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The Assessment of Neuromuscular Performance Responses to In-Season sRPE Internal Load in Professional Rugby Union Players, during an 8-Week Period, Using the PUSH Band 2.0 Wearable Device

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Abstract: *Nolan, J.D. and Moody J.A. The assessment of neuromuscular performance responses to in-season sRPE internal load in professional rugby union players, during an 8-week period, using cost-effective means. Rugby union athletes are consistently exposed to high levels of physiological and mechanical stress through weekly training and competition. Monitoring practices employed by clubs in-season aim to quantify these demands by assessing athlete performance responses. Technologies used to quantify athlete readiness and physical state represent a financial burden to clubs with lower budgets. The purpose of this study was to identify cost-effective means to quantify and assess athlete physical performance responses to in-season training and competition demands. Weekly training and competition load for the 8-week in-season period was quantified using the sRPE (AU) method (2456 ±338). Athlete neuromuscular performance monitoring for the study period was performed using peak concentric jump velocity (m/s) in a CMJ quantified using a "PUSH" band (3.0773 ± 0.11 m/s). Subjects were drawn from a professional rugby union team in the 2nd tier of professional rugby in England (23.1 ±1.8 years). To examine the change in jump performance from week to week a repeated measures ANOVA of peak concentric jump velocity was performed. To examine the interaction between load (AU) and jump performance (m/s) a correlational matrix was used. While no statistically significant results were found for changes in CMJ performance and the interaction of CMJ performance and weekly load, the PUSH band 2.0 did detect changes in CMJ performance during the study period and were sensitive to changes in load. The use of the PUSH band 2.0 to assess lower limb neuromuscular performance in professional rugby union athletes offers a reliable and potentially cost-effective measure to track athlete performances responses in season with potential sensitivity to detect responses to load adjustments.*

Keywords: *monitoring, load, sRPE, countermovement jump, PUSH band, m/s, cost-effective*

Abbreviations*(In order of appearance in text):* *Self Rating of Perceived Exertion (sRPE), Countermovement Jump (CMJ), Statistical Package for Social Sciences (SPSS), Strength and Conditioning (S&C), Arbitrary Units(AU), Meters Per Second (m/s)*

1. Introduction

At an elite or professional level of field sport, competition places a significant level of physiological and mechanical stress upon the athlete, which can cause disruption to an athlete's internal homeostasis [1]. With respect to rugby union, physiological or mechanical stress comes in the form of collision-based periods of match play in addition to bouts of high intensity running and bouts of low intensity jogging/walking [2]. In order to prepare for the physical demands which competition places upon a player, it is essential that players engage in focused and deliberate activities to improve either technical abilities or physical abilities that underpin technical abilities [3]. Professional level club rugby union typically engages in these activities 1-2 times daily with training occurring on 3-4 days in the week with consecutive days typically scheduled for no more than two days concurrently at any given point in the week [4]

The quantification of the demands placed upon an athlete from both competition and training has led to the development of the term training "load". This term has now been accepted as encompassing the total stressors place upon the system and comprises activities related to the sport and activities not directly related to sport (ie; strength and conditioning sessions) [5].

Training load can be expressed as either internal or external load upon the athlete. External load refers to activities performed or "work done" which is independent of the physiological response to the activity [6]. Internal load refers to physiological stress experienced by the athlete resulting from the demands of training or competition [1]. External load for rugby union is typically quantified using GPS systems providing variables such as distance, high speed running meters and maximal sprint velocity [2]. Internal load for rugby union can be quantified using a number of methods including sRPE [7], heart rate response [3], blood lactate levels, oxygen consumption [8] and testosterone-cortisol ratio [9]. When considering what practices to employ in order to quantify either external or internal training load, physical performance departments must first consider the available budget to finance these processes. For clubs with significantly reduced budgets in lower playing divisions of professional sport, technologies such as GPS and heart rate monitors may not be feasible.

