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Applied sports science and sports medicine in women's rugby: systematic scoping review and Delphi study to establish future research priorities

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ABSTRACT

Objectives In part 1, the objective was to undertake a systematic scoping review of applied sports science and sports medicine in women's rugby, and in part 2 to develop a consensus statement on future research priorities.

Design In part 1, a systematic search of PubMed (MEDLINE), Scopus and SPORTDiscus (EBSCOhost) was undertaken from the earliest records to January 2021. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020, the PRISMA extension for Scoping Reviews, and the PRISMA extension protocols were followed. In part 2, 31 international experts in women's rugby (ie, elite players, sports scientists, medical clinicians, sports administrators) participated in a three-round Delphi consensus method. These experts reviewed the findings from part 1 and subsequently provided a list of priority research topics in women's rugby. Research topics were grouped into expert-based themes and expert-based subthemes via content analysis. Expert-based themes and expert-based subthemes were ranked from very low to very high research priority on a 1–5 Likert scale. Consensus was defined by ≥70% agreement. The median research priority agreement and IQR were calculated for each expert-based theme and subtheme.

Data sources PubMed (MEDLINE), Scopus and SPORTDiscus (EBSCOhost).

Eligibility criteria for selecting studies Studies were eligible for inclusion if they investigated applied sports science or sports medicine in women's rugby.

Results In part 1, the systematic scoping review identified 123 studies, which were categorised into six sports science and sports medicine evidence-based themes: injury (n=48), physical performance (n=32), match characteristics (n=26), fatigue and recovery (n=6), nutrition (n=6), and psychology (n=5). In part 2, the Delphi method resulted in three expert-based themes achieving consensus on future research priority in women's rugby: injury (5.0 (1.0)), female health (4.0 (1.0)) and physical performance (4.0 (1.0)).

Summary/Conclusion This two-part systematic scoping review and Delphi consensus is the first study to summarise the applied sports science and sports medicine evidence base in women's rugby and establish future research priorities. The summary tables from part 1 provide valuable reference information for researchers and practitioners. The three expert-based themes that achieved consensus in part 2 (injury, female health and physical performance) provide clear direction and guidance on future research priorities in women's rugby. The findings of this two-part study facilitate efficient and coordinated use of scientific resources towards high-priority research themes relevant to a wide range of stakeholders in women's rugby.

Key messages

What is already known

⇒ Women's rugby has grown substantially in global popularity and professionalisation. As women's rugby continues to grow and develop, it is important to systematically identify and map the volume and nature of research on applied sports science and sports medicine to establish the current evidence base in the scientific literature and future research priorities.

What are the new findings

⇒ The scoping review part of this study identified 123 studies investigating applied sports science and sports medicine in women's rugby. Studies were categorised into six evidence-based themes, with the most researched evidence-based themes identified being injury, physical performance and match characteristics. The summary tables of the applied sports science and sports medicine evidence base provide valuable reference information.

⇒ Based on the current evidence base, experts established consensus on three expert-based themes for future research priority: injury, female health and physical performance. The findings of this study guide future research priorities in women's rugby and have relevance to a wide range of stakeholders (eg, practitioners, coaches, players, researchers and governing bodies).

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INTRODUCTION

Rugby union, rugby league and rugby sevens are all codes of rugby (rugby codes collectively referred to as 'rugby' hereafter). Men and women play rugby at junior, senior, amateur and elite levels.[1–3] At the elite level, each team in rugby union, rugby league and rugby sevens matches consists of 15, 13 and 7 players, respectively, on the pitch, with 8, 4 and 5 players, respectively, on the bench as interchanges or substitutions. There are rule variations at lower performance levels (eg, in rugby union, the Rugby Football Union (RFU) has stipulated not more than five replacements and substitutions at levels 3 and 4, and not more than three replacements and substitutions at levels 5 and below).[4] Players are broadly categorised into the positional playing groups of forwards or backs.[1–3] Specialist positions within the broad positional categories exist for each rugby code.[2 3 5] Match duration can vary by country. For example, women's rugby union and rugby league in England are played over two 40 min halves. In the Australian women's rugby league domestic competition, each half is 30 min in length, less than the Australian women's rugby union competition and the domestic women's rugby league competition in England, which is 40 min per half. Although rugby sevens is played under essentially the same rules as rugby union, it is played over 7 min halves. Rugby sevens is typically played in a tournament-style format, with five to six games played over 2–3 days. Another key difference between the rugby codes is that when the ball leaves the field of play, rugby union and rugby sevens restart with a line-out, whereas rugby league restarts with a scrum. Additionally, following a tackle, in rugby union and rugby sevens, players can contest the ball via ruck or maul, whereas rugby league requires a play-the-ball. In rugby union, a ruck involves one or more players from each team, close around the ball, which is on the ground, while a maul consists of a ball carrier and at least one player from each team, bound together and on their feet.[6] In rugby league, a play-the-ball is the act of bringing the ball into play after a tackle.[7]

Women's rugby has grown substantially in global popularity and professionalisation. In the 2016 Rio Olympics, men's and women's rugby sevens were introduced, which helped increase the spotlight on women's game.[8] Internationally, women's rugby union participation increased by 28% from 2017 to 2019, resulting in 2.7 million registered players.[9] Major investment into women's rugby in England was seen in 2017 with the introduction of top-tier competitions (RFU: Premier 15s; Rugby Football League: Women's Super League), supporting the growth and profile of women's rugby. In 2019, the England senior women's rugby union squad became the world's first professional women's rugby union team when the RFU awarded 28 full-time playing contracts ahead of the women's Six Nations Championship.[10] This is in contrast to men's rugby union, which went professional in 1995.[11]

Alongside the global growth in women's rugby, recent systematic reviews of the emerging evidence base in women's rugby have been provided on injury,[12] match demands and physical characteristics[13] for specific rugby codes. These reviews are limited to a single rugby code or research theme. Similarities exist between rugby codes (ie, physiologically demanding intermittent contact sports that involve high-intensity actions (eg, tackling, sprinting) interspersed with low-intensity actions (eg, walking))[2 14 15] in comparison with non-contact sports. Therefore, it is important to collate the evidence base within women's rugby to facilitate cross-code knowledge transfer and collaboration. Identifying and mapping the current research literature within women's rugby and then highlighting evidence gaps are important to ensure the current evidence base is applied in policy and practice, and the evidence base continues to evolve systematically in areas where limited research exists. A systematic scoping review, by definition, is well suited to achieving these objectives.[16] Systematic scoping reviews aim to examine the extent, range and nature of the evidence, summarise findings from a body of knowledge, and identify gaps in the literature to aid planning of future research.[16]

Once the evidence base is known, it is important to establish research priorities. Developing research priorities facilitates efficient and coordinated use of scientific resources towards meaningful topics and outcomes. Research priorities should be co-constructed by various stakeholders (including the athlete) in women's rugby to ensure the research has translational impact and benefit.[17–22] Previous literature has not included the athlete in the construction of collaborative sports science research.[19] Inclusion of the athletes' views in developing research priorities advances not only previous work[19 22] but also ensures relevant player-focused research questions, development of player-friendly information and the translational impact of the research.[20] The Delphi technique is well suited to achieving these outcomes as it is a method used to achieve consensus or determine priorities.[23] The technique is highly structured and generally uses a panel to rate a series of statements on a defined Likert scale.[23] A key strength of this method is that it allows balanced stakeholder participation, which minimises the risk of bias, thus enhancing scientific rigour.[23] Therefore, the aims of this study were as follows: in part 1, to undertake a systematic scoping review of applied sports science and sports medicine in women's rugby; and in part 2, to develop a consensus statement on future research priorities.

METHODS

Design

This research follows a two-part study design. Although this study was not registered, the protocol has been previously published.[24]

Part 1: systematic scoping review of women's rugby

A systematic scoping review of applied sports science and sports medicine in women's rugby was performed in line with the updated guideline for reporting systematic reviews (Preferred Reporting Items for Systematic Reviews and Meta-Analyses 2020),[25] the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews,[16] and the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension.[26]

Part 2: consensus on future research priorities in women's rugby

A three-round Delphi consensus method was performed to identify future research priorities.[23 27 28] The CREDES (Conducting and Reporting Delphi Studies) guidance was followed.[29] This process involved expert stakeholders reviewing findings from part 1 and subsequently providing a list of priority research topics in women's rugby. Research topics were grouped into expert-based themes and expert-based subthemes via content analysis.[30 31] Expert-based themes and subthemes were ranked from very low to very high research priority on a 1–5 Likert scale. Consensus was defined as achieving ≥70% agreement.[28 32–34]

All participants provided informed consent.

Part 1: systematic scoping review of women's rugby

Search strategy

To carry out this review, a systematic search of electronic databases (PubMed (MEDLINE), Scopus, SPORTDiscus (EBSCOhost)) was performed from the earliest records to 20 January 2021. Search terms were constructed using previously published sports science and sports medicine reviews as a guide.[5 12 35 36] All study designs were included. The search strategy combined women ("female", "women*") AND rugby ("rugby", "rugby league", "rugby union", "rugby sevens"), with terms covering topics related to the applied sports science and sports medicine in women's rugby: "performance" OR "match*" OR "characteristics" OR "peak" OR "game" OR "competition" OR "skill" OR "technical" OR "anthropometric" OR "composition" OR "physical" OR "strength" OR "power" OR "jump" OR "speed" OR "fitness" OR "aerobic" OR "training" OR "qualities" OR "neuro*" OR "muscle damage" OR "fatigue" OR "recovery" OR "nutrition" OR "iron" OR "injury" OR "incidence" OR "psychology" OR "menstrual" OR "period" OR "menses". Searches were performed in the title and abstract fields. Searches were limited to the English language. The reference lists of selected studies were manually searched for additional eligible papers.

Study selection

After removing duplicates, search results were independently screened by two researchers (OH, SS) against the eligibility criteria. Disagreements were resolved through discussion or via a third researcher (BJ) if required. The title and authors were not masked to the reviewers. Studies were eligible for inclusion if they investigated applied sports science or sports medicine in women's rugby. Only peer-reviewed original research studies in the English language were included. Studies including both women's and men's rugby players were included if data were reported separately for men and women. Studies were excluded in cases where they did not investigate rugby, or they used rugby players as participants but did not investigate applied sports science and/or sports medicine in rugby players. For example, one study[37] used women's university rugby players as participants but the purpose of the investigation was to examine the relationship between the composite Functional Movement Screen and the modified Star Excursion Balance Test scores on agility performance and was therefore excluded. Such studies using women's rugby players to examine broader concepts have minimal direct application to women's rugby. Review articles, conference proceedings, editorials, case studies, letters to editors and theses were excluded.

Data charting

The categorisation of studies into evidence-based sports science and sports medicine themes was determined by each study's primary aims and outcome measures. Similar methods have been used in a recent scoping review.[38] When studies investigated multiple themes, they were categorised by the primary theme. Primary themes were determined by the main study aim, as stated in the study and/or by the theme of the journal where the paper was published. Evidence-based theme subcategories were identified where appropriate. Data charting was conducted by one researcher (OH) and confirmed by a second (SS) using a predeveloped charting form,[39] which included the general study characteristics (ie, year of publication, geographical location, cohort (rugby code, playing level), sample size) of each study, data relating to participants' characteristics (eg, age, height, body mass), the aim, outcome measures and key findings.

Data analysis

As the purpose of a scoping review is to map the extent, range and nature of literature and summarise heterogeneous findings, data analysis was not conducted.[16] All data are presented as mean±SD unless otherwise stated.

Part 2: consensus on future research priorities in women's rugby

Delphi technique

Expert panel

A group of 52 international experts on sports science and/or sports medicine in women's rugby were invited to participate. The invited experts included 27 women and 25 men across (n=6 elite players, n=19 sport scientists, n=17 medical clinicians, n=10 sports administrators). A minimum of 10 experts were required for reliable results.[40 41] Including a greater number of experts increases the reliability.[40 41] Eligibility criteria were defined as a researcher, professional or elite player with experience and/or affiliation with women's rugby at the national level or above. Furthermore, for players to be included in the expert panel, they must have met the following criteria: (1) currently play internationally and (2) actively involved in sports science or medicine (eg, PhD (candidate), lecturer, medical doctor). Although the criteria for players may limit the number of included participants, as per sampling guidelines, it enhances the possibility of players drawing clear interpretations from published research studies.[42] All participants were recruited via a purposeful sampling technique, which involved selecting knowledgeable individuals with specific experience in women's rugby.[43] Consideration was given to having multiple national governing bodies represented across rugby codes, as well as representation by elite players and practitioners in sports science (eg, researcher, strength and conditioning coach), medicine (eg, chief medical officer, team doctor) or sports administrators (eg, director of women's rugby, programme manager). This wide array of international experts was included to ensure multiple participant views would be captured, thus enhancing the translational impact and benefit of the research.[17 18 21 22]

Round 1

In the first round of questioning, the expert panel were asked to read the results from part 1 (online supplemental tables 1–7) to inform them about the current research in women's rugby. Via the Qualtrics online software (Qualtrics, Provo, USA), experts were then asked to provide a list of priority research topics. Research topics from the first round were grouped, by inductive content analysis,[30 31] into expert-based themes and expert-based subthemes. This process has recently been used in both netball[36] and women's football (soccer)[38] reviews. It involves an abstraction process whereby expert-based subthemes were given categories to develop expert-based themes.[30 31] When the final list of expert-based themes and expert-based subthemes was identified, the list was refined to enhance clarity and remove duplicates and typographical errors. In each round, participants were given 1 week to respond to the questionnaire, with reminder emails sent out to non-responders 2–3 days before the deadline.

Round 2

As per the inductive content analysis process,[30 31] the expert panel received the refined list of expert-based themes and subthemes developed in round 1. The expert panel were then required to (1) rate the research priority of each of the applied sports science and sports medicine expert-based themes and expert-based subthemes from low to high on a 5-point agreement Likert scale (1: very low priority; 2: low priority; 3: medium priority; 4: high priority; 5: very high priority). The expert panel were again provided with an opportunity to include any additional sports science and sports medicine expert-based themes or expert-based subthemes. Experts were given 1 week to respond to the questionnaire. When assessing consensus, Likert scale ratings were combined (ie, low: 1 and 2; medium:3; high: 4 and 5).[44] As per previous literature,[32–34] consensus was defined as achieving ≥70% agreement.

Round 3

The expert panel was asked to rerate (using the same 5-point Likert scale) the criteria from round 2 that did not reach consensus, including any new themes or subthemes that panel members included in round 2. The expert panel received feedback on round 2 in descriptive statistics (ie, mean priority rating of expert-based themes and expert-based subthemes), which enabled reflection before expressing their final opinion. Experts were given 1 week to provide their final responses to the questionnaire. As the aim of the Delphi consensus method was to ascertain the research priority of all expert-based applied sports science and sports medicine themes and subthemes, no expert-based themes or subthemes were removed on the grounds of low priority. Expert-based themes or subthemes that did not reach consensus after round 3 were not removed as they may be important to some but not all stakeholders. To manage confidentiality and experts discussing their responses during the Delphi process, the names of experts were not disclosed or shared publicly.[23]

Research priority agreement ratings were obtained separately for each expert-based theme and expert-based subtheme. The median research priority agreement and IQR were calculated for each expert-based theme and subtheme.

RESULTS

Part 1: systematic scoping review of women's rugby

Search and selection of studies

The database search identified 2417 articles. After removing duplicates (using Mendeley Desktop V.1.19.8) and applying the eligibility criteria, 123 studies remained for inclusion in the scoping review. The flow of articles from identification to inclusion is shown in figure 1.

General characteristics of the studies

Expert-based sports science and sports medicine themes

The 123 articles included in this systematic scoping review were categorised into six evidence-based sports science and sports medicine themes: injury (n=48, 39%), physical performance (n=32, 26%), match characteristics (n=26, 21%), fatigue and recovery (n=6, 5%), nutrition (n=6, 5%), and psychology (n=5, 4%) (figure 2).

Rugby codes

Figure 3 shows the overview of rugby codes that were included in this review: rugby union (n=42, 34%), rugby sevens (n=41, 33%), code not reported (n=24, 20%), rugby league (n=11, 9%) and multiple codes included (n=5, 4%).

Publication year

Table 1 shows the recent rapid growth in published research, with 80% of studies published between 2011 and 2021. Only evidence-based themes of injury and physical

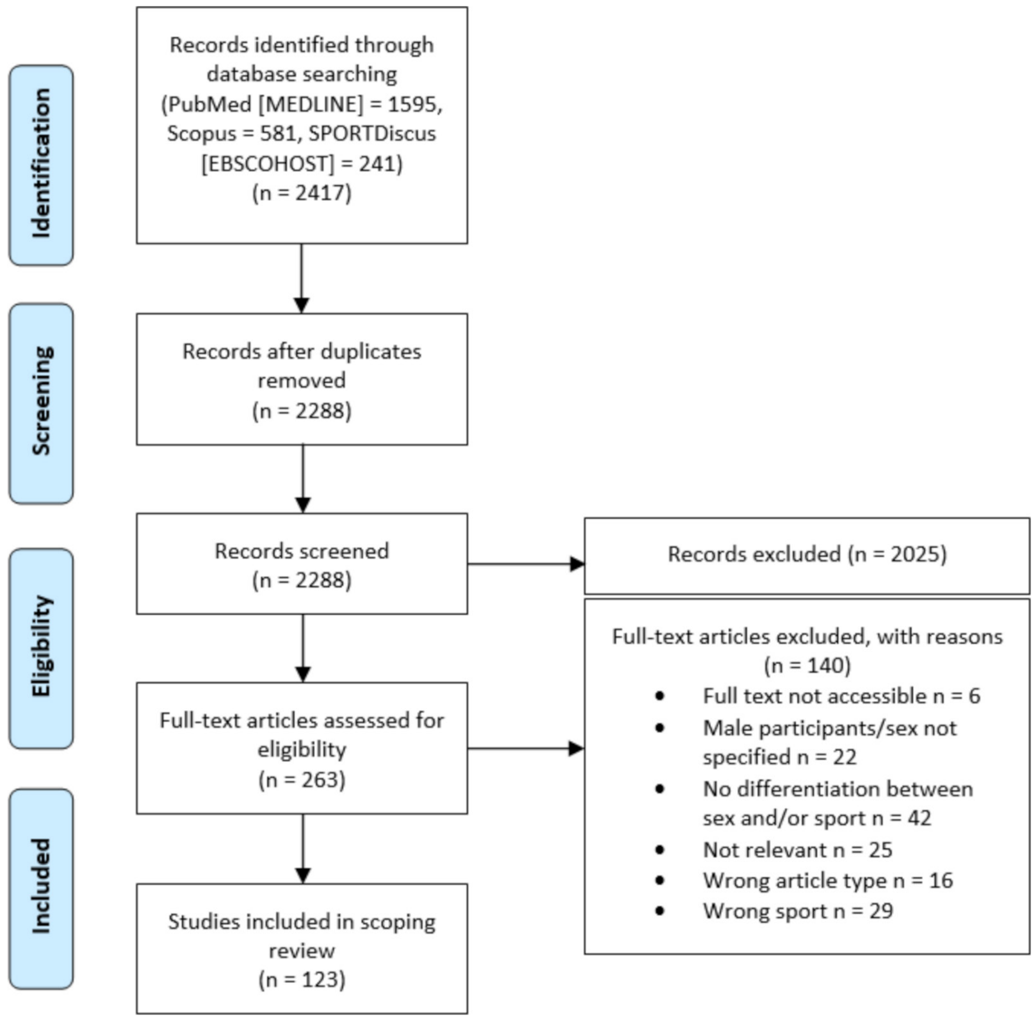

Figure 1 Flow of articles from identification to inclusion.

performance include studies across all-year group classifications. All studies categorised in fatigue and recovery, match characteristics, nutrition, and psychology evidence-based themes were published between 2011 and 2021.

Geographical location of the studies

Studies were published in 16 different countries: Australia, Brazil, Canada, France, Hong Kong, Ireland, New Zealand, Norway, Romania, South Africa, Spain, Switzerland, Thailand, The Netherlands, the UK and the USA. The greatest number of studies was from the USA (n=23, 19%), followed by New Zealand (n=18, 15%), Australia (n=17, 14%), Canada (n=17, 14%) and the UK (n=17, 14%). Within the injury evidence-based theme, the greatest number of studies was from the USA (n=13, 27% of 48 studies) and then New Zealand (n=11, 23% of 48 studies). For the physical performance evidence-based theme, the greatest number of studies was from the USA (n=7, 22% of 32 studies) and then the UK (n=6, 19% of 32 studies). Most studies on match characteristics were from Australia (n=8, 31% of 26 studies), Spain and the UK (n=5, 19% of 26 studies for both countries).

Fatigue and recovery

Six studies investigated fatigue and recovery in women's rugby (online supplemental table 1). All studies were performed in rugby sevens. Two studies (33% of 6 studies)[45 46] used both state-level and national-level athletes, while the remaining four studies used either university-level,[47] national-level[48] or international/elite-level[49 50] players. Four studies (66%) investigated the fatigue responses resulting from tournament play.[45–47 50] One study[49] (16%) quantified core temperature during tournament play and the efficacy of cold water immersion recovery protocols. Another study[48] (16%) characterised sleep in team sport athletes.

