Do Subjective Workload Monitoring Variables Predict Contact and Non-Contact Injuries in Elite Female Rugby 7's Players?

By Emily Muscatt

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First supervisor: Stephen Patterson

Second supervisor: Mark Waldron

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CHAPTER 1

ABSTRACT

Objectives: The purpose of this study was to investigate the relationships between subjective measures of load and injuries in elite female rugby 7's players.

Methods: The data was collected from 18 players from July 2017-April 2018. Measures of well-being were self-reported by the players each morning on an app with scales from 1-6. Rate of perceived exertion (SRPE) was measured within 30mins of the activity for all training sessions and matches which was included as a measure of load. Variables were analysed using a binary logistic regression model against contact and non-contact injuries to assess relationships. Further analysis was performed to assess the pattern of variables 21 days prior to injury.

Results: 55 injuries were recorded over the study period with an injury rate of 165/1000 match hours and 14/1000 training hours. Readiness to train (OR=0.651), duration of sleep (OR=0.994), SRPE (OR=0.998), upper (OR=0.514) and lower limb (OR=1.437) soreness were significant ($p=<0.05$) independent predictors of injury for non-contact injuries. Match play was the only variable to significantly predict contact injuries (OR=5.558). There were no significant relationships seen in the 21 days prior to injury. The relationship between training load and injuries was seen to follow a U-shaped pattern with an acute:chronic ratio >1.5 having the most risk of injury.

Conclusion: Subjective load monitoring variables are associated with an increased injury risk in elite female rugby 7's players. Monitoring and reacting to these variables could be a method of reducing non-contact injuries in this group.

CHAPTER 2

INTRODUCTION

Rugby 7's is an intermittent high-intensity contact sport that is categorised by frequent, maximal speed running bouts and short recovery times [1]. To be successful in elite sport, player durability (i.e. the ability to tolerate the demands of the sport and training without injury) is thought to be a key component to success [2]. Williams et al.[3] looked at the correlation between injury burden and team success in elite men's rugby union over 7 years. They found a negative association between injury burden and league points tally due to the availability of key players for selection and players absence from training disrupting tactical planning. To mitigate the loss of player availability, attention has turned to many aspects of load monitoring to ensure the players are responding in the desired way. Whilst objective measures have offered some solutions, the greater understanding of psychosocial elements in a player's well-being and response to load is being sought to highlight when a player is at risk of injury and prevent time loss as much as possible.

Injuries in rugby 7's are common due to the amount of collisions that occur and the amount of running that is involved, including high-speed changes of direction [4]. With 7's having greater 'ball-in -play' time and fewer set plays than 15's, the physical demands on the players differs in intensity in rugby 7's [5]. As it is a shorter game (2x7min halves) the amount of sprints to rest ratios is increased (from 1:0.5 vs 1:2 in 15's rugby) needing a greater repeat sprint ability [6,7]. The larger distances between players leads to high energy tackles with players in an acutely fatigued state when entering into tackles and trying to evade opponents [8]. Sevens players cover more metres per minute (~100 vs ~55-70m/min) [9] with the average speed in a 7's match 6.4km/h vs 4.2km/h in 15's [6] indicating a higher level of anaerobic ability is required in rugby 7's. During the female rugby 7's world cup, match play has seen to have an injury rate of 187/1000 hours during matches and 10/1000 hours in training [10]. This is higher than in men's 7's (106/1000) [11] and in women's rugby 15's (36/1000) [12]. In Mirsafaei-Rizi et al's [13] study it was observed that women were 8x more likely to sustain a severe injury than men in rugby 7's. In keeping with other codes of rugby, the lower extremity is the most injured in elite female 7's players with ligaments being the most commonly damaged structure [5,11,13]. This is unsurprising given the nature of sevens rugby involving cutting, twisting and pivoting into contact situations, and the observed higher injury risk women have to suffer knee ligament injuries [14]. It has been postulated that the reason for the significant difference in injury rates in women's sevens vs either men's sevens or women's 15's is due to the relatively young age of the sport leading to under developed physicality and technical skills compared to the men's players and other rugby codes [5]. In studies analysing the nature of injuries in seven's rugby, contact, namely tackling (both being tackled and tackling), remains the number one cause of injuries in matches (83.9%)[5,11,13]. In training, running was the biggest cause of injury which is comparable to data from the men's game which has been investigated more extensively [15-16].

Although collisions are unavoidable in rugby 7's, a considerable amount of injuries are non-contact injuries due to excessive training loads, inadequate recovery and overtraining [17]. Coaches strive to find a balance between potential improvements in performance and potential increase in risk of injury to players when planning training [18]. The ideal training stimulus is the one that maximises net performance potential through a sustainable training load whilst minimising the negative side effects of training (i.e. illness, injury fatigue and overtraining [19]. There is mixed evidence to state whether there is a linear relationship between training and injuries [20]. Some argue that higher training loads, and therefore higher fitness and skill, can lead to less injuries in competition. Whereas others have suggested the higher training volumes lead to muscle damage and fatigue, making players more susceptible to injury [21-23]. Some of the studies that state injuries increase with the amount of training are in amateur athletes, which might be due to the increased optimization of recovery in elite athletes. Brooks et al.[24] did not find a correlation with training load and injury but did see that players training over 9.1h per week have more severe injuries than those training less. Gabbett and Ullah [25] found that elite rugby league players who performed greater amounts >9m of over 7m/s running per session were 2.7 times more likely to sustain a non-contact, soft-tissue injury than those running less high-speed running per session. In Gabbett et al.'s [20] article it was observed that when weekly training load was increased by over 15% above the previous weeks load, injury risk escalated between 21-49%. Their recommendation by that weekly load should increase no more than 10% to minimise injury risk was supported at the World Rugby expert panel review [26].

With this in mind many studies have looked to training load monitoring to seek to reduce injuries in sport. This can range from objective measures of external and internal load such as GPS data on distance run, number of sprints, blood substrate monitoring and subjective measures such as rate of perceived exertion and stress questionnaires [27-29]. The initial difficulty comes in capturing all of the demands a player is exposed to, with load in rugby encompassing many things. In 2014, a World Rugby expert panel [26] defined load as 'the total stressors and demands applied to the players'. Figure 1 displays the internal and external stressors that the expert panel proposed an elite rugby player is exposed to:

Figure 1. Loads to which Professional Rugby Players are Subjected Page 2 Quarrie et al.[23]

Category	Demand

Physical Load	• Matches
	• Training:
	  • Team practice
	  • Gym loading
	  • Rugby conditioning
	  • Pool/recovery
	  • Fitness test

	• Injury and Illness
Travel	• Jet lag • Travel fatigue
Performance Analysis	• Learning team tactics • Match reviews/previews
Nutrition	• Eating to maintain body composition • Timing of meals for performance • Alcohol/drug use • Supplement use
Interpersonal relationships	• Family • Friends • Team mates • Team staff • Agent/managers • Fans • Media
Personal development	• Career planning for life after rugby • Study/other employment
Other demands/loads	• Community promotions of rugby • Sponsorship/commercial obligations • Media coverage • Drug testing • Socialising

Subjective measures of internal loads have been seen to be at least as, if not more consistent and sensitive when compared to objective measures of acute and chronic changes [27]. Sessional rate of perceived exertion (SRPE) has been shown to be a valid measure of internal load when compared to heart rate and blood lactate levels (0.89 and 0.86)[22,24]. It is the most commonly used subjective measure of load due to its ease of use [26]. It was developed by Foster at al.[30] whereby the player rates their perceived exertion (RPE) based on the CR-10 Borg scale and this is multiplied by the session duration to get a training load measure in arbitrary units (AUs). A limitation of RPE is that you can get the same score for different physiological stresses i.e. 6/10 for a weights, tempo run and tactical session, however by combing this with other workload monitoring data you can get a clearer picture of which systems are effected [20].

