Neck Strength Assessment Offers No Clinical Value in Predicting Concussion in Male Professional Rugby Players: A Prospective Cohort Study

Mairead Liston, MSc[1],*, Chris Leckey, MSc[1,2], Andrew Whale, PhD[1], Nicol van Dyk, PhD[1,2,3]

[1]High Performance Unit, Irish Rugby Football Union, Dublin, Ireland.
[2]School of Public Health, Physiotherapy and Sport Sciences, University College Dublin, Dublin, Ireland.
[3]Section Sports Medicine, Faculty of Health Sciences, University of Pretoria, Pretoria, South Africa.

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*Corresponding Author details:

Mairead Liston

High Performance Unit, Irish Rugby Football Union

10-12 Lansdowne Road

Ballsbridge

Dublin 4public

D04 F720

Email: mairead.liston@irfu.ie

ABSTRACT

OBJECTIVE: To determine if neck muscle strength and endurance are associated with concussion injuries in professional, male rugby players. Playing position, history of previous concussion, and age were also considered.

DESIGN: Prospective cohort study

METHODS: One hundred thirty-six male, professional rugby players completed neck strength testing that comprised a peak isometric test, an endurance test, and a concussion screening questionnaire. Electronic medical records were analyzed for head injury data.

RESULTS: Out of 136 players (mean age, 25.3 ± 3.4 years; height, 186 ± 7 cm; weight, 103 ± 13.2 kg), 40 players suffered from 51 concussions in the 2017/18 playing season. A history of concussion was reported by 65% of the cohort. Multiple logistic regression analysis found that peak isometric flexion strength was not associated with concussion risk. Increased peak isometric extension strength was associated with significantly greater odds of sustaining a concussion (odds ratio [OR] = 1.01; 95% CI: 1.00, 1.01, does not include 1; P = .04) that is likely too small to be clinically relevant. Players with a self-reported history of concussion had over 2 times greater odds of sustaining a concussion (OR = 2.25; 95% CI: 0.73, 6.22). More than 2 concussions in the past 12 months was associated with almost tenfold greater odds of concussion (OR = 9.51; 95% CI: 1.66, 54.55). Age, playing position, and neck muscle endurance were not associated with concussion.

CONCLUSION: The strongest predictor of concussion injury was previous concussion. Players who sustained concussions in season had similar neck muscle strength to players who had not sustained a concussion. J Orthop Sports Phys Ther 2023;53(5):317–323. Epub: 5 April 2023. doi:10.2519/jospt.2023.11723

Concussion continues to be the most common injury in many field-based sports, including the National Football League (NFL), Australian Football league, Rugby League, and Rugby Union, hereafter referred to as rugby.12 In the 2019 Rugby World Cup, more than a quarter of all injuries were to the head and neck; concussion was the most reported match injury.15

The 2016 Concussion in Sport Group consensus statement called for better understanding of the potentially modifiable risk factors for concussion and for study of appropriate injury risk reduction strategies.22 Neck muscle strength may be an important factor to reduce the risk of concussion in sport; however, few studies have investigated the risk factors for head or neck injury in rugby.5,7 In addition, there is little consensus around what "ideal" neck strength in rugby players is, making the identification of players at an increased risk of injury challenging.11 A recent investigation identified poor isometric neck strength as a risk factor for concussion, although the methodology and test procedure have received criticism.13,16,26

Previous studies have measured neck muscle strength using devices that are not accessible across various levels of play or reproducible in a gym setting, which limits the application of these findings in the performance setting.25,28 For example, custom-built fixed frame-dynamometry where neck strength is measured in a standing, hip-flexed position is difficult to compare to a seated, handheld dynamometer assessment.4,29 Many reports of isometric neck strength present data for all playing positions combined, which limits interpretation across different playing positions in rugby.17,24

To date, no reliable and valid test protocol has investigated the relationship between neck strength and endurance with concussion in rugby. We aimed to examine whether isometric neck flexion and extension strength and endurance were associated with concussion in a large cohort of male professional rugby players.

