statistically significant ($p > 0.05$) association with RR nor were ABS and ASYM related to any other measure of injury outcome. However, REL was found to have a significant moderate negative correlation ($\rho = -0.33$, CI -0.55, -0.07, $p = 0.02$) to lower body injury burden and with a 70% hazard reduction ($HR = 0.30$). A note of caution must be applied to these results, as although significant, the magnitude of the effect did not achieve the threshold level, for this sample size (ES > 0.36). MBD testing indicated that although the size of the effect did not meet the statistical power threshold, there was only <5% chance of harm.

Consequently, the current study does offer some limited evidence for the heuristic that increasing leg strength may positively influence the time lost to injuries, in RL players, with low chance of negative consequences. When coupled with the beneficial effects on performance the application of strength training in RL preparation seems sound, yet in need of further substantiating evidence for injury time-loss reduction.

Practical applications

- Increasing relative leg strength was significantly but not meaningfully related to reduced time lost to injury.
- Strength asymmetry between legs was not related to either incidence or severity which does not support the development of symmetrical athletes, for injury reduction.
- This study introduces the heuristic the development of lower-body strength is possibly beneficial for both performance and reduction of injury time loss.

Confirmation of ethical compliance

This study was conducted with Ethical approval from Leeds Beckett University.

Ethical approval

This study was approved by the institutional ethical review process for Leeds Beckett University.

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Declaration of competing interest

None

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Appendix A. Supplementary data

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