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Christian Cook has acted as a paid consultant to rugby teams over the previous 36 months.
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Ken Quarrie led the drafting and editing of the paper.

All authors:

- Provided substantial contributions to the meeting at which the content of the paper was developed, provided editorial comment.
- Assisted in the drafting and editing of the paper.
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- Agree to ensuring the integrity of the work.

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Not applicable

Multiple Choice Questions

Q1. How did the World Rugby Working Group define 'load' as it relates to professional rugby players?

a) The product of frequency and intensity of physical training
b) The total stressors and demands applied to the players
c) The total of session-RPE scores reported by players in a week
d) The number of matches and training sessions a player in which a player participates in a competition

Q2. Professional players who appeared in 30 matches or more over the four competitions for which data were provided in the paper were on which percentile in Table 2:

a) P5
b) P10
c) P50
d) P90
e) P95

Q3. Based on the available research evidence, matches typically comprise what proportion of exposure to physical rugby activities over a competition?

a) 91-100%
b) 45-51%
c) 15-21%
d) 5-11%
e) 0-4%

Q4. According to a meta-analysis of the rugby injury epidemiology of professional rugby players by Williams et al., matches had how many times higher rate of injury per 1000 player-hours than training?

a) 2
b) 11
c) 17
d) 27
e) 32

Q5. The Working Group noted that the terms 'measurement' and 'monitoring' as used in the paper referred to:

a) Loads applied and individual responses to load respectively
b) Individual responses to load and loads applied respectively
c) Physical elements of load only
d) The ethical and legal issues involved in capturing large amounts of information on players
e) 'Objective' and 'subjective' approaches respectively

Abstract

Background: The loads to which professional rugby players are subjected has been identified as a concern by coaches, players and administrators. In November 2014, World Rugby commissioned an expert group of rugby administrators, player representatives, sports medicine practitioners and sports scientists to identify both the physical demands and non-physical load issues associated with participation in professional rugby.

Objective: To describe the current state of knowledge about the loads encountered by professional rugby players and the implications for their physical and mental health.

Findings: The group defined 'load' as it relates to professional rugby players as the total stressors and demands applied to the players. In the 2013-2014 seasons, 40% of professional players appeared in 20 matches or more, and 20% appeared in 25 matches or more. Only 5% of players appeared in 30 matches or more. Matches account for approximately 5-11% of exposure to rugby related activities (matches, team, and individual training sessions) during professional competitions. The match injury rate is about 27 times higher than that in training. The working group surmised that players entering a new level of play, players with unresolved previous injuries, players who are relatively older, and players who are subjected to rapid increases in load are probably at increased risk of injury. Several methods exist for measuring the physical and non-physical loads players encounter, and monitoring their responses to those loads. A mix of 'objective' and 'subjective' measures in conjunction with effective communication among team staff and between staff and players was held to be the best approach to monitoring and managing player loads. While comprehensive monitoring holds promise for individually addressing player loads, it brings with it ethical and legal responsibilities that rugby organisations need to address to ensure that players' personal information is adequately protected.

Conclusions: Administrators, broadcasters, team owners, team staff and the players themselves have important roles in balancing the desire to have the 'best players' on the field with the ongoing health of the player. Although coaches have limited influence over match activities, they do control the exposure players have to matches via their selection decisions. By contrast, the coaching, fitness and medical staff exert significant control over the activities, duration and intensity of training sessions. If load is a major risk factor for injury then managing training loads should be an important element in enabling players to perform in a fit state as often as possible.