METHODS

Study Design

Male professional rugby players, aged older than 18 years, were recruited during the 2017/18 preseason training period (July and August 2017) to participate in a prospective cohort study.

Players were screened prior to participation and were included if they were not currently undergoing treatment for a cervical spine injury and were able to fully participate in match and/or training activities on the day of testing. Any player who underwent cervical spine surgery in the preceding 3 months was excluded from the study. All participants provided written informed consent for the study, and ethical approval was obtained from the Clinical Research Ethics Committee (CREC), University College Cork, Ireland.

Experimental Procedure for Neck Strength Assessments

Players completed a standardized warm-up prior to testing, including cervical range of motion exercises into flexion, extension, right and left lateral flexion, and self-resisted isometric holds in each direction, which lasted 3 to 4 minutes. Height and weight were measured on the morning of testing.

Participants completed 2 testing protocols: neck muscle peak isometric force testing (using the Vald Performance head harness device) in 4 directions and a neck muscle endurance test adapted from a test used by Halvorson and Peolsson, in 2 directions.18,27 As the endurance protocol measures the point at which the neck muscles fatigue, it was performed after the peak isometric force protocol. There was a 5-minute recovery period between extension endurance and flexion endurance tests, with the extension test carried out first.

Peak Isometric Strength Test

A reliable isometric neck strength testing protocol was used, which has been shown to have good to excellent test-retest, and intrarater and interrater reliability (intraclass correlation coefficient test-retest reliability [0.86–0.92]).14 A single-axis load cell strain gauge (Vald Performance Pty Ltd, Australia) measured maximal voluntary isometric force with the player in an upright seated position (SUPPLEMENTAL FIGURE A) with the head in neutral position, hands by the side holding onto the seat base, and feet hip-width apart and flat on the floor throughout the test.14 All recordings were manually triggered via Vald Performance software, with real-time data transmitted to the laptop computer via a USB sensor connection. The strain gauge was automatically calibrated after each test. Participants were tested in 4 directions (flexion, extension, right, and left lateral flexion) and the order of testing was randomized in each case. A slack harness was placed around their forehead across the frontal and parietal bones above the ear line. The strain gauge was in line with the direction of movement. Participants were given a verbal 3-second countdown and then asked to pull, producing maximum possible force for 4 seconds and then told to rest. Thirty-second rest was given between each of 3 repetitions, with only the highest score being counted.

Isometric Endurance Test

The endurance test used a heavy-duty head harness (VodiSport, Ireland) to hold weights on participants' heads in supine and then in prone. A pilot study of 19 players was carried out prior to the main study to determine the optimal weight that would ensure the test was both feasible and challenging in this cohort. This pilot group was a representative sample of the final study cohort. Previous studies27 used a 4-kg weight for extension and no weight for flexion, in an untrained, nonathletic population. As participants in this study are highly trained athletes, it was hypothesized that the aforementioned weights would not prove an appropriate challenge. The aim of the pilot study was to determine the percentage body weight for both flexion and extension tests to produce an endurance test time of 180 to 240 seconds and 60 to 120 seconds, respectively. Results of the pilot study determined that 20% and 7% of the player body weight for extension and flexion, respectively, would be an appropriate weight to challenge players, without being too heavy so that the neck muscles were unable to sustain the weight rather than being fatigued.

A trained physiotherapist spotted the weight throughout the endurance test, whereas an assistant recorded the time. For extension, the player lay prone with arms by their sides, shoulders, and chest on the plinth. The harness was fitted with the player in sitting and the load was applied after the player lays down (SUPPLEMENTAL FIGURE B). Players were instructed to extend their head so that the tip of their chin was pointing at the floor. Players were immediately prompted to reposition if there was any deviation. The test was terminated if the player could not maintain the standard position following 2 prompts. There was a similar procedure for flexion, with the player in supine and instructed to flex the upper cervical spine and to maintain retracted cranio-cervical flexion until exhaustion. Players were advised to stop when they felt they could not maintain the correct position, when they had reached fatigue, or if they immediately felt any pain or discomfort.