Studies investigating fatigue responses reported that national-level rugby sevens players displayed smaller performance decrements between tournament days 1 and 2 when compared with state-level players[45] and that post-tournament leucocyte count increased similarly (30%–50%) at both playing levels.[46] Furthermore, well-being, fatigue, muscle soreness, stress levels, mood and total quality of recovery are impaired after match day 1 and do not return to baseline until 2 days post-tournament.[50]

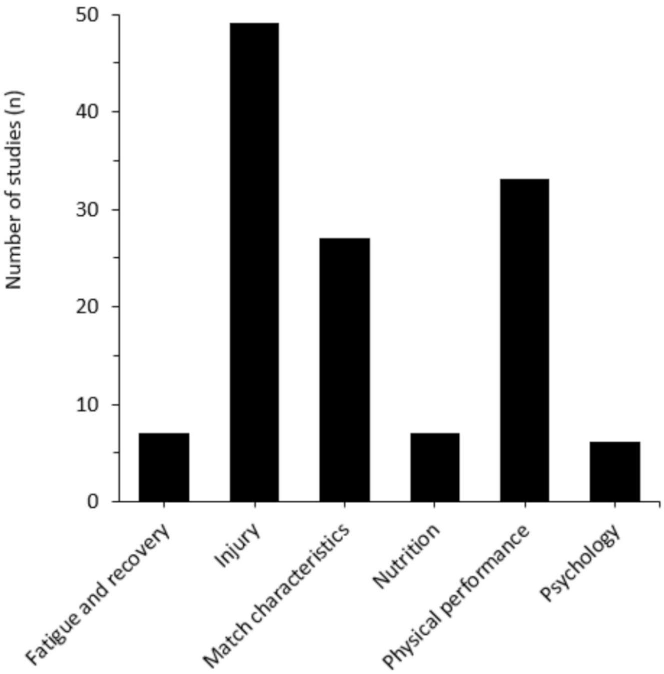

Figure 2 Number of studies per sports science and sports medicine theme.

Creatine kinase after tournament play has been shown to increase twofold and fourfold in national-level and state-level rugby sevens players, respectively,[45] but remain constant in university players.[47] Henderson *et al*[49] found that cold water immersion did not entirely remove body heat accumulated during warm-up and match-play in international-level rugby sevens players. Finally, national-level rugby sevens players may suffer poor sleep quality with high levels of associated daytime sleepiness.[48]

Injury

Epidemiology

Of the 48 studies investigating injury in women's rugby, 32 (66%) had an injury epidemiology focused theme (online supplemental table 2). These studies included participants from rugby union (n=13, 41% of 32 studies), rugby sevens (n=8, 25%), rugby league (n=3, 9%), a combination of both union and league (n=1, 3%), or the code was not reported (n=7, 22%). The cohorts used in these studies varied widely and included amateur,[51–53] high school/junior/U19,[54–56] provincial,[57 58] collegiate,[59 60] collegiate club,[61] club,[62] Olympic/international/world series[63–68] or a combination of levels.[69–73] Nine studies (28%) reported injuries to rugby patients/claimants.[74–82] The majority of the epidemiological studies (69%) collected data over longer time periods (eg, ≥1 season/year).[51–57 59 60 63 68–74 76–82] Some studies collected data during shorter time periods (eg, ≤4 days/tournaments)[52 58 64–67] and one study did not report the time course of data collection.[62]

Multiple approaches to injury definition were taken within the included studies. Many studies (n=17, 53%) used similar definitions to a consensus statement[83] on injury definitions in rugby union.[51–54 56 57 61 63–67 70–73 84] Ten studies did not report an injury definition.[58 62 69 74 75 78–82] Very broad (eg, 'any physical damage') or narrow (eg, specific body region) definitions were also used.[55 59 60]

Studies typically reported injuries per hours of exposure[52–57 60 61 63 64 67 68 70 72] or number of players.[58 59 69 78] Injury incidence was reported as between 1 and 106 injuries per 1000 exposures.[52–57 60 63 64 67 68 71 72 85] The site and/or type of injury were frequently reported. The lower limb[53 56 57 60 61 63 64 67 72 77 81] and the head were the most common injury sites in comparison with other injury locations, as identified by the included studies.[52 54 57 59 64 72 82] In women's rugby sevens, lower limb injuries have been reported as the most prevalent injury location, at 63.2% of all injuries at the senior level[63] and 38.1% at the U19 level.[72] Furthermore, in rugby union, injuries to the knee were the most common, accounting for 40.3% of moderate-to-serious national insurance claims.[77] Regarding the knee, in collegiate rugby, ACL injury incidence was reported 5.3 times higher in women compared with men.[61] The proportion of head injuries has been reported as 33.3% in amateur rugby sevens,[52] 23% in rugby-playing patients presenting to emergency departments,[82] 22.1% in high school rugby union[54] and 12.7% in international rugby union.[64] Collisions or tackles were typically reported as the cause of injuries.[52 54 64 72 74] Tackling has been reported to account for ~74%[52 72] and 63.6%[64] of injuries in rugby sevens and rugby union, respectively. Injury severity in rugby sevens has been reported as 53.4 days lost in international players[68] and 36.7 days lost in regional, collegiate and national players.[71] When comparing elite with non-elite rugby sevens players, injury severity has been reported as 74.9 and 41.8 days lost per injury, respectively.[72] Injury severity in amateur rugby union has been reported to be as high as 170 days lost per injury for the lower limb.[53] Injury severity in international women's rugby union and junior girls rugby league has been reported as 55 and 13 days lost per injury, respectively.[55 67]

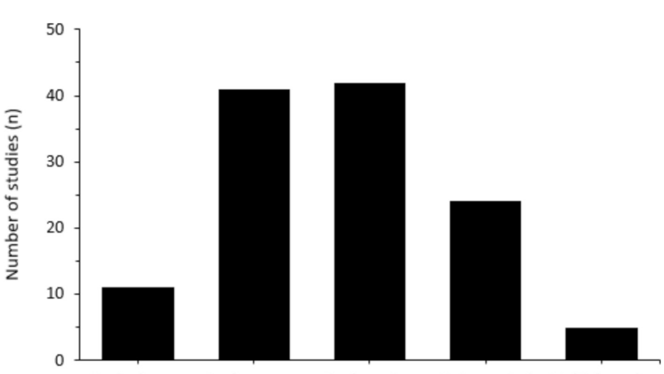

Figure 3 Number of studies per rugby code.

Risk, management and prediction

Of the 48 studies investigating injury in women's rugby, 16 (33%) had an injury risk, management and prediction

Table 1 Period of publication of studies included in the systematic scoping review

Evidence-based themes	Period published							
	<1990		1990–2000		2001–2010		2011–January 2021	
	Studies (n)	%	Studies (n)	%	Studies (n)	%	Studies (n)	%
Fatigue and recovery	0	0	0	0	0	0	6	100
Injury	1	2	5	10	10	21	32	67
Match characteristics	0	0	0	0	0	0	26	100
Nutrition	0	0	0	0	0	0	6	100
Physical performance	1	3	2	6	2	6	27	84
Psychology	0	0	0	0	0	0	5	100
Total	2	2	7	6	12	10	102	83

% represents the percentage of studies in each evidence-based theme for each period.

focused theme (online supplemental table 3). These studies included participants from rugby union (n=9, 56% of 16 studies), rugby sevens (n=1, 6%), a combination of union, sevens and league (n=1, 6%), or the code was not reported (n=5, 31%). The cohorts used in these studies varied widely and included amateur/community,[86–88] high school,[89] rugby schools,[90] club,[91] university/college,[92–95] international,[84] or a combination of levels.[96–100]

Many included studies aimed to determine the relationship between injury and potential risk factors. Some potential risk factors included physical characteristics,[86 92 95] concussion history,[88 89] wellness,[86] demographics,[89] foul play[100] and Functional Movement Screen scores.[93] Concussion was commonly assessed within injury risk, management and prediction studies (44% of 16 studies).[84 87–89 91 94 97] These studies provided Sport Concussion Assessment Tool reference values[89] and determined whether limits should differ between sexes,[84] evaluated standardised assessment and management of concussion,[97] investigated the use of the King-Devick Assessment Tool for a sideline concussion assessment,[87] investigated the neurological deficits that accompany head impacts,[94] explored concussion history on head control,[91] and determined the association between concussion and lower limb injury.[88]

From a concussive symptom standpoint, more symptoms and symptom severity were reported in women's rugby union players compared with men's players.[84] In high school rugby union, the median symptom severity was also found to be highest in women with concussion history and lowest in men with no concussion history.[89] Women have been reported to perform better in orientation, concentration and balance assessments when compared with men.[84] Investigations of balance across the duration of a collegiate women's rugby competitive season have shown reductions in static balance and improvements in dynamic balance at postseason testing.[94] Significant associations between concussion and lower extremity musculoskeletal injury have been reported in women's community rugby union players (OR=2.49).[88] Furthermore, women's senior club-level players with concussion history have been shown to exhibit greater head accelerations and reduced trapezius and splenius capitis electromyography amplitudes.[91] When returning to sport after a concussion in rugby, postconcussive syndrome has been shown to last longer in women than men (median number of days: 15 vs 4).[97] A delay in women's return to sport was also found compared with men (30 days vs 21 days; p=0.19).[97] For concussion assessment, the King-Devick test has shown good to excellent reliability for baseline (intraclass correlation coefficient (ICC): 0.84–0.89), postinjury (concussion) sideline screening (ICC: 0.82–0.97) and postseason evaluation (ICC: 0.79–0.83).[87]

Match characteristics

Physical match characteristics

Of the 26 studies investigating match characteristics in women's rugby, 21 (81%) had a physical demands focused theme (online supplemental table 4). These studies investigated rugby sevens (n=11, 52% of 21 studies), rugby union (n=5, 24%) or rugby league (n=5, 24%). Many of these studies used an international/elite/professional cohort (n=12, 57%).[101–112] Other cohorts used included provincial,[113] collegiate,[114] domestic,[115] premier division[116 117] or a combination of levels.[118–121] Sixteen of the 21 studies (76%) investigating physical characteristics within the match-play theme sampled ≤10 matches (online supplemental table 4).

The mean total distance covered during match-play was typically reported. The mean whole-match total distance covered was reported as 4982–5820 m in rugby union,[109 110 113 116] 4680–6582 m in rugby league[103 121] and ~1416–1642 m in rugby sevens.[104–107 112 118–120] Maximum velocity and 'high-speed' distance were also typically reported. Peak demands over various epochs (1–10 min) were quantified in two studies.[110 121] The average speed demands of international women's rugby league backs and forwards peaked at 144 m/min over a 1 min epoch.[121]

In international women's rugby union, the 1 min average speed demands were 150 m/min for forwards and 157 m/min for backs.[110] Comparisons between international and domestic locomotor characteristics during women's rugby league match-play found that generally the demands were greater for international competition (eg, 241±146 m vs 190±156 m high-speed distance in international and domestic backs, respectively).[121] Collisions or impacts were assessed in five studies.[101 111 114 115 117] Two studies investigated the ability of Global Positioning Systems to detect collisions compared with video-coded analysis[101 111] and found precision to be ~72%–83% in women's rugby league and that 62% of rugby sevens collisions were incorrectly labelled. Two studies quantified head impacts over one competitive season.[114 115] These studies found the mean number of head impacts per player per match to be 0.4–14. In domestic women's rugby league, the median peak linear acceleration >10 g was reported as 15 g (25th–75th, IQR=12–21).[115] One study quantified movement patterns through time-motion analysis and assessed physical demands during premier division rugby union competition and found that backs, when compared with forwards, spent more time sprinting (37±12 min vs 25±16 min) and less time in scrums, rucks, mauls and tackles (25±11 min vs 61±12 min).[117]

Technical-tactical match characteristics

Of the 26 studies investigating match characteristics in women's rugby, 5 (22%) had a technical-tactical focused theme (online supplemental table 5). These studies included participants from rugby sevens (n=4, 80% of 5 studies)[122–125] and rugby union (20%).[126] All these studies were performed in an international cohort.

Studies investigating the technical-tactical characteristics of international women's rugby sevens match-play found that successful teams gained more possession from handling turnovers, used more quick line-outs, threw more passes, made more ball-jolting tackles[124] and had a higher percentage of positive phases[122] compared with unsuccessful teams. In international women's rugby union, winning teams achieved a greater amount of line breaks, higher tackle completion, fewer pick and go's and fewer rucks in the opposition 22–50 m[126] when compared with unsuccessful teams. In rugby sevens ruck situations, when attacking players arrived first, there was a greater chance of maintaining possession.[123] Additionally, one study investigated the effects of caffeine on technical performance in international rugby sevens and found no effects on any rugby-specific actions.[125]

Nutrition

Six studies investigated nutrition in women's rugby (online supplemental table 7). Three of these studies were performed in rugby sevens (50% of 6 studies),[127–129] one in rugby league (17%),[130] one in rugby union (17%)[131] and one did not report the rugby code (17%).[132] Four studies used an elite/international cohort,[127–130] one study used university athletes[131] and one used both professional and amateur players.[132] Two studies investigated player hydration status during training[130 131] and match-play,[130] three studies investigated haematological (specifically iron and vitamin D) status,[127–129] and one study investigated dietary supplementation consumption.[132]

Investigation of hydration status in international women's rugby league found that on arrival to training and matches, urine osmolality values were indicative of euhydration.[130] The mean body mass reduction in university rugby union did not exceed 2% in training.[131] This aligns with the findings of Jones and colleagues,[130] who found ~0.5% reduction in body mass during both rugby league training and match-play. In international rugby sevens, investigation of haematological status found that 23% of women's players were classified as iron-deficient (ferritin <30 µg/L).[127] The greatest iron deficiency incidence occurred in mid-season (30% of players), but full recovery was evident by the end season.[127] Suboptimal iron stores in elite women's rugby sevens were mirrored in another study, where 29%–35% of players were identified with ferritin <45 µg/L at some stage in the study.[129] Women's rugby sevens players were found to be vitamin D-sufficient.[128] Regarding dietary supplementation in a mixed cohort of professionals and amateurs, 25%–43% of women's players were identified to consume whey protein, sports drinks, caffeine or sports bars.[132]

Physical performance

Anthropometrics

Of the 32 studies investigating physical performance in women's rugby, 7 (22%) had an anthropometrical focused theme (online supplemental table 6). Four of these studies included participants from rugby union (57% of 7 studies).[133–136] The remaining three studies did not report the rugby code (43%).[137–139] These studies included cohorts from university/college,[134 138 139] a combination of club and university,[133] semiprofessional,[137] or elite levels.[135 136]

One study investigated positional differences in anthropometric characteristics in elite rugby union women's players and found the sum of eight skinfold thickness (128.2±36.6 mm and 94.4±29.0 mm) and body fat percentage (26.5%±3.1% and 20.8%±3.0%) were greater in forwards compared with backs, respectively.[135] In division 1 collegiate rugby union, forwards displayed greater height (167.7±7.2 cm vs 164.5±5.1 cm), body mass (81.5±15.1 kg vs 64.5±7.7 kg) and body fat percentage (28.2%±6.1% vs 21.9±3.7%) relative to backs.[134] Body mass investigations, between playing tiers, in elite women's rugby union found forwards mass increased by 4.8% from 2010 to 2017 (79 kg to 83 kg) in tier 1 nations, with no changes in either tier 2 nations or backs from either tier.[136] Mean Q-angle (21.5°), pelvic width (29 cm) and femur length (41 cm) were described in a university-level cohort.[138] Compared with athletes of other (non-contact) sports or controls, semiprofessional women's rugby players had greater body mass, fat-free mass, fat mass and bone mineral density and increased thickness of abdominal musculature.[133 137 139]

Biomechanics

Of the 32 studies investigating physical performance in women's rugby, 3 (9%) had a biomechanical focused theme (online supplemental table 6). One of these studies was performed in rugby sevens with an international cohort (33% of 3 studies).[140] In comparison, the other two were performed in rugby union (67%) with amateur[141] and combined (club and international)[142] cohorts. In amateur women's rugby union, improvements in 5 m and 20 m sprint performance and mechanical properties related to the horizontal power–force–velocity profile were observed over the course of an 8-week sled training intervention.[141] In international women's rugby sevens, asymmetry of running mechanical variables was investigated, and symmetry angle remained mostly constant across all kinetic, kinematic, spring-mass characteristics and horizontal force production variables.[140] Finally, machine scrummaging forces were described in club and international rugby union, and women's peak compressive force was 8.7 kN.[142]

Performance

Of the 32 studies investigating physical performance in women's rugby, 13 (41%) had a performance testing focused theme (online supplemental table 6). Six of these studies included participants from rugby union (46% of 13 studies),[1 143–147] three were from rugby sevens (23%),[148–150] two from rugby league (15%),[151 152] one used both rugby union and sevens (8%),[153] and one did not report the code (8%).[154] These studies included various cohorts including amateur,[151] university/college,[144 145 147 154] national,[146] international[143 148–150 152] or a mixed sample.[1 153]

In women's rugby union, studies investigating performance testing between positions found that backs were significantly quicker than forwards over 5, 10, 20, 30 and 40 m and in the 505 agility test and also demonstrated greater vertical jump height (44±5 cm vs 38±5 cm) compared with forwards.[1 143 146] In both rugby union and rugby sevens,[1 148] forwards were found to demonstrate greater initial sprint momentum (eg, 367±20 kg/m/s vs 399±22 kg/m/s)[148] compared with backs. In university women's players, anaerobic power was found to be greater in forwards than backs.[154] In rugby union National All-Star Championship players, backs performed better on all running tests (ie, 40-yard speed, 100 m and 300 m speed, bleep test) than forwards.[146] Similar findings were reported in senior and schoolgirl rugby union, where backs outperformed forwards on the aerobic shuttle test.[1] Significant correlations were observed between total body fat and all fitness variables in international rugby league.[152] When sex comparisons were made between female and male youth rugby league players, respectively, one repetition max squat (115±41 kg vs 104±31 kg) and bench press (46±17 kg vs 47±14 kg) were not different.[151] In international rugby sevens, women demonstrated lower performances than men in all speed-power assessments and change of direction tasks (effect size=0.61–2.09), except for the zigzag drill, where no significant differences were identified between men and women.[149] Additionally, women displayed a lower change of direction deficits in all tests and lower sprint momentum.[149] Sprint times with different ball-carrying techniques were assessed in university-level rugby union and 10 m sprint speed was slower for women beginners who were carrying the ball versus not carrying the ball.[147] This study did not find a difference in sprint speed for experienced women or men carrying or not carrying the ball.[147] Multidirectional ability was specifically examined in two collegiate rugby union studies,[144 145] which found vertical jump height correlated with 20 m speed, standing long jump distance correlated with 5 m and 10 m speed and the left-leg 505 performance (r=–0.71 to –0.88) and predicted 0–5 m and left-leg 505 time.[144] No correlation was found between the change of direction deficit and sprint times.[145] International rugby sevens players with high playing minutes (≥70 min) were older (24±3 years vs 21±4 years), had greater experience in a national training centre (2.4±0.8 years vs 1.7±0.9 years), had faster 1600 m time (375±20 s vs 394±30 s) and greater one repetition max strength (bench press: 68±6 kg vs 62±8 kg; pull-up: 84±8 kg vs 79±5 kg) than athletes who played fewer minutes.[150]

Physiology

Of the 32 studies investigating physical performance in women's rugby, 7 (22%) had a physiology focused theme (online supplemental table 6). Three of these studies (43% of 7 studies) were performed in rugby sevens with an international/Olympic cohort.[155–157] Of the remaining four studies, the rugby code was not reported, and the cohort was either varsity (14%),[158] subelite and elite (14%),[159] international (14%)[160] or not reported (14%).[161]

Studies investigated a range of physiological-themed topics. One study investigated the relationships between blood rheology and body composition and found red blood cell aggregability negatively correlated with isometric handgrip and adductor strength (r=–0.58 to –0.50).[161] From a women's health perspective, 93% of international-level athletes reported menstrual cycle-related symptoms. Furthermore, perceived heavy menstrual bleeding was reported by 33% of players, and 67% considered symptoms to impair physical performance.[160] Urinary incontinence prevalence has been reported by 54% of varsity players, and as many as 90% of affected players leaked urine during match-play.[158] When investigating resting metabolic rate in subelite and elite women's players, indirect calorimetry-derived measurements have been reported at 1651±167 kcal/day.[159] When comparing resting metabolic rate prediction equations with indirect calorimetry, the Cunningham, Ten Haaf and Watson (body mass) values did not differ from measured metabolic rate (p>0.05).[159] Two studies investigated physiological and physical variables in rugby sevens[155 156] and found that the critical velocity test was correlated with the Yo-Yo Intermittent Recovery Test Level 1 test (r=0.86).[155] Furthermore, compared with the mean speed at the second ventilatory threshold (3.5 m/s), the industry-used threshold of 5 m/s underestimated the absolute amount of high-intensity running completed by individual players by up to 30%.[156] One final study investigated the relationship between skeletal muscle properties and peak power production capacity in Olympic rugby sevens and found a strong relationship (r=−0.75, 90% CI −0.90 to −0.44) between vastus lateralis contractile properties and power output.[157]

Training

Of the 32 studies investigating physical performance in women's rugby, 2 (6%) had a training focused theme (online supplemental table 6). One of these studies used an elite cohort of sevens players (50%),[162] while the other used women's rugby sevens, league and union strength and conditioning coaches (50%).[163] One study evaluated countermovement jump performance over 6 weeks of progressively increasing training load and found training load to increase from week 2 to week 6. Analysis of countermovement jump variables indicated diminished neuromuscular function in elite rugby sevens players throughout the training intervention.[162] When exploring current physical preparation practices across all rugby codes,[163] it was found that physical testing was more commonly performed during preseason (97% of participants) and inseason (86%) phases when compared with off-season (23%). Resistance, cardiovascular, sprint and plyometric training, and recovery sessions were all believed to be important to enhancing performance and were implemented by most participants (≥89%). Physical preparation coaches identified the most frequent unique aspects of consideration in women's rugby as psychosocial, menstrual cycle and physical differences.[163]

Psychology

Five studies investigated the psychological aspect of women's rugby (online supplemental table 7). One of these studies was performed using rugby union athletes (20% of 5 studies),[164] one used a combination of rugby union and sevens athletes (20%),[165] and the remaining three studies did not report the rugby code (60%).[166–168] The investigated cohorts included varsity,[168] university,[166] international,[164 167] or a combination of both collegiate and national levels.[165]

Studies investigated a range of psychologically themed topics. One study investigated early maladaptive schema elements in international players and identified an average of five per player.[167] The most frequent were self-sacrifice (83%) and unrealistic standards/hypercriticism (78%).[167] When investigating participant motivation in international rugby union, multifaceted motives were discovered. The four major participation motivation themes identified were (1) getting started with rugby, (2) physical aspects, (3) achievement and success, and (4) on-field and off-field player interactions.[164] A study on rugby union and rugby sevens athletes investigated the role of mental toughness during injury and found that those who would play through injury reported higher mental toughness than those who would not.[165] When examining avoidance behaviours during a head-on collision course, varsity rugby athletes avoided significantly later than non-athletes.[168] One study assessed the four-stage sequence of relationships between coaches' perceived interpersonal coaching styles and university players' basic psychological needs, self-determined motives and performance.[166] It was found that all basic psychological needs were perceived to be highly fulfilled.