One cost-effective measure used to quantify load is the use of session rating of perceived exertion or "sRPE" method. This method involves an athlete self-report subjective assessment of the intensity of exercise performed, provided within 30 minutes of training or competition cessation [10]. Total load is then quantified by multiplying the given rating (0-10, modified Borg scale) by the duration in minutes [11]. This method is seen to be very effective given the ease of application, zero cost and non-invasive means [12]. This method has been shown to be both valid and reliable under constant-load exercise and during repeat bouts exercise when compared to measures of heart rate response and oxygen consumption [13]. sRPE method has been questioned for its ability to quantify load in collision sports such as rugby league and rugby union, with a possible inability to account for the physical strain applied from collision bouts and intermittent nature of high-intensity actions [14]. However, recent research has provided insight into the validity of the sRPE method for collision sports. Findings indicate that there exists "significant within-individual correlations between sRPE and various internal and external measures of training intensity and load" [12]. Lovell et al. (2013) demonstrated sRPE's validity in rugby training with strong correlations to GPS (distance, HSR) and accelerometery (body load, impacts) measures. This evidence suggests that sRPE presents a cost-effective method to determine internal load in rugby athletes.

The nature of rugby competition involving repeat bouts of high intensity sprinting and collisions places the athlete under levels of physiological stress which lead to muscle damage following both high training days and competition [15]. It is essential for physical performance staff to not only quantify load experienced by an athlete but also their individual responses to that load [1]. Given the nature of in-season competitive phases in rugby union, turnaround times between fixtures places time constraints on the recovery periods athletes have [16]. In order to balance the process of recovery from one fixture with a sufficient training stimulus to prepare both physically and technically for the next fixture, it is essential that physical performance practitioners monitor athlete's responses to load.

The most important aspects of rugby union game play involve activities requiring high levels of muscular force production at high velocities, in a repetitive nature typically performed by lower limb musculature [2]. The presence of neuromuscular fatigue has been demonstrated in lower limb musculature for athletes in contact sports within 24-72 hours post competition [17]. It has been proposed that this decrement in neuromuscular performance occurs due to skeletal muscle damage from eccentric stress which leads to a "disorganization of the my filament alignment affecting cross bridge cycling and subsequent muscular contractile force capabilities" [18]. In order to avoid performance decrement, functional overreaching and potential muscular injury risk due to the accumulation of chronic muscular fatigue, longitudinal measurements of athlete neuromuscular performance can be taken and inform training prescription[19].

The most commonly used measure to assess lower limb neuromuscular performance is the countermovement jump (CMJ) assessment [20]. CMJ assessment has been shown to be a valid and reliable measure of neuromuscular performance in collision sport athletes with several studies demonstrating the relationship between load application and changes in CMJ performance [21] [4] [22] [23]. CMJ testing and changes in performance can be measured using a number of variables such as peak power (W), relative power (W/kg), flight time and jump height [24]. The gold standard for the measurement of CMJ performance is the force plate, however similar to the aforementioned technologies, this presents a significant financial burden to a physical performance department. For those clubs in lower leagues with significantly reduced budgets, a more cost-effective means of assessing athlete neuromuscular performance must be found.

Recent research into the area of velocity-based strength and power training has led to an increase in the availability of technologies to track barbell or athlete movement velocity [25]. When compared to gold standard force plate, a number of devices have been tested with the most common technology being “GymAware” and PUSH band. Research by Wadhi et al. (2018) [26] into the validity and reliability of “GymAware” technology has shown that when compared to the gold standard force plate, the device overestimates the jump height metric. This is consistent with research from O’Donnell et al. (2018) [27] in female basketball athletes, with a systemic overestimation of jump height found in CMJ trials when compared to the force plate. However, it is noted by Wadhi et al. (2018) [26] that the measurement of peak velocity was shown to be reliable as well as the device demonstrating very high test-retest reliability for jump height. Similarly, O’Donnell et al. (2018) [27] while demonstrating overestimations in jump height found the device to be reliable in measuring jump performance with high within-athlete reliability for measurements of peak velocity. This device however, similar to technologies mentioned previously, presents a financial burden with 1 device retailing at $2,200.