Reporting of Concussion

Players were asked to complete a questionnaire on their concussion history and risk factors, such as anxiety or depression, learning disorders (including attention deficit hyperactivity disorder), issues with sleep disturbance, and history of migraine (or familial history with any of these factors). This was a self-reported questionnaire (SUPPLEMENTAL APPENDIX A), and data were collected at the time of testing.

During the study period, a diagnosis of concussion was made by the team's medical staff using the Head Injury Assessment process for in-game injuries and the Sport Concussion Assessment Tool - 5th Edition (SCAT5) for injuries that occurred in training.8 All diagnosed concussions were recorded on the team's electronic medical records system (Kitman Labs, Dublin, Ireland) using the Orchard Sport Injury Classification System (OSICS). Players' date of birth was also taken from these medical records.

Statistical Analyses

For the analysis, we only included the first instance of concussion for each player. Univariate analyses (independent t tests) were performed to compare demographic variables between the injured and the uninjured players. A P value of <0.05 was considered statistically significant.

A generalized linear model (GLM) was used to perform logistic regression using statistical programming language, R (R Core Team, Vienna, Austria). This model was related to the variables and the magnitude of the variance of each measurement to be a function of its predicted value. All strength variables were included, and a flexion-extension ratio was derived for peak isometric strength. To account for the potential influence and variability between players, strength variables were also adjusted for bodyweight.15 Variables independently associated with concussion were determined from the univariate analysis. With a number of associated nominal variables, we also performed Cramer's V (where 0 represents no association and 1 a strong association) to determine collinearity.

We calculated receiver operating characteristic (ROC) curves to describe the sensitivity and specificity of the significant strength variables. The area under the curve indicates how well the strength variables under consideration would discriminate between injured and uninjured players, and were interpreted as excellent (0.90–1), good (0.80–0.90), fair (0.70–0.80), poor (0.60–0.70), or fail (0.50–0.60).1

RESULTS

There were 136 male professional rugby players (mean age, 25.3 ± 3.4 years; height, 186 ± 7 cm; weight, 103 ± 13.2 kg) who participated. The isometric endurance test was completed by all 136 participants, and 129 of these players also completed the isometric strength tests; 7 players did not complete the isometric strength test due to availability. Playing position was documented in 3 categories, front-row forwards (n = 37), other forwards (n = 38), and backs (n = 61).

In total, 40 of the 136 players suffered a concussion during the 2017/18 season.

There were no differences in age, height, or body mass index between injured and uninjured groups (TABLE 1). A history of concussion was reported by 65% (n = 88) of the cohort, significant among injured players compared to uninjured players (TABLE 1).

Table 1. Characteristics of all players and per playing position. Data reported as mean values with SD.

	All n=136	**Backs** n=61	**Front row forwards** n=37	**Other forwards** n=38	**p-value (ANOVA)**
Age (years)	25.3 ± 3.4	24.3 ± 3	26 ± 3.1	26.2 ± 3.8	0.006
Height (cm)	185.9 ± 7	182.3 ± 5.5	183.5 ± 3.4	193.8 ± 5.2	<0.001
Weight (kg)	103 ± 13.2	91.5 ± 7.7	113.9 ± 10	110.7 ± 6.4	<0.001

There were no differences in playing position between the injured and uninjured groups (TABLE 1). Positional differences in peak isometric strength and endurance strength are included in SUPPLEMENTARY FILE A.

Other factors present at the time of testing were reported by 8 players (6%), being either one or a combination of anxiety and/or depression, sleep disturbance, headaches, migraine, or learning difficulties. Twenty-three players (17%) reported having previously experienced such symptoms, whereas family history of either one or combination of these factors was reported by 96 players (71%).