Part 2: consensus on future research priorities in women's rugby

Expert panel

Fifty-two international experts on women's rugby were invited to participate. Thirty-one invited experts participated in the study, while the remaining experts did not respond to the invitation. The participating experts represented multiple nations (Australia n=4, Canada n=3, England n=10, France n=1, Ireland n=5, Scotland n=5, USA n=1, Wales n=2) across rugby codes (rugby union and/or sevens n=25, rugby league n=6) and governing bodies (experts who consented to public recognition are included in the acknowledgement section). Experts were categorised into elite player (n=4), sports science (n=11), medical clinician (n=9) or sports administrator (n=7) domains. When experts crossed multiple domains, they were classed by their primary domain expertise. The expert group consisted of 12 men and 19 women. The average number of years of experience in participants' respective domains (ie, player, sports science, medical clinician or sports administrator) were 6.4±4.4 years (range: 2–20 years). The response rates in this Delphi consensus method, from the original 52 international experts, were 60% (n=31; round 1), 56% (n=29; round 2) and 58% (n=30; round 3). Our retention rate was 97%, which is substantially greater than the expected rate of 75%.[169]

Consensus on future research priorities

During round 1, experts identified 183 individual meaning units. A meaning unit represents an idea, argument/reasoning chain or discussion topic in content analysis.[170 171] Twenty-one meaning units were removed as they were irrelevant to applied sports science and sports medicine in women's rugby (eg, meaning units pertaining to sociology). To form expert-based subthemes, meaning units were streamlined for clarity and concision. The abstraction process revealed 68 expert-based subthemes, which were categorised into 5 expert-based themes (ie, female health, injury, match characteristics, physical performance and psychology). After subtheme duplicates were removed, 41 unique expert-based

Table 2 Expert-based subthemes that reached consensus, median research priority (IQR) calculated from a 5-point Likert scale and percentage of expert agreement

Expert-based theme	Subthemes	Median research priority (IQR)	Low (%)	Medium (%)	High (%)
Female health	Relationship between the menstrual cycle and injury	5.0 (1.0)	3	7	90
	Long-term health of women's rugby players	5.0 (1.0)	7	7	87
	Relationship between the menstrual cycle and training load	4.0 (1.0)	3	21	76
	Menstrual-related symptom management	4.0 (0.8)	3	23	73
	Relationship between menstrual cycle and performance	4.0 (2.0)	7	21	72
	Relative energy deficit in sport	4.0 (2.0)	7	21	72
	Relationship between the menstrual cycle and well-being	4.0 (2.0)	7	21	72
Injury	Concussion occurrence, risk factors, mechanisms and return-to-play management (eg, protocols, baseline testing) (including performance levels (eg, junior, elite) and playing positions)	5.0 (0.0)	0	7	93
	Women's response to concussion	4.0 (1.0)	7	3	90
	Injury occurrence, risk factors and mechanisms (including performance levels (eg, junior, elite), playing positions and activity types (eg, match, training))	4.0 (1.0)	0	13	87
	Injury (including concussion) and risk reduction strategies (eg, warm-ups, neuromuscular training, tackle technique)	5.0 (1.0)	3	10	86
	Occurrence of recurring injuries (eg, multiple ACL or concussion injuries in a single athlete)	4.0 (0.0)	3	20	77
Physical performance	Strength and conditioning practices and efficacy in women's rugby	4.0 (0.0)	3	20	77
	Fatigue and recovery (eg, biochemical markers) (including match and tournament play)	4.0 (0.0)	7	17	76
Psychology	Mental health (eg, stress, body dysmorphic disorders, depression, eating disorders)	4.0 (1.0)	7	17	76

subthemes emerged. The expert-based themes that reached consensus on future research priority during round 2 included injury (median research priority=5.0 (1.0)), female health (median research priority=4.0 (1.0)) and physical performance (median research priority=4.0 (1.0)). Furthermore, two expert-based injury subthemes and one expert-based physical performance subtheme reached consensus. An additional five expert-based female health subthemes and one expert-based psychology subtheme reached consensus. During round 3, although no expert-based themes reached consensus, subthemes in female health (n=2), injury (n=3) and physical performance (n=1) did. All expert-based themes and subthemes of research priority that reached consensus are listed in table 2. Likert scale ratings were combined (ie, low: 1 and 2; medium: 3; high: 4 and 5).[44]

Expert-based (sub)themes that did not reach consensus

Match characteristics (median research priority=3.0 (1.0)) and psychology (median research priority=4.0 (1.0)) were the two expert-based themes that did not reach consensus. Unique expert-based subthemes that did not reach consensus (n=43) are listed in online supplemental table 8. Although consensus was not reached, these themes and subthemes may be important to some but not all stakeholders in women's rugby.

DISCUSSION

This systematic scoping review and Delphi consensus aimed to summarise the current evidence and provide consensus on future research priorities in women's rugby. Part 1 of this study, the systematic scoping review, identified 123 studies that were categorised within six evidence-based applied sports science and sports medicine themes (ie, fatigue and recovery, injury, match characteristics, nutrition, physical performance, and psychology). Part 2 of this study, the Delphi consensus, included an international group of expert stakeholders in women's rugby, including elite players, sport scientists, medical clinicians and sports administrators, to determine consensus on future research priorities. Consensus on future research priorities for injury, female health and physical performance expert-based themes was achieved. The findings of this systematic scoping review and Delphi consensus provide clear future research priorities in women's rugby for several stakeholders, including practitioners, researchers, policy makers and governing bodies.

Experts identified the injury as a very high-priority research theme (median research priority=5.0). Five unique research subthemes were identified within this expert-based theme, with 77%–93% of experts stating these were a high priority. Concussion occurrence, risk factors, mechanisms and return-to-play management (median research priority=5.0, 93% high-priority expert agreement) and women's response to concussion (median research priority=4.0, 90% high-priority expert agreement) were the two highest priority subthemes. This systematic scoping review supports the notion to investigate concussion further, as women's rugby injury locations were commonly the head and lower limb, with collisions or tackles frequently reported as the cause (online supplemental table 2). Injury incidence was variable in women's rugby and reported between injury types at 1–106 injuries per 1000 hours (online supplemental table 2). In professional men's rugby union, match injury incidence has been reported to be 87 per 1000 hours.[172] The large range in injury incidence found in this systematic scoping review may be due to various codes, cohorts, injury definitions and injury surveillance time course (eg, one season, 5 years) between the included studies (online supplemental table 2). Similar to women's rugby, men's rugby league[173] and union[172] found the head/face/neck, knee and lower limb to be frequent injury sites and the tackle as a common injury cause. For example, in professional men's rugby union, tackle was responsible for 46% of ankle injuries, 45% of knee injuries and 66% of shoulder injuries.[172] Furthermore, injury risk reduction strategies (eg, warm-ups, neuromuscular training and tackle technique) (median research priority=5.0, 86% high-priority expert agreement) were deemed a very high priority by experts. When considering the high research priority for injury risk reduction strategies and the tackle being responsible for a high percentage of injuries in women's rugby (online supplemental table 2), the investigation of tackle technique and injury is justified within women's rugby research.

Experts identified female health as a high-priority research theme (median research priority=4.0). In this expert-based theme, seven unique subthemes were identified, with 72%–90% of experts stating these were a high priority for research. The menstrual cycle, and its relationship to applied sports science and sports medicine, was found to be a common priority among experts. Menstrual cycle and injury, training load, performance, well-being and symptom management all achieved expert consensus (median research priority=4.0–5.0, 72%–90% high-priority expert agreement). Although in the evidence base there are recent meta-analyses available that investigate menstrual cycle[39] and oral contraceptive[174] effects on exercise performance in women, this systematic scoping review found that menstrual cycle research in rugby populations is sparse (n=1).[160] Similar to the female health research priority that achieved expert consensus (table 2), a recent narrative review of health and performance in women's football (soccer)[175] highlighted menstrual cycle and performance, menstrual cycle and injury, menstrual cycle and responses to training, hormonal contraceptives, and energy availability as important considerations for women's football. While female health has been highlighted as a high-priority expert-based theme, insufficient studies were identified in this systematic scoping review to warrant female health as an evidence-based theme. This is likely owing to the limited number of published research articles on women's rugby at present. Despite this, relevant female health studies identified in this systematic scoping review include investigations of menstrual cycle on performance,[160] breast injuries,[96] urinary incontinence[158] and iron deficiency.[127 129] It remains clear, based on expert consensus and evidence base gaps, that further female health research is required in rugby to support both player health and performance.

Experts identified physical performance as a high-priority research theme (median research priority=4.0). In accordance with previously published scoping reviews on women's football (soccer)[38] and netball,[36] the present systematic scoping review found that physical performance was a highly researched theme (n=32 of 123 studies). The two expert-identified physical performance research subthemes were strength and conditioning practices and efficacy in women's rugby (median research priority=4.0, 77% high-priority expert agreement) and fatigue and recovery (median research priority=4.0, 76% high-priority expert agreement). This systematic scoping review highlighted that, although physical performance was the second most researched evidence-based theme, a research gap is still evident. Only two studies were identified that investigated strength and conditioning practices,[162 163] and all the identified fatigue and recovery studies[45–50] were performed in rugby sevens. In contrast, the fatigue and recovery research in men's rugby, for example, comprises enough studies to compile reviews on male age-grade rugby union[35] and senior men's rugby league and union.[176] Given both expert consensus and the current evidence base limitations, future physical performance research could aim to improve understanding of (responses to) strength and conditioning training, and fatigue and recovery responses to various physical stimuli women's rugby players are exposed to (eg, collisions, high-speed running).

Although the expert-based theme of psychology did not reach consensus (ie, <70% expert agreement), its subtheme of mental health (eg, stress, body dysmorphic disorders, depression, eating disorders) was deemed a high research priority (median research priority=4.0) by

76% of experts. As per our systematic scoping review findings, the evidence base on psychology in women's rugby is sparse (n=5). Studies investigating psychological aspects in women's rugby were varied in their topics and included maladaptive schemas,[167] mental toughness,[165] avoidance behaviours,[168] coach–athlete relationship[166] and participant motivation.[164] This evidence scarcity is also apparent in psychological research on male rugby in both senior and junior populations.[35 177] Furthermore, although not achieving consensus, four expert-based subthemes in psychology attained a high priority from ≥57% of experts (online supplemental table 8) (ie, psychological aspects of dual-career players, psychological demands of rugby, optimising the relationship between (male) coaches and women's rugby players, psychological barriers to rugby participation). When considering expert consensus and the current lack of psychological evidence on women's rugby, future research could investigate mental health in women's rugby.

This systematic scoping review revealed a further two evidence-based themes, nutrition and match characteristics, that subsequently did not achieve expert consensus as research priorities. An absence of literature on nutrition in women's rugby is apparent (n=6). This finding is comparable with reviews on men's rugby union,[35 178] men's rugby league,[179] women's football (soccer)[38] and netball.[36] Three expert-based subthemes on nutrition were identified (nutritional strategies to reduce concussion risk, interventions (training, nutritional) to enhance performance, and nutritional requirements and supplementation), all of which did not achieve consensus (median research priority=3.5, 4.0 and 3.0, respectively; high priority expert agreement=23%, 53% and 27%, respectively). These findings suggest that, overall, nutrition investigations are of moderate to high research priority but may be of high priority to some stakeholders. In the match characteristics evidence-based theme, a relatively high proportion of studies investigated physical match characteristics (n=21) compared with technical-tactical characteristics (n=5). This systematic scoping review found that no technical-tactical characteristics studies were performed below the international standard. Although they did not reach consensus, five expert-based subthemes on match characteristics were identified (online supplemental table 8). The highest priority match characteristics subtheme (relationship between match characteristics and injury) achieved a median priority of 4.0, and 63% of experts agreed it was a high priority. Match characteristics may not be deemed a high research priority by experts as, overall, this theme accounts for a high percentage (21% of 123 included studies) of all studies included in this systematic scoping review.

Overall, this systematic scoping review and Delphi consensus highlights key future research priorities in applied sports science and sports medicine in women's rugby. Expert-based themes and subthemes that have achieved consensus represent high research priorities that have been agreed upon by a diverse range of international stakeholders (elite players, sports scientists, medical clinicians and sports administrators). Results from part 1 of this study highlight that some themes are under-researched (eg, female health, fatigue and recovery, nutrition, psychology). Due to the broad nature of scoping reviews and the aim of developing a consensus statement on future research priorities in mind, not all research gaps have been highlighted in this study. Additionally, combining rugby codes (ie, rugby sevens, rugby union and rugby league) may have impacted consensus as some expert-based themes (and subthemes) may be relevant to some but not all rugby codes. Furthermore, some expert-based themes (and subthemes) may be important to only specific expert groups (eg, players), which may explain why consensus was not reached (see online supplemental table 8). The (sub)themes that did not reach consensus may provide specific stakeholders with valuable information for further investigation. Finally, this systematic scoping review and Delphi consensus employed robust methodology by sampling several experts from various domains. Typically, athletes have not been included in the co-construction of sports science research.[19 22] Including elite players in our expert panel not only develops upon previous research[19 22] but also ensures findings are relevant to women's rugby players.[20] A wide range of international experts were included to ensure several opinions would be captured, thus enhancing the translational impact and benefit of the research.[17 18 21] Although there was a wide array of international experts included, recruitment of experts may have been limited by selection bias. Due to the limited time allotment (ie, 1 week) for experts to review the findings of part 1 (online supplemental tables 1–7) to inform expert-based research priorities, some expert-based research subthemes may be already appropriately covered by existing literature. Future research on applied sports science in women's rugby can use the data presented in this study to prioritise research topics and streamline projects to ensure the best use of scientific resources.

CONCLUSIONS

This systematic scoping review and Delphi consensus summarises the applied sports science and sports medicine in women's rugby evidence base and provides consensus on future research priorities. Part 1 of this study, the systematic scoping review, identified 123 studies investigating applied sports science and sports medicine in women's rugby (ie, rugby union, rugby sevens, rugby league). Most of the included studies (83%) were published in the last decade (table 1). Studies with rugby union or rugby sevens cohorts were the most common (n=83, 67%). Studies were categorised into six sports science and sports medicine evidence-based themes, namely injury, physical performance, match characteristics, fatigue and recovery, nutrition, and psychology. Summary tables of the systematic scoping review (online supplemental tables 1–7) provide valuable reference information for researchers and practitioners. In part 2 of this study, the Delphi consensus on future research priorities in women's rugby, international experts (elite players n=4, sport scientists n=11, medical clinicians n=9, sports administrators n=7) identified and achieved consensus on three expert-based themes, namely injury, female health and physical performance. The findings of this two-part study facilitate efficient and coordinated use of scientific resources towards high-priority themes. The findings of this systematic scoping review and Delphi consensus can be used to further develop the applied sports science and sports medicine support provided to women's rugby players. The results of this study have relevance to a wide range of stakeholders in women's rugby, including practitioners, players, researchers and governing bodies.

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REFERENCES

1 Quarrie KL, Handcock P, Waller AE, *et al*. The New Zealand rugby injury and performance project. III. anthropometric and physical performance characteristics of players. *Br J Sports Med* 1995;29:263–70.
2 Ball S, Halaki M, Orr R. Movement demands of rugby Sevens in men and women: a systematic review and meta-analysis. *J Strength Cond Res* 2019;33:3475–90.
3 Gabbett T, King T, Jenkins D. Applied physiology of rugby League. *Sports Med* 2008;38:119–38.
4 England Rugby. RFU Regulation 13 - Adult Competitions (Appendix 2); 2020.
5 Owen C, Till K, Weakley J, *et al*. Testing methods and physical qualities of male age grade rugby union players: a systematic review. *PLoS One* 2020;15:e0233796.
6 World Rugby. Laws of the game, 2021. Available: https://www.world.rugby/the-game/laws/definitions
7 International Rugby League. The International laws of the game and notes on the laws; 2021.
8 International Olympic Committee. Rugby: history of rugby at the Olympic Games; 2017.
9 British Broadcasting Corporation. World Rugby launches campaign to increase participation in women's game, 2019. Available: https://www.bbc.co.uk/sport/rugby-union/48348245
10 Rugby Football Union. England women announce contracts and squad, 2019. Available: https://www.englandrugby.com/news/england-women-contracts-red-roses-and-squad/
11 Rugby Football Union. History of the RFU, 2010. Available: https://web.archive.org/web/20100422210444/http://www.rfu.com/AboutTheRFU/History.aspx
12 King D, Hume P, Cummins C, *et al*. Match and Training Injuries in Women's Rugby Union: A Systematic Review of Published Studies. *Sports Med* 2019;49:1559–74.
13 Sella FS, McMaster DT, Beaven CM, *et al*. Match demands, anthropometric characteristics, and physical qualities of female rugby Sevens athletes: a systematic review. *J Strength Cond Res* 2019;33:3463–74.
14 Woodhouse LN, Tallent J, Patterson SD, *et al*. Elite international female rugby Union physical match demands: a five-year longitudinal analysis by position and opposition quality. *J Sci Med Sport* 2021;24:1173–9.
15 Brazier J, Antrobus M, Stebbings GK, *et al*. Anthropometric and physiological characteristics of elite male rugby athletes. *J Strength Cond Res* 2020;34:1790–801.
16 Tricco AC, Lillie E, Zarin W, *et al*. PRISMA extension for scoping reviews (PRISMA-ScR): checklist and explanation. *Ann Intern Med* 2018;169:467–73.
17 Sacristán JA, Aguarón A, Avendaño-Solá C, *et al*. Patient involvement in clinical research: why, when, and how. *Patient Prefer Adherence* 2016;10:631–40.
18 Boivin A, Currie K, Fervers B, *et al*. Patient and public involvement in clinical guidelines: international experiences and future perspectives. *Qual Saf Health Care* 2010;19:e22.
19 Malone JJ, Harper LD, Jones B, *et al*. Perspectives of applied collaborative sport science research within professional team sports. *Eur J Sport Sci* 2019;19:147–55.

20 Brett J, Staniszewska S, Mockford C, *et al*. Mapping the impact of patient and public involvement on health and social care research: a systematic review. *Health Expect* 2014;17:637–50.
21 Hendricks S. Rethinking innovation and the role of stakeholder engagement in sport and exercise medicine. *BMJ Open Sport Exerc Med* 2021;7:e001009.
22 Weissensteiner JR. The importance of listening: engaging and incorporating the athlete's voice in theory and practice. *Br J Sports Med* 2015;49:839–40.
23 McMillan SS, King M, Tully MP. How to use the nominal group and Delphi techniques. *Int J Clin Pharm* 2016;38:655–62.
24 Heyward O, Emmonds S, Roe G, *et al*. Applied sport science and medicine of women's rugby codes: a systematic-scoping review and consensus on future research priorities protocol. *BMJ Open Sport Exerc Med* 2021;7:e001108.
25 Page MJ, McKenzie JE, Bossuyt PM, *et al*. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ* 2021;372:n71.
26 Rethlefsen ML, Kirtley S, Waffenschmidt S, *et al*. PRISMA-S: an extension to the PRISMA statement for reporting literature searches in systematic reviews. *Syst Rev* 2021;10:39.
27 Shrier I. Consensus statements that fail to recognise dissent are flawed by design: a narrative review with 10 suggested improvements. *Br J Sports Med* 2021;55:545–9.
28 Diamond IR, Grant RC, Feldman BM, *et al*. Defining consensus: a systematic review recommends methodologic criteria for reporting of Delphi studies. *J Clin Epidemiol* 2014;67:401–9.
29 Jünger S, Payne SA, Brine J, *et al*. Guidance on conducting and reporting Delphi studies (CREDES) in palliative care: recommendations based on a methodological systematic review. *Palliat Med* 2017;31:684–706.
30 Elo S, Kyngäs H. The qualitative content analysis process. *J Adv Nurs* 2008;62:107–15.
31 Crowe M, Inder M, Porter R. Conducting qualitative research in mental health: thematic and content analyses. *Aust N Z J Psychiatry* 2015;49:616–23.
32 van der Horst N, Backx F, Goedhart EA, *et al*. Return to play after hamstring injuries in football (soccer): a worldwide Delphi procedure regarding definition, medical criteria and decision-making. *Br J Sports Med* 2017;51:1583–91.
33 Kleynen M, Braun SM, Bleijlevens MH, *et al*. Using a Delphi technique to seek consensus regarding definitions, descriptions and classification of terms related to implicit and explicit forms of motor learning. *PLoS One* 2014;9:e100227.
34 Verhagen AP, de Vet HC, de Bie RA, *et al*. The Delphi list: a criteria list for quality assessment of randomized clinical trials for conducting systematic reviews developed by Delphi consensus. *J Clin Epidemiol* 1998;51:1235–41.
35 Till K, Weakley J, Read DB, *et al*. Applied sport science for male Age-Grade rugby union in England. *Sports Med Open* 2020;6:p. 14.
36 Whitehead S, Weakley J, Cormack S, *et al*. The applied sports science and medicine of Netball: a systematic scoping review. *Sports Med* 2021;51:1715–31.
37 Armstrong R, Greig M. The functional movement screen and modified StAR excursion balance test as predictors of t-test agility performance in University rugby Union and netball players. *Phys Ther Sport* 2018;31:15–21.
38 Okholm Kryger K, Wang A, Mehta R. Research on women's football: a scoping review. *Sci Med Footb* 2021:1–10.
39 McNulty KL, Elliott-Sale KJ, Dolan E, *et al*. The effects of menstrual cycle phase on exercise performance in eumenorrheic women: a systematic review and meta-analysis. *Sports Med* 2020;50:1813–27.
40 Vergouw D, Heymans MW, de Vet HCW, *et al*. Prediction of persistent shoulder pain in general practice: comparing clinical consensus from a Delphi procedure with a statistical scoring system. *BMC Fam Pract* 2011;12:1–10.
41 Delbecq A, de VAV, Gustafson D. *Group techniques for program planning: a guide to nominal group and Delphi processes*, 1975.
42 Kemper EA, Springfield S, Teddlie C. Mixed methods sampling strategies in social science research. *Handb Mix Methods Soc Behav Res* 2003:273–96.
43 Palinkas LA, Horwitz SM, Green CA, *et al*. Purposeful sampling for qualitative data collection and analysis in mixed method implementation research. *Adm Policy Ment Health* 2015;42:533–44.
44 Zambaldi M, Beasley I, Rushton A. Return to play criteria after hamstring muscle injury in professional football: a Delphi consensus study. *Br J Sports Med* 2017;51:1221–6.
45 Clarke AC, Anson JM, Pyne DB. Neuromuscular fatigue and muscle damage after a women's rugby Sevens tournament. *Int J Sports Physiol Perform* 2015;10:808–14.
46 Clarke A, Anson J, Pyne D. The effect of running demands and impacts on post-tournament markers of inflammation and haemolysis in women's rugby sevens. *New Zeal J Sport Med* 2015;42.
47 González Fernández Álvaro, de la Rubia Ortí JE, Franco-Martinez L, *et al*. Changes in salivary levels of creatine kinase, lactate dehydrogenase, and aspartate aminotransferase after playing rugby sevens: the influence of gender. *Int J Environ Res Public Health* 2020;17:1–10.
48 Swinbourne R, Gill N, Vaile J, *et al*. Prevalence of poor sleep quality, sleepiness and obstructive sleep apnoea risk factors in athletes. *Eur J Sport Sci* 2016;16:850–8.
49 Henderson MJ, Chrismas BCR, Stevens CJ, *et al*. Changes in core temperature during an elite female rugby Sevens tournament. *Int J Sports Physiol Perform* 2020:571–80.
50 Doeven SH, Brink MS, Huijgen BCH, *et al*. High match load's relation to decreased well-being during an elite women's rugby Sevens tournament. *Int J Sports Physiol Perform* 2019;14:1036–42.
51 Alsop JC, Chalmers DJ, Williams SM, *et al*. Temporal patterns of injury during a rugby season. *J Sci Med Sport* 2000;3:97–109.
52 Lopez V, Galano GJ, Black CM, *et al*. Profile of an American amateur rugby Union sevens series. *Am J Sports Med* 2012;40:179–84.
53 King D, Hume PA, Clark T, *et al*. Training injury incidence in an amateur women's rugby Union team in New Zealand over two consecutive seasons. *J Sci Med Sport* 2021;24:544-548.
54 Collins CL, Micheli LJ, Yard EE, *et al*. Injuries sustained by high school rugby players in the United States, 2005-2006. *Arch Pediatr Adolesc Med* 2008;162:49–54.
55 Orr R, Hamidi J, Levy B, *et al*. Epidemiology of injuries in Australian junior rugby League players. *J Sci Med Sport* 2021;24:241-246.
56 Lopez V, Ma R, Weinstein MG, *et al*. United States Under-19 Rugby-7s: incidence and nature of match injuries during a 5-year epidemiological study. *Sports Med Open* 2020;6:41.
57 Carson JD, Roberts MA, White AL. The epidemiology of Women`s rugby injuries. *Clinical Journal of Sport Medicine* 1999;9:75–8.
58 Laoruengthana A, Poosamsai P, Fangsanau T, *et al*. The epidemiology of sports injury during the 37th Thailand national games 2008 in Phitsanulok. *J Med Assoc Thai* 2009;92 Suppl 6:S204–10.
59 Havkins SB. Head, neck, face, and shoulder injuries in female and male rugby players. *Phys Sportsmed* 1986;14:111–8.
60 Levy AS, Wetzler MJ, Lewars M, *et al*. Knee injuries in women collegiate rugby players. *Am J Sports Med* 1997;25:360–2.
61 Peck KY, Johnston DA, Owens BD, *et al*. The incidence of injury among male and female intercollegiate rugby players. *Sports Health* 2013;5:327–33.
62 Schildknecht S, Krastl G, Kühl S, *et al*. Dental injury and its prevention in Swiss rugby. *Dent Traumatol* 2012;28:465–9.
63 Toohey LA, Drew MK, Finch CF, *et al*. A 2-year prospective study of injury epidemiology in elite Australian rugby Sevens: exploration of incidence rates, severity, injury type, and subsequent injury in men and women. *Am J Sports Med* 2019;47:1302–11.
64 Schick DM, Molloy MG, Wiley JP. Injuries during the 2006 women's rugby world cup. *Br J Sports Med* 2008;42:447–51.
65 Fuller CW, Taylor A, Raftery M. 2016 Rio Olympics: an epidemiological study of the men's and women's Rugby-7s tournaments. *Br J Sports Med* 2017;51:1272–8.
66 Steffen K, Soligard T, Mountjoy M, *et al*. How do the new Olympic sports compare with the traditional Olympic sports? injury and illness at the 2018 youth Olympic summer games in Buenos Aires, Argentina. *Br J Sports Med* 2020;54:168–75.
67 Taylor AE, Fuller CW, Molloy MG. Injury surveillance during the 2010 IRB women's rugby world cup. *Br J Sports Med* 2011;45:1243–5.
68 Fuller CW, Taylor A. Eight-season epidemiological study of match injuries in women's international rugby sevens. *J Sports Sci* 2021;39:865–74.
69 Bohu Y, Klouche S, Lefevre N, *et al*. The epidemiology of 1345 shoulder dislocations and subluxations in French rugby union players: a five-season prospective study from 2008 to 2013. *Br J Sports Med* 2015;49:1535–40.
70 Bird YN, Waller AE, Marshall SW, *et al*. The New Zealand rugby injury and performance project: V. epidemiology of a season of rugby injury. *Br J Sports Med* 1998;32:319–25.
71 Lopez V, Ma R, Weinstein MG, *et al*. Concussive injuries in rugby 7S: an American experience and current review. *Med Sci Sports Exerc* 2016;48:1320–30.
72 Ma R, Lopez V, Weinstein MG, *et al*. Injury profile of American women's Rugby-7s. *Med Sci Sports Exerc* 2016;48:1957–66.

73 Gerrard DF, Waller AE, Bird YN. The New Zealand rugby injury and performance project: II. previous injury experience of a rugby-playing cohort. *Br J Sports Med* 1994;28:229–33.
74 Underhill J, Dostaler SM, Brison RJ, *et al*. Rugby injury in Kingston, Canada: a ten-year study. *Chronic Dis Can* 2007;27:163–70.
75 King DA, Hume PA, Milburn P, *et al*. Women's rugby League injury claims and costs in New Zealand. *Br J Sports Med* 2010;44:1016–23.
76 King D, Gissane C, Brughelli M, *et al*. Sport-Related concussions in New Zealand: a review of 10 years of accident compensation Corporation moderate to severe claims and costs. *J Sci Med Sport* 2014;17:250–5.
77 King D, Hume PA, Hardaker N, *et al*. Female rugby Union injuries in New Zealand: a review of five years (2013-2017) of accident compensation Corporation moderate to severe claims and costs. *J Sci Med Sport* 2019;22:532–7.
78 Quarrie K, Gianotti S, Murphy I. Injury risk in New Zealand rugby Union: a nationwide study of injury insurance claims from 2005 to 2017. *Sports Med* 2020;50:415–28.
79 Wood AM, Robertson GA, Rennie L, *et al*. The epidemiology of sports-related fractures in adolescents. *Injury* 2010;41:834–8.
80 Robertson GAJ, Wood AM, Heil K, *et al*. The epidemiology, morbidity and outcome of fractures in rugby Union from a standard population. *Injury* 2014;45:677–83.
81 Yard EE, Comstock RD. Injuries sustained by rugby players presenting to United States emergency departments, 1978 through 2004. *J Athl Train* 2006;41:325–31.
82 Sabesan V, Steffes Z, Lombardo DJ, *et al*. Epidemiology and location of rugby injuries treated in US emergency departments from 2004 to 2013. *Open Access J Sports Med* 2016;7:135–42.
83 Fuller CW, Molloy MG, Bagate C, *et al*. Consensus statement on injury definitions and data collection procedures for studies of injuries in rugby Union. *Br J Sports Med* 2007;41:328–31.
84 Tucker R, Falvey E, Fuller G, *et al*. Baseline SCAT performance in men and women: comparison of baseline concussion screens between 6288 elite men's and 764 women's rugby players. *Clin J Sport Med* 2021;31:e398–405.
85 Lopez V, Ma R, Weinstein MG, *et al*. An American experience with a new Olympic collision sport: rugby Sevens. *Orthop J Sports Med* 2014;2:2325967114S0005.
86 Yeomans C, Comyns TM, Cahalan R, *et al*. The relationship between physical and wellness measures and injury in amateur rugby union players. *Phys Ther Sport* 2019;40:59–65.
87 King DA, Hume PA, Clark TN, *et al*. Use of the King-Devick test for the identification of concussion in an amateur domestic women's rugby union team over two competition seasons in New Zealand. *J Neurol Sci* 2020;418:117162.
88 Hunzinger KJ, Costantini KM, Swanik CB, *et al*. Diagnosed concussion is associated with increased risk for lower extremity injury in community rugby players. *J Sci Med Sport* 2021;24:368-372.
89 Black AM, Miutz LN, Kv VW, *et al*. Baseline performance of high school rugby players on the sport concussion assessment tool 5. *J Athl Train* 2020;55:116–23.
90 Leahy TM, Kenny IC, Campbell MJ, *et al*. Injury surveillance and prevention practices across rugby schools in Ireland. *Phys Ther Sport* 2020;43:134–42.
91 Bussey MD, McLean M, Pinfold J, *et al*. History of concussion is associated with higher head acceleration and reduced cervical muscle activity during simulated rugby tackle: an exploratory study. *Phys Ther Sport* 2019;37:105–12.
92 Mirsafaei Rizi R, Yeung SS, Stewart NJ, *et al*. Risk factors that predict severe injuries in University rugby sevens players. *J Sci Med Sport* 2017;20:648–52.
93 Armstrong R, Greig M. Injury identification: the efficacy of the functional movement SCREEN™ in female and male rugby union players. *Int J Sports Phys Ther* 2018;13:605–17.
94 Black SE, Follmer B, Mezzarane RA, *et al*. Exposure to impacts across a competitive rugby season impairs balance and neuromuscular function in female rugby athletes. *BMJ Open Sport Exerc Med* 2020;6:e000740.
95 Lévesque J, Rivaz H, Rizk A, *et al*. Lumbar multifidus muscle characteristics, body composition, and injury in University rugby players. *J Athl Train* 2020;55:1116–23.
96 Brisbine BR, Steele JR, Phillips E, *et al*. Breast injuries reported by female contact football players based on football code, player position and competition level. *Sci Med Footb* 2020;4:148–55.
97 Chermann JF, Klouche S, Savigny A, *et al*. Return to rugby after brain concussion: a prospective study in 35 high level rugby players. *Asian J Sports Med* 2014;5:e24042.
98 Marshall SW, Waller AE, Loomis DP, *et al*. Use of protective equipment in a cohort of rugby players. *Med Sci Sports Exerc* 2001;33:2131–8.
99 Comstock RD, Fields SK, Knox CL. Protective equipment use among female rugby players. *Clin J Sport Med* 2005;15:241–5.
100 Comstock RD, Fields SK. The fair sex? Foul play among female rugby players. *J Sci Med Sport* 2005;8:101–10.
101 Clarke AC, Anson JM, Pyne DB. Proof of concept of automated collision detection technology in rugby Sevens. *J Strength Cond Res* 2017;31:1116–20.
102 Griffin JA, McLellan CP, Presland J, *et al*. Quantifying the movement patterns of international women's rugby sevens preparation training camp sessions. *Int J Sports Sci Coach* 2017;12:677–84.
103 Quinn K, Newans T, Buxton S, *et al*. Movement patterns of players in the Australian women's rugby League team during international competition. *J Sci Med Sport* 2020;23:315–9.
104 Goodale TL, Gabbett TJ, Tsai M-C, *et al*. The effect of contextual factors on physiological and activity profiles in international women's rugby Sevens. *Int J Sports Physiol Perform* 2017;12:370–6.
105 Malone S, Earls M, Shovlin A, *et al*. Match-Play running performance and exercise intensity in elite international women's rugby Sevens. *J Strength Cond Res* 2020;34:1741–9.
106 Reyneke J, Hansen K, Cronin JB, *et al*. An investigation into the influence of score differential on the physical demands of international women's rugby sevens match play. *Int J Perform Anal Sport* 2018;18:523–31.
107 Suarez-Arrones L, Nuñez FJ, Portillo J, *et al*. Match running performance and exercise intensity in elite female rugby Sevens. *J Strength Cond Res* 2012;26:1858–62.
108 Del Coso J, Portillo J, Muñoz G, *et al*. Caffeine-containing energy drink improves sprint performance during an international rugby sevens competition. *Amino Acids* 2013;44:1511–9.
109 Suarez-Arrones L, Portillo J, Pareja-Blanco F, *et al*. Match-play activity profile in elite women's rugby union players. *J Strength Cond Res* 2014;28:452–8.
110 Sheppy E, Hills SP, Russell M, *et al*. Assessing the whole-match and worst-case scenario locomotor demands of international women's rugby Union match-play. *J Sci Med Sport* 2020;23:609–14.
111 Cummins C, Charlton G, Naughton M, *et al*. The validity of automated tackle detection in women's rugby League. *J Strength Cond Res* 2022;36:1951–5.
112 Misseldine ND, Blagrove RC, Goodwin JE. Speed demands of women's rugby Sevens match play. *J Strength Cond Res* 2021;35:183–9.
113 Busbridge AR, Hamlin MJ, Jowsey JA, *et al*. Running demands of provincial women's rugby Union matches in New Zealand. *J Strength Cond Res* 2022;36:1059–63.
114 Langevin TL, Antonoff D, Renodin C. Head impact exposures in women's collegiate rugby. *Phys Sportsmed* 2020:1–6.
115 King DA, Hume PA, Gissane C, *et al*. Head impact exposure from match participation in women's rugby League over one season of domestic competition. *J Sci Med Sport* 2018;21:139–46.
116 Bradley EJ, Board L, Hogg B, *et al*. Quantification of movement characteristics in women's English premier elite domestic rugby Union. *J Hum Kinet* 2020;72:185–94.
117 Virr JL, Game A, Bell GJ, *et al*. Physiological demands of women's rugby Union: time-motion analysis and heart rate response. *J Sports Sci* 2014;32:239–47.
118 Clarke AC, Anson JM, Pyne DB. Game movement demands and physical profiles of junior, senior and elite male and female rugby sevens players. *J Sports Sci* 2017;35:727–33.
119 Vescovi JD, Goodale T. Physical demands of women's rugby Sevens matches: female athletes in motion (FAiM) study. *Int J Sports Med* 2015;36:887–92.
120 Portillo J, González-Ravé JM, Juárez D, *et al*. Comparison of running characteristics and heart rate response of international and national female rugby sevens players during competitive matches. *J Strength Cond Res* 2014;28:2281–9.
121 Emmonds S, Weaving D, Dalton-Barron N. Locomotor characteristics of the women's inaugural super league competition and the rugby league world cup. *J Sports Sci* 2020:1–8.
122 Barkell JF, O'Connor D, Cotton WG. Situational coupling at the ruck and its effects on phase momentum and success in international men's and women's rugby sevens. *Jhse* 2017;12:294–306.
123 Barkell JF, O'Connor D, Cotton WG. Effective strategies at the ruck in men's and women's World Rugby Sevens Series. *Int J Sports Sci Coach* 2018;13:225–35.
124 Barkell FJ, O'connor D, Cotton GW. Characteristics of winning men's and women's sevens rugby teams throughout the knockout

Cup stages of international tournaments. *Int J Perform Anal Sport* 2016;16:633–51.
125 Portillo J, Del Coso J, Abián-Vicén J. Effects of caffeine ingestion on skill performance during an international female rugby Sevens competition. *J Strength Cond Res* 2017;31:3351–7.
126 Hughes A, Barnes A, Churchill SM, *et al*. Performance indicators that discriminate winning and losing in elite men's and women's Rugby Union. *Int J Perform Anal Sport* 2017;17:534–44.
127 Clarke AC, Anson JM, Dziedzic CE, *et al*. Iron monitoring of male and female rugby sevens players over an international season. *J Sports Med Phys Fitness* 2018;58:1490–6.
128 Todd J, Madigan S, Pourshahidi K, *et al*. Vitamin D status and supplementation practices in elite Irish athletes: an update from 2010/2011. *Nutrients* 2016;8. doi:10.3390/nu8080485. [Epub ahead of print: 09 Aug 2016].
129 Smith S, Sims ST, Thorpe H, *et al*. Hepcidin and iron: novel findings for elite female rugby Sevens players. *J Sports Med Phys Fitness* 2020;60:289–93.
130 Jones B, Till K, King R, *et al*. Are habitual hydration strategies of female rugby League players sufficient to maintain fluid balance and blood sodium concentration during training and Match-Play? A research note from the field. *J Strength Cond Res* 2016;30:875–80.
131 Muth T, Pritchett R, Pritchett K, *et al*. Hydration status and perception of fluid loss in male and female university rugby union players. *Int J Exerc Sci* 2019;12:859–70.
132 Sánchez-Oliver AJ, Domínguez R, López-Tapia P. A survey on dietary supplement consumption in amateur and professional rugby players. *Foods* 2021;10.
133 Egan E, Reilly T, Giacomoni M, *et al*. Bone mineral density among female sports participants. *Bone* 2006;38:227–33.
134 Harty PS, Zabriskie HA, Stecker RA, *et al*. Position-Specific body composition values in female collegiate rugby Union athletes. *J Strength Cond Res* 2021;35:3158–63.
135 Posthumus L, Macgregor C, Winwood P, *et al*. The physical characteristics of elite female rugby union players. *Int J Environ Res Public Health* 2020;17:6457–10.
136 Tucker R, Lancaster S, Davies P, *et al*. Trends in player body mass at men's and women's Rugby World Cups: a plateau in body mass and differences in emerging rugby nations. *BMJ Open Sport Exerc Med* 2021;7:e000885.
137 Abuín-Porras V, de la Cueva-Reguera M, Benavides-Morales P, *et al*. Comparison of the abdominal wall muscle thickness in female rugby players versus non-athletic women: a cross-sectional study. *Medicina* 2019;56. doi:10.3390/medicina56010008. [Epub ahead of print: 25 Dec 2019].
138 Ali Kerim Y, Menderes K, Hakan MM. Analysis of Q angle values of female athletes from different branches. *Ovidius Univ Ann Ser Phys Educ Sport Mov Heal* 2017;2:141–6.
139 Harty PS, Zabriskie HA, Stecker RA, *et al*. Upper and lower thresholds of fat-free mass index in a large cohort of female collegiate athletes. *J Sports Sci* 2019;37:2381–8.
140 Girard O, Racinais S, Couderc A, *et al*. Asymmetries during repeated treadmill sprints in elite female rugby Sevens players. *Sports Biomech* 2020:1–11.
141 Escobar Álvarez JA, Jiménez-Reyes P, da Conceição FA, *et al*. Does the initial level of horizontal force determine the magnitude of improvement in acceleration performance in rugby? *Eur J Sport Sci* 2021;21:1–9.
142 Preatoni E, Stokes KA, England ME, *et al*. The influence of playing level on the biomechanical demands experienced by rugby Union forwards during machine scrummaging. *Scand J Med Sci Sports* 2013;23:e178–84.
143 Hene NM, Bassett SH, Andrews BS. Physical fitness profiles of elite women's rugby union players. *African J Phys Heal Educ Recreat Danc* 2011:1–8.
144 Lockie RG, Orjalo AJ, Amran VL, *et al*. An introductory analysis as to the influence of lower-body power on multidirectional speed in collegiate female rugby players. *Sport Sci Rev* 2016;25:113–34.
145 Lockie R. Change-of-Direction Deficit in Collegiate Women'S Rugby Union Players. / Slabo Razvijena Sposobnost Za Promenu Pravca Na Primeru Studentkinja Učesnica Univerzitetske Ragbi Lige. *Facta Univ Ser Phys Educ Sport* 2018;16:19–31.
146 Townsend MB, Sauers RJ, Weiss CB. Fitness evaluation: physical fitness evaluation of elite women rugby athletes. *Natl Strength Cond Assoc J* 1992;14:42–5.
147 Walsh M, Young B, Hill B, *et al*. The effect of ball-carrying technique and experience on sprinting in rugby Union. *J Sports Sci* 2007;25:185–92.
148 Agar-Newman DJ, Goodale TL, Klimstra MD. Anthropometric and physical qualities of international level female rugby sevens athletes based on playing position. *J Strength Cond Res* 2017;31:1346–52.
149 Freitas TT, Alcaraz PE, Calleja-González J, *et al*. Differences in change of direction speed and deficit between male and female national rugby Sevens players. *J Strength Cond Res* 2021;35:3170–6.
150 Goodale TL, Gabbett TJ, Stellingwerff T, *et al*. Relationship between physical qualities and minutes played in international women's rugby Sevens. *Int J Sports Physiol Perform* 2016;11:489–94.
151 Alonso-Aubin DA, Chulvi-Medrano I, Cortell-Tormo JM, *et al*. Squat and bench press force-velocity profiling in male and female adolescent rugby players. *J Strength Cond Res* 2021;35:S44–50.
152 Jones B, Emmonds S, Hind K, *et al*. Physical qualities of international female rugby League players by playing position. *J Strength Cond Res* 2016;30:1333–40.
153 Agar-Newman DJ, Klimstra MD. Efficacy of horizontal jumping tasks as a method for talent identification of female rugby players. *J Strength Cond Res* 2015;29:737–43.
154 Sedlock DA, Fitzgerald PI, Knowlton RG. Body composition and performance characteristics of collegiate women rugby players. *Res Q Exerc Sport* 1988;59:78–82.
155 Clarke AC, Presland J, Rattray B, *et al*. Critical velocity as a measure of aerobic fitness in women's rugby sevens. *J Sci Med Sport* 2014;17:144–8.
156 Clarke AC, Anson J, Pyne D. Physiologically based GPS speed zones for evaluating running demands in women's rugby Sevens. *J Sports Sci* 2015;33:1101–8.
157 Valenzuela PL, Montalvo Z, Sánchez-Martínez G, *et al*. Relationship between skeletal muscle contractile properties and power production capacity in female Olympic rugby players. *Eur J Sport Sci* 2018;18:677–84.
158 Sandwith E, Robert M. Rug-pee study: the prevalence of urinary incontinence among female university rugby players. *Int Urogynecol J* 2021;32:281–5.
159 O'Neill JERG, Walsh CS, McNulty SJ, *et al*. Resting metabolic rate in female rugby players: differences in measured versus predicted values. *J Strength Cond Res* 2022;36:845–50.
160 Findlay RJ, Macrae EHR, Whyte IY, *et al*. How the menstrual cycle and menstruation affect sporting performance: experiences and perceptions of elite female rugby players. *Br J Sports Med* 2020;54:1108–13.
161 Brun J-F, Varlet-Marie E, Cassan D, *et al*. Blood rheology and body composition as determinants of exercise performance in female rugby players. *Clin Hemorheol Microcirc* 2011;49:207–14.
162 Gathercole R, Sporer B, Stellingwerff T. Countermovement jump performance with increased training loads in elite female rugby athletes. *Int J Sports Med* 2015;36:722–8.
163 Heyward O, Nicholson B, Emmonds S, *et al*. Physical preparation in female rugby codes: an investigation of current practices. *Front Sports Act Living* 2020;2:584194.
164 Kerr JH. The multifaceted nature of participation motivation in elite Canadian women rugby union players. *Int J Sport Exerc Psychol* 2021;19:74–89.
165 Madrigal L, Wurst K, Gill DL. The role of mental Toughness in coping and injury response in female roller Derby and rugby athletes. *J Clin Sport Psychol* 2016;10:137–54.
166 Pope JP, Wilson PM. Testing a sequence of relationships from interpersonal coaching styles to rugby performance, guided by the coach–athlete motivation model. *Int J Sport Exerc Psychol* 2015;13:258–72.
167 Gherghişan A-I. The analysis of early maladaptive schemas which facilitate high performance in women Handball and rugby players. *Sport Sci Rev* 2015;24:145–69.
168 Pfaff LM, Cinelli ME. The effects of sport specific training of rugby players on avoidance behaviours during a head-on collision course with an approaching person. *Hum Mov Sci* 2018;62:105–15.
169 Mokkink LB, Terwee CB, Patrick DL, *et al*. The COSMIN checklist for assessing the methodological quality of studies on measurement properties of health status measurement instruments: an international Delphi study. *Qual Life Res* 2010;19:539–49.
170 Henri F. Computer Conferencing and content analysis. *Collab Learn Through Comput Conf* 1992:117–36.
171 MTH C. Quantifying qualitative analyses of verbal data: a practical guide. *J Learn Sci* 1997;6:271–315.
172 West SW, Starling L, Kemp S, *et al*. Trends in match injury risk in professional male rugby Union: a 16-season review of 10 851 match injuries in the English Premiership (2002-2019): the professional rugby injury surveillance project. *Br J Sports Med* 2021;55:676–82.
173 King DA, Hume PA, Milburn PD, *et al*. Match and training injuries in rugby League: a review of published studies. *Sports Med* 2010;40:163–78.

174 Elliott-Sale KJ, McNulty KL, Ansdell P, *et al*. The effects of oral contraceptives on exercise performance in women: a systematic review and meta-analysis. *Sports Med* 2020;50:1785–812.
175 Randell RK, Clifford T, Drust B, *et al*. Physiological characteristics of female soccer players and health and performance considerations: a narrative review. *Sports Med* 2021;51:1377–99.
176 Tavares F, Smith TB, Driller M. Fatigue and recovery in rugby: a review. *Sports Med* 2017;47:1515–30.
177 Hill A, MacNamara Áine, Collins D. Psychobehaviorally based features of effective talent development in rugby union: A coach's perspective. *Sport Psychol* 2015;29:201–12.
178 Calleja-González J, Mielgo-Ayuso J, Ostojic SM, *et al*. Evidence-Based post-exercise recovery strategies in rugby: a narrative review. *Phys Sportsmed* 2019;47:137–47.
179 Kelly VG, Oliver LS, Bowtell J, *et al*. Inside the belly of a beast: Individualizing nutrition for young, professional male rugby League players: a review. *Int J Sport Nutr Exerc Metab* 2021;31:73–89.

Supplementary Table 1. Rugby code, participant characteristics, aims, outcome measures and key findings of studies within 'Fatigue and Recovery' evidence-based theme (n=6)

Study	Rugby Code	*Cohort, sample size (n)	*Participant characteristics: age (yrs), height (cm), body mass (kg)	Study aims	Study outcome measures	Key findings
[45]	Sevens	State (n=10) and national (n=12)	State: 24 ± 4 yrs, 167 ± 3 cm, 66 ± 8 kg National: 22 ± 3 yrs, 167 ± 4 cm, 66 ± 5 kg	To examine relationships between on-field movement patterns and changes in markers of neuromuscular fatigue and muscle damage during a 2-day tournament.	Perceptual (self-reported soreness and recovery), muscle damage (CK) and neuromuscular (CMJ) responses. GPS (SPI HPU) derived external match load: duration, distance, relative distance, and distance covered in various speed zones and total impacts in various zones.	National players had greater on-field movements for total time, distance, high-speed running, and impacts (ES = 0.55–0.97) and displayed a smaller decrement in performance from day 1 to day 2. State players had a 4-fold increase in CK compared with the 2-fold increase in national players (ES = 0.73). Both groups had similar perceived soreness and recovery while CMJ was unchanged. High-speed running and impacts >10 g were largely correlated (r = .66–.91) with ΔCK for both groups.
[46]	Sevens	State (n=10) and national (n=12)	State: 24 ± 4 yrs, 167 ± 3 cm, 66 ± 8 kg National: 22 ± 3 yrs, 167 ± 4 cm, 66 ± 5 kg	To quantify the short-term changes in biochemical and haematological variables of inflammation and haemolysis induced by a 2-day tournament and explore the relationship between on-field movement patterns and select biomarkers.	Biochemical and haematological variables. GPS (SPI HPU) derived external match load: playing time, TD, distance covered at high speed, total number of impacts and impacts >10 g.	National players completed greater on-field movements (ES = 0.55–0.97), post-tournament leukocyte count increased similarly (30-50%) in both groups (ES = 1.52-1.95). Neutrophil count positively correlated (r = 0.57–0.89) with all on-field movements for both groups. Haptoglobin were 94% higher at baseline in national players (ES = 1.33) but declined ~20-40% in both groups. CK increased 4-fold in state players, and 2.5-fold in national players (ES =2.86–4.10).
[50]	Sevens	Elite (n=12)	25 ± 4 yrs, 169 ± 4 cm, 64 ± 5 kg	To determine time courses of wellbeing, TQR and neuromuscular performance within and after an elite women's rugby sevens tournament and to assess the influence of match load indicators.	Wellbeing (self-reported wellbeing and recovery), neuromuscular (CMJ). Internal (sRPE) and external (GPS derived [JOHAN Sports]: TD and TD covered during various running intensities; video-based notational analysis derived number of physical contacts)	Wellbeing, fatigue, general muscle soreness, stress levels, mood and TQR were significantly (p≤0.005) impaired after match day 1 and did not return to baseline values until day plus two. Greater high-intensity running was related to more fatigue (r=-.60; p=.049) and a larger number of physical contacts with more general muscle soreness (r=-.69; p=.013).
[185]	Sevens	University (n=13)	22 ± 2 yrs, 162 ± 5 cm, 65 ± 5 kg	Establish the release dynamics of the muscle damage markers of the enzymes CK, LDH, and AST	Salivary CK, LDH and AST	CK and LDH did not change after match play. AST increased after match 3 (13.4 vs. 21.1; p < 0.05).
[49]	Sevens	International (n=12)	23 yrs, 169 cm, 68 kg	To characterize player core temperature across a World Rugby Women's Sevens Series tournament day and determine the efficacy of commonly employed CWI protocols.	Tc, symptoms of exertional heat illness, perceptual scales, CWI details. GPS (EVO, GPSports) derived external load: playing minutes, average speed, high-speed running, average accelerations and decelerations	Average Tc was *very likely* lower (ES = -0.33) in game 1 than in game 2. Peak Tc was *very likely* (ES = 0.71) associated with increased playing time. CWI did not remove the accumulated Tc due to warm-up and match play activity (~1°C–2°C rise in Tc still present compared with Tc at warm-up onset for players ≥6-min match play).
[48]	Sevens	National (n=20)	24 ± 3 yrs, 170 ± 6 cm, 72 ± 10 kg	To characterise sleep quality among team sport athletes; explore sleep-associated issues; compare sleep quality between groups, and early versus daytime and evening trainers; evaluate relationship between validated sleep quality and perceived sleep quality, quality of life and daytime sleepiness.	Pittsburgh sleep quality index, Epworth sleepiness scale score, quality of life questionnaires and an OSA risk factor screen	Epworth sleepiness scale score = 9.0 ± 4.2 (a score of >10 indicates excessive daytime sleepiness), Pittsburgh sleep quality index = 8.2 ± 3.3 (a score >5 is associated with poor sleep quality). It appears women's sevens players suffer poor sleep quality, with associated high levels of daytime sleepiness.

*Cohort, sample size and participant characteristics for women's rugby athletes only. AST = aspartate aminotransferase; CK = creatine kinase; CMJ = countermovement jump; CWI = cold water immersion; ES = effect size; GPS = global positioning systems; LDH = lactate dehydrogenase; OSA = obstructive sleep apnoea; sRPE = session ratings of perceived exertion; Tc = core temperature; TD = total distance; TQR = total quality of recovery

Supplementary Table 2. Rugby code, participant and study characteristics, and key findings of studies within epidemiology focussed 'injury' evidence-based theme (n=32)

Study	Rugby Code	*Cohort, sample size (n)	Time course	Injury definition	Key findings
[51]	Union	Amateur (n=87)	1 season	Rugby-related injuries experienced in past week that either required medical attention or caused the player to miss at least one scheduled match or practice	Decrease in injury rate for females across the season (p=0.024) with an average decrease of 6.1% per week Female injury rate was generally lower than in males.
[70]	Union	Women (n=64) and schoolgirl (n=23)	1 season	All injury events that caused the player to seek medical attention or to miss at least one scheduled game or team practice	Games per person: women = 11.6, schoolgirls = 5.6 Game injuries per 100 player-games: women = 6.4, schoolgirls = 4.7 Practices per person: women = 19.6, schoolgirls = 7.3 Practice injuries per 100 player-games: women = 0.7, schoolgirls = 0 Inside backs had the highest game (12.3 per 100 player-games) and practice (1.5 per 100 player-practices) injury rate.
[69]	Union	Senior professionals, amateurs, juniors, cadets and school players (n=54340)	5 yrs	NR	28 women suffered an episode of dislocation/subluxation. ~5/10 000 women reported an episode of shoulder dislocation/subluxation per season
[57]	NR	Provincial (n=40)	1 season and 1 tournament	A rugby-related event that kept a player out of practice or competition for >24 hours or required the attention of a physician (e.g., suturing lacerations) and in addition included all dental, eye, and nerve injuries and concussions	35 injuries in 4958 player-hours and 2926 athletic exposures resulting in a rugby injury rate of 7.1 ± 0.4 per 1000 player-hours and 12.0 ± 2 per 1000 athletic exposures. 16 injuries occurred to the lower extremity, 9 to trunk and shoulders, 8 head and neck and 2 upper extremity
[54]	Union	High school (n=77)	2 seasons	An injury that occurred as a result of participation in an organized high school rugby match or practice; required medical attention; and resulted in restriction of the high school rugby player's participation in regular school or rugby activities for 1 or more days beyond the day of injury	Girls injury rate = 4.1 injuries per 1000 total rugby athletic exposures The most commonly injured body sites for girls were the head (22.1%), ankle (13.2%), and shoulder (13.2%), with common diagnoses of fracture (16.8%), concussion (16.1%) and ligament sprain (14.9%). The mechanism of girls' injuries were impact with another player (51.8%) or impact with surface or ground (24.4%), with the activity mostly being tackled (31.1%) or tackling (28.2%). Time loss from girls' injuries was typically <10 days (45.1%).
[65]	Sevens	2014-15 SWS (n=197), 2015-16 SWS (n=221), 2016 Olympic (n=148)	12 tournaments over 3 yrs	Any injury sustained during the period of a Rugby-7s tournament (match or training session) that prevents a player from taking a full part in all training activities and/or match play for more than one day following the day of injury	Match injuries: 2014-15 SWS = 58, 2015-16 SWS = 56, 2016 Rio Olympics = 8 Player-match hour exposures: 2014-15 SWS = 655.2, 2015-16 SWS = 511.7, 2016 Rio Olympics = 8
[68]	Sevens	International (n=1562)	36 tournaments over 8 seasons	Any physical complaint sustained by a player during a SWS match that prevented the player from taking a full part in all training activities or match play for more than 1 day following the day of injury, irrespective of whether a match or training session was actually scheduled	Overall player-match-hour exposure = 3938 hrs Overall injury incidence = 105.6 injuries/1000 player-match-hours Overall mean severity = 53.4 days
[73]	Union	Senior and Schoolgirl (n=92)	1 yr	Any injury that required medical treatment of caused the player to miss at least one scheduled game or team practice.	59.6% of female players reported at least one injury during the 1992 season

[59]	Union	Collegiate (n=75)	1 season	Any physical damage suffered by a player	Overall injury rates = 68 and per 100 women players Disabling injuries rates = 12 per 100 women players Females sustained 14 injuries to the head, 8 to the neck, 7 to the eye and 7 to the nose
[75]	League	Rugby league ACC claimants	8 yrs	NR	320 moderate-to-serious injury claims 37.9±9.5 injury claims per year The lower limb accounted for 65% of the total female injury claims Concussion/brain injuries accounted for 3.8% of total female moderate to serious injury claims The 25–29 age group recorded 31.9% of injury claims
[76]	Union and League	Rugby league and union ACC claimants	10 yrs	Any injury that had been assessed and reported by a registered health practitioner as a result of sports participation. The injury had to have been classified and recorded as a concussion utilizing the ACC read code	Female rugby union players were responsible for an average of 3.3 per 1000 moderate-to-severe claims Female rugby league player were responsible for 0.6 per 1000 moderate-to-severe claims
[77]	Union	Rugby union ACC claimants	5 yrs	Any injury (minor, moderate-to-serious and serious injury) that had been assessed and reported by a registered health practitioner as a result of sports participation	26,070 total claims for female rugby union The 15–19-year age group recorded 40% of the total female rugby union moderate-to-serious and serious claims The knee was the most commonly recorded injury site accounting for 40.3% of moderate-to-serious claims
[53]	Union	Amateur (n=69)	2 seasons	Any physical complaint, which is caused by a transfer of energy which exceeds the ability of the body's ability to maintain its structural and/or functional integrity, that is sustained by a player during rugby trainings, irrespective of the need for medical attention or time-loss from rugby activities	Injury incidence = 11.4 per 1000 training-hours Time loss injury incidence = 3.6 per 1000 training hours The lower limb recorded the highest total days-lost (170 days) with a mean of 7.4 ± 12.5 days per injury
[58]	Union	Provincial (n=143)	1 tournament	NR	9 injuries to female rugby players at 15.7 per 100 athletes
[60]	NR	Collegiate (n=810)	4 seasons	Any injury to the knee region that resulted in a player missing one game or two practices. All injuries had to have been diagnosed by a physician or an athletic trainer. Any intraarticular injuries had to have been confirmed by arthroscopic evaluation or magnetic resonance imaging.	76 total knee injuries in 58 296 exposures Knee injury rate = 1.3 per 1000 exposures 21 ACL tears were reported for a 0.36 incidence per 1000 exposures; other injuries included meniscal tears (n=25), MCL sprains (n=23), patellar dislocations (n=5), and posterior cruciate ligament tears (n=2) Forwards sustained 61% of MCL sprains, backs sustained 67% of ACL tears
[52]	Sevens	Amateur (n=658)	4 1-day tournaments over 2 months	Any physical complaint caused by transfer of energy that exceeded the body's ability to maintain its structural and/or functional integrity, sustained by a player during a rugby match	Female injury rate = 10.0 injuries per 1000 playing hours No sex-difference was observed based on player position or average age of injured players For both men and women 48 injuries occurred over 4 tournaments, for an injury rate of 55.4 injuries per 1000 playing hours. Head and neck injuries were most common (33.3% of injuries), followed by upper extremity (31.3%), trunk (18.8%) and lower extremity (14.6%). The most common type of injury was ligament sprain (25.0%); followed by concussion (14.6%) and hematoma/contusion (12.5%). Tackling was the most common mechanism of injury (74.5%)

[71]	Sevens	Regional, collegiate and national (n=3876)	37 tournament days during 28 tournaments over 4 yrs	Any physical complaint caused by transfer of energy that exceeded the body's ability to maintain its structural and/or functional integrity, sustained by a player during a rugby match.	Women encountered concussions at 8.1/1000 ph, and men at 7.6/1000 ph Women missed 36.7 days absence from play The incidence of repetitive concussions was not statistically different between genders (Relative risk = 1.09, P = 0.754). Most concussions occurred from tackles (63%) and collisions (24%) (P = 0.056).
[56]	Sevens	U19 (n=39)	24 tournaments over 5 years	Any physical complaint caused by transfer of energy that exceeded the body's ability to maintain its structural and/or functional integrity, sustained by a player during a rugby match	Overall injury incidence = 85.9 per 1000 player-hours. Lower extremity injuries were most prevalent injury location (38.1%). Joint (non-bone)/ligament was the most common injury type (42.9%)
[72]	Sevens	Amateur U19 to elite/national (n=113)	26 tournaments over 3 yrs	Any physical complaint caused by transfer of energy that exceeded the body's ability to maintain its structural and/or functional integrity, sustained by a player during a rugby match	120 time-loss injuries were encountered with an injury rate of 46.3 injuries/1000 ph Injury rates in nonelite were 49.3/1000 ph, and in national level (elite) candidates, 32.6/1000 ph (RR = 1.5, p=0.130) Mean days missed: elite = 74.9 days per injury; nonelite = 41.8 days per injury The main mechanism of injury occurred when tackling players (73%) The most common type of injury seen were ligament sprains (37%, 13.9/1000 ph), involving the lower extremity (45%, 20.5/1000 ph). The most common body parts injured were the knee and head/face (16%, 7.3/1000 ph)
[55]	League	Junior (n=935)	1 season	Results in a player requiring first aid or medical attention	Incidence = 22.2 per 1000 player-hours (U13-U18 female) Severity = 13 ± 11 days Joint injuries and bruises/contusions/haematoma/cork accounted for 69.4% of female injuries
[61]	NR	Collegiate club (n=129)	5 yrs	Any new event that occurred during a rugby practice or match that required medical attention. The injury definition was not limited to time-loss injuries due to the common practice of athletes continuing to participate with minor and major injuries.	71 members of the women's team sustained 200 injuries during 68 633 athletic exposures Injuries included 9 ACL, 18 glenohumeral instability, 9 AC joint sprain, 30 concussions, 5 face lacerations, 5 eye injuries, 1 head other injuries and 6 fractures. Incidence rate 30% lower in women than men (IRR = 1.30). ACL incidence rate was 5.3 times higher in women (IRR = 5.32) than in men
[78]	Union	Rugby union ACC claimants (n=~181440)	12 yrs	NR	3138 ± 925 claims were made per year by 15 120 ± 4370 female players Mean injury type claim rate per 1000 female players per year = 168 soft tissue, 20 fracture/dislocation, 6.5 for both laceration and concussion/brain injury and 2.6 for dental. For female players, the probability of making at least one injury claim increased from 0.4% per year at age 5 years through 58-64% for players aged 22 through to 40 years
[80]	Union	Rugby patients presenting to orthopaedic services (n=242)	1 yr	NR	8 fractures sustained Fractures by age group in females; 15-19 years: 3, 20-24 years: 3, 25-29 years: 1, 30-34 years: 1.
[82]	NR	Rugby patients presenting to emergency	10 yrs	NR	Women were most frequently injured in the head (23%) and shoulder (12.3%) The biggest variation for injury proportion rates between men and women was shown in the regions of the mouth (IPR 4.23), ear (IPR 3.48), face (IPR 2.62), and eyeball (IPR 2.57) which all occurred more frequently in men Women were most prone to sprain/strains (34.4%), followed by contusions (15.7%) and fractures (15.1%).

		departments (n=27824)			
[64]	Union	International (n=339)	20-day tournament	Any physical complaint, which was caused by a transfer of energy that exceeded the body's ability to maintain its structural and/or functional integrity, that was sustained by a player during a rugby match or rugby training, irrespective of the need for medical attention or time-loss from rugby activities.	Overall IIR = 10/1000 player hours, match-play IIR = 37.5/1000 player hours, practice IIR 12.5/1000 player hours IIR for forwards = 39.3/1000 player hours, IIR for backs = 42.2/1000 The front row had the highest injury rate (62.5/1000 player hours). 63.6% of injuries occurred during the tackle. Most injuries occurred to the neck, knee and head/face. Most injuries were sprains, muscle injuries and contusions
[62]	League	Club (n=90)	NR	NR	% of injury = 53.3 Facial injuries = 30.0% 26.7% of women's league players reporting having observed a dental injury Women's league players had the lowest percentage of dental injuries (4.4%).
[66]	Sevens	Youth Olympic (n=71)	13-day tournament	Received medical attention, regardless of the consequences with respect to absence from competition or training	Number of female rugby sevens injuries = 26 Five of these injuries were estimated to have a >7 day time-loss 36.6% of female rugby sevens players were injured (greatest in all female sports) IIR = 43% (both male and female rugby players)
[67]	Union	International (n=285)	1 tournament	Any physical complaint, which was caused by a transfer of energy that exceeded the body's ability to maintain its structural and/or functional integrity, that was sustained by a player during a rugby match or rugby training, irrespective of the need for medical attention or time-loss from rugby activities.	Incidence of match injury = 35.5/1000 player-hours Mean severity = 55 days, median severity = 9 days One training injury was reported. Knee-ligament injuries were the most common (15%) and resulted in most days lost (43%). The tackle was the cause of most injuries.
[63]	Sevens	International (n=35)	2 yrs	A medically diagnosed physical complaint sustained while undertaking rugby training or rugby competition that resulted in loss or abnormality of bodily structure or functioning, irrespective of time loss from rugby activities.	27 women's squad players sustained 152 injuries at an incidence of 40.8 per 1000 player hours. Female injuries commonly occurred in the lower limb (63.2%). The knee (13.2%) and the ankle (12.5%) were the most injured sites. The nature of injuries were typically joint sprains (24.3%) or muscle injuries (20.4%).
[74]	NR	Rugby patients presenting to emergency departments (n=443)	10 yrs	NR	Tackling phase of play accounted for the highest number of injuries in females (155/443; 35%) 21% of injuries sustained from collision and 14.9% from contact on ground. 34.8% of injuries were sprains and strains
[79]	NR	Adolescent fracture patients	1 yr	NR	3 female rugby injuries. Females were responsible for 5% of 20 (male and female) clavicle fractures and 14% of 7 (male and female) distal radius/ulna fractures.
[81]	NR	Rugby patients presenting to emergency departments (n=30217)	26 yrs	NR	Females presented with more knee injuries (IPR = 1.67), more contusions/abrasions (IPR = 1.48) and strains/sprains (IPR = 1.39) than males (p<0.001) Females were most often treated for injuries to the knee (12.6%), ankle (11.9%), shoulder (11.4%, face (11.2%), and head (11.1%). Females were diagnosed with a greater proportion of knee injuries than males (12.6 vs. 7.5%).

*Cohort and sample size characteristics for women's rugby athletes only. AC = acromio-clavicular; ACC = Accident Compensation Corporation; ACL = anterior cruciate ligament; IIR = injury incidence rate; IPR = injury proportion ratio; IRR = incidence rate ratio; MCL = medial collateral ligament; NR = not reported; RR = relative risk; SWS = Sevens World Series

Supplementary Table 3. Rugby code, participant characteristics, aims, outcome measures and key findings of studies within 'injury risk, management, prediction' focussed evidence-based theme (n=16)

Study	Rugby Code	*Cohort, sample size (n)	*Participant characteristics: age (yrs), height (cm), body mass (kg)	Study aims	Study outcome measures	Key findings
[94]	Union	University (n=64)	20 ± 2 yrs; 167 ± 11 cm; 74 ± 21 kg	To determine whether the FMS components can predict injury in female and male rugby union players and whether differences exist in the FMS scores of injured and non-injured players.	FMS scores, injury type, location, mechanisms, severity, playing exposure	Female training injury rate: 5.80 injuries/1000 hours Female match injury rate: 55.56 injuries/1000 hours FMS individual components predicted 37.4% of the variance in total days injured in females.
[90]	Union	High school (n=170)	16.5 yrs	To provide reference scores for high school rugby union players on the SCAT5, including immediate memory using the 10-word list, and examine how age, sex, and concussion history affected performance.	SCAT5 scores, including total number of symptoms, symptom severity, 10-word immediate memory, delayed memory, modified Standardized Assessment of Concussion, and balance examination.	Median symptom severity was highest in females with a concussion history (13, range = 0–45). Median total scores on immediate memory were 21 for females. Being female was associated with a higher total symptoms score, higher total symptom severity score, and lower number of errors on the balance examination
[95]	NR	Collegiate varsity (n=13)	21 ± 2 yrs; 167 ± 7 cm; 73 ± 6 kg	To investigate subtle underlying neurological deficits that may accompany recurrent mild head impacts in female rugby	Centre of pressure, time to target and time to centre during static and dynamic balance tasks; Soleus H-reflexes; concussive events	172 potential concussive events were verified. Static balance performance was worse at post-season (p≤0.03). Dynamic postural performance improved after the season (p<0.01). Spinal cord excitability did not change, but deviated from normative values at baseline.
[97]	Union, Sevens, League	Sub-elite and elite	NR	To investigate the occurrence, causes and perceived performance effects of contact breast injuries sustained by female contact football players; how the occurrence injuries varied among codes, positions and competition levels; and the awareness and perceptions of coaches and medical professionals about contact breast injuries.	Questionnaire assessing self-reported breast injury occurrence and cause, and perceived performance effects	46-68 players reported contact breast injuries (code dependant) 48% of female contact football codes perceived that injury affected performance 63% female rugby union players reported sustaining breast injuries caused by contact with another player
[92]	Union	Club (n=13)	NR	To explore the effect of concussion history on head control during front on rugby tackles in non-professional male and female Rugby Union players.	Concussion history, triaxial accelerometer (CSx): linear and rotational head acceleration, normalized Surface EMG amplitude of the bilateral sternocleidomastoid, upper trapezius and splenius capitis.	Players with 12-month concussion history had the highest head acceleration (females = 48.6g, males = 68.3g, p<0.05) with lower trapezius (6.9–11.7%, p<0.05) and splenius capitis (3–12%, p<0.05) amplitudes compared to athletes with no-concussion.
[98]	NR	High level and professional (n=5)	NR	To evaluate a standardized management of brain concussion among rugby players to prevent the recurrence	Time to return to play, concussion recurrence rate, Cantu Grading system for concussion, SCAT2, Trail Making Test, CT or MRI,	33 (male and female) patients returned to rugby after a mean 22.1 ± 10 days. Post-concussive syndrome lasted a median of 15 days in women and 4 in men (p=0.04). Return to sport delay was longer in women than in men (30 vs. 21 days; p = 0.19)
[101]	NR	Varied quality/levels (n=258)	27 ± 7 yrs	To describe the patterns of injury among USA female rugby players, to assess the players' perception of foul play and the referee response to foul play, and to evaluate the association between players' perception of foul play and injury.	Questionnaire assessing injuries, perceived history of foul play	107 total injuries. Match injury rate = 4.4 per 100 matches. Practice injury rate = 0.2 injuries per 100 practices 16.5% of players admitted to perpetrating foul play without an assessed penalty. 13.8% of players had been penalised for foul play 24.3% of injured players believed they had been injured as a result of foul play
[100]	NR	Varied quality/levels (n=234)	26 ± 6 yrs	To assess the prevalence of protective equipment-use among a sample of USA female rugby players and to evaluate their motivation for using different types of protective equipment	Questionnaire assessing rugby participation and protective equipment use	Mouthguards use = 90.8% < 15% of players reported having always worn other types of protective equipment. Mouthguards, padded headgear, and shoulder pads were worn 'to prevent injury', ankle braces,

						neoprene sleeves, and athletic tape on joints were worn 'to protect a current/recent injury.'
[89]	Union	Community (n=425)	29 ± 8 yrs	Identify the association between diagnosed concussion and injury in a group of rugby players and the risk of injury between males and females	Online questionnaire assessing injury history	Diagnosed concussion = 278 Lower extremity musculoskeletal injury = 396 Females had significant associations for concussion and lower extremity musculoskeletal injury (OR = 2.49)
[88]	Union	Amateur (n=69)	27 ± 7 yrs; 165 ± 7 cm; 87 ± 16 kg	To investigate the use of the King-Devick test for the sideline assessment of concussive injuries in an amateur women's rugby union team	Match and training exposure, concussion incidence, King-Devick test scores	There was good to excellent reliability of the King-Devick test for baseline (ICC:0.84 to 0.89), post-injury (concussion) sideline screening (ICC: 0.82 to 0.97) and post-season evaluation (ICC:0.79 to 0.83).
[91]	Union	Rugby schools	NR	To ascertain the extent of injury surveillance and prevention practices currently in operation and the availability of qualified personnel across Rugby playing schools in the Republic of Ireland.	Questionnaire assessing school demographics, personnel access, strength and conditioning, injury monitoring and prevention	Respondents = 93 schools [356 (97% male, 3% female) teams] Schools monitoring rugby injuries = 86% Schools providing physiotherapy = 28% Schools providing medical doctors = 14% Schools providing strength and conditioning coach = 44% Schools not implementing injury prevention measures = 31%
[96]	NR	University (n=20)	22 ± 2 yrs; 168 ± 5 cm; 71 ± 9 kg	Examine lumbar multifidus characteristics in male and female university rugby players and their possible associations with low back pain and lower limb injury	Ultrasound measurements of lumbar multifidus cross-sectional area, thickness, and % change in thickness during contraction, in prone and standing positions. Dual-energy x-ray absorptiometry body composition. Self-reported low back pain and lower limb injury history	Prone CSA (cm^2): Left = 7.8; Right = 7.5 Standing CSA (cm^2): Left = 9.0; Right = 8.7
[99]	Union	Women and schoolgirl (n=87)	NR	To describe the level of usage of protective devices and equipment in a cohort of New Zealand rugby players	Percentage of all player-weeks of follow-up for which each equipment item was used	Women = mouth guards 58.9%, shin guards 8.7%, padded head gear 1%, taping (body joints) 13.4%. Schoolgirls = mouth guards 55.0%, shin guards 0.5%, padded head gear 0%, taping (body joints) 3.6%.
[93]	Sevens	University (n=14)	20 ± 1 yrs; 161 ± 4 cm; 53 ± 5 kg	To investigate injury incidence and the influence of physical fitness parameters on the risk of severe injuries in players on rugby sevens university teams	Injury: location, type, new or recurrent, mechanisms, contact vs. non-contact, diagnosis, treatment, and number of days lost Physical fitness: YYIRT, push-up test, IMTP, single leg bridge test, vertical jump test, 40-m speed test, Illinois agility test, Y balance test, sit and reach test and Thomas test	4 female players injured Match incidence (male and female): 59.3 per 1000 player-hrs Training incidence (male and female): 3.3 per 1000 player-hrs Female (HR = 8.35), slower (HR = 3.51, and less agile (HR = 2.22) players as well as those with hip flexors tightness (HR = 1.12) were at significantly greater risk for sustaining severe injuries.
[84]	Union	International (n=764)	NR	Compare SCAT5 baseline performance in large groups of professional men's and women's rugby players to determine whether reference limits used for the management and diagnosis of concussion should differ between sexes	SCAT5 scores	Women endorse more symptoms than men, report symptoms with a higher severity than men, and perform better than men in orientation and concentration, and balance sub-modes ($p<0.05$)
[87]	Union	Amateur (n=24)	Forwards: 170 ± 4 cm; 87 ± 14 kg Backs: 166 ± 7 cm; 70 ± 11 kg	To investigate intrinsic and extrinsic risk factors associated with injury in amateur male and female Rugby Union players.	Hamstring flexibility, dorsiflexion range of movement, adductor muscle strength and foot position, sleep quality, coping skills, support levels. Injury: nature, the timing of injury during the match and the event surrounding the injury, diagnoses and total days absence from rugby.	18 female players sustained one or more injuries Female time loss injury incidence rate = 45.2/1000 player hours Male and female players with weaker adductor muscle strength had a higher injury incidence (injury rate = 1.57).

*Sample size and participant characteristics for women's rugby athletes unless otherwise specified. CT = computerized tomography; FMS = Functional Movement Screen; HR = hazard ratio; IMTP = isometric midthigh pull; MRI = Magnetic resonance imaging; NR = not reported; OR = odds ratio; SCAT = Sport Concussion Assessment Tool; YYIRT = Yo-Yo Intermittent Recovery Test

Supplementary Table 4. Rugby code, participant characteristics, aims, outcome measures and key findings of studies within physical characteristics focussed 'match characteristics' evidence-based theme (n=21)

Study	Rugby Code	*Cohort, sample size (n)	*Participant characteristics: age (yrs), height (cm), body mass (kg)	Study aims	Number of matches (n)	Study outcome measures	Key findings
[117]	Union	Premier division forwards (n=68) and backs (n=61)	Forwards: 25 ± 5 yrs; 173 ± 6 cm; 79 ± 7 kg Backs: 25 ± 6 yrs; 165 ± 8 cm; 66 ± 5 kg	To determine the match demands of elite English women's rugby union, identify positional differences, and between-player variability.	14	GPS (Catapult Minimax S4): TD, distance in various speed zones, maximum speed, PlayerLoad, RHIE	Mean TD = 4982 m, relative distance = 54.8±9.1 $m \cdot min^{-1}$, PlayerLoad = 531±97 Backs *moderately* > forwards for maximum speed, high-intensity running, sprinting ($p<0.05$). Forwards *moderately* > backs for time spent jogging ($p<0.05$)
[114]	Union	Provincial (n=20)	24 ± 4 yrs; 170 ± 6 cm; 79 ± 11 kg	To quantify running demands in female rugby union players during Farah Palmer Cup matches (New Zealand).	7	GPS (VX Log, VX Sport): TD, high-intensity running, meters per minute, maximum speed	Average TD = 5720±921 m Backs were faster than forwards (26±2 vs. 22±3 $km \cdot h^{-1}$) and covered greater high-intensity running distance (651±252 vs. 252±229) ($p<0.05$)
[124]	Sevens	Junior (n=13), senior (n=22), elite (n= 11)	Junior: 164 ± 7 cm; 64 ± 12 kg Senior: 170 ± 7 cm; 70 ± 9 kg Elite: 169 ± 2 cm; 69 ± 4 kg	To quantify the game running movement patterns, anthropometric and physical characteristics of male and female rugby sevens players across 3 playing levels.	6	GPS (SPI HPU GPSports) derived: TD, max speed, max acceleration, number of impacts >10 g, relative TD, total and percent distance covered >3.5 $m \cdot s^{-1}$ and >5 $m \cdot s^{-1}$, total and percent sprint distance, and mean sprint duration. Physical characteristics: height, body mass, and sum of 7 skinfold sites, 40m sprint, vertical jump test, YYIRT-1	In females, elite players had more favourable on- (max speed = 8.05±0.55, distance >5 $m \cdot s^{-1}$ = 120±41) and off-field performance measures than juniors (max speed = 7.08±0.83, distance >5 $m \cdot s^{-1}$ = 89±52) and seniors (max speed = 7.40±0.52, distance >5 $m \cdot s^{-1}$ = 102±44)
[102]	Sevens	International (n=12)	23 ± 4 yrs; 169 ± 2 cm; 69 ± 4 kg	To assess the ability of automated collision detection software in GPSports units, compared to manually coded video notational analysis, in men's and women's rugby sevens.	1 men's, 1 women's	Video-derived notational analysis for collision events Accelerometer (SPI HPU, GPSports) derived collisions >3.5G	Precision (men's and women's) = ~0.72 (scale: 0.00–1.00) 62% of collisions for women were incorrectly labelled
[109]	Sevens	International (n=16)	23 ± 2 yrs; 166 ± 7 cm; 66 ± 7 kg	To determine the effectiveness of a commercially available energy drink on the running activity profiles of elite female rugby sevens players during an international tournament.	2	GPS (SPI PRO X): distance, speed, impacts HR Urine analysis (Agilent Technologies HPLC 1200): caffeine, paraxanthine, theobromine, and theophylline concentrations Physical characteristics: 15 sec maximal jump test, 6 x 30-m sprint test	Energy drink increased muscle power output during the jump series, running pace during the games and pace at sprint velocity ($p \le 0.05$). Energy drink did not affect maximal running speed during the repeated sprint test but did increase mean HR during games ($p<0.05$).
[112]	League	Elite (n=17)	25 ± 6 yrs; 171 ± 5 cm; 74 ± 7 kg	To investigate the validity of the Catapult algorithm to automatically detect and differentiate tackles when compared with video-coded tackles	1	Video-derived notational analysis for tackle events GPS (Optimeye S5) derived tackle	Players engaged in 512 tackle events (30 ± 17 per player) Sensitivity = 76%; Precision = 83%
[122]	League	International and domestic (n=58)	NR	To describe the whole match and peak duration-specific locomotor characteristics at international and domestic levels	4 international, 5 domestic	GPS (Otpimeye S5): TD, high-speed distance, sprinting, average speed, average acceleration	International forwards *most likely* > domestic forwards for peak 1-min average acceleration and peak 3-min acceleration (0.79 and 0.60 vs. 0.70 and 0.54). International backs *likely* > domestic backs for peak 1-min average acceleration and *possibly* for high-speed distances (0.78 and 241 vs. 0.73 and 190).

[105]	Sevens	International (n=20)	24 ± 4 yrs; 168 ± 6 cm; 69 ± 5 kg	To evaluate the effects of contextual game factors on activity and physiological profiles of international-level women's rugby sevens players	5 tournaments	GPS (Minimax S4): TD, distance in different speed zones, PlayerLoad (relative and absolute). HR	TD (776±118 vs. 640±180m), high-speed distance (154±57 vs. 124±59m), PlayerLoad (84±18 vs. 69±20AU) > 1st half vs. 2nd half ($p<0.05$) TD (1455±294 vs. 1312±290m), moderate-speed distance (964±204 vs. 913±208m) and very high-speed distance (133±59 vs. 104±42m) > losses vs. wins ($p<0.05$)
[103]	Sevens	International (n=24)	24 ± 5 yrs; 168 ± 5 cm; 68 ± 6 kg	To quantify the movement patterns and compare sessions of preparation training camps for international women's rugby sevens players	28 training sessions	GPS (SPI Pro, GPSports): TD, sprint distance, accelerations, decelerations, sprints and repeated sprints sRPE	Women's sevens players median TD = 3823 m (relative distance of 44 $m \cdot min^{-1}$) Average session duration 91 mins 0.47 $sprints \cdot min^{-1}$; 0.17 repeated $sprints \cdot min^{-1}$
[116]	League	Domestic (n=21)	29 ± 8 yrs	To quantify impacts to the head via an instrumented patch worn behind the ear for women rugby league players over one season	9	Accelerometer and Gyroscope (XPatch): linear acceleration and angular velocity	1659 impacts to the head >10g were recorded (range: 10g–91g) Impacts per match = 184±18 Impacts per player per match = 14±12 Highest median peak resultant linear acceleration = 16g
[115]	League	Collegiate (n=23)	20 ± 1 yrs	To describe head impact kinematics and subsequent concussive events in a collegiate level women's rugby team throughout one competitive season including both practices and games.	47 practices, 8 matches	Smart Impact Monitors (Triax Technologies): frequency, magnitude and location of head impacts	120 total head impacts ≥15 g (18.1 g – 78.9 g) and 4 concussions with 1199 total athlete exposures 67 match head impacts; mean rate of 0.40±0.22 hits per-player per-match, median peak linear acceleration = 32.2 g, and peak rotational velocity = 13.5 $rad \cdot sec^{-1}$ 53 practice head impacts; mean rate of 0.05±0.04 hits per-player per-practice, median peak linear acceleration = 29.8 g and peak rotational velocity of 15.7 $rad \cdot sec^{-1}$
[106]	Sevens	International (n=27)	24 ± 2 yrs; 168 ± 7 cm; 68 ± 4 kg	To report the running and physiological demands of women's rugby sevens match-play with respect to halves of play and positions of play.	36	GPS(Statsports Viper Pod): distance in various speed zones, number of sprints, average maximal sprint distance, average minimal sprint distance, accelerations in various zones, and maximal velocity. HR	Mean distance = 1 625 ± 132 m (116.1 ± 9.4 $m \cdot min^{-1}$) High-speed distance = 199 ± 44 m (14.2 ± 3.1 $m \cdot min^{-1}$) Reductions in high-speed running ($p = 0.003$) and increases in lower speed running were observed across halves of play ($p = 0.04$) Players spent >75% of the time >80% of HR maximum
[113]	Sevens	Professional forwards (n=5) and backs (n=7)	Forwards: 27 ± 3 yrs; 170 ± 3 cm; 70 ± 2 kg Backs: 25 ± 5 yrs; 167 ± 5 cm; 62 ± 4 kg	Quantify absolute and max velocity-relative speed characteristics, establish if max velocities are reached, investigate importance of max velocity to game outcomes	6	GPS (JOHAN Sports): distance in different speed zones, number of sprints at different intensities Sprint influence on a visual-analogue scale	Mean peak velocity per game = 90.6 ± 7.9% Vmax TD per game = 1,556 ± 233 m
[121]	Sevens	National (n=10) and international (n=10)	International: 26 ± 4 yrs; 167 ± 7 cm; 65 ± 5 kg National: 32 ± 6 yrs; 167 ± 3 cm; 66 ± 5 kg	To investigate the distance and speed demands and HR responses of female rugby sevens players competing at international and national levels.	4	GPS (SPI Pro X): distance in various speed zones, accelerations and impacts. HR	International > national players for TD (1642±171 vs. 1363±222 m), average speed (6.0±0.3 vs. 5.2± 0.6$km \cdot h^{-1}$), number of sprints (6.1±3.1 vs. 1.9±1.4), sprint distance (119± 61 vs. 47± 39 m) ($p<0.01$). Work-rest ratio was different ($p<0.01$) between international (1:0.3) and national players (1:0.4)
[104]	League	International (n=18)	26 ± 4	To describe the movement patterns of the Australian Women's Rugby League team during international competition.	7	GPS (SPI Pro X): mean speed, high-intensity running in various speed zones	TD was greater in the 1st half (3333 m vs. 3249 m), as well as TD at speeds >15 km·h-1 ($p < 0.05$). Players covered greater TD speeds <6 km·h-1 in the 2nd half ($p = 0.005$). Backs travelled further at speeds <6 km·h-1 ($p = 0.002$) and >15 km·h-1 ($p = 0.007$) compared to forwards. Mean speed reduced across the 1st and 2nd halves ($p < 0.05$)
[107]	Sevens	International (n=15)	24 ± 4 yrs; 168 ± 7 cm; 68 ± 6 kg	To determine whether the score differential of a match outcome influences the physical demands of match play in women's rugby sevens.	15	GPS (VX sport 220): distance in various speed zones Video derived notational analysis for ball carry, ball taken into contact, pass, own ruck attended, opposition ruck attended, tackles, missed tackle,	TD covered were *moderately* greater in high score differential games (87.8±8.9 vs. 91.6±9.7 $m \cdot min^{-1}$; mean difference:3.8) *Moderately* greater numbers of missed tackles (0.5±0.6 vs. 0.4±0.7; count ratio: 0.7) and lineouts (1.1±0.9 vs. 0.6±1.3; count ratio 0.54) in low score differential versus high score differential games

						scrum, lineout. Performance: low (<21) and high (>= 21) score differentials	
[111]	Union	International (n=29)	24 ± 3 yrs; 167 ± 4 cm; 75 ± 11 kg	To profile distances covered during women's rugby union match-play and assess WCS locomotor demands over 1-10min epochs, whilst comparing the FIXED vs ROLL methods and assessing positional influences.	8	GPS (Optimeye S5): TD and high speed running	TD = ~5.8 km per match, with reduced distances in the 2nd vs 1st half (p < 0.001). FIXED underestimated ROLL WCS total and high-speed distance (p<0.001). In ROLL, WCS relative total and high-speed distances reduced from ~144-161 $m\cdot min^{-1}$ and ~30-69 $m\cdot min^{-1}$ over 60-s, to ~80-89 $m\cdot min^{-1}$ and ~5-16 $m\cdot min^{-1}$ in the 600-s epoch, respectively. Forwards < backs for high-speed running and TD during 60-s, 180-s, 420-s and 480-s epochs (p<0.001)
[186]	Sevens	International (n=12)	28 ± 4 yrs; 166 ± 6 cm; 64 ± 5 kg	To examine the match running demands and exercise intensity associated with elite women rugby sevens.	5	GPS (SPI GPSports): distance in various speed zones. HR	Average distance per game = 1 556±189 m % of time spent: standing and walking = 30; jogging = 33; cruising = 12; striding = 16; high-intensity running = 4; sprinting = 5 Average maximal sprint distance = 25.8±16.1 m; mean sprint distance = 17.2±8.8 m; # of sprints = 5.3±3.2 Work-to-rest ratio = 1:0.4
[110]	Union	International (n=8)	Backs: 27 ± 3 yrs; 170 ± 2 cm; 68 ± 4 kg Forwards: 27 ± 2 yrs; 174 ± 6 cm; 77 ± 10 kg	To describe locomotive activities and exercise intensity during international female rugby union and compare playing positions.	1	GPS (SPI Pro X, GPSports): distance in various speed zones, accelerations, body impacts. HR	TD = 5820 ± 512 m TD for backs > forwards (6 356 ± 144 vs. 5 498 ± 412 m; p=0.01) % time spent: standing or walking = 43; jogging = 35; low intensity running = 10; medium intensity running = 10; high-intensity running = 2; sprinting = 1 Mean sprint count = 4.7±3.9; Mean max sprint distance = 20.6±10.5 m; Mean sprint distance = 12.0±3.8 m
[123]	Sevens	International (n=22) and developmental (n=25)	NR	To examine locomotor, metabolic power and HR demands across standards. To determine the match demands and physical performance associations.	5 per playing standard	GPS (SPI Pro): running at various intensities. HR, metabolic power, YYIRT1, 35/40m sprint test	International > developmental players for TD (1468±88m vs. 1252±135m), high-intensity running (224±55m vs. 131±44m), sprint distance (128±67m vs. 57±44m) and more distance in high (264±36m vs. 210±54m), elevated (118±17m vs. 76±20m) and maximal (69±17m vs. 30± 15m) metabolic power categories Developmental > international for peak (187±6bpm vs. 194±5bpm) and mean (172±7bpm vs. 180±9bpm) HR International > developmental for YYIRT1 (1160±191m vs. 781±129m) and maximal sprint speed (27.3±0.7 vs. 26.0±1.5$km\cdot h^{-1}$).
[118]	Union	Premier division (n=38)	24 ± 4 yrs; 169 ± 7 cm; 73 ± 11 kg	To determine and quantify movement patterns through time–motion analysis and to assess the physical demands during competition	10	Notational analysis: standing, walking, jogging, striding, sprinting, ruck/maul/tackle, pack down, scrum, lift, kick, jump, open field tackle. HR	Backs spend more time sprinting (37±12 vs. 25±16) and less time in ruck/maul/tackles (25±11 vs. 61±12) compared to forwards (p<0.05) Forwards > back for mean HRs (173±10 vs. 161±10) and time above 80% of maximum HR (81±14 vs. 63±20) (p<0.05)

*Cohort, sample size and participant characteristics for women's rugby athletes only. HR = heart rate; FIXED = fixed epoch; NR = not reported; RHIE = repeated high intensity efforts; ROLL = rolling average; sRPE = session rating of perceived exertion; TD = total distance; WCS = worst-case scenario; YYIRT = Yo-Yo intermittent recovery test

Supplementary Table 5. Rugby code, participant characteristics, aims, outcome measures and key findings of studies within technical-tactical focussed 'match characteristics' evidence-based theme (n=5)

Study	Rugby Code	*Cohort, sample size (n)	*Participant characteristics: age (yrs), height (cm), body mass (kg)	Study aims	Number of matches (n)	Study outcome measures	Key findings
[128]	Sevens	International	NR	To analyse variables associated with winning teams in knock out Cup games, and to illustrate if winning characteristics are valid across genders.	30	Notation analysis: possessions, restarts, gaining possession, set piece, penalties, offensive options, defensive statistics, scoring.	Winning women's teams gained more possession from handling turnovers, utilised more quick lineouts, had less ineffective set lineouts, threw more passes and made more ball-jolting-tackles than losing women's teams (p<0.05) Winning men's teams utilised non-contested restarts more frequently, won a higher percentage of contested restarts, had more scrum feeds and made more effective tackles than losing men's teams (p<0.05)
[126]	Sevens	International	NR	To examine link between coupling at the ruck, phase momentum and success	35	Notation analysis: Ruck type and frequency, winning and losing team	Winning women's teams had a higher percentage of positive phases (p<0.01) Positive phase momentum is associated with four or more passes (p<0.001) Winning women created significantly more positive phases from 4&0 rucks than losing teams (p<0.05). Winning women's teams scored significantly more tries from 2&2 rucks (p<0.05).
[127]	Sevens	International	NR	To identify and understand any relationships between ruck actions and ruck success in rugby sevens	65	Notation analysis: player numbers in the ruck, the actions of the first players to the ruck, ball placement, the body height, weight distribution and position of the attacking player in the ruck, ruck outcome	Attacking teams maintained ball possession: men = 69.2%; women = 72.5% Women's and men's successful ruck actions were similar; 1 vs. 1 rucks were most commonly formed. If an attacking player arrived first, there was a greater chance of maintaining possession (p<0.001). An early jackal was most successful at producing turnovers (p<0.001)
[130]	Union	International	NR	To compare performance indicators in elite men's and women's rugby union and identify those that discriminate winning and losing teams	8	Notation analysis: of tries, penalty kick success, conversion success, drop goals lineout success, scrum success, ruck frequency, kick in play, tackle completion, carries, breaks, visit to opponents 22, turnover conceded, penalty conceded, ball possession.	Successful women's teams displayed frequency of greater breaks, higher tackle completion, less pick and go's, less rucks in the opposition 22-50m, more rucks in own 22-50m, less kicks in opposition 22-50m and less penalties conceded in their own 22 (p≤0.038)
[129]	Sevens	International (n=16)	23 ± 2 yrs; 166 ± 7 cm; 66 ± 7 kg	To determine the effects of caffeine on the technical performance of female elite rugby sevens players and to assess whether caffeine improved the number of body impacts.	2	Notational analysis: tackle, ruck, pass, pass receive, ball carry Accelerometer (GPSports): impacts in various zones	Frequency or the quality of any rugby-specific technical actions during the games were not affected by caffeine (p>0.05). The ingestion of the caffeinated energy drink increased the rate of body impacts in zones 1-3 and 5 (p<0.05)

*Cohort, sample size and participant characteristics for women's rugby athletes only. N/A = not applicable; NR = not reported

Supplementary Table 6. Rugby code, participant characteristics, aims, outcome measures and key findings of studies within 'physical performance' evidence-based theme (n=32)

Study	Rugby Code	*Cohort, sample size (n)	*Participant characteristics: age (yrs), height (cm), body mass (kg)	Comparisons between	Intervention duration	Study aims	Study outcome measures	Key findings
Anthropometrics								
[141]	NR	Semi-professional (n=16)	25 ± 5 yrs	Non-athletic women	N/A	To compare and quantify with USI the thickness of the TrAb, EO, IO, RA, and IRD in female rugby players versus non-athletic women.	Ultrasound imaging (Logic S7): thickness of TrAb, EO, IO, RA, and IRD	There were statistically significant differences for the ultrasound evaluation thickness of the right TrAb (p=0.011), EO (p=0.045), IO (p=0.003), and RA (p=0.001) showing a thickness increase for the rugby group with respect to the control group.
[142]	NR	University (n=NR)	28 ± 4 yrs; 161 ± 7 cm; 54 ± 6 kg	Badminton, Volleyball, Basketball, Futsal	N/A	To examine the Q angle values of female athletes in different branches.	Q angle, pelvic width, femur length	Q angle = 21.5±7.1 ° Pelvic width = 28.9±4.7 cm Femur length = 41.3±9.4 cm
[137]	Union	Club and university (n=30)	21 ± 2 yrs; 167 ± 5 cm; 73 ± 11 kg	Netball players, distance runners, sedentary controls	N/A	To determine local, regional and segmental DXA measurements of BMD among female rugby union, netball, and distance running participants and sedentary controls and to compare body composition measures.	Whole-body, lumbar spine, and total left hip areal bone mineral density Fat mass, fat free soft tissue mass, and fat percentages	Total body BMD = 1.26±0.17 Body fat (%) = 29.5±4.7 Rugby players had greater body mass, FFM and fat mass compared to controls, runners and netball players (p<0.001). Rugby players has greater total body BMD compared to controls (p<0.001).
[143]	NR	Collegiate (n=99)	NR	Collegiate athletes (cross country, gymnastics, dance, swim & dive, syncrhonized swimming, wrestling, olympic weightlifting, track & field, basketball, ice hockey, lacrosse, volleyball, water polo)	N/A	To report sport-specific norms for FFM index in a diverse sample of female athletes, to determine whether these values differ between sports, and to identify a naturally-attainable threshold for FFM index in female athletes.	FFM index, fat mass, FFM, BMD, bone mineral content, body fat %	FFM index = 20.09±2.23 FFM was significantly higher (p<0.05) in rugby than in gymnastics, ice hockey, lacrosse, swim & dive, and volleyball.
[138]	Union	Div 1 Collegiate (n=101)	20 ± 2 yrs; 166 ± 7 cm; 74 ± 15 kg	Positions	N/A	To report anthropometrics in female collegiate rugby union players and to identify between-position differences in these variables.	BMI, body fat percentage, fat mass, FM index, FFM, FFM index, lean soft tissue, bone mineral content, bone mineral area, and bone mineral density	Significant differences (p < 0.014) were identified between forwards and backs for every anthropometric variable, with forwards displaying greater height (167.7 ± 7.2 cm), body mass (81.5 ± 15.1 kg), and body fat percentage (28.2 ± 6.1%) relative to backs (164.5 ± 5.1 cm; 64.5 ± 7.7 kg; 21.9 ± 3.7%)
[139]	Union	Elite (n=30)	26 ± 4 yrs; 171 ± 8 cm; 84 ± 14 kg	Positions	N/A	Investigate the anthropometric and body composition characteristics of New Zealand elite female rugby union players	Body mass, Sum of 8 skinfolds, lean mass, fat mass, fat %, bone mineral content, and bone mineral density	Sum of 8 skinfolds (mm): backs = 94.4, forwards = 128.2 Fat (%): backs = 20.8, forwards = 26.5 Bone mineral content (kg): backs = 2.7, forwards = 3.1 (all p<0.05)

[140]	Union	Elite (n=958)	Forwards = 80 kg; Backs = 67.5 kg	Position, sex, tier, time	N/A	To document the body mass of elite international men's and women's players at Rugby World Cups from the emergence of professionalism (early 1990s for men, 2010 for women) to the present day	Body mass	Women's forwards mass increased by 4.8% in Tier 1, with no changes in Tier 2 or backs from either tier
Biomechanics								
[145]	Union	Amateur (n=31)	24 ± 3 yrs; 168 ± 5 cm; 69 ± 9 kg	Positions, control group, pre- and post-test	8 weeks	To observe the effect of 8 weeks of sled training with optimal loading for maximal power output production sprint performance	5 and 20 m sprint time and sprint mechanical outputs: index of balance between force and velocity, max force, max velocity, PPO, Rfmax and Drf	Both forwards and backs significantly improved (p ≤ 0.05) in 5 and 20 m sprint performance, and in the mechanical properties related to the horizontal Power-Force-Velocity profile.
[144]	Sevens	International (n=18)	24 ± 4 yrs; 172 ± 7 cm; 69 ± 7 kg	N/A	N/A	To characterise asymmetry of the main running mechanical variables (with special reference to horizontal force production) during repeated treadmill sprints in elite female Rugby Sevens players.	Symmetry angle Step kinematic variables: contact time, aerial time, swing time, step frequency and step length. Peak braking and peak propulsive forces, duration of braking and propulsive phases, absolute and relative net braking and propulsive impulses.	Symmetry angle remained mostly constant (~1-8%) across sprint repetitions for 20 gait variables
[146]	Union	Club (n=16) and international (n=16)	NR	Playing level	N/A	To describe the forces developed during machine scrummaging as a factor of playing level and evaluate the magnitude and characteristics of the force load on players may represent an issue for potential injury	Peak compression, average sustained push, drop from peak to sustained force, rise from minimum to sustained force, positive and negative impulse. Range of lateral force, average sustained lateral push	Women's peak compressive force = 8.7 kN Sustained compression forces spanned between 8.3 kN (International men) and 4.8 kN (Women)
Performance								
[157]	Union and Sevens	Inter-provincial, U20 International, Senior International (n=114)	18 ± 3 yrs; 67 ± 7 kg	Top and bottom 50% of SLJ and STJ performance	N/A	To determine whether horizontal jumping can differentiate sprinting ability, to evaluate relationship between horizontal jumping and speed, to determine whether horizontal jumping and anthropometrics can predict kinematics variables	SLJ, STJ, ISS, MSS, initial sprint momentum, and maximal sprint momentum	When categorized by SLJ there was a *very large* ES for top and bottom 50% SLJ and STJ (p<0.001) and a *large* ES for MSS (p<0.001). When categorized by STJ there was a *very large* ES for top and bottom 50% SLJ and STJ (p<0.001) and a *large* ES for ISS and MSS (p<0.001). A linear regression developed from STJ and body weight adequately predicted ISS (r = 0.645, p<0.001) and MSS (r = 0.761, p<0.001).
[152]	Sevens	International backs (n=13) and forwards (n=11)	Backs: 21 ± 4 yrs; 166 ± 6 cm; 66 ± 3 kg Forwards: 24 ± 4 yrs; 171 ± 4 cm; 73 ± 5 kg	Positions	N/A	To describe the anthropometric and physical qualities of international level female sevens athletes and determine whether positional differences exist.	Sum of 7 skinfolds, 0-10 and 30-40m speed and momentum, SLJ, STJ, 1RM power clean, front squat, bench press, and neutral grip pull-up, 1600m average speed	The backs and forwards had significant differences in body mass (66±3 vs. 73±5 kg; p=0.019) and initial sprint momentum (367±20 vs. 399±22 kg·m·s^{-1}; p=0.028). No other measures showed positional differences.

[155]	League	Amateur (n=41)	15 ± 1 yrs; 163 ± 12 cm; 59 ± 13 kg	Sex	N/A	To examine the force-velocity profiling generated by adolescent rugby players in the squat and bench exercises and to compare sex-related differences.	Bench press and squat 1RM, power (W) and velocity ($m{\cdot}s^{-1}$)	1RM squat (115±41 vs. 104±31) and bench (46±17 vs. 47±14) were not different between females and males Females demonstrated greater bench press power than males (326±196 vs. 190±151; p<0.001). No differences between females and males for squat power (591±353 vs. 522±299)
[153]	Sevens	International (n=18)	23 ± 5 yrs; 167 ± 6 cm; 64 ± 7 kg	Sex	N/A	To investigate differences in COD ability and speed- and power variables between male and female players; examine COD deficit differences; and analyse the relationships between COD deficit and COD speed.	Squat jump, CMJ, 45cm depth jump, horizontal jump, triple horizontal jump, 40m sprint, Pro agility (5-10-5) test, L-drill, zig-zag test, 1RM back squat	Women demonstrated *likely* to *almost certainly* lower performances than men in all speed-power assessments and COD tasks (ES range 0.61-2.09; p<0.05), except for the Zig-zag drill (ES=0.24; p>0.05). Women displayed lower COD deficits in all tests and lower sprint momentum (ES range 0.78-2.95; p<0.05)
[154]	Sevens	International (n=24)	23 ± 4 yrs; 168 ± 6 cm; 69 ± 5 kg	High and low minutes played	N/A	To examine which, if any, physical qualities differentiate playing minutes in international women's rugby sevens players.	Sum of 7 skinfolds, 40m sprint, STJ, STJ, 1RM strength, 1600m speed, playing minutes	High-playing-minute players (≥70 min) were older (24±3 vs 21±4 yrs, p=0.05), had greater experience in a national-training-centre (2.4±0.8 vs 1.7±0.9 yrs, p=0.03), had faster 1600-m time (375±20 vs 394±30 s, p=0.09), greater 1RM strength (bench press 68±6 vs 62±8 kg, p=0.07, pull-up 84±8 vs 79±5 kg, p=0.12) than athletes who played fewer minutes.
[147]	Union	International (n=32)	Forwards: 165 ± 7cm; 79 ± 13 kg Backs: 161 ± 6 cm; 63 ± 6 kg	Positions	N/A	To investigate the physical fitness characteristics of elite female rugby union players	Sum of 7 skinfolds, sit and reach, vertical jump, 10 and 40m speed, 1RM bench press, pull-up and push up endurance, multistage shuttle run	Forwards had a greater sum of skinfolds than backs (137±31 vs. 107±19, p < 0.01). Backs demonstrated superior vertical jump (44±5 vs.38±5), 10 (1.9±0.1 vs. 2.1±0.1) and 40 m (6.0±0.2 vs. 6.5±0.3) speed and push up endurance (25±9 vs. 16±9) than forwards (p<0.001).
[156]	League	Elite International (n=27)	Backs: 24 ± 4 yrs; 163 ± 4 cm; 66 ± 7 kg Forwards: 26 ± 6 yrs; 167 ± 7 cm; 81 ± 14 kg	Positions, relationship between physical variables	N/A	To present the characteristics of elite female rugby league players by playing position and investigate the relationships between the measured variables.	Body composition: DXA; total and percentage body fat and lean mass, BMC, and regional fat and lean mass Speed and agility: 5, 10, 20, 30, 40 m sprint, and 505 agility Running endurance: YYIRT-1 Lower-body power: CMJ, 20 kg jump squat, and 30 cm drop jump	Forwards were significantly taller (ES=0.79), heavier (ES=1.34), with a greater total fat mass (ES=1.31), total lean mass (ES=0.96), and percentage body fat (ES=1.12) (p ≤ 0.05). Backs were significantly (p ≤ 0.05) quicker than forwards over 5, 10, 20, 30, 40 m (ES = 1.03–1.17), and 505 agility (ES = 0.85–0.92). Backs jumped higher than forwards (ES = 1.00-1.50; p ≤ 0.05). Relationships were observed between total body fat and all fitness variables (p ≤ 0.05).
[148]	Union	Collegiate (n=8)	22 ± 2 yrs; 160 ± 6 cm; 68 ± 10 kg	Other team sport athletes (basketball, soccer, softball), relationship between physical variables	N/A	To provide an introductory investigation of the relationships between lower-body power and multidirectional speed in collegiate female rugby players.	SLJ, vertical jump, 505 test, 5, 10 and 20m sprint	For the rugby players, the vertical jump correlated with the 0-20 m interval (r = -0.73). The SLJ correlated with the 0-5 and 0-10 m intervals, and the left-leg 505 (r = -0.71 to -0.88) and predicted 0-5 m and left-leg 505 time (r_2 = 0.50-0.58).
[149]	Union	Division 1 College (n=17)	22 ± 2 yrs; 161 ± 5 cm; 64 ± 9 kg	Relationship between physical variables	N/A	To evaluate the relationship between linear speed (0-5 m, 0-10 m, and 0-20 m sprint), and COD ability. To determine if the COD deficit identified a different metric of COD ability for individuals when compared to the traditional 505 time.	5, 10 and 20-m sprint and 505 tests	The COD deficit did not correlate with the sprint interval times (r = -0.370 to -0.045). Right-leg 505 time did correlate with the 0-10 and 0-20 m intervals (r = 0.483-552).

[1]	Union	Senior and schoolgirl (n=92)	Senior forwards: 22 yrs; 167 cm; 76 kg Senior backs: 20 yrs; 164 cm; 61 kg Schoolgirl forwards: 16 yrs; 166 cm; 67 kg Schoolgirls backs: 16 yrs; 159 cm; 55 kg	Positions, grades	N/A	To document the size, shape, and physical performance characteristics of a cohort of New Zealand rugby players drawn from various grades, and to make comparisons between grades and positional categories	Neck circumference, somatotype, agility and turning ability test, CMJ, modified repeated high intensity endurance test, rolling and static 30-m speed, push up capacity, fatigue index	Female forwards were taller and heavier than backs ($p<0.02$), senior players were heavier than schoolgirls ($p\leq0.001$). Forwards possessed larger neck circumferences across grades and were more endo-mesomorphic and less ectomorphic than backs ($p\leq0.001$). Backs generally performed better than forwards in physical assessments. *Large* differences on the aerobic shuttle test, the vertical jump, the sprint from a rolling start, and momentum were found ($p\leq0.002$).
[158]	NR	University (n=19)	21 ± 3 yrs; 165 ± 5 cm; 64 ± 11 kg	Positions	N/A	To describe the body composition and performance characteristics of collegiate women rugby players and to compare the forwards to the backs regarding these variables	Body composition: % body fat, bone density Physical qualities: isometric knee extension, elbow flexion, maximal alactic anaerobic power, agility, heart rate.	Forwards were significantly heavier ($p<0.05$) than the backs. Backs had significantly less relative fat and fat mass than the forwards ($p<0.05$). The forwards had significantly greater anaerobic power than the backs ($p<0.05$).
[150]	Union	National All-Star Championship (n=24)	30 ± 4 yrs; 167 ± 6 cm; 68 ± 9 kg	Positions	N/A	To represent fitness levels for elite world-class women rugby players.	Body mass, body fat, vertical jump, squats, seated press, 40yard speed, 100m speed, bleep test, 300m speed	Backs had greater vertical jump, squat and seated press performances compared to forwards. Backs performed better on all running tests compared to forwards.
[151]	Union	University beginners (n=10) and experienced (n=8)	Beginners: 19 ± 1 yrs; 165 ± 5 cm; 68 ± 12 kg Experienced: 20 ± 1 yrs; 164 ± 3 cm; 67 ± 10 kg	Sex, experience level, ball-carrying technique	N/A	To assess sprint times with different ball-carrying techniques and to examine the effects of experience and sex.	10m and flying 20m (10m build) speed	10m sprint speed was slower for female beginners carrying the ball vs without the ball ($p<0.01$); there was no difference for experienced females or males. Flying 20m sprint speed was slower for males carrying the ball with two hands and beginner females ($p<0.05$) but was not different for experienced females.
Physiology								
[165]	NR	NR (n=19)	24 ± 1 yrs	Relationships between variables	N/A	To investigate in female rugby players the relationships between these specific aspects of body composition and blood rheology.	Hemorheological in vitro measures: apparent viscosity of whole blood at native hematocrit, plasma viscosity, and blood viscosity at corrected hematocrit, RBC aggregation. Physical/physiological qualities: isometric handgrip, VO_2max, adductor isometric strength Anthropometry: Fat mass, FFM	VO2max was not related to blood rheology (hematocrit: p=0.770; plasma viscosity: p=0.9533). Isometric handgrip strength was negatively correlated to red blood cell aggregability (Myrenne M: r = −0.57839; p=0.00948; M1 r = −0.58910; p=0.00795). Adductor isometric strength was negatively correlated to red blood cell aggregability Myrenne M (r = −0.5033; p=0.0280). Fat mass is a major determinant of VO2max either measured by a field test (r = −0.766; p=0.00013) or exercise test (r = −0.575; p=0.00994).
[159]	Sevens	International (n=22)	25 ± 5 yrs; 168 ± 6 cm; 69 ± 7 kg	Relationship between physical and physiological variables	N/A	To compare a field-based critical velocity running test to routine laboratory and field-based tests of aerobic fitness in women's rugby 7's players.	YYIRT-1, VO_2max, critical velocity running test GPS (SPI Pro X, GPSports): total distance, average speed, high-intensity running and sprinting distance	The critical velocity test was *highly* correlated with the YYIRT1 test (r = 0.86). Average speed correlated *largely* with the YYIRT1 (r = 0.62) and critical velocity (r = 0.51) tests. Total game distance correlated *moderately* with the YYIRT1 (r = 0.49) and critical velocity (r = 0.36)

[160]	Sevens	International (n=12)	24 ± 5 yrs; 168 ± 4 cm; 68 ± 8 kg	Relationship between physiological variables	N/A	To establish a physiologically defined threshold for the analysis of high-intensity running. To explore game movement patterns using individualised speed thresholds, as well as the industry-used threshold.	VT_{2speed} (m·s^{-1}), velocity at VO2max (vVO2max;m·s^{-1}) and relative VO2max (mL·kg^{-1}·min^{-1}); GPS (SPI HPU, GPSports): distance covered at various intensities, VT2speed, maximal velocity	Compared to the mean VT_{2speed} threshold (3.5 m·s^{-1}), the industry-used threshold of 5 m·s^{-1} underestimated the absolute amount of high-intensity running completed by individual players by up to 30%. Using an individualised threshold, high-intensity running could over- or underestimating high-intensity running by up to 14% compared to the mean VT_{2speed} threshold.
[164]	NR	International (n=15)	25 ± 6 yrs	N/A	N/A	To explore athletes' past and current experiences and perceptions of the menstrual cycle in relation to its impact on sporting performance.	Questionnaire assessing menstrual cycle symptoms, perceptual impact, perceptual resolution and support	Almost all athletes (93%) reported menstrual cycle-related symptoms. 33% perceived heavy menstrual bleeding and 67% considered these symptoms impaired their performances. Two-thirds of athletes self-medicated to alleviate symptoms. Thematic analysis 4 general dimensions: symptoms; impact; resolution and support.
[163]	NR	Sub-elite and elite (n=36)	26 ± 5 yrs; 168 ± 6 cm; 73 ± 10 kg	RMR prediction equations	N/A	To determine the accuracy of 7 equations in predicting RMR of female rugby athletes, and in addition to explore biomarkers of muscle damage and LEA.	Body composition, RMR, risk of LEA, and CK	Measured RMR (indirect calorimetry) = 1651±167 kcal·d^{-1}. The Cunningham, Ten Haaf, and Watson (body mass) predicted values did not differ from measured ($p>0.05$), while all other predicted values differed significantly ($p<0.001$)
[162]	NR	Varsity (n=95)	20 ± 2 yrs	N/A	N/A	To determine the prevalence of urinary incontinence among female university varsity rugby player	Self-administered questionnaire including demographics, Urogenital Distress Inventory short form, rugby related activities, degree of bother, previous treatment, desire for treatment and coping strategies	Urinary incontinence prevalence = 54% 90% leaked urine when competing in a rugby game. Most players reported they were not bothered or only slightly bothered by their urinary leaking.
[187]	Sevens	Olympic (n=14)	27 ± 5 yrs; 169 ± 5 cm; 68 ± 5 kg	High and low power production	N/A	To analyse the relationship between skeletal muscle properties measured through TMG and the peak power output production capacity.	TMG: vastus lateralis, rectus femoris, vastus medialis 30s Wingate	High power presented an *almost certainly* higher PPO (ES = 3.00) than low power, as well as a *very likely* lower radial displacement (ES = 1.68) and velocity of deformation (ES = 1.87) of the vastus lateralis. PPO was *very largely* related to the radial displacement (r = −0.75) and velocity of deformation (r = −0.70) of vastus lateralis.
Training								
[188]	Sevens	Elite (n=12)	24 ± 4 yrs; 169 ± 6 cm; 70 ± 5 kg	N/A	6 weeks	To evaluate weekly changes in CMJ performance in elite female rugby sevens players over the course of a 6-week training block of progressively increasing training load.	CMJ variables: power, force, velocity, height, displacement and mechanistic characteristics; training load, wellness	Training load increased from weeks 2-6 (ES = 2.47). CMJ flight time, peak displacement, time to peak force and force at zero velocity displayed multiple changes indicative of diminished neuromuscular function.
[167]	Sevens League Union	Women's rugby S&C coaches	NR	N/A	N/A	To explore a comprehensive approach to physical preparation practices currently utilized in female rugby codes	Questionnaire assessing participant characteristics, pre-season, in-season and off-season physical preparation, recovery, monitoring and sport science technology, and unique aspects in female rugby	National or regional/state level female athletes = 78% Performance testing frequency = pre- (97%) and in-season (86%), off-season (23%) Menstrual cycle monitoring = 22% Unique considerations = psycho-social, menstrual, physical

*Sample size and participant characteristics for women's rugby athletes only. 1RM = one repetition maximum; BMD = bone mineral density; BMI = body mass index; CK = creatine kinase; CMJ = countermovement jump; COD = change of direction; Drf = rate of decrease in the ratio of force; DXA = dual-energy X-ray absorptiometry; EO = external oblique; ES = effect size; FFM = fat-free mass; IO = internal oblique; IRD = interrecti distance; ISS = initial sprint speed; LEA = low energy availability; M1 = red blood cell facilitated aggregation at low shear rate after shearing at 600 s-1; MSS = maximal sprinting speed; Myrenne M = red blood cell aggregation during stasis after shearing at 600 s-1; N/A = not applicable; NR = not reported; PPO = peak power output; r = correlation coefficient; RA = rectus abdominis; Rfmax = maximal value for the ratio of force; RMR = resting metabolic rate; SLJ = standing long jump; STJ = standing triple jump; TMG = tensiomyography; TrAb = transversus abdominis; VT2speed = speed at the second ventilatory threshold; W = watts

Supplementary Table 7. Rugby code, participant characteristics, aims, outcome measures and key findings of studies within 'nutrition' (n=6) and 'psychology' (n=5) evidence-based themes.

Study	Rugby Code	*Cohort, sample size (n)	*Participant characteristics: age (yrs), height (cm), body mass (kg)	Study aims	Study outcome measures	Key findings
Nutrition						
[131]	Sevens	International (n=23)	24 ± 5 yrs; 172 ± 5 cm	To quantify haematological changes in male and female rugby sevens players over a competitive season, and to quantifying the incidence of iron deficiency in female players.	Biochemical analysis: iron, ferritin, transferrin Contraceptive use	Female pre-season ferritin concentrations = 51±24 μg·L; which declined substantially (~20%) by mid-season, but recovered by end-season 23% female players were classified as iron deficient (ferritin <30 μg·L); greatest deficiency incidence occurred in mid-season (30%). Oral contraception and dietary iron intake had unclear influence on female players' ferritin concentration, while age was largely positively correlated (r=0.66±~0.33).
[134]	League	International (n=10)	25 ± 6 yrs	To establish hydration status, determine sweat loss, fluid intake, sweat, and Δblood sodium during training and match-play in female rugby league.	Urine osmolality, body mass, blood sodium concentration	Urine osmolality on arrival to match-play (382 ± 302 mOsmol·kg^{-1}) and training (667 ± 260 mOsmol·kg^{-1}) were indicative of euhydration. Players experienced a body mass loss of 0.50 ± 0.45 and 0.56 ± 0.53% during match-play and training, respectively. During match-play, players consumed 1.21 ± 0.43 kg of fluid and had a sweat loss of 1.54 ± 0.48 kg. During training, players consumed 1.07 ± 0.90 kg of fluid, in comparison with 1.25 ± 0.83 kg of sweat loss.
[135]	Union	University (n=16)	21 ± 2 yrs; 158 ± 40 cm; 78 ± 15 kg	To observe the hydration status, in male and female university rugby union players over 3 training sessions and to examine changes in sweat loss estimations.	Body mass, urine specific gravity, and self-reported thirst scores	Mean body mass changes did not exceed 2% lost for either gender on any of the three training sessions. Females significantly underestimated sweat loss by ~64% on day one (p<0.01), and improved estimations to ~60% on day three, however, still significantly underestimated (p<0.01). This finding was similar in males.
[136]	NR	Professional and amateur (n=61)	24 ± 5 yrs; 168 ± 6 cm; 68 ± 11 kg	Analyse the dietary supplementation consumption pattern in federated rugby players, including possible differences based on sex and competitive level	Questionnaire on dietary supplementation consumption	43% of female players consumed sports bars 39% of female players consumed caffeine 38% of female players consumed sports drinks 25% of female players consumed whey protein
[133]	Sevens	Elite (n=17)	24 ± 3 yrs; 170 ± 4 cm	To describe hepcidin concentrations in conjunction with serum ferritin amongst elite female rugby sevens players.	Iron, SF, soluble transferrin receptor, high sensitivity C-reactive protein and hepcidin	18% were iron deficient (SF<30 μg·L) with 29-35% of players with sub-optimal iron stores at some point during the study (SF<45 μg·L) Serum hepcidin was strongly correlated with SF (r=0.61, P=0.0001).
[132]	Sevens	Elite (n=43)	25 ± 4 yrs; 168 ± 6 cm; 68 ± 7 kg	To assess the vitamin D status of elite Irish athletes participating in high-profile sports and establish if travel, supplementation and/or sunbed-use predict vitamin D status	25-hydroxyvitamin D, plasma parathyroid hormone, serum calcium concentrations lifestyle questionnaire	Total 25-hydroxyvitamin D was 66.20 ± 24.44 nmol·L which was less than in boxing and cricket (p<0.05). On average, women's rugby seven athletes were vitamin D sufficient.
Psychology						
[171]	NR	International (n=18)	NR	To identify early maladaptive schema elements, that stimulate a "repair and healing game", leading to high level athletic performance	Young's Schemas Questionnaire	An average of 5 early maladaptive schemas per rugby player were identified. This included a wide variety (17 of 18). 83.3% of players showed self-sacrifice, 77.8% unrealistic standards/hypercriticism, 55.6% punishment, 50% entitlement/grandiosity and 50% approval seeking. Rugby players were deemed to have stronger emotional distress in comparison to handball players.

[168]	Union	International (n=10)	32 yrs	To examine the participant motivation of Canadian women players by identifying positive influences on participation and what it is about rugby that motivates women to start and continue playing to an elite level.	Open-ended, semi-structured interviews	Participant motivation was multifaceted, encompassing motives which changed and evolved over time. As these players progressed from lower level teams to elite level, their motivation developed from their initial motivation to participate in rugby to focussing on achievement. Players' rugby experiences were generally positive. Four major participation motivation themes comprised were identified: Getting started with rugby; Physical aspects; Achievement and success; and On- and off-field player interaction.
[169]	Union and Sevens	Collegiate and national (n=122)	20 ± 1 yrs	To investigate the role of mental toughness in injury response and coping with female athletes in rugby and roller derby.	Self-reported mental toughness, hardiness, optimism, coping with injury and psychological response to injury	Rugby players had positive associations between mental toughness and adaptive responses such as problem-focused, emotion-focused coping and feeling reorganized ($p<0.05$). Rugby players who would play through injury reported higher mental toughness than those who would not play through injury.
[172]	NR	Varsity (n=10)	20 ± 1 yrs; 168 ± 7 cm; 72 ± 15 kg	To identify the effects of sport-specific training on avoidance strategies during a head-on (180°) collision course with an approaching person.	Time to contact	Rugby athletes avoided significantly later than non-athletes (0.94±0.30s vs. 1.52±0.14s, $p<0.001$).
[170]	NR	University (n=221)	20 ± 2 yrs	To test the four-stage sequence of relationships between coaches' perceived interpersonal coaching styles, to athletes' basic psychological needs, self-determined motives, and performance.	The Coach Interpersonal Scale, Basic Needs Satisfaction in Sport Scale, three of the six subscales from the Behavioural Regulation in Sport Questionnaire, A revised version of the seven-item Game Performance Assessment Instrument	All basic psychological needs were perceived to be highly fulfilled. Of the three interpersonal coaching styles, athletes' perception of the autonomy support and involvement provided by their coaches were more strongly correlated with all three basic needs than structure.

*Cohort, sample size and participant characteristics for women's rugby athletes only. NR = not reported; SF = serum ferritin

Supplementary Table 8. Expert-based sub-themes that did not reach consensus, median research priority (interquartile range) calculated from 5-point Likert scale, and percentage of expert agreement.

Expert-based Theme	Sub-themes	Median Research Priority (IQR)	Low (%)	Medium (%)	High (%)
Female health	Relationship between hormonal contraceptive use, training and performance	4.0 (1.0)	17	27	57
	Pelvic health	3.0 (1.0)	13	50	37
	Effects of the menstrual cycle and hormonal contraceptives on concussion testing and treatment	3.0 (1.0)	13	43	43
	Use and decision-making process of hormonal contraceptive use	3.0 (1.0)	23	40	37
	Pregnancy and childbirth	3.0 (2.0)	30	33	37
	Breast health	3.0 (1.8)	33	30	27
	Urinary incontinence	2.5 (1.0)	50	33	17
	Polycystic ovarian syndrome	3.0 (1.0)	43	47	10
Injury	Strength profiling for high-risk areas (e.g., neck, shoulder)	4.0 (1.0)	10	23	67
	Recovery time-frames from specific injuries	3.5 (1.0)	13	33	53
	Injury and wellness (e.g., sleep, stress, mood, soreness) relationship	4.0 (1.0)	10	33	57
	Knowledge and attitudes of injury prevention	3.0 (1.0)	13	40	47
	Strategies to optimise injury education of players and coaches	3.5 (1.0)	13	37	50

	Neuropsychological testing (e.g., memory, executive function, dementia) of players, and relationship to injury history	4.0 (1.0)	20	23	57
	Head acceleration kinematics	3.0 (1.0)	13	43	43
	Nutritional strategies to reduce concussion risk	3.0 (1.0)	33	43	23
Match Characteristics	Relationship between match characteristics (e.g., total distance) and injury	4.0 (1.0)	10	27	63
	Relationship between match characteristics (e.g., running distance) and key performance indicators (e.g., tackle success, time spent attacking)	3.5 (1.0)	13	37	50
	Technical and tactical match-play characteristics (e.g., tackle, pass, decision-making)	3.0 (1.0)	13	47	40
	Match characteristics e.g., total distance, high-speed running distance (incl. performance levels [e.g., junior, elite], positional differences, halves of play and changes over time)	3.0 (1.0)	17	47	37
	Peak sequences in match-play (e.g., worst-case scenarios)	3.0 (1.8)	30	43	27
Physical Performance	Physical characteristics (e.g., strength, speed, power) (incl. performance levels [e.g., junior, elite] and changes over time)	4.0 (1.0)	13	27	60
	Interventions (training, nutritional) to enhance performance (e.g., strength training to optimise ball-carrying)	4.0 (1.0)	3	43	53
	Preparation for tournament-play (e.g., short match turnaround in rugby world cups)	4.0 (1.0)	10	33	57
	Training adaptations (incl. positional differences)	4.0 (1.0)	13	30	57

	Longitudinal wellness (e.g., sleep, stress), training load (e.g., rating of perceived exertion) and physical performance (e.g., strength)	4.0 (1.0)	13	33	53
	Difference in physical and performance characteristics between women and transwomen	3.5 (2.0)	30	23	47
	Physiological profiles of women's rugby players (e.g., biochemical markers)	3.0 (1.0)	23	30	47
	Optimising microtechnology for female athletes (e.g., global positioning system [GPS] vests designed for women's bodies, female-specific running speed thresholds)	3.0 (2.0)	30	23	47
	Biomechanical effects (e.g., Q angle) on rugby performance (e.g., tackle, scrum, jackal)	3.0 (1.0)	23	43	33
	Nutritional requirements and supplementation (incl. performance levels [e.g., junior, elite])	3.0 (0.8)	17	57	27
	Relationship between physical performance (e.g., lower body strength) and rugby (e.g., dominant tackle)	3.0 (2.0)	30	37	33
	Reliability of microtechnology for rugby specific skills (e.g., collisions, accelerations)	3.0 (1.0)	23	47	30
	Anthropometric characteristics (e.g., body mass, bone mineral density) (incl. levels of performance [e.g., junior, elite])	3.0 (1.0)	17	57	27
	Transwomen participation in rugby	3.0 (2.0)	33	23	43
	Reliability and validity of physical performance tests	3.0 (1.8)	30	43	27
	Residual training effect of physical characteristics (i.e., how long it takes to de-train)	2.0 (1.0)	53	33	13
Psychology	Psychological aspects of dual-career players	4.0 (1.8)	20	20	60

Psychological demands of rugby	4.0 (1.0)	7	33	60
Optimising the relationship between (male) coaches and women's rugby players	4.0 (1.0)	13	30	57
Psychological barriers to rugby participation	4.0 (1.0)	17	27	57
Psychological aspects of post-rugby career players	3.0 (1.0)	17	33	50
Mental toughness	3.0 (2.0)	33	33	33

IQR, interquartile range.