Alongside SRPE, other perceptual wellbeing scales have been used to assess how players are responding to loads (both training and non-training). In a study by Roos et al.[31] coaches reported that simply asking a player how they are feeling was the most important indication of how they are responding to training. To make the collection of qualitative information more standardised, studies have used a variety of tools ranging from a simple 1-5 Likert scale questionnaire [32] to multi-question tools such as the Recovery-Stress Questionnaire (REST-Q)[33] or Daily Analysis of Life Demands for Athletes Questionnaire (DALDA)[34] to capture the wellbeing of an athlete. Saw et al.'s[27] review of subjective load monitoring tools concluded that subjective measures are consistently more responsive to training load than objective markers. In particular measures of perceived stress, recovery, sleep quality, willingness to train, motivation and energy were recommended to monitor a player's response to training and current ability to train. The use of psychological scales in research has been seen to correlate with a lower injury rate in contact sports [35-37], however in contrast, some studies have seen a decrease in perceptual fatigue associated with a higher injury rate [32-33]. This is thought to be due to players feeling less fatigued playing at higher intensities and putting themselves in riskier situations.

Sleep has been considered as an important factor in player welfare [39]. It has been shown in many studies to be an important variable for optimal player performance and is considered an essential part of recovery [40]. However, it is often overlooked in studies of workload monitoring. It has been considered in regard to travel demands and post-match sleep disturbances but not as a time loss indicator [41-42]. Measuring sleep quality has been done with simple diaries and perceived quality as well as actigraphy from wrist devices, which provide more data on sleep efficiency, sleep latency and routines [43]. The only study that has looked at the relationship between sleep and injury found no significant difference in sleep duration and efficiency in the week after and 2 weeks preceding injury in 22 elite footballers [44]. With the amount of travel an elite 7's player has over a season, sleep is likely to be an important factor in player welfare and readiness to train. 7's is played in a tournament format which are typically held in Australia, Japan, Hong Kong and Dubai resulting in travel distances over 70000 miles. This is comparable to the furthest distances NBA and NHL teams travel [45]. It has been seen that jet lag can lead to a decrease in physical and mental performance [46] which could increase the risk of injuries.

A key difference when looking at female athletes compared to male is the presence of the menstrual cycle. Research into the effects of the menstrual cycle on women's performance and injury risk is fairly limited, however some studies have highlighted a particular risk with anterior cruciate ligament (ACL) injuries and different stages of the menstrual cycle. In a review of 7 studies [47] the collated results showed a strong trend to sustain ACL injuries in the 1st half of the menstrual cycle (pre-ovulatory) ($p>0001$). The reason for this potential increase is still unclear with initial thoughts that hormone fluctuations cause increase ligament laxity and decrease neuromuscular control having mixed results in research [48]. As well as the potential increased injury risk, the menstrual cycle is thought to affect performance due to the effects of oestrogen and progesterone on substrate metabolism, body temperature, the cardio vascular system, proprioception and mood [49]. Therefore, including the monitoring of an athlete's menstrual cycle could provide key insight into variations in performance over the month.

When looking at load management in rugby it has been suggested that an acute and chronic comparison of workload should be considered [26]. The use of acute:chronic (A:C) ratio provides a score for the training load a player performs vs. the load they are trained for [50]. If a player has a high acute training load and chronic training load is low, then the player may be in a fatigued state with a ratio over 1. Conversely if the chronic score is high and the acute score is low the player should be in a well-prepared state having developed 'fitness' or tolerance to the training, giving a ratio of 1 or less [20]. In a study of A:C ratio in cricketers using SRPE and balls bowled, if the ratio exceed 1.5 the risk of injury was 2-4x greater in the next week compared to a risk of 4% if the ratio was under 0.99 [50]. Similar results have been seen in rugby league and football with an A:C ratio over 1.5 proving the critical number [51-53]. Interestingly Bowen et al.[52] noted that although spikes in acute workload increased the injury risk in soccer players, the appropriate development of chronic load (fitness) could provide protection from contact injuries with fitter players being able to respond quicker to unpredictable situations that typically precede contact injuries. Blanch and Gabbett [54] hypothesised that the training 'sweet spot' falls between A:C ratios of 0.8-1.3 with loads outside of this increasing the injury risk. This includes loads that are too low highlighting that it is a U-shaped curve rather than a linear relationship between load and injury risk.

These correlations and models have been developed into algorithms that aim to predict injuries. Gabbett [17] looked to develop an injury prediction model in rugby league based on two seasons data then apply it to two further seasons SRPE was used to measure load. The accuracy of the model was 62.3% for predicting injury. They found if training load was over 3000-5000 AUs the likelihood of injury increased 50-80%. If players exceeded that threshold they were 70x more likely to test positive for a non-contact injury compared to 1/10 if they were under the load. The model had a false positive rate of 23.9%, highlighting that the model was better at predicting when injuries were unlikely to occur than predicting injuries. Gabbett [17] added that this type of modeling might be best in a sport that has a lower collision rate such as basketball or football that are more running based and therefore more predictable. This study was assessing rugby league players, which despite some similarities to rugby 7's has higher levels of contact and length of the game, so care must be taken extrapolating the data to the women's 7's game. Gabbett et al.[20] acknowledged that 'any regression model that predicts injury is best suited to the population which it's derived.'

Hypothesis

The aim of this study is to determine which variables provide the greatest indicator of time loss injuries and then to provide a basis to predict injury risk based on the relationships found. We hypothesize that SRPE will be an independent predictor of non-contact injuries in elite, female rugby 7's players as well as a combination of measures of subjective well-being. For contact injuries we predict that subjective variables will not predict injuries.

CHAPTER 3

METHOD

Participants

Data was collected from 18 full time players registered in the England national first team female rugby 7's squad (age: 25.5±3.86 years, height: 169.9±4.99 cm, weight: 70.2±5.81 Kg body fat: 12.2±0.89 %). The data was collected from July 2017 up to and including the Commonwealth Games (April 2018). The study was approved by the University of St Mary's Ethics Committee, Rugby Football Union and English Institute of Sport and written informed consent was obtained by all participants. The study was outlined to all participants in a meeting and players were given the opportunity to ask questions. The right to withdraw data at any time was explained to the participants and they were given a study information pamphlet for their records.

Procedures

Training load and injury data collected by the coaching and strength and conditioning staff over the 2017/8 season was analysed retrospectively. Injury was defined in accordance with the international consensus statement in rugby union as "any physical complaint sustained during a match or training session that prevented the athlete from taking full part in training or a match for one day or more following the date of injury, irrespective of whether a match or training sessions were actually scheduled"[55]. Injuries were catagorised using the Orchard Sports Injury Classification System (OSICS) which is a 4-character system allowing for greater accuracy and inclusion of all possible diagnoses in sports medicine [56].

The intensity of all training sessions was measured using the Borg CR-10 rating of perceived exertion scale collected confidentially by coaching staff 30 min after the training session as recommended by Comyns and Flanagan [29]. Each player was familiar with the scale and had it as a visual guide at the end of each session. This was then multiplied by the session time to calculate SRPE in arbitrary units (AU) as described by Foster et al.[30] . SRPE has been seen to have an intraclass coefficient of 0.88

indicating high test- retest reliability [57]. Duration of all training activities and matches were recorded in minutes with match minutes tripled to include warm up and game time on the pitch and to account for in-game stoppages. Each morning before 10am players gave a daily rating on sleep duration and quality, lower limb (LL) soreness, upper limb (UL) soreness, readiness to train (RTT), energy levels and menstruation. This was collected using a performance data management system (PDMS) that had been specifically designed for the squad. Likert scale scores from 1-6 were used with descriptive text prompts as well as sleep volume in minutes which was exported into the coaches PDMS database. Likert scales have been seen to have reliability between 0.64-0.67 for a 6-point scale [58]. Compliance with PDMS completion was monitored by the coaching staff and players were prompted to complete any missing days. Injury data was recorded by the physiotherapist including the date and mechanism of injury, location and injury classification as well as the estimated and actual return to play date.

Statistical Analysis

Incidence of injury during matches and training were calculated as the number of injuries per 1000 player hours (total number of injuries/number of hours exposure) as per Phillips [59]. The A:C ratio was calculated by dividing the players 7-day SPRE average by the average of the previous 28 days [46]. As suggested by Lolli et al.[60] the 28-day data did not include the acute data to avoid mathematical coupling. Data from each player was collated into training zones for both SRPE data and the acute: chronic ratio and plotted against injuries sustained to assess the relationship between training load and injuries in this group.

Data collected by the PDMS app was exported into Microsoft Excel alongside the SPRE data collected by the coaching staff. Injury incidence, the presence of matches and travel were added with values of 0 for not present and 1 for injures/travel or a match providing the data set for regression. The data players completed whilst injured was excluded leaving comparisons between non-injured and injured days. To account for the potential lag effect of increased training load and injuries as described by Drew et al.[61], further analysis was performed including the 21 days prior to injury. The workload data from each injured player was averaged over the 21 days with each figure compared to the mean score for the squad (periods were omitted as it was likely to be falsely significant with 21 out of a regular 28-day cycle). The number of variances from the means were counted then run through proportional analysis on R (R: A language and environment for statistical computing program. Vienna, Austria: R Foundation for Statistical Computing, 2015).

Binary logistic regression was used to compare the independent variables (sleep rating, sleep duration, energy level, UL soreness, LL soreness, RTT, menstruating yes or no, matches, travel and SRPE) against the dependent variable, injured or not. Both contact and non-contact injuries were recorded and analysed separately in two regression models to evaluate any key differences. The models included 95% confidence intervals and significance was set at a P value of ≤0.05. The data was analysed using SPSS version 24.0 (IBM Corp). Analysis was performed to check multicollineraity has not interfered with the overall results including a correlation matrix. The A:C ratio was not included in the regression analysis due to the fact it contained another variables data (SRPE). The model was evaluated using the adjusted R square value.

CHAPTER 4

RESULTS

Injury Incidence

A total of 55 injuries were sustained in the study period. Of these 21 were during matches and 34 in training. The injury rates were 165/1000 match hours and 14/1000 training hours respectively. The amount of time lost was 700 hours for non-contact injuries. The distribution of injuries over the season are displayed in figure 2 alongside the SRPE. The highest period for sustaining injuries was in the late competition phase whereas the highest month for injuries was October (Figure 3). The injury breakdown is displayed in table 1**.** The lower limb comprised the most injuries in line with other studies into rugby 7's injuries, with the hamstrings being the most common site of injury (13/55;24%), followed by the lower leg/Achilles (9;16%) and the knee and head (7/55;13% respectively). The most common injury type were muscle strains (21/55;38%), followed by bone stress (10/55;18%) and ligament sprains (13/55; 24%). Within the contact injuries, being tackled was the most common mechanism of injury (10/21;48%), whereas overload was the most common mechanism for non-contact injuries (19/34;56%).

Figure 2: An Overview of the Weekly Injury Rate and Average SRPE

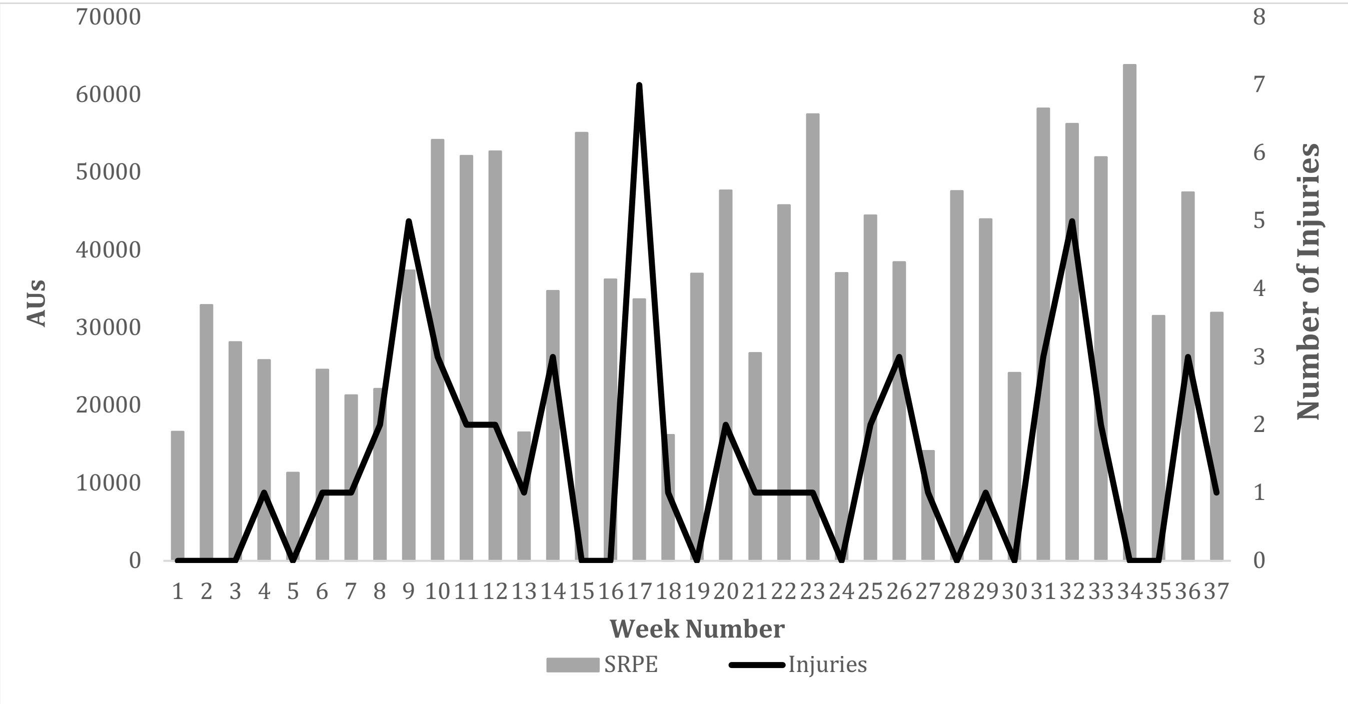

Figure 3: Average SRPE and Injuries for the Different Phases of the Season

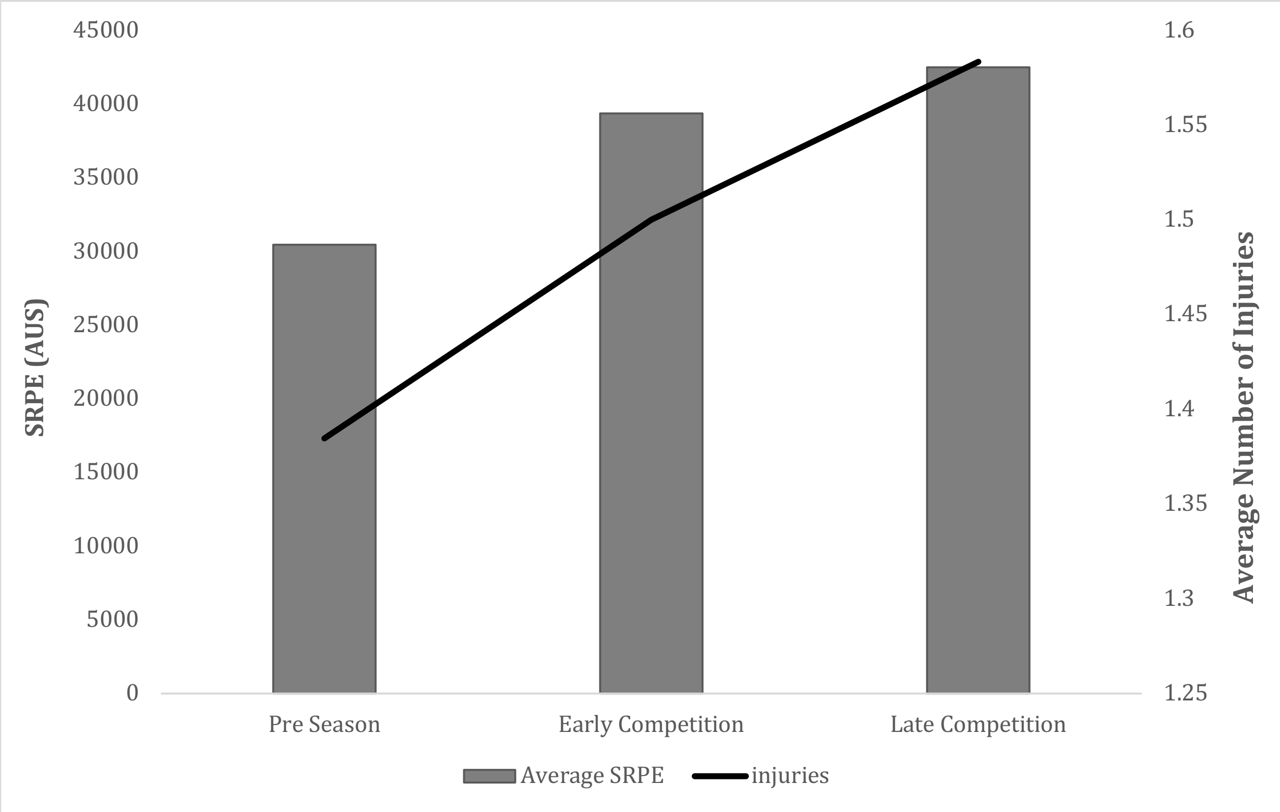

Table 1: Site and Type of Injures Sustained During the 2017/8 Season

		Number of Injuries	Percentage
Time of injury	Match21	38%	
	Training	34	62%
Body region	Ankle	4	7%
	Hip	6	11%
	Shoulder	4	7%
	Knee	7	13%
	Head	7	13%
	Hamstring	13	24%
	Toes	2	4%
	Hand	1	2%
	Back	2	4%
	Lower limb/Achilles	9	16%
Injury type	Ligament sprain	7	13%
	Ligament tear	1	2%
	Muscle strain	21	38%
	Concussion	7	13%
	Tendon	1	2%
	Bone Stress	10	18%
	Cartilage	2	4%
	Cellulitis	1	2%
	Haematoma	3	5%
	Epidural	1	2%
	Chondral damage	1	2%
Injury Mechanism	**Contact**	21	38%
	Collision	4	19%
	Tackled	10	48%
	Tackler	3	14%
	Other	4	19%
	Non-Contact	34	62%
	Change of Direction	5	15%
	Overload	19	56%
	Other	2	6%
	Sprint	7	20%
	Illness	1	3%
Injury Severity (days)	Slight (0-1)	1	2%
	Min (1-3)	2	4%
	Mild (3-7)	19	35%
	Mod (7-21)	17	31%
	Severe (>21)	16	29%

Absolute and A:C Workload

The average weekly SPRE were 2189 AUs. The weekly SRPE data and A:C ratio were plotted against injuries sustained (figure 4) which initially produced an inverted U shape (figure 4A,B), however, when this was normalized to account for the relative risk vs. exposure time in each zone the mid-points (0.8-1.3 A:C and 900-1800 AUs) had the lowest injury rates (figure 4C,D). The proportional analysis showed strong statistical significance ($p<0.0001$) for each zone as seen in table 2 and 3.

Figure 4: A Graphical Representation of the Relationship between Workload and Injury Rates

Figure A and B represent the absolute injury rate in each zone. Figures C and D represent the same data when normalized for each zone

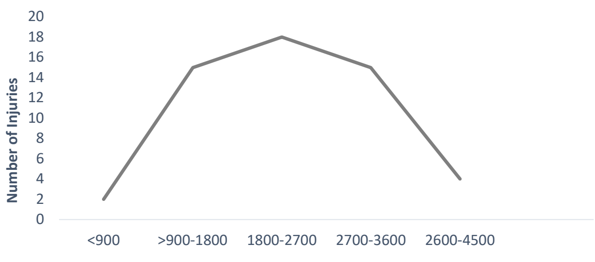

Figure A

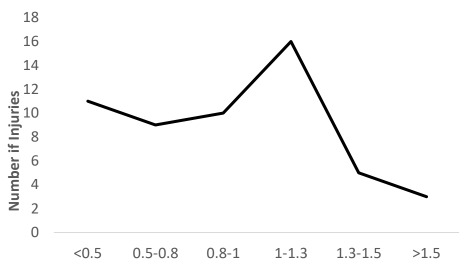

Figure B

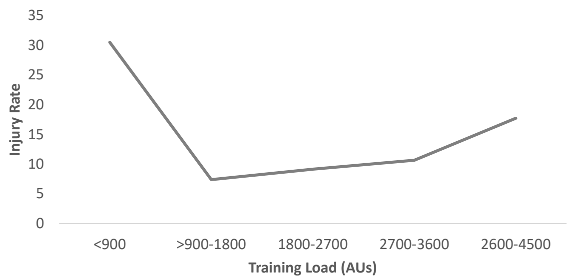

Figure C

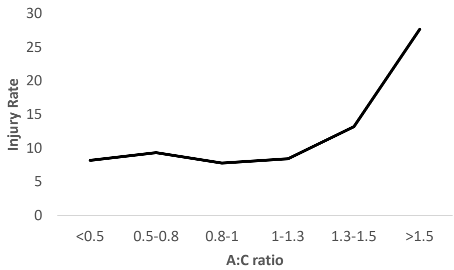

Figure D

Table 2: Proportional analysis of the Acute:Chronic Ratio Zones

A:C Ratio	Number of Instances	Injuries	Injury Risk*	sig	CI
<0.5	90	11	8.18182	p=<0000.1	0.07-0.21
0.5-0.8	84	9	9.33333	p=<0000.1	0.05-0.20
0.8-1	78	10	7.8	p=<0000.1	0.06-0.23
1-1.3	135	16	8.4375	p=<0000.1	0.06-0.21
1.3-1.5	66	5	13.2	p=<0000.1	0.03-.18
>1.5	83	3	27.6667	p=<0000.1	0.01-0.11

*Injury risk = number of injuries/number of instances

Table 3: Proportional analysis of the SRPE Zones

SRPE (AUs)	Number of Instances	Number of Injuries	Injury Risk*	sig	CI
<900	61	2	30.5	p=<0000.1	0.01-0.12
>900-1800	111	15	7.4	p=<0000.1	0.08-0.22
1800-2700	165	18	9.16667	p=<0000.1	0.07-0.17
2700-3600	160	15	10.6667	p=<0000.1	0.06-0.15
2600-4500	71	4	17.75	p=<0000.1	0.01-0.13

*Injury risk = number of injuries/number of instances

Subjective Variables and Regression Models

The data was initially evaluated to determine missing data in SRPE and well-being variables. Compliance was found to be 98.6% overall and no obvious differences in missing data were found with respect to date, age or individual participants. As a result, missing values were ignored, and all available data was included for analysis. The regression analysis model for non-contact injuries was seen to explain between 3% (Cox & Snell R squared) and 8% (Nagelkerke R square) of the variance in injuries. The contact injuries model had a 1.2-7% detection of variance. Both models although showing significance (p=<0.0001), had low detection abilities. Within each model several variables were statistically significantly correlated to injuries. With the contact injuries model (table 4) playing a match displayed an odds ratio (OR) of 5.56x more likely to sustain a contact injury which was the only significant variable in this model. Within the non-contact injury model (table 5) there were multiple factors that were significant. SRPE (OR=0.998), LL soreness (OR=1.437), RTT (OR=0.651), sleep duration (OR=0.994) and UL soreness (OR=0.514) were seen as having significant correlations with injuries. The 21-day proportional analysis results are displayed in table 6. this showed poor significance when tested for proportional difference with all variables having p values >0.05. Within the correlation matrix the only moderate correlation for the non-contact and contact variables was readiness to train and reported energy level (r=-0.617 and r=0.582). The individual variables that did show a significant relationship to non-contact injuries can be displayed in a predictive formula as seen below.

Injury risk = 5.771+(SRPE*0.998)+(LL soreness*1.437)+(RTT*0.651)+(sleep duration*0.99)+(UL soreness*0.514)

Table 4: Binary Regression Output for Contact Injuries

	B	S.E.	Wald	df	Sig.	Odds Ratio	95% C.I.for Odds Ratio	
							Lower	Upper
Energy Level	-.188	.320	.344	1	.558	.829	.443	1.552
LL soreness*	-.322	.243	1.760	1	.185	.725	.450	1.166
Period	.231	.634	.132	1	.716	1.259	.363	4.364
RTT*	-.191	.348	.303	1	.582	.826	.418	1.632
Sleep Duration	-.003	.003	.776	1	.378	.997	.990	1.004
Sleep Quality	.097	.259	.141	1	.707	1.102	.663	1.832
Stress	-.040	.350	.013	1	.908	.961	.484	1.907
UL Soreness*	.009	.311	.001	1	.976	1.009	.549	1.855
SRPE*	.000	.001	.773	1	.379	1.000	.999	1.002
Travel	17.794	8798.424	.000	1	.998	.000	.000	.000
Match	1.715	.526	10.629	1	.001	5.558	1.982	15.587
Constant	-1.499	2.173	.476	1	.490	.223		

*(LL=Lower limb, RTT = Readiness to train, UL = Upper Limb, SRPE = Session Rate of Perceived Exertion)

Table 5: Binary Regression Output for Non-Contact Injuries

Variable	B	S.E.	Wald	df	Sig.	Odds Ratio	95%C.I.for Odds Ratio	
							Lower	Upper
Energy Level	.323	.169	3.656	1	.056	1.381	.992	1.923
LL soreness*	.363	.136	7.095	1	.008	1.437	1.101	1.877
Period	-.210	.281	.556	1	.456	.811	.467	1.407
RTT*	-.430	.202	4.523	1	.033	.651	.438	.967
Sleep Duration	-.006	.002	12.018	1	.001	.994	.990	.997
Sleep Quality	-.021	.131	.025	1	.875	.980	.758	1.266
Stress	-.022	.163	.018	1	.894	.979	.712	1.346
UL Soreness*	-.665	.205	10.561	1	.001	.514	.344	.768
SRPE*	-.002	.000	16.386	1	.000	.998	.998	.999
Travel	-.618	.491	1.585	1	.208	.539	.206	1.411
Match	.246	.527	.218	1	.641	1.279	.455	3.595
Constant	1.753	1.310	1.791	1	.181	5.771		

*(LL=Lower limb, RTT = Readiness to train, UL = Upper Limb, SRPE = Session Rate of Perceived Exertion)

Table 6: Proportional Analysis of the Variables in the 21 Day Lag Time Prior to Injury

Variable	Number of Incidence in 21-day period*	P value	CI
Energy Level	23	0.89	0.37-0.66
Lower Limb Soreness	24	1	0.36-0.64
Readiness to train	28	0.31	0.43-0.72
Sleep Duration	20	0.31	0.43-0.72
Sleep Quality	23	0.19	0.26-0.55
Stress	19	0.19	0.26-0.55
Upper Limb Soreness	21	0.47	0.30-0.59
SRPE	24	1	0.36-0.64

* Number in Incidence in the 21 days prior to injury that was over the squad average score for the variable

CHAPTER 5

DISCUSSION

The aim of this study was to investigate the predictive ability of subjective variables on injuries in elite female rugby 7's players. Alongside this, the relationship between workload and injury rates was explored. We found a non-linear relationship with workload and injuries showing the polar ends of training to have the highest risk of injury. The results suggest that there is a significant influence of some of the subjective values on predicting injuries. SRPE, RTT, LL and UL soreness and sleep duration show significance when predicating non-contact injuries. Whereas for contact injuries, only the presence of a match was significant. The overall power of the regression models were weak; therefore, care should be taken when extrapolating the results. However, there are some key relationships to explore.

Firstly, the relationship between training load and injuries in this study was similar to the work of Blanch and Gabbett [54] and Cross et al.[22] showing a non-linear relationship with increased load and injury rate. This differs from the linear pattern that increased workload increases injuries which has been seen in research into footballers [62-63] and rugby league players [64]. As the 0.8-1.3 A:C ratio and 1800-2700 AU zones were where the players spent the most time, the highest number of injuries occurred within them, which could be misinterpreted as the zone with the highest risk displaying an inverted U shape (seen in figure 4A+B). It should be noted that the average weekly SRPE was 2189 AUs which is lower than seen in similar studies in male rugby players where 3000 AUs are commonly reported as mid-range [17], indicating ranges need to be defined for each population they are being applied to. When converted to injury rate (as seen in figure 4C+D) the pattern is not a full U shape but has similar implications of the lower (<900 AUs) and higher ends of workload (2600-4500 AUs, A:C ratio >1.5) carrying the greater risk of injury. This has been described in the past as a representation of the athlete being in a state of undertraining or overtraining [22]. The undertrained athlete being at greater risk of sudden spikes in workload and likely being deconditioned for the demands of the sport or not returned fully to normal training loads following an injury [20], and the over trained athlete being pushed too hard too quickly, putting them at greater injury risk. This can be mitigated by monitoring workload and training stress balance either in the form of SRPE, or in the case of rugby 7's, high speed running or number of sprints to reflect the demands of the sport [1,52]. In the current group their GPS data (total distance ran) is monitored in terms of the A:C ratio and training stress balance which could have already had a preventative effect on the number of injuries sustained and more appropriate A:C loads throughout the season.

The highest month for injuries was October which fell in the late preseason phase. This may indicate a lack of chronic load or 'fitness' as described by Gabbett et al.[20] leading to less resilience to injury from training increases. Although the late competition phase was seen to have the higher average SRPE scores and injuries perhaps due to the nature of the competition phase involving much more contact and higher intensity work, the biggest jump in A:C ratios were in the preseason phase. The preseason phase had an average A:C ratio of 1.17 vs the early competition (1.01) and late competition phase (1.05). This may indicate the increase in load in the preseason phase wasn't gradual enough for the players fitness to overcome the acute training demands leading to higher injuries [65].

The prevalence of injuries in this study was slightly higher than the results seen in Gabb et al.[10] work in elite female rugby 7's with 34 vs 55 injuries in this study. The injury rates were 165/1000 match hours vs. 187/1000 in Gabb et al.[10] and 14/1000 vs. 10/1000 training hours respectively. With the studies being 4 years apart but in the same team it reflects that the measures to decrease training injury rates have not improved.

Predicting Non-Contact and Contact Injuries

The logistic regression model for non-contact injuries showed SRPE, increased LL soreness, RTT, sleep duration and decreased UL soreness as significant predictors of injuries. This corresponds with work that showed SRPE to be a key variable in monitoring training load and injury risk [50,52-4]. However, the findings of limb soreness, sleep duration and RTT correlating with injuries are novel.

An increase in LL soreness (1 being none, 5 being severe) was seen to increase the risk of injury 1.44x, however UL soreness was seen to have an odds ratio of 0.51, indicating for every additional unit on the UL soreness scale players were 0.51x less likely to sustain an injury. With 7's being a running based game reporting fatigued legs may lead to decreased ability to change direction, poorer generation of force and ability to move freely to avoid contact leading to sub optimal biomechanics. The decrease in UL soreness predicting injuries however is harder to explain in non-contact situations. With the nature of 7's involving the lower limbs much more (in non-contact scenarios) it might be that the UL soreness scores were more consistently reported as lower (average 1.69 for UL soreness vs 2.17 LL soreness) leading to this result.

An increase in reported RTT presented with a 0.65x OR indicating that for every increase in confidence to perform, players would be 0.65x less likely to sustain an injury. This highlights the importance of self-belief and confidence in ability for any session, which echo's the thoughts of Roos et al.[31] that asking a player how they are feeling about training can be a key indicator, but again there is little reported data on this measure. Unsurprisingly the correlation matrix showed a negative relationship between energy level and RTT, yet energy level did not correlate with injuries independently. They could be considered to have a similar meaning to a player and with this study showing a moderate correlation (r=-0.62), energy level could be removed as a variable to 'slim down' a questionnaire if RTT is present. Sleep duration had a small effect (OR= 0.99) indicating that a decrease of 0.01% in sleep duration could put a player more at risk of an injury. This may point to an optimal sleep duration for a player that could be gathered over a season and correlated with the overall rating of sleep and energy the following day. It has been suggested in previous work that as well as the physiological effects of poor sleep on performance, the cognitive impairments on players with disordered sleep could also lead to a higher injury risk [39]. Interestingly travel was not a significant variable for contact or non-contact injuries or a strong correlator with sleep (r=-0.213 duration, r=-0.111 quality) which may be explained by the current practices of the team taking a week to acclimatize to the new time zone pre-tournament which is in line with recommendations when crossing multiple time zones [66].

Other work on subjective variables have found the cumulation of wellness scores to significantly correlate with a change in physical performance [27,67-68], with wellness and physical output seen to drop in the initial 3 days following a game [67]. Many studies in this area have combined wellness scores to Z scores in their analysis of training effects. Whilst this has been seen to be more sensitive than any single variable alone [69], the ability to detect specific relationships between individual variables such as in this study, are lost [67]. For example, in Guvos et al.'s [69] study the Z score for wellness did not correlate to SRPE however limb soreness did. The self-reported limb soreness and increase SRPE relationship could be explained by the player experiencing the loss of peak force and short-term muscle damage following a hard session, therefore reporting higher RPE's for the subsequent days. The relationships explored in the above studies do not explore the risk of injury with changes to the players reported wellness. In our study the individual variables that did show a significant relationship to injuries can be displayed in a predictive formula as displayed in the results section. Future studies in this subject group could apply this equation to assess ability to predict injuries and perhaps act as a preventative tool should it show a good fit.

Given the low power of the logistic regression further analysis was done assessing the 21day lag time prior to the injuries sustained. This showed poor significance when analysed for proportional difference indicating there are no predictive indicators of an imminent non-contact injury in the 21days prior. This may have been too small a sample to detect predictive values as this timeframe has been seen to be significant in the lead up to injuries in other populations [2]. Further analysis could include and compare various lag times (7,14,21,28 days) as this is likely to play a role in non-contact injuries, particularly overuse. This was demonstrated in Carey et al.'s [70] work in footballers, however they did find a similar ability to predict injuries with different combinations of the acute (3 days prior to injury) and chronic phase (28,21 and 32 days), indicating that each sport and individual player may vary in how they are affected over time.

As previously thought the only significant predictor of contact injuries in our regression model for was the presence of a match (OR=5.56). This supports our hypothesis that subjective variables will not predict contact injuries. In previous work predisposing factors such as decreased aerobic power [71] or increased fatigue from strength sessions [64] have been observed to correlate with sustaining a contact injury but no study has been able to predict contact injuries. This makes logical sense with the unpredictability of contact both in how frequently it will occur in a game as well the biomechanics that a player will be subjected to in contact situations will change on a game to game basis. The presence of a match is likely to expose the player to more contact scenarios than in training and at a higher intensity, making injuries more likely.

Limitations

This study has several limitations, the small sample size limits the statistical power as seen in the logistic regression/proportional analysis. The collection of data was down to the players input on a daily basis and whilst compliance was seen to be high, the data could be misrepresented for fear of losing starting spots, being pulled from training or simply inaccurate if not taken seriously [43]. The use of the PDMS scores is not validated in research and can be restrictive in detail given the 5 or 6-point rating scale compared to the RESTQ and DALDA questionnaires seen in Saw et al.'s [27] review, however shorter scores that have a sub 1min completion time are easier to implement, therefore have a greater practical application in elite sport.

When rating the presence of a period at the time of injury, the current analysis model did not take into account the phase of the menstrual cycle which has been suggested to be a factor in injury rates [72]. The status of being in the luteal, ovulatory or follicular phase could be included in future models to increase sensitivity.

The presence of a previous injury is commonly cited as a significant risk factor for injury [54, 73]. Unfortunately, we did not have access to the players previous injury history to include this variable in our regression analysis. This would be of value to include in future studies.

This study used the rolling average method of collecting the A:C ratio meaning each week was treated equally. It has been proposed that using exponentially weighted moving averages (EWMA) can be a more sensitive method of collecting A:C data as it considers the decaying nature of fitness and fatigue [74]. This was seen in Murray and Gabbett's [75] study using GPS data in Australian footballers and could be considered in future work on A:C ratios.

Due to the time constraints of the study we couldn't complete data for the whole season which may have given a more powerful data set. As per Bowen et al.[52] and Hulin et al.[51] it would have been beneficial to include a measure of external load such as GPS data, in particular sprint numbers, metabolic power and high-speed running zones [1,9], to build a bigger picture of the demands the players are exposed to. Unfortunately, this was outside the scope of the current project. Future studies should look to replicate such methods that include subjective and objective workload data in female populations to ensure more power in predictive models and seeing if the inverted U shape is repeated.

Implications for practice

This study has added to the growing body of research in the relationships between workload and injuries which to date had been under reported in female populations. We have shown that the application of A:C ratios between 0.8-1.3 does apply to this group of 7's players and can be utlised in similar cohorts as a 'sweet spot' for training load. The inclusion of subjective wellness monitoring is common practice in elite sport however little is known about the relationships to injuries. This study has shown there may be some significant factors to consider when trying to avoid non-contact injuries in particular: RTT, LL and UL soreness and sleep duration which should be monitored to add to the overall understanding of how a player is responding to training. The finding that contact injuries cannot be predicted by subjective variables gives some scientific background to this commonly assumed notion. Whilst contact injuries may not be predictable, the preparation of players to work at similar intensity to match scenarios in training and ensure tackling techniques are well rehearsed can be important steps to address the most common scenario for contact injuries.

CHAPTER 6

CONCLUSION

This study has demonstrated subjective workload monitoring variables can play a role in predicting injuries in elite female rugby 7's players. Despite the model having small power the closer attention to sleep, limb soreness and RTT would be of value for future studies and for coaches to monitor as well as SRPE. We have also shown that subjective data does not correlate with contact injuries in female rugby 7's players. As the relationship between injuries and training is a complex and multi-factoral one, further research is warranted on the subjective information gathered from the players perspective to ensure we have more power behind these variables and their role in predicting injuries.

WHAT ARE THE KEY FINIDINGS?

- There is a relationship between subjective measures of load and non-contact injuries
- The acute chronic ratio of workload follows a U shape in this population indicating a training 'sweet spot'
- Subjective variables did not correlate with contact injures

CHAPTER 7

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CHAPTER 8

APPENDIX

Appendix 1: Participant Information Form

Section A: The Research Project

1. Title of project

Which workload monitoring variables provide the best indicator of training time loss in elite female rugby 7's players?

2. Purpose and value of study

This research project aims to investigate the relationships between workload variables and injury rates in elite female rugby 7's players. Data that is collected on a regular basis on your readiness to train, GPS speeds, mood, sleep quality, menstrual cycle and training load will be compared to the injuries that occur over the season to see if there are certain criteria that make you more likely to get injured. This will then allow the team to better understand your injury risks and when you might need modified training. The overall aim is to understand what happens in the build-up to injuries and therefore be able to better prevent them in future. The data being used will be analysed from the start of the season (August 2017) to the end of the season in 2018.

3. Invitation to participate

You are being invited to take part in this research project. Before you agree to take part, it is important that you understand why the research is being done and how the information will be used. Please take time to read this information carefully and ask us if there is anything you don't understand or would like further information on. Thank you for considering to take part.

4. Who is organising the research

This project is being conducted by Emily Muscatt an MSc student at St Mary's university. It is being done in collaboration with the EIS with Katie James (S&C coach) being the link person. Emily is supervised by Dr Stephen Patterson and Mark Waldron (St Mary's university).

5. **What will happen to the results of the study**

Results of the research will be presented as part of Emily's MSc thesis with the aim to be published in a scientific journal. You will not be identified in any report or publication. If you wish to be given a copy of the research or reports please ask to be added to the circulation list.

6. **Source of funding for the research**

This research is being conducted by St Mary's university with no external funding or payment for participation.

7. **Contact for further information**

Emily Muscatt (lead researcher) – 135225@stmarys.ac.uk
Stephen Patterson (supervisor) - stephen.patterson@stmarys.ac.uk
Mark Waldron (supervisor) - mark.waldron@stmarys.ac.uk
Katie James (EIS lead S&C coach rugby 7's) – Katie.James@eis2win.co.uk

Section B: Your Participation in the Research Project

1. **Why you have been invited to take part**

You have been chosen to participate as you are playing at the top level of rugby 7's and you participate in training full time.

2. **Whether you can refuse to take part**

You can choose whether to take part or not. You can refuse to take part at any time and your data will be withdrawn. If you do decide to take part you need to complete the consent form. You can keep a copy of this information sheet and your consent form for your records.

3. **Whether you can withdraw from the project at any time, and how**

You can withdraw from the study at any time by filling out the slip at the bottom of the consent form. Please contact Katie James who will let the lead researcher know which participant's data to withdraw.

4. **What will happen if you agree to take part (brief description of procedures/tests)**

If you agree to take part you will not need to do anything differently. You will complete the app questions as normal and participate in training monitoring i.e. wearing GPS monitors and giving your perceived exertion scores.

5. **Whether there are any risks involved (e.g. side effects) and if so, what will be done to ensure your wellbeing/safety**

Participating in the research has no increased risk to you. The risk of injury is the same as your normal participation in training and matches.

6. **What will happen to any information/data/samples that are collected from you**

Data will be collected as normal by Katie James and given to Emily via encrypted emails. Data will be stored securely on St Mary's university servers.

7. Whether there are any benefits from taking part

We are aiming to prevent future injuries with the data you provide. You will be able to see a detailed report on your training load and how it is effecting your body.

8. How much time you will need to give up to take part in the project

None. There will be an option to attend a meeting to discuss the project prior to it starting and when data collection is finished to feedback the results.

9. How your participation in the project will be kept confidential

You will be assigned a number by Katie James therefore Emily, Stephen, Mark and readers will not know which player corresponds to each number. The team will not be identified other than an elite female rugby 7's squad.

YOU WILL BE GIVEN A COPY OF THIS FORM TO KEEP TOGETHER WITH A COPY OF YOUR CONSENT FORM

Appendix 2: Consent Form

St Mary's University Twickenham London

Name of Participant: ____

Title of the project: ___ Which workload monitoring variables provide the best indicator of training time loss in elite female rugby 7's players?

Main investigator and contact details: Emily Muscatt
__135225@live.smuc.ac.uk_______________________________

Members of the research team: Katie James, Stephen Patterson, Mark Waldron

1. I agree to take part in the above research. I have read the Participant Information Sheet which is attached to this form. I understand what my role will be in this research, and all my questions have been answered to my satisfaction.
2. I understand that I am free to withdraw from the research at any time, for any reason and without prejudice.
3. I have been informed that the confidentiality of the information I provide will be safeguarded.
4. I am free to ask any questions at any time before and during the study.
5. I have been provided with a copy of this form and the Participant Information Sheet.

Data Protection: I agree to the University processing personal data which I have supplied. I agree to the processing of such data for any purposes connected with the Research Project as outlined to me.

Name of participant (print)………………………………………………………………………..

Signed…………………..………………… Date……………………….........

If you wish to withdraw from the research, please complete the form below and return to the main investigator named above.

Title of Project: ___ Which workload monitoring variables provide the best indicator of training time loss in elite female rugby 7's players?

I WISH TO WITHDRAW FROM THIS STUDY

Name:_______________________________________

Signed: ________________________________ Date: ____________________

Appendix 3: Signed Ethical Approval Form

St Mary's University Twickenham London

Approval Sheet

Name of applicant: Emily Muscatt

Name of supervisor: Stephen Patterson

Programme of study: MSc Strength and Conditioning

Title of project: Which workload monitoring variables provide the best indicator of training time loss in elite female rugby 7's players?

Supervisors, please complete section 1 or 2. If approved at level 1, please forward a copy of this Approval Sheet to the School Ethics Representative for their records.

SECTION 1

Approved at Level 1

Signature of supervisor (for student applications)..

Date..

SECTION 2

Refer to School Ethics Representative for consideration at Level 2 or Level 3

Signature of supervisor..... [signature] ....

Date........29.11.17..

SECTION 3

To be completed by School Ethics Representative

Approved at Level 2

Signature of School Ethics Representative.......... ..... Date: 03/01/18
SECTION 4 To be completed by School Ethics Representative. Level 3 consideration is required by the Ethics Sub-Committee. Signature of School Ethics Representative... Date... Level 3 approval – confirmation will be via correspondence from the Ethics Sub-Committee

Appendix 4: Confidentiality Agreement RFU

RUGBY FOOTBALL UNION

CONFIDENTIALITY AGREEMENT

THIS AGREEMENT is dated 26.11.2017

And is made between:

Rugby Football Union a society registered under the Co-Operative and Community Benefit Societies Act 2014 (Register Number 27981R) whose registered office is at Rugby House, 200 Whitton Road, Twickenham TW2 7BA (**the "RFU"**) and Emily Muscatt.

Emily Muscatt who lives at 45 Lyme Farm Road London SE12 8JQ (**"the Individual"**)

It is hereby agreed as follows:

Definitions

1. In this Agreement:

"Confidential Information" means all trade secrets and information in whatever form relating to the RFU or any Associated Company or its or their businesses and its or their past, current or prospective sponsors, suppliers, clients or customers, which shall include (without limitation):

a. processes or methods used or to be used by any of those businesses;
b. any information concerning the business, accounts or finances of any of those businesses;
c. any computer systems, software or know-how used in any of those businesses;
d. business development plans, marketing or promotional plans and future product ideas of any of those businesses;
e. information on business strategy, research and development, resourcing plans and market opportunities of any of those businesses;
f. any confidential report or research commissioned by any of those businesses in connection with the business or affairs of any of those businesses;
g. any intellectual property rights relating to any of those businesses and
h. lists and details of current or prospective sponsors, suppliers, clients or customers of the RFU or any Associated Company.

"Associated Company" means any undertaking (other than the RFU) which from time to time is the RFU's subsidiary or its ultimate holiday company or is a subsidiary of the RFU's ultimate holding company, and "subsidiary" and "holding company" shall have the meanings attributed to them by the Companies Act 2006, as amended, modified, consolidated, re-enacted or replaced from time to time, and ultimate holding company shall mean a holding company which is not a subsidiary.

Obligation of confidentiality

2. The Individual agrees to treat as confidential all Confidential Information acquired through the Individual's dealings with the RFU.

3. The Individual shall not without the prior written consent of the RFU (except as authorised or required by law) make or use copies of, allow to pass outside of his or her control, exploit or disclose to any person, company or organisation any Confidential Information.

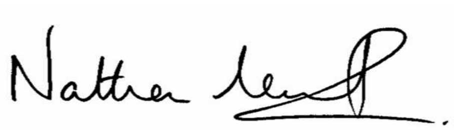
4. All Confidential Information and any and all copies of Confidential Information shall be and remain at all times the property of the RFU. On termination of the Individual's engagement, or at the request of the RFU, the Individual shall deliver up all Confidential Information and any copies, and delete irretrievably any Confidential Information stored in any electronic or intangible form.

Exclusions

5. The provisions of this confidentiality agreement shall not apply to, and shall cease to apply to, any information already in the public domain or any information which comes into the public domain other than by reason of the Individual's default.

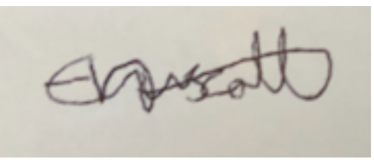
6. Nothing in this agreement shall prevent any Individual from making a protected disclosure in accordance with Section 43A of the Employment Rights Act 1996, under the RFU's Whistleblowing Procedure, where applicable.

SIGNED:



....
Nathan Martin
For and on behalf of the RFU

SIGNED:



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Emily Muscatt