Strength Measurements

When comparing the injured to the uninjured players, a statistically significant difference is observed for peak isometric strength in both flexion and extension (TABLE 2). For every unit increase in strength (N), there was less than 1% increase in concussion risk. When normalized to bodyweight, this finding is maintained only for extension (TABLE 2). There was substantial population overlap in flexion and extension strength between the injured and uninjured groups (FIGURES 1 and 2). This was similar for flexion and extension normalized to bodyweight (SUPPLEMENTAL FIGURES C and D). There were no significant differences between injured and uninjured players for either flexion or extension endurance (TABLE 2).

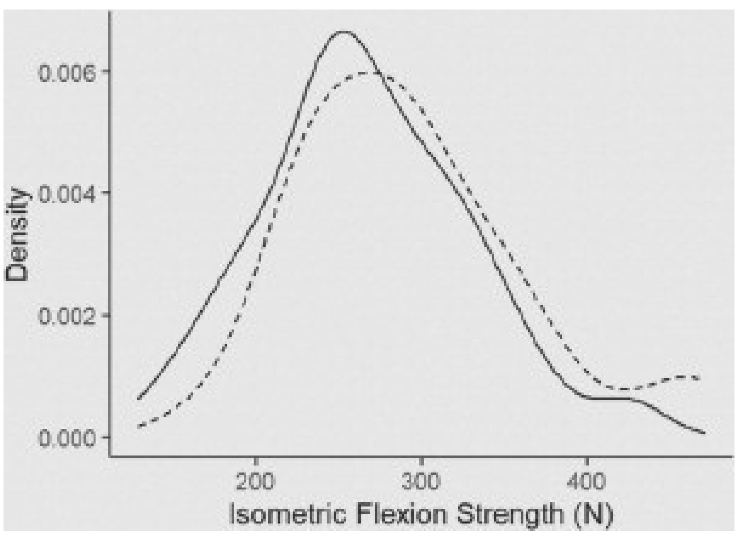

FIGURE 1. Distribution of peak isometric flexion strength in the injured (broken line) versus uninjured (unbroken line) groups.

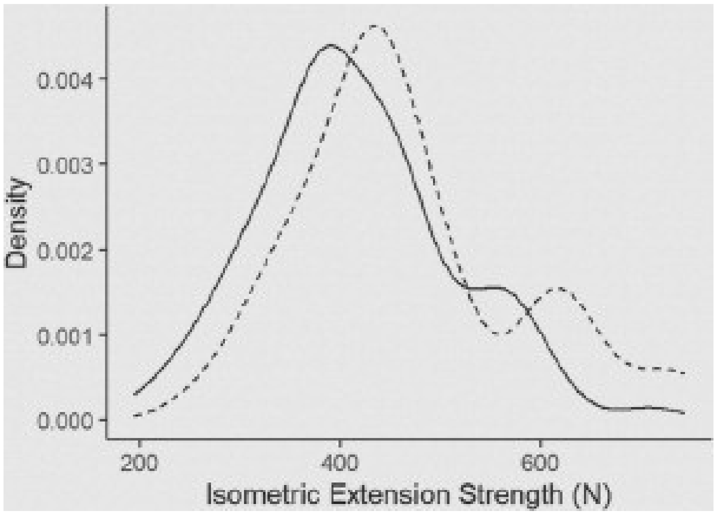

FIGURE 2. Distribution of peak isometric extension strength in the injured (broken line) versus uninjured (unbroken line) groups.

Table 2. Isometric endurance and peak isometric cervical strength scores. All values are reported in seconds (s), Newtons (N) or Newtons per kilogram (N/kg)

Peak isometric strength (N)

	All n=129	Backs n=58	Front row forwards n=35	Other forwards n=36	p-value (ANOVA)	
Flexion	275 ± 65	247 ± 48	319 ± 70	276 ± 61	<0.001	0.641
BW adjusted	2.53 ± 0.79	2.57 ± 0.76	2.63 ± 0.82	2.37 ± 0.78	0.07	0.027
Extension	429 ± 104	380 ± 82	516 ± 116	424 ± 62	<0.001	0.281
BW adjusted	3.95 ± 1.22	3.94 ± 1.19	4.25 ± 1.37	3.64 ± 1.05	0.02	0.079
Left lateral flexion	306 ± 73	282 ± 68	348 ± 70	304 ± 66	<0.001	0.125
BW adjusted	2.82 ± 0.90	2.94 ± 0.94	2.86 ± 0.87	2.60 ± 0.83	0.04	0.035
Right lateral flexion	308 ±70	277 ± 65	362 ± 59	307 ± 53	<0.001	0.245
BW adjusted	2.84 ± 0.87	2.88 ± 0.93	2.99 ± 0.86	2.63 ± 0.75	0.01	0.052

Isometric endurance (s)

	All n=136	Backs n=61	Front row forwards n=37	Other forwards n=38	p-value (ANOVA)	Effect size (ω^2)
Extension	55.7 ± 17.1	58.2 ± 16.9	57.1 ± 19.9	50.2 ± 13.4	0.06	0.03
Flexion	52.9 ± 20.1	52.5 ± 18.9	54.7 ± 22.9	51.8 ± 19.7	0.81	0.01

BW: body weight, ω^2, Cohen's omega squared

Multivariable Logistic Regression Analysis

Age, body weight, height, playing position, self-reported concussion history, and more than 2 concussions in the past 12 months were tested as potential confounding variables using univariate population-average logit analysis. Age, concussion history, and more than 2 concussions in the past 12 months were established as significant factors and included in the final model. All additional univariate analysis with point estimates and associated CIs are in SUPPLEMENTAL TABLE B. Cramer's V was 0.1736, indicating no collinearity between a history of concussion and more than 2 concussions in the past 12 months.

The parameter estimates of the multivariable logistic regression analysis are presented in TABLE 3 expressed as odds ratios per 1-unit (N) strength increase. Peak isometric extension was associated with increased odds of sustaining concussion (TABLE 3). ROC analysis revealed an area under the curve of 0.59 and 0.63 for peak isometric flexion and extension, respectively, indicating a failed combined sensitivity and specificity of the 2 strength variables identified in the logistic regression models. The ROC analysis for all the strength variables is available in SUPPLEMENTAL FILE A. More than 2 concussions in the past 12 months resulted in 9.5-fold greater odds of sustaining a concussion.

Table 3: Multiple linear regression analysis estimating the change in peak isometric force and endurance, adjusted for playing position. Values reported in Newton (N) and seconds (s). *,p<0.01, df, degrees of freedom

	Peak isometric strength			
	Flexion	**p-value**	**Extension**	**p-value**
Backs (comparator)	247.8 (233.2 to 262.3)		379.7 (356.9 to 402.5)	
Peak isometric strength				
Front row forwards	70.9 (47.2 to 94.6)	<0.001	136.9 (99.8 to 174)	<0.001
Other forwards	29.9 (6.4 to 53.4)	0.02	45.3 (8 to 82.6)	0.02
Isometric endurance strength				
Flexion (s)	0.79 (0.29 to 1.29)	0.003		
Extension (s)			0.23 (-0.72 to 1.18)	0.64
R^2	0.27		0.30	
Adjusted R^2	0.25		0.28	
Residual standard error (df = 125)	56.6		88.37	
F-statistic (df = 3; 125)	15.07*		17.51*	

DISCUSSION

Peak isometric neck extension strength represented a significant but trivial increased odds of concussion. History of concussion and, specifically, more than 2 concussions in the past 12 months were associated with greater odds of concussion.

The wide overlap shown in the neck strength distribution graphs (FIGURE 1 and 2), together with small absolute differences in strength measures between the injured and uninjured players, demonstrate the difficulty with distinguishing players at greater risk clinically based on these neck strength assessments.

Peak Isometric Strength

Neck muscle strength that meets the demands of the game has been described as a vital element of injury prevention.3,10 As catastrophic events in rugby have substantially reduced with law changes to the game and greater awareness around safety, current focus is on reduction of significant time loss injuries.23 A lower composite neck strength score was associated with risk of concussion in a mixed group of high school athletes.5 Neck muscle function and head movement velocity during simulated impacts have not been associated with increased risk of injury.29 Recently, the extensor muscles have been proposed to have a larger role to play than previously thought in attenuating forces of impact.13 It is suggested that a cutoff value, or minimal acceptable cervical extension strength of 41 kg, would identify 2 in every 3 players who are concussed.13 This method would fail to identify 1 in 3 players who sustain a concussion and a group-wide approach to cervical muscle strengthening is still suggested. Our results support this proposal.

In comparing strength measures between the injured and uninjured groups (TABLE 2), we highlight how although this type of testing has clinical validity, it lacks clinical utility. Identifying the at-risk player is not possible given the overlap in strength between the injured and uninjured players. The univariate logistic analysis demonstrated significant associations for both flexion and extension peak isometric strength to concussion injury; however, the absolute difference is negligible. Considering different body compositions of players within a rugby team, it seems sensible to normalize this finding to bodyweight. When doing so, the effect observed for extension strength is amplified. This finding of a weak association with strength is supported by recent findings, yet the fact that there was no group difference in strength suggests little clinical value.13 Comparison to previous findings is difficult, with differences in testing protocol, inclusion criteria, duration of the follow-up period, and injury definition possibly influencing the outcomes. It is remarkable that only 1 out of 7 strength variables evaluated (2 isometric endurance tests, 4 peak isometric strength tests, and a flexion/extension ratio) was unconvincingly associated with an increased risk of concussion. We suggest there is limited value in focusing on cervical strength as a risk factor in isolation.

In a normal population of healthy adult males (similar age range to this study), average neck strength values were reported as 223 N for extension and 147 N for flexion compared to 429 N and 275 N, respectively, in elite rugby players.6 A large difference is notable here and it should not be assumed that increasing neck strength in untrained individuals would not protect against concussion.

The density distribution of peak isometric extension strength approaches a bimodal distribution. This raises concern around a large increase in extension strength, and whether this adds to the risk of concussion. However, this study is inadequately designed to answer these questions.

Individual variability and seasonal changes must also be considered when interpreting these results. It is unlikely that strength will remain static for any player over the course of a season, and our results continue to emphasize the complex nature of these injuries. This study did not examine whether a player's neck strength changed following a concussion injury or if it had returned to preseason scores at return to play.

Isometric Endurance Strength

The sustained demands on the cervical muscles in rugby make endurance capacity a key focus for physical preparation. Forwards engage in an average of 18.8 scrums per match, and there are over 200 tackle events in a standard professional rugby match.9,30 There were no significant differences between injured and uninjured players for flexion or extension endurance using the adapted neck endurance test. Although not statistically significant, it should be noted that the other forwards had an average of 50.2 seconds for extension compared to 57.1 and 58.2 for the front-row forwards and backs, respectively (SUPPLEMENTAL TABLE A). This represents a difference of almost 14% and may be relevant in the clinical setting (remembering that other forwards had a similar concussion prevalence when compared to the other position groups).

Nonmodifiable Risk Factors

Previous history of concussion remains a strong prognostic factor for a worse clinical outcome postconcussion.2 Multiple concussions appear to be a risk factor for cognitive impairment and mental health problems in some individuals.21 Our results suggest that the risk of concussion is significantly increased when a history of concussion is reported. When multiple concussions have been recorded in a 12-month period, the odds of subsequent concussion increase almost tenfold.

Players were asked about any previous diagnosis of anxiety or depression, learning disorders, issues with sleep disturbance, and history of migraine (or familial history). Low prevalence (n = 8 [6%]) meant we were unable to analyze these factors in this study. They have been identified as factors that can worsen clinical outcome following a concussion.19,20

Our results emphasize the influence of prior concussion, with the strong association between a history of concussion and odds of sustaining a subsequent concussion. A graduated return-to-play process in professional rugby has been in place for 10 years and has recently been updated by World Rugby.31 This process includes computerized neurocognitive testing, independent medical clearance, and an individualized return to play, where mandatory stand-down time is the only modifiable, compulsory element to the process.

Limitations

To detect strong to moderate associations in prospective cohort studies, it is suggested that 30 to 40 injury cases are needed, whereas for small to moderate associations to be detected, 200 injury cases are needed.4 Importantly, even though this is one of the largest prospective studies to date on risk factors for concussion, we were not able to include enough cases to detect small associations during a single season. Future studies should look across multiple seasons to sufficiently power the study. In addition, we were unable to collect exposure data during this study. This must be considered when comparing these results to other studies that have done so.

All tests performed utilized the same testing system with highly experienced assessors in a clinical setting for professional athletes. Previous limitations around the type of testing performed to assess isometric strength were overcome in our study, with adequate reliability determined prior to the study.14,16,26

We acknowledge the homogeneity of our study population of professional male rugby players, which limits the generalization of these findings to other sports, age groups, or female players. Other factors such as training culture and possible prevention strategies within different teams could have influenced the results.

A self-reported questionnaire was used to determine existing risk factors and history of concussion, and we must consider recall bias and accuracy of these data when interpreting the results.

Clinical Implications

Isolated isometric neck strength variables, including an adapted neck endurance test specifically for rugby players, have limited clinical application in identifying individual players at risk of sustaining a concussion. The continued pursuit of risk factor identification through performance tests seems futile. Muscle strength continues to form part of a multifactorial complex model that may lead to concussion. However, our findings should urge the clinician to exercise caution and not translate the results of common screening tests into risk of injury for the individual player.

CONCLUSION

Only 1 of the 7 neck muscle strength-related variables was associated with concussion in male professional rugby players. Increased peak isometric strength in extension was associated with concussion, although the magnitude of this difference is likely too small to be clinically relevant. A history of concussion and more than 2 concussions in the same season carried a substantial, tenfold increase in risk.

KEY POINTS

FINDINGS: The strongest predictor of concussion was previous concussion. Two or more concussions in the prior 12 months increased the risk tenfold. Players who sustained concussions in-season had similar cervical strength to players who did not.

IMPLICATIONS: Strength testing in isolation should not be used for identifying those at risk of concussion, in male professional rugby players.

CAUTIONS: This study was conducted on highly trained individuals, and it should not be assumed that increasing cervical strength in untrained individuals would not protect against concussion.

STUDY DETAILS

AUTHORS CONTRIBUTIONS: Mairead Liston contributed to study concept and design, data collection, data synthesis, and the outline and editing of the manuscript. Chris Leckey and Dr Andrew Whale contributed to the statistical modelling, analysis and interpretation of the data, writing and revision of the manuscript. Dr Nicol van Dyk contributed to outline and editing, analysis and interpretation of the data, writing, and revision of the manuscript. All authors approved the final version, and agreed to be accountable for all aspects of the work in ensuring the accuracy or integrity of any part of the work.

DATA SHARING: Individual participant data that underlie the results reported in this article, after deidentification may be available upon request by contacting Mairead Liston at Mairead.liston@irfu.ie. The data may be made available, as well as the study protocol, informed consent form, appendices and statistical analysis plan, to researchers who provide a methodologically sound proposal, in order to achieve the aims approved in the proposal, for up to 3 years after publication

PATIENT AND PUBLIC INVOLVEMENT: Players were subjects in this study and were not involved in the design, conduct, interpretation, and/or translation of the research

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