Introduction

Rugby Union (rugby) is a collision sport with a high reported incidence of training and match injuries.[1] According to World Rugby's website,[2] there are currently 120 countries affiliated to World Rugby with approximately 7 million players world-wide; the International Rugby Players Association reports that there are around 4000 professional players (Blackie, Personal Communication, 2015). Rugby became openly professional in 1995, an occurrence that was associated with marked increases in both the number of physical contact events typically occurring per match at the elite level of the sport and the body mass and physical performance characteristics of elite players.[3] The development, expansion and popularity of professional competitions have resulted in an extension of the playing season for many elite rugby players. Although rugby was traditionally a 'winter sport', the professional rugby season now lasts up to ten months with players potentially able to play in more than 30 matches per season. Because elite-level players are regularly required to play for different teams across multiple competitions, they often have very limited time available following the end of one competition to recover and attempt to improve their level of conditioning before beginning their next competition.[4]

Concerns have been expressed by administrators, managers, coaches, medical teams and players and their representative associations about the increasing loads that players face and the consequent implications for injury, ill-health and potential long-term sequelae (e.g.[5, 6]). Given these concerns, the measurement of load and monitoring of players responses to those loads has become increasingly prioritized within elite rugby. In November 2014, World Rugby convened an 'expert group' meeting of coaches, rugby administrators, player representatives, sports medicine practitioners and sports scientists to discuss the physical demands and non-physical load issues associated with participation in professional rugby. This paper, which resulted from that meeting, describes the current state of knowledge with respect to the typical loads encountered by professional rugby players and the implications for their physical and mental health.

Load definition – measuring loads applied to athletes and monitoring athlete responses

'Workload' and 'load' are terms widely used in rugby and other sports. There has been a lack of consistency regarding definition and use, in particular with respect to whether the term 'load' relates to the measurement of external stressors applied to an individual or to the monitoring of an individual's physiological and psychological responses to those stressors.

The group defined ‘load’ as it relates to professional rugby players as *the total stressors and demands applied to the players*. Load comprises rugby-related and non-rugby related inputs, of which the physical components can readily be characterized according to the FITT acronym – frequency, intensity, time and type.[7-9] The individual’s *response* to the load applied may be appraised through either ‘objective’ or ‘subjective’ monitoring, which are discussed below.[9] The relevance of load to athlete performance, well-being, and injury risk should be considered from both an acute and cumulative perspective. In order to reduce confusion this paper will refer to *measurement* of loads applied and *monitoring* of an individual’s response to load.

Some of the common elements that contribute to the loads experienced by professional rugby players are shown in Table 1. These vary both between players, and, within players, from day to day, over competitions and across their career. Note that some listed items could appear under more than one heading.

Table 1. Loads to which professional rugby players are subjected

- Physical loads
  - Matches
  - Training
    - Team practice
    - Individual gym-based training (e.g. strength and power training/cross training/flexibility and proprioception work)
    - Rugby conditioning (e.g. interval running/speed training/agility drills)
    - Pool/recovery
    - Fitness tests
  - Injury/illness management/rehabilitation
- Preparation for matches
  - Travel
    - Jet lag
    - Travel fatigue
  - Performance analysis
    - Learning team tactics/play patterns
    - Match reviews/previews
- Nutrition
  - Eating for body composition management
  - Timing/content of meals for performance
  - Alcohol/drug use
  - Supplement use
- Interpersonal relationships
  - Family
  - Friends
  - Team mates
  - Team staff
  - Agents/managers
  - Fans
  - Media
- Personal development
  - Career planning for life after rugby
  - Study/other employment
- Other demands/loads
  - Community promotions of rugby (e.g. coaching sessions at schools/clubs)
  - Sponsorship/commercial obligations
  - Media coverage
  - Drug testing
  - Socialising

Mellalieu and colleagues, who have provided more detailed breakdowns of stressors experienced by sports performers, categorized the demands faced by professional athletes under three main sources - competition, organisational, and personal.[10, 11]