A more cost-effective accelerometer-based assessment device to assess CMJ performance may be the “PUSH band 2.0”. This device retails at £275 per PUSH band and presents a significantly reduced financial burden on clubs looking to utilise technology to assess athlete’s responses to load. Research by Ripley & McMahon (2016) [28] assessed the performance of “PUSH band 2.0” technology during CMJ performance in comparison with the force plate. In this study, for measures of peak velocity and peak power, within-session reliability was high for the PUSH band and force plate individually. The PUSH band was shown to overestimate all metrics compared to the force plate however, there was positive relationships for measures of peak velocity between both measuring technologies with high correlation. More recent research from Lake et al. (2018) [29] demonstrated that the PUSH band 2.0 was suitable for the evaluation of peak and mean velocity during CMJ exercise when compared with the force plate. There was no fixed or proportional bias evident when comparing measures of peak velocity for both technologies (McBride et al. 2011). It is suggested in this study that performance of an unloaded CMJ for measurements of peak velocity have acceptable agreement when comparing metrics derived from the PUSH band 2.0 and force plate technology. This research demonstrates the efficacy of utilising the PUSH band 2.0 as a cost-effective alternative to measuring athlete neuromuscular performance during CMJ, when compared to the gold standard force plate.

To this author’s knowledge, there currently exists a gap in the research for a study of this type. There is limited research into the area of in-season neuromuscular performance and its response to load utilising cost-effective means for professional rugby clubs with significantly lower performance department budgets. Research from Kennedy & Drake (2015) [30] in to CMJ performance in academy rugby union athletes found decrements in both eccentric phase duration and force output following an intense training day. This research however used a force plate and was performed in a pre-season non-competitive training period. A similar study from Roe et al. (2015) [31] looked at CMJ performance in academy and transitional rugby union athletes with sRPE load. This study however took place during an 11-week pre-season period. Reduced neuromuscular performance during a pre-season training period is expected as this time represents the only dedicated window in the professional rugby union calendar for physiological adaptation where physical readiness for weekend fixtures is not to the forefront [32]. Another study in to CMJ performance with respect to increased training loads looked at a 6-week general preparation phase training in female rugby 7s athletes [33]. While findings clearly demonstrated progressive decrements in a number of CMJ output variables from week to week, data was collected and assessed using force plate technology.

Two studies have looked at CMJ performance as a measure of neuromuscular fatigue with respect to in-season training loads. Oliver et al. (2015) [34] demonstrated longitudinal neuromuscular fatigue within an amateur youth rugby union population over a 7-week in-season period. Significant decreases in jump height and leg stiffness were found by week 4 with performance levels below baseline when assessed pre-competition. By week 7, negative CMJ performance variables were evident due to cumulative load fatigue. This study highlights the potential risk of cumulative loads on neuromuscular performance if not managed with respect to load and the necessity to track these during competitive phases to ensure strength and power performance does not suffer. This study utilised the Fusion Sport contact mat which retails at £750+, significantly more expensive than the PUSH band 2.0 device. Tavares et al. (2018) [35] performed one of the most detailed studies of the interaction of training load with neuromuscular performance in addition to measures of muscle soreness and wellness. This study took place in-season during a non-competitive 4-week regeneration phase with a professional male rugby union team however it was only one week in duration. In this study, load was calculated using GPS and neuromuscular performance measured using force plate technology. While the study found significant decreases in CMJ peak force on day 2 and 3 of the training week with respect to load, the technologies used to quantify metrics in this study again present a heavy financial commitment for a physical performance department.

The aim of this study therefore is to assess changes in neuromuscular performance in professional male rugby union athletes using PUSH band 2.0 accelerometer-based device with respect to training load as quantified by sRPE means, for an in-season competition phase. The aim is to investigate if any relationships exist between changes in training load and neuromuscular performance as assessed by the PUSH band 2.0, therefore providing a cost-effective alternative for physical performance departments to track athlete responses to load.

2. Methods

2.1. Data Source & Study Rationale

All data used in the study was collected as part of the daily athlete monitoring practices which were conducted at a professional rugby union club in the RFU Championship, during the 2019-2020 competitive season. The data collection was completed in accordance with end of season review procedures which are part of the formal operations of the club. The research serves to offer data and scientific rationale to support the usage of the club’s current monitoring processes given the budget available to the physical performance department for these practices.

2.2. Participants

The team’s playing squad consists of a 37-man playing squad with 19 forwards and 18 backs. Exclusion criteria for participant monitoring data to be considered for the study was taken into account. Any player suffering a time loss injury or season-ending injury which affected their ability to carry out daily monitoring uninhibited was not considered. Any players whom are not full-time professionals contracted to the club, who do not carry out the daily team rugby and strength & conditioning activities were not considered. Any players who did not engage in all components of the weekly training schedule for the duration of the 8-week mid-season time period which data is to be taken from, due to illness or injury was not considered.

19 players monitoring data was confirmed to be aligned to the inclusion criteria to be considered valid for the purpose of the study. This group includes 11 forwards and 8 backs. All 19 players are full time contracted professional rugby players and compete in the RFU Championship. The RFU Championship is the second tier of professional rugby union in England with 12 teams competing in a league structure. Teams play each other home and away in the league running from October to May.

2.3. Procedures & Training Schedule

The 8 week in-season period used for the purposes of the study includes 3 cup fixtures, 1 league fixture, 1 recovery week (Christmas period), 1 non-competitive training week and finally 2 more league fixtures. This 8-week in-season period was preceded by a recovery-regeneration week (7 days). CMJ peak velocity (m/s) values were taken on the morning of each training day in the week but not on game days or during restitution days where players did not attend the training facility. Depending on the day of the week on which fixtures take place

(Friday, Saturday or Sunday), players completed either 3 or 4 days of data collection for CMJ peak velocity measures. All rugby and S&C session loads were recorded and quantified using sRPE method. A training week consisted of 2-4 resistance training sessions, 2-3 rugby sessions and 1 captain's run 24 hours prior to competition. Players not selected for competitive fixtures completed an additional on-feet and off-feet conditioning session within the training week.

2.4. Countermovement Jump Monitoring

On the morning of each training day, players completed a 15-minute mobility and whole-body movement circuit lead by an S&C coach. Following this, players performed 3 x CMJ tests consecutively using the PUSH band 2.0 accelerometer device, worn on the forearm with test feedback provided through the "Train with Push" application on iPad. Peak velocity values for each individual jump performed were recorded and players provided their highest peak velocity value of the 3 attempts as their CMJ peak velocity value for that given training morning. Players were instructed to keep their arms fixed firmly on their hips throughout the jump with failure to do so resulting in a failed test. Depth of downward phase in the CMJ was at player's discretion and players were instructed to perform the jump with maximal intent. This process was completed as the first activity of each training day. All submissions within a given training week were recorded and an average CMJ score for each week provided.

2.5. Training Load

Quantification of all training loads was performed using the session rating of perceived exertion using the modified Borg scale with values from 0 (rest) to 10 (maximal exertion) (Foster et al. 2001). Players self-reported sRPE for all rugby and S&C sessions using a self-report google form submission completed within 30 minutes of training cessation. Players provided session RPE and were instructed on session duration by S&C staff in order to quantify session load (duration x RPE). In order to ensure accuracy of data submission, players were educated in this process during the pre-season period. In order to ensure timely submission and accuracy of RPE to a session, one member of the S&C staff was appointed to data processing all RPE submissions following each training activity. Loads were expressed in AU with cumulative weekly loads provided.

2.5.1. Training Monotony

Training monotony is an additional variable that can be calculated from the sRPE load method. It is identified as the variation of training sessions within the training week (Comyns & Flanagan, 2013). It is derived from the mean sRPE / StnDev and expressed as a weekly value.

2.5.2. Training Strain

Training strain is a variable calculated to express the overall training stress from the week given utilising the calculations from total weekly load (AU) and monotony (Comyns & Flanagan, 2013). It is calculated through weekly sRPE load / weekly monotony.

2.6. Statistical Analysis

Data was analysed using SPSS for Mac (version 25) in addition to excel for Mac (2015**).** All data was tested for normality of distribution using the Shapiro-Wilks test on CMJ and load data with all data satisfying the test (SW = >0.05). Means and standards deviations for data were calculated and are presented in the results section.

A within-group 1-way repeated measures ANOVA was performed to analyse changes in CMJ peak velocity measures during the in-season 8-week period. Magnitude-based inferences were analysed to determine changes in weekly CMJ performance. As per Hopkins et al. (2009), the smallest worthwhile change was calculated as the 0.3 x Standard Deviation. To determine whether or not changes were of practical relevance and greater than the SWC, thresholds were set based on Cohen's D effect size where Cohen's D = (M2-M1)/SD pooled. Thresholds were set at <0.2 (trivial), 0.2-0.5 (small), 0.5-0.8 (moderate), >0.8 (large) (Hopkins, 2004).Within subject CMJ means and standard deviations were calculated for each week. This data was then used to calculate within-group standard deviation and from this weekly SWC data was calculated. Weekly changes in CMJ were calculated as the difference between the within-group weekly mean CMJ for a given week compared to week 1. This change was expressed with respect to the SWC to determine the effect size. Weekly changes in CMJ peak velocity (m/s) were calculated in comparison to the previous week's CMJ data.

To determine the relationship between CMJ and load, a Pearson correlational matrix was performed to determine the individual weekly relationships between these metrics. The correlation was considered to be significant when p = 0.05 with either a small effect (0.1-0.3), moderate effect (0.3-0.5) or large effect (0.5-1.0).

3. Results

3.1. Neuromuscular Performance

Data for weekly mean, standards deviation, smallest worthwhile change and Cohen's D effect size for each week in the study period for CMJ data are presented in table 1;

Table1. *Lower limb neuromuscular performance values expressed as m/s values for peak velocity of CMJ. Cohen's effect sizes set as <0.2 (trivial), 0.2-0.5 (small), 0.5-0.8 (moderate), >0.8 (large)*

	Means StnDev	*Smallest Worthwhile Change*	*Change from Baseline / Weekly Change*	*Effect Size Cohen's D*
Week 1	3.1198 ±0.11	0.0332		
Week 2	3.0666 ± 0.12	0.0356	-.0532	-0.38 (small)
Week 3	3.0734 ± 0.08	0.0247	-.0464 / +.0068	-0.37 (small)
Week 4	3.1039 ± 0.11	0.0327	-.0159 / +.0305	-0.12 (trivial)
Week 5	NO DATA			
Week 6	3.0561 ± 0.13	0.381	-0.0637	-0.71 (moderate)
Week 7	3.0689 ± 0.10	0.0299	-0.0510 / +.0128	-0.35 (small)
Week 8	3.0526 ± 0.11	0.0317	-0.0672 / -.0163	-0.54 (moderate)

Results of the 1-way repeated measures ANOVA demonstrated that data for the test group across the 8 week in-season period CMJ performance (3.0773 ± 0.11 m/s) was not statistically significantly different. Results from Wilks' Lambda test show no significance (p = .158), with Mauchly's test of sphericity failed with significance (p = 0.00). Usage of the Greenhouse-Geiser test demonstrates the differences to not be statistically significant (p = .446). However, results of the between subjects' effects demonstrates very high statistical significance (p = .00) where subjects differ greatly from each other within the group.

Results of the analysis in excel on neuromuscular performance revealed small negative effects on CMJ in week 2 and 3, trivial negative effect in week 4, moderate negative effect in week 5 following the recovery week, small negative effect in week 6 and finally a moderate negative effect in week 8.

3.2. Load (Strain) & Neuromuscular Performance

Data for training load (2456 ±338), monotony (0.95 ± 0.19) and subsequently strain (2436 ±798) are shown in figure 1 for data across the 8 week in-season period.

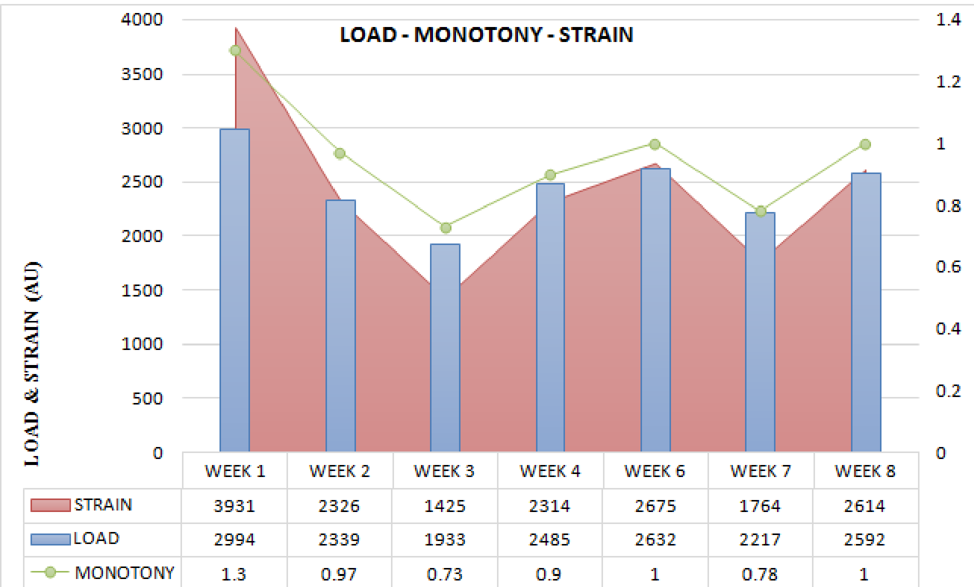

Figure1. *Weekly averages for group load, monotony and strain expressed as AU for each week*

Results of the correlational matrix for CMJ (3.0773 ± 0.11 m/s) and load ((2456 ±338) demonstrated a variety of results across the time period with week 3 the only week demonstrating a statistically significant correlation (r=.487, p = .034) between load and neuromuscular performance. Results of the correlational matrix can be seen in table 2. Weekly values for group mean load and group mean CMJ m/s can be seen on figure 2 (discussion).

Table2. *Pearson correlation values (r) and values for statistical significance (p) shown as results of a correlational matrix for each week for* ***CMJ performance (m/s) and Training Load (AU)****. Thresholds for Pearson correlation set at 0.1-0.3 (small), 0.3-0.5 (moderate), 0.5-1.0 (large). Correlation deemed statistically significant when p = <.05*

	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
Pearson (r)	-.126	-.008	.487	-.006	***NO DATA***	.199	-.412	.098
Sig (p)	.606	.974	.034*	.980		.415	.079	.698
Correlation	small	small	medium	small		small	medium	small

Negative correlations can be seen for CMJ data and load in week's 1,2,4 and 7 with positive correlations in week 3,6 and 8. Of the above results only 2 weeks demonstrate medium correlations with one of these showing a statistically significant result.

4. Discussion

The aim of this study was to assess changes in neuromuscular performance and its response to load over an 8-week in-season competitive phase for elite male rugby union athletes utilising cost-effective methodologies. Weekly means for load (AU) and CMJ (m/s) can be seen in figure 2. While no statistical significance was found for changes in CMJ performance and consistently large or strong correlations for weekly CMJ performance and weekly load were not found, the PUSH band 2.0 did detect changes in CMJ performance during the study period.

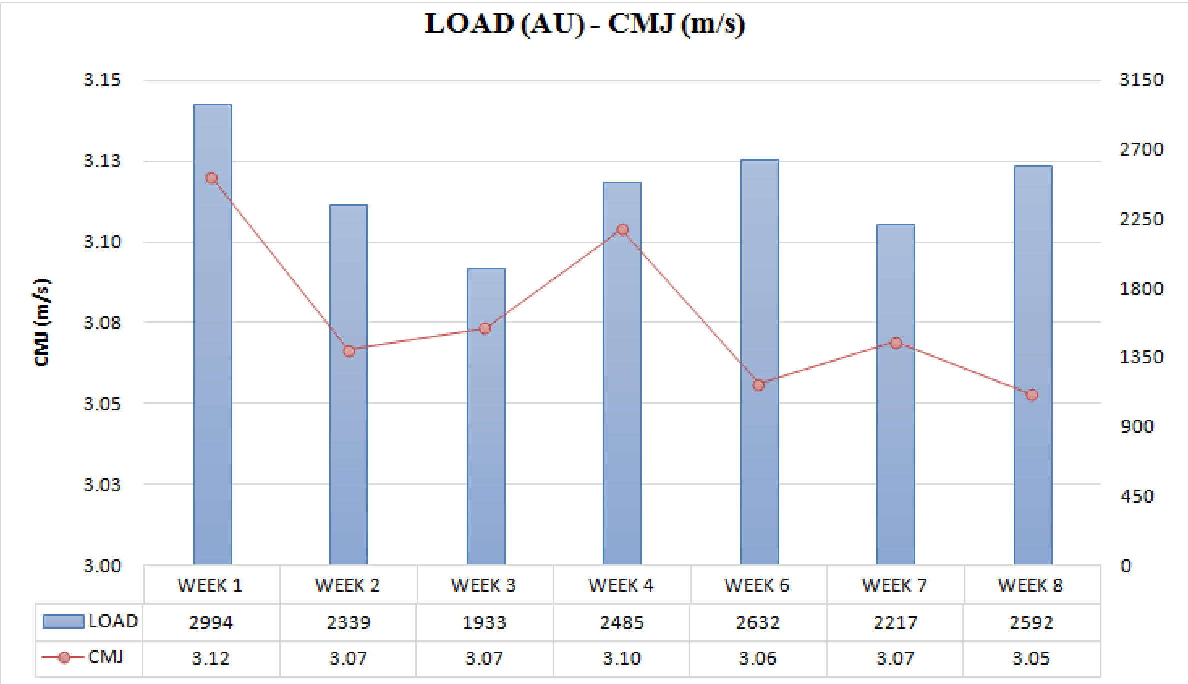

Figure2. *Weekly averages for load (AU) and CMJ (m/s) for full participants group*

Results of the 1-way repeated measures ANOVA did not demonstrate statistically significant results for differences in CMJ performance from week 1 to week 8, the test of between-subjects effects demonstrated high statistical significance (p=<0.01). As stated by Foster et al. (1996) [11] is it essential for physical performance staff to monitor the physical response of athletes to applies training and competition stress. However, given the results of the above statistical test, monitoring each individual athlete's response to training load using the PUSH band 2.0 for lower limb neuromuscular performance may offer greater accuracy given the high variability between athlete outputs.

It is worth noting that during the 8-week in-season phase there was evidence of long-term neuromuscular fatigue as demonstrated in the negative trend of CMJ (m/s) performance in Figure 2, using the PUSH band 2.0 peak velocity measure. The change in group mean for CMJ performance was greater than that of the smallest worthwhile change (SWC) statistic for 5 out of the 6 weeks, as recommended by Turner et al. (2015) [36] to detect worthwhile changes in an athletic performance population. Reductions in CMJ peak velocity are evident in week 2 and 3 with an increase in neuromuscular performance evident in week 4. Following the regeneration week, there is still neuromuscular fatigue evident which is still present in week 7 and week 8 when compared to week 1.

While the results of the statistical analysis demonstrated no statistical significance in the changes in CMJ performance during the 8-week in-season period, the use of PUSH band 2.0 to quantify athlete training response may be performed in another way. As seen in figure 2, there is a trend of increasing neuromuscular fatigue throughout this in-season training period. The two greatest periods of neuromuscular performance decrement evident on the graph appear to occur after two of the highest weeks of total training load and strain (AU). Additionally, there appears to be a minor increase in neuromuscular performance in week 4 following two progressive weeks of reducing load (AU). It must be noted however that none of these findings are statistically significant but do offer a visual representation of the squad lower limb performance over this time period.

A previous study by Gathercole et al. (2015) [21] investigating CMJ responses to increased training loads utilising force plate technology, suggested that measurements such as flight time and jump height may be insensitive to neuromuscular fatigue. It is suggested that more direct measurements of jump output such as peak displacement or jump velocity are advantageous measures of neuromuscular fatigue. This measure detects the peak velocity of the direct upward movement phase (concentric) of lower limb muscle action following eccentric contraction and are not directly affected by jump technique where landing or altered kinematics from ground contact can affect data output. This lends additional support to the usage of CMJ peak concentric velocity (m/s) metric which can be measured using the PUSH band 2.0.

The weekly training loads (2456 ±338 AU) observed in this study are greater than those reported for previous studies of elite level male professional rugby union by Cross et al. (2015) (2175 ± 380) [37]. It must be noted however, that one significant limitation of this study was the data collection process of sRPE data for competition. The submission process for sRPE for competitive fixtures had not been established prior to the season and subsequently for all competitive fixtures, all participating players were given an sRPE of 10 (maximal exertion). