Open access Review

BMJ Open Sport & Exercise Medicine

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

Omar Heyward ,[1,2,3] Stacey Emmonds,[1,4] Gregory Roe,[1,5] Sean Scantlebury,[1,4] Keith Stokes,[2,6] Ben Jones [1,3,4,7,8]

To cite: Heyward O, Emmonds S, Roe G, *et al*. Applied sports science and sports medicine in women's rugby: systematic scoping review and Delphi study to establish future research priorities. *BMJ Open Sport & Exercise Medicine* 2022;**8**:e001287. doi:10.1136/bmjsem-2021-001287

► Additional supplemental material is published online only. To view, please visit the journal online (http://dx.doi.org/10.1136/bmjsem-2021-001287).

Accepted 7 July 2022

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).

For numbered affiliations see end of article.

Correspondence to
Omar Heyward;
o.heyward@leedsbeckett.ac.uk

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

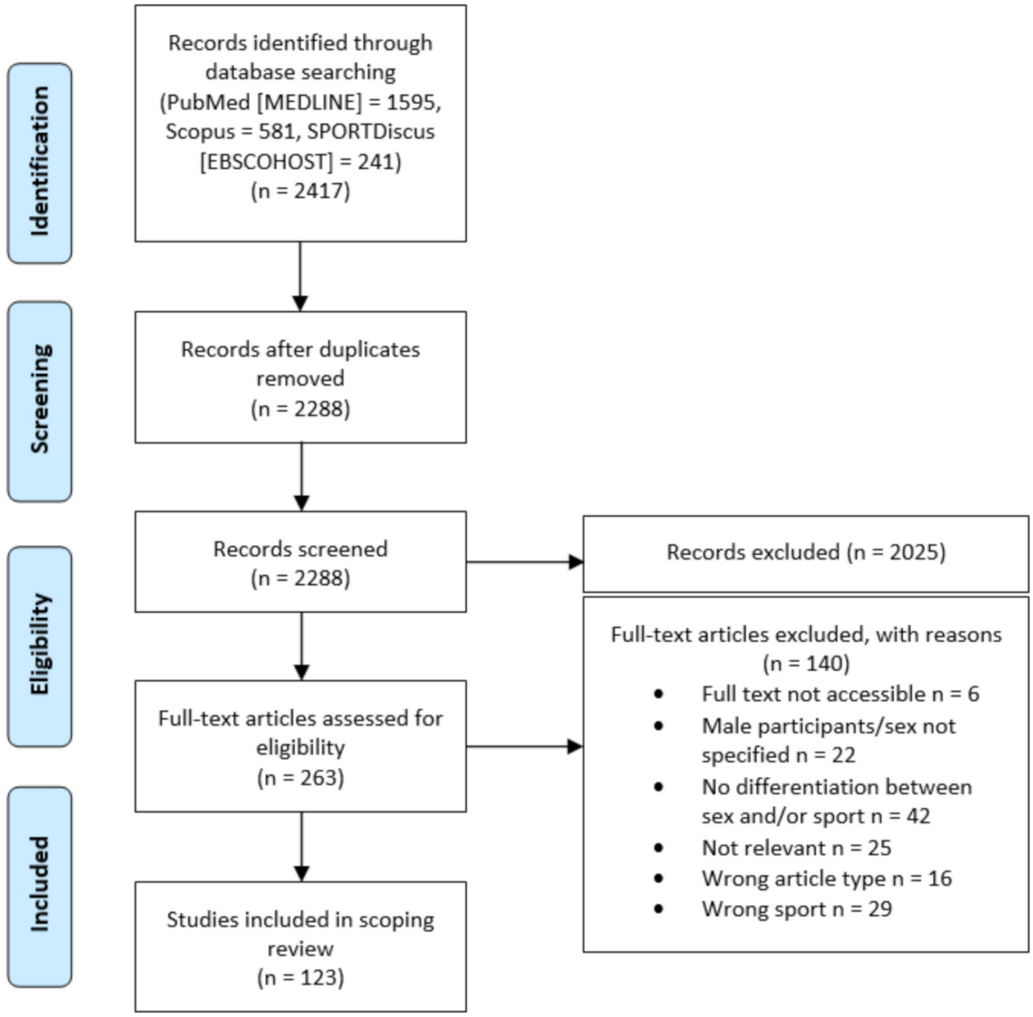

Figure 1 Flow of articles from identification to inclusion.

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]

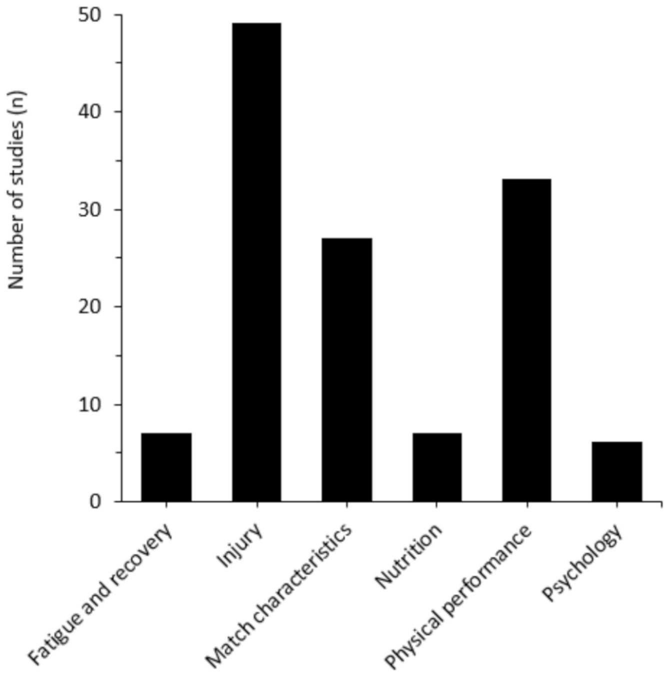

Figure 2 Number of studies per sports science and sports medicine theme.

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]

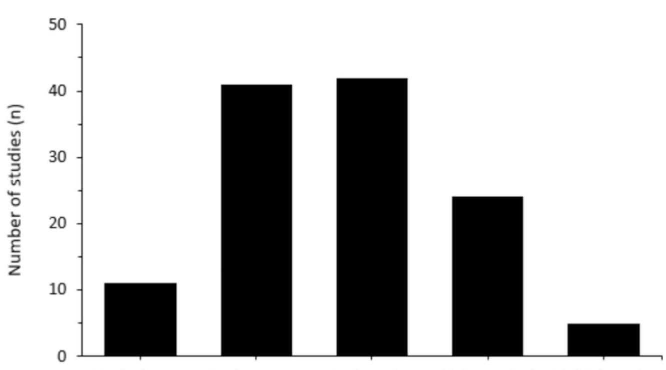

Figure 3 Number of studies per rugby code.

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.

Author affiliations
[1]Carnegie Applied Rugby Research (CARR) Centre, Carnegie School of Sport, Leeds Beckett University, Leeds, UK
[2]Rugby Football Union, Twickenham, UK
[3]Leeds Rhinos Rugby League Club, Leeds, UK
[4]England Performance Unit, Rugby Football League, Leeds, UK
[5]Bath Rugby, Bath, UK
[6]Department for Health, University of Bath, Bath, UK
[7]School of Science and Technology, University of New England, Armidale, New South Wales, Australia
[8]Division of Exercise Science and Sports Medicine, Department of Human Biology, Faculty of Health Sciences, the University of Cape Town and the Sports Science Institute of South Africa, Cape Town, South Africa

Twitter Omar Heyward @Omar_Heyward, Stacey Emmonds @S_Emmonds, Gregory Roe @GregoryRoe, Sean Scantlebury @SeanScants, Keith Stokes @drkeithstokes and Ben Jones @23benjones

Acknowledgements The authors would like to extend their gratitude to all members of the expert panel for their contributions. The expert panel members included the following: Allan Macdonald (Scottish Rugby), Andy Boyd (Scottish Rugby), Dr Anthea Clarke (La Trobe University), Dr Anthony Couderc (French Rugby Federation), Caoimhe Morris (Rugby Academy Ireland), Professor Carolyn Emery (University of Calgary), Dr Claire McLaughlin (Irish Rugby), Associate Professor Clare Minahan (Griffith University), Dr Éanna Falvey (World Rugby), Dr Izzy Moore (Cardiff Metropolitan University), Dr Gemma Phillips (Rugby Football League), Gemma Fay (Scottish Rugby), Dr Ian Sampson (Rugby Football League), Isla Shill (University of Calgary), Kathryn Dane (Irish Rugby), Dr Katy Hornby (England Rugby), Kris Robertson (Rugby Canada), Lauren Delany (Irish Rugby), Lesley McBride (University of Coventry), Lindsay Starling (University of Bath), Luke Woodhouse (England Rugby), Nicky Ponsford (England Rugby), Orlaith Curran (Irish Rugby), Rachel Faull-Brown (England Rugby), Dr Rachel Malcolm (Scottish Rugby), Robert Cain (USA Rugby), Dr Sharron Flahive (Australian Rugby), Stuart Barrow (Rugby Football League), Thomas Brindle (Rugby Football League) and Dr Thomas Longworth (Australian Rugby League Commission).

Contributors OH, KS and BJ conceptualised the manuscript. OH, SE, GR and BJ identified the method and framework for the manuscript. OH and SS proposed the search strategy and screened the studies. OH prepared the manuscript. All authors contributed to subsequent drafts and approved the final version.

Funding The authors have not declared a specific grant for this research from any funding agency in the public, commercial or not-for-profit sectors.

Competing interests None declared.

Patient consent for publication Consent obtained directly from patient(s).

Ethics approval This study involves human participants and was approved by the Leeds Beckett University Research Ethics Committee (#80327). Participants gave informed consent to participate in the study before taking part.

Provenance and peer review Not commissioned; externally peer reviewed.

ORCID iDs
Omar Heyward http://orcid.org/0000-0002-7390-6511
Ben Jones http://orcid.org/0000-0002-4274-6236

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 Gherghișan 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.