Elite player exposure to rugby

Performance dominates the world of elite sport and the initial impetus for measurements of load and monitoring of athletes was driven by the desire to improve performance. Despite this, the typical exposure of elite players to rugby matches does not appear to have been published previously. Match appearance information (for the 2013-2014 Northern Hemisphere season, and the 2014 Southern Hemisphere season) for players in the Aviva Premiership, the Guinness Pro 12, Super Rugby and the French Top 14 league was obtained from Opta, a commercial sports data provider (Tables 2 and 3). Players in these tournaments can also appear in international matches and competitions below the level reported on, so in an attempt to provide an estimate of exposure that was as accurate as possible, information was integrated with player appearances in the following tournaments:

- Six Nations, the Rugby Championship, the Nations Cup, the Pacific Nations Cup, non-tournament internationals
- National Rugby Championship, ITM Cup, Currie Cup (provincial competitions in Australia, New Zealand and South Africa, respectively)
- The LV (Anglo-Welsh) Cup, the Heineken Cup and the European Challenge Cup (knock-out competitions in Europe)
- Invitational matches (e.g. Barbarians, trial matches)

Table 2. Percentile (P) breakdown of match appearances by professional players in 2014

	Competition				
Percentile	Aviva Premiership	Guinness Pro 12	Super Rugby	French Top 14	Overall
P1	1	1	1	1	1
P5	1	1	3	2	1
P10	2	2	6	4	2
P20	4	4	9	8	6
P30	8	9	12	12	10
P40	13	13	14	16	14
P50	16	15	16	20	17
P60	20	18	19	22	20
P70	24	21	21	24	23
P80	27	24	24	26	25
P90	29	27	26	29	28
P95	32	28	28	32	30
P99	36	33	30	36	34

Table 3. Percentile (P) breakdown of minutes played by professional players in 2014

	Competition				
Percentile	Aviva Premiership	Guinness Pro 12	Super Rugby	French Top 14	Overall
P1	8	6	11	11	8
P5	21	20	100	54	30
P10	50	56	206	118	80
P20	131	156	392	349	240
P30	322	333	560	548	451
P40	578	571	724	784	665
P50	821	789	873	961	852
P60	1042	940	1019	1152	1042
P70	1310	1180	1183	1338	1261
P80	1545	1409	1432	1518	1482
P90	1887	1644	1702	1792	1769
P95	2040	1853	1859	2005	1968
P99	2445	2171	2212	2352	2241

Information was obtained for 2348 players, of whom 673 played in at least one international over the period examined. Forty percent of players appeared in 20 matches or more, and 20% appeared in 25 matches or more. Fifty-six percent of those who appeared in 25 matches or more appeared in one or more internationals. Only 5% of players appeared in 30 matches or more. The median number of minutes played was 852 (Range: 2 to 2577). The median exposure (852 minutes) is equivalent to playing 10.7 full matches and the highest exposure (2577) is equivalent to 32.2 full matches. Because of substitutions and replacements elite players play on average two-thirds of each match in which they appear. The typical exposure to match play varies by position. Some positions (e.g. hookers) are substituted more often than others (e.g. wings), and at earlier points in matches.[12]

Physical demands of elite rugby

In general, backs run further, and at higher speeds, than forwards during both team training sessions [13, 14] and in matches.[12, 15-18] The typical distances covered during an in-season training week for a professional squad were reported by Bradley et al. to be 9600 ± 1200m for backs, and 7800 ± 950m for forwards.[13] Reported distances covered during matches have varied. The typical distance covered per match by backs appears to range from 5000m to 8000m, and for forwards from 4500m to 7000m.[12, 15-17] Reardon and colleagues have pointed out that because the maximal running speed of players varies substantially from player to player both across and within positions, evaluating the high-speed running demands of international matches needs to be done on an individual basis, rather than through the use of standard speed thresholds.[18] Forwards typically sustain higher collision loads per match than backs due to greater involvement in rucks, mauls and tackles, and the fact that only forwards participate in scrums. For example, backs are usually involved in about 11 ± 3 rucks per match whereas forwards are involved in 30 ± 5.[12]

Evaluating the relative intensity of matches compared with training sessions is difficult - during a competition players attempt to reach a physical and emotional peak for each match. The intensity of matches compared with training is reflected in the relative injury rates of the activities per 1000 hours of exposure. A meta-analysis of the injury epidemiology of men's professional rugby reported that the injury incidence in matches (~ 81 per 1000 player-hours) was 27 times higher than that in training (~ 3.0 per 1000 player-hours).[1] The same meta-analysis indicated that tackles, ruck/mauls, collisions and scrums (the elements of the sport where the greatest player-to-

player contact occurs) were associated with 92% of match injuries.[1] Despite the fact that matches are intense, they form a small percentage of the total rugby exposure experienced by a professional player. The RFU from England have administered an injury surveillance system for the teams competing in the English Premiership competition from 2002 through to 2014. Over that period, matches accounted for 7% of exposure, and training 93%.[19] Injury surveillance projects at the 2007 and 2011 Rugby World Cups indicated that matches comprised about 11% of exposure by time, and training 89%.[20, 21] A South African study of a Super Rugby team over the 2002-2004 seasons reported that matches represented 2% of total exposure during the pre-season and 9% in-season. Overall, matches comprised 5% of exposure.[22] Excluding match time, and taking both the pre-season and in-season phases into account, rugby training sessions formed 53% of the total training time, gym training 23%, rugby conditioning training 8%, 'Captain's runs' 7%, pool recovery sessions 3%, and fitness tests 1%. A 24 hour endurance training challenge in one season accounted for the remaining 5% of training time.[22]

Studies using session-RPEs [23, 24] have reported that match loads account for 15-27% of total rugby-related load. Although more research is needed to clarify the accuracy of the information on match and training exposure, it appears that elite rugby players' training loads are significantly higher than match loads.

Load and injury

Models of injury causation (Figure 1), such as that by Meeuwisse et al.[25] identify that the interactions between athlete-related (intrinsic) and activity-related (extrinsic) risk factors modify the likelihood of an athlete incurring an injury given a particular amount of exposure to events with the potential to result in injury.

<Insert Figure 1 here>

One postulated outcome of excessive load is that the injury burden on teams and players increases. Examples of high competition and training loads as a risk factor for injury have been identified in rugby,[26] football,[27] rugby league,[28-30] Australian Rules Football,[31] cricket,[32-34] and long-distance running.[35]

Injuries result from transfers of energy that exceed the tolerance of player's bodies to maintain their normal structure or function.[36-38] The group conjectured that sudden *changes* (especially

increases) in any or all of the factors that comprise physical load (frequency, intensity, duration, and type of activity) would increase the susceptibility of athletes to injury. In a recent opinion paper, Gabbett [39] hypothesized that the balance between recent (acute) and longer term (chronic) training loads may be an important determinant of injuries related to training load. Players who have minimal exposure to training and matches may be at a higher risk due to their lack of conditioning, while players who have very high levels of exposure to rugby training and match play may also become more susceptible to both acute and gradual onset injuries due to factors such as physical and mental fatigue and cumulative microtrauma.[39] While further research is needed to ascertain the extent to which these ideas hold true in practice, a recent study by Cross et al.[40] provides some support. Cross et al. found a U-shaped relationship between four-week cumulative load and subsequent injury risk among players in the English Premiership rugby competition.[40]

Hendricks and Lambert proposed a theoretical model of the tackle in which the risk of injury was represented as a function of the number of tackles a player had made over a given period (resulting in either acute or chronic fatigue), the magnitude of impact, or energy loads of each of the tackles, and the resulting muscle damage.[41] The model acknowledged that a sufficiently high energy impact would overcome the tolerance of even the best conditioned player using good tackle technique. Players with high levels of physical conditioning along with a high level of tackle skill, however, were postulated to be at lower risk of injury for any given combination of number of tackles per unit of time and the magnitude of impact of the tackles. Although high chronic loads have been linked to lower injury risk in some sports,[42] Hendricks and Lambert's model suggests that high chronic loads may reduce the tolerance of the player to future loads.[41]

There is evidence linking injury and team success in several football (soccer) studies [43-45] and a recent seven year prospective study by Williams et al. found that time loss injuries compromised team success in elite rugby.[46] The work by Williams et al. aside, it is important to recognize that most of the research into physical loads and injury in rugby to date has been conducted on single teams over short follow up periods, with resulting low numbers of injuries available for analysis. Given the level of evidence, many conclusions drawn from these studies are speculative. The problem of underpowered studies is widespread in applied sports science research, where the collection of reliable and valid data on large numbers of teams over extended periods presents considerable challenges. Clearly, larger, longer-term prospective studies are required, although the

degree to which such multi-organisation investigations would be supported in high performance sport also requires careful consideration.

While coaches can manage player exposure to matches via their selection decisions, the activities, duration and intensity of training are generally under more direct control. If physical load is a modifiable risk factor for injury then the focus of load management within rugby teams should primarily be directed towards training. Issues regarding total match exposure and competition calendars need to be addressed through discussion and negotiations between rugby administrators, team/club owners, player representatives, and broadcasters and sponsors, and informed by the best available evidence from sport science and medicine.

Load and psychological well-being

In comparison to other team-based collision sports, such as rugby league (see Twist and Highton, 2013 for a review [47]), little research has examined the relationship between load and players' psychological well-being in rugby union. Nicholls et al.[48] examined the mood and stressors of 16 young professional rugby players via daily questionnaires over a month. Nicholls et al. found that the players experienced negative affect (mood), and that they reported a range of sport and non-sport related stressors. The authors suggested that consideration be given to the impact of the stressors on the mental and physical readiness of players to perform and recover from matches and training.

Two studies have examined relationships between perceptions of the load experienced and the subsequent strategies adopted to manage and recover from the stress associated with these demands.[49, 50] A study of the relationship between perceived load, stress, and recovery in Australian adolescent male players (n=106) over an entire competitive season found increases in participation demands, feelings of stress and under-recovery during intensive phases of competition.[50] Grobbelaar et al. [49] reported similar relationships in a sample of South African collegiate players (n=41) over a 5-month pre-season and competition period, and recommended that playing position, experience level and starting status be considered when monitoring players to attempt to reduce the likelihood of overtraining and burnout. Interestingly, in the study by Hartwig et al.,[50] those players with the highest training and physical activity volumes during the season demonstrated more favourable recovery–stress states than players with moderate- and low-

volume demands, suggesting potential adaptation or protective processes may occur in players as a result of prolonged exposure to increased loads.

There is an interest in examining the relationship between load and mood because as well as compromising physical performance, fatigue as a result of load may manifest as changes in an athlete's emotional behaviour, such as reduced motivation, emotional disturbances, and increased perceived effort and muscle soreness.[47] A dose-response relationship between training load and mood has been reported in several sports, including cycling, rowing and kayaking.[51] West et al. [52] examined mood changes in addition to recovery time of neuromuscular and hormonal variables after a professional rugby match. While no relationships were noted between mood and changes in peak power output, testosterone, cortisol, or testosterone to cortisol ratio, mood disturbance was found to increase for up to 12 hours post-match, before returning to baseline between 36 and 60 hours post-match. This suggests that mood may be more sensitive to load than physiological measures or hormonal markers, and thus a useful monitoring tool, in the immediate aftermath of high physiological loads. Whether mood changes are equally sensitive to chronic loading over the course of a season, as well as to training activities and non-rugby related stressors are topics that require further research.

Burnout is considered a possible consequence of prolonged exposure to training and competition load on an individual's psychological state, and is defined as an enduring sport-related experiential syndrome characterized by: (a) emotional and physical exhaustion; (b) perceptions of lack of achievement and success, and c) devaluation of the perceived benefits gained from sport involvement. Significant changes were observed in characteristics of burnout during a competitive rugby year among a sample (n=109) of New Zealand Super Rugby players, with reduced accomplishment observed moving from pre-season to in-season.[53, 54]

Burnout was found to be associated with injury, non-selection, rugby experience and team environment, with more injuries leading to greater feelings of exhaustion/devaluation. Players *attributed* burnout to the following: competition transitions, pressure to comply with demands, heavy training and playing load, injury, the competitive rugby environment, an 'anti-rest culture', pressure to perform and media/public pressure and expectation.[55] Interestingly, players with greater international experience were more likely to report exhaustion/devaluation.[54] A follow up study by the same authors [56] found that while all individuals experienced demands associated

with burnout, the key indicator of whether burnout symptoms were reported was the individual's perception of these demands and the available resources to cope with the demands.

Measurement of physical loads in rugby

The quantification of physical loads in rugby has historically posed challenges, as both rugby matches and team training sessions comprise periods of high and low intensity running, interspersed with high intensity collision (e.g. tackles and rucks) and pushing (e.g. scrums and mauls) activities. Individual training also involves a range of activities, typically including resistance exercises, running, and cross training exercises of varying intensity and duration.

Measurements of physical loads applied to rugby players range from simply recording exposure in terms of minutes trained or games played to sophisticated measurements that include notational analysis (counts and descriptions of activities) either directly or from video recordings, speed of movement and distances covered via Global Positioning Systems or camera based tracking systems, and accelerations via inertial measurement units.[14] In-depth evaluation of the pros and cons of methods for measuring the loads to which players are subjected, and monitoring their responses to those loads, was beyond the scope of this paper, but these issues have been discussed in several chapters of a recent book. [57]

The sophistication of measurements of physical load and the use of the data obtained depends on the availability of technology, and the experience and expertise of the training and analysis staff. It is unclear whether the commonly used measurement tools adequately assess the loads applied during rugby matches or training sessions, particularly the load associated with contact and collisions between players.

Measurement of non-physical loads in rugby

Travel (especially air travel through multiple time zones), sponsorship and commercial obligations, relationship stressors (both within and external to the team), selection (or non-selection) pressures, media coverage and contracting/salary negotiations are all likely to play a part in the current state of readiness of a player to sustain further work. As yet, there has been relatively little research into the importance of these factors in professional rugby union teams — most of the work to date has been limited to single teams over short follow up periods.

The Super Rugby competition is played by countries that are widely spread geographically, which results in high travel demands. A paper by George et al.[58] examined the effect of travel on team performance indicators in the 2012 Super Rugby competition and found that air travel had a negative effect on points scored in the second half of matches, and teams that had travelled internationally to play matches tended to miss more tackles in the second half of matches than they did in the first half. Players competing in the Super Rugby competition who also represent their national team can face multiple trips around the world per year - examination of the flights taken by one All Black in the 2014 season indicates that over the course of the season he flew over 158,000 km, or the equivalent of four times around the world, and crossed 74 time zones (Quarrie, Personal Communication, 2016). Fuller et al.[59] found no evidence to suggest that travelling through multiple time zones to compete in the World Sevens rugby tournament increased the risk of injury to players.

Monitoring rugby players' responses to loads

The purpose of monitoring a player's response to the loads they sustain is to obtain information that may be used by coaches, medical and conditioning staff, and the player, to inform decisions about the effectiveness of training, recovery and nutrition regimes, injury management protocols, and team selection. It has been reported by coaches that the most important aspects of monitoring is the collection of personal comments from athletes about the perceived training load and the duration and type of training (e.g. simply asking players how they are feeling).[60] Collecting this type of data and then responding to the reported symptoms by adjusting training protocols, rather than simply adhering to a structured training plan, has been shown to produce greater adaptations among a group of cyclists.[61] As with measurements of physical load, monitoring responses to load can range from simple observation, through recording of responses to activities via diaries, to physical performance and anthropometric assessments and collecting data from players directly via, for example, body fluid samples. Saw et al.[9] summarised indices of response to load and athlete well-being both during activity and at rest. 'Objective' measures of response to load included heart-rate, oxygen uptake, endocrine, haematological and immunological responses, and direct measures of performance. 'Subjective' measures were athlete (or coach/trainer) ratings of mood, stress, life demands, and overtraining. Using a combination of objective and subjective measures was held to be the most useful approach; although subjective measures tended to be more

responsive to changes in athlete well-being, objective measures were valuable for assessing current performance capacities and identifying medical conditions.[9] The potentially useful approach of monitoring psychomotor speed [51] requires further validation of its serial use in team settings.

Session ratings of perceived exertion (RPE) combine subjective ratings of intensity of activity with measures of duration (minutes), and are considered to be a simple, inexpensive and easily implemented system that is both valid and reliable in terms of monitoring physical loads.[62-64] Comprehensive monitoring requires the integration of objective match load (match movement patterns and activities), physiological data and biomarkers, and subjective coach and player perceptions. Any desired approach must be valued by players and coaches, achieve high compliance, and must be conducted in a supportive environment underpinned by a desire to protect player welfare and team performance. Effective measurement of load and monitoring of athlete responses must also fulfil the principles of clinimetrics, in that qualities and quantities should be valid, reliable, sensitive to change and predictive; in addition, they should be non-invasive, non-aversive and inexpensive in order to be effective in a dynamic competitive sporting environment.[65, 66] Effective monitoring also requires an individual approach, both with respect to the collection of data, and to its interpretation. Individual players appear to respond differently to given training and competition loads based on personal characteristics such as age, position, playing training and injury history, and current physiological attributes.[39]

Within a given context, in the absence of significant differences between players' conditioning and fatigue levels, measuring load via session-RPE has been shown to correlate with objective physiological indices of load, such as heart rate, blood lactate and GPS derived measures, across a range of sports [65, 67, 68] and to be sensitive to changes in the intensity and duration of activities.[69, 70] Studies have also shown acute and chronic session-RPE measures to be related to injury and illness incidence,[29, 71-73] which suggests that this simple tool is an effective means of monitoring the response to load. Questions remain about whether sessions comprising different activities that are rated by players to be of similar intensity are truly equivalent in terms of training load. For example, a gym-based strength session, a running session and a contact training session, may be assigned similar RPE scores by an athlete, but they may have very different physiological effects, result in different energy expenditure, require different amounts of recovery time to return to baseline performance level and result in different training adaptations.

Automating and standardizing data capture and improvements in integrating data from a range of sources (e.g. match and training activities, injuries, physiological and self-report responses to rugby exposure) both within and across teams should facilitate individual player management and yield information that can be used to inform decisions about modifications to in-match activities (via the laws and regulations of the sport) and tournament structures. It is important that teams and administrators are aware of the responsibilities that employment and privacy laws and regulations place upon them regarding data capture, storage and use/dissemination of personal information if they adopt such systems, as well as the ethical, psychological and social issues involved.[74, 75]

Conclusions and recommendations

Elite rugby players typically participate in about 17 matches per year; 20% are involved in 25 matches or more, and 5% appear in 30 matches or more. Estimates of training exposure indicate that matches make up between 7% and 27% of total player exposure to rugby. While coaches can manage player exposure to matches via their selection decisions, the activities, duration and intensity of training are generally more modifiable. If load is a major risk factor for injury then the focus of load management in rugby should primarily be training.

It appears that subjective measures of player response to load (e.g. self-ratings of state) are more sensitive to changes in physical loads than most objective markers that have been the subject of published research to date. Objective measures can be useful for quantifying current physiological capacity and diagnosing illnesses. Combining objective and subjective measures is currently held by experts to be the most effective method for ongoing monitoring of athlete response to load. Developments in the ease of capture, integration and storage of large amounts of information on players *may* enable better decisions to be made based on the current state of players in response to the acute and chronic loads to which they have been exposed. Such technologies brings with them ethical and workplace issues, and it is important that teams and administrators are aware of the responsibilities that employment and privacy laws and regulations place upon them regarding data capture, storage and use/dissemination.

Because players vary widely in their response to a given load, management of player load should be individualised. Ideally, all staff who play a part in planning and implementing training and playing schedules should communicate both among themselves and in close consultation with players to balance short-term (e.g. within a competition) goals with the longer term objectives of

ongoing improvement and development of players to enable them to play at the highest level of which they are capable for as long as they wish to do so.

Professional rugby union has a relatively high rate of injury. Although all players are at risk of injury whenever they are playing or training, further research is required to ascertain what factors play important roles in moderating an individual's response to the loads they face, and whether there is a level of exposure beyond which the risk of injury and negative health states increases rapidly. The extent to which sudden changes in load, as opposed to total load per se, is a risk factor should be investigated. Much of the research evidence available regarding relationships between loads, injury and performance in rugby has come from studies that are limited in terms of sample sizes and follow-up periods. Larger studies with longer follow-up periods are required to enable evidence-informed decisions to be made with a reasonable degree of confidence that the relationships observed in the studies are likely to generalise to other playing populations. Further research is also needed to examine what effects exposure to elite rugby has on the long-term physical and mental health of players.

This international World Rugby working group recommends that:

- Coaches/team staff look closely at managing load via planning and manipulating training activities;
- At a minimum, measuring load at professional level should incorporate session-RPE and exposure time;
- Monitoring systems that include a range of subjective and objective measures, including mood, are desirable. Responses that are abnormal should feed into decisions regarding up-coming match, training and travel loads for the individual;
- Caution should be used when incorporating sudden changes in frequency, intensity, time and type of training, such as those that often accompany moving from preseason training to matches, or within competitions when teams are returning from scheduled 'byes' or inter-competition breaks;
- Loads should be individually managed. Some players *may* be at higher risk - specifically less experienced players entering a new (higher) level of competition, those who are returning from injuries, and (relatively) old players. Research is needed to quantify the extent to which these risk factors impact on injury and wellbeing for a given physical load;

- Further research into the importance of loads outside of playing or training (e.g. air travel through multiple time zones, sponsorship and commercial obligations, relationship stressors, selection pressures, media coverage and contracting/salary negotiations) associated with playing professional rugby is required. In the interim, these factors should to be taken into account when assessing the current state of readiness of a player to sustain further work;
- Coaching should attempt to bring the fitness and technical ability of all players in their squad up to a level such that the playing team is minimally affected by the substitution of one player for another;
- Rugby administrative bodies and interested parties such as broadcasters carefully consider the demands that tournament structures can potentially place on player health and well-being; and
- Research projects of substantially larger scale than have been typically conducted in sport science are needed to provide evidence of sufficient quality to inform decision-making regarding player load and welfare.

What are the new findings?

- The World Rugby working group defined load as it relates to professional rugby players as 'the total stressors and demands applied to the players'.
- 20% of professional rugby players appeared in 25 matches or more in the 2013-2014 seasons; 5% appeared in 30 matches or more.
- Matches account for approximately 5-11% of exposure to rugby-related activities (matches, team, and individual training sessions, recovery sessions).
- Players face multiple stressors - these vary between players, and, within players, from day to day, across competitions and over their careers.
- Player loads should be individually managed, preferably using a combination of 'objective' and 'subjective' measures, along with effective communication among team staff and with the player.
- The quality of evidence regarding relationships between many elements of load and subsequent player performance and injury risk is poor. Further research using larger samples sizes and longer follow-up periods than has been the norm to-date is recommended.

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Figure legend:

Figure 1. A dynamic, recursive model of injury causation [25]. Used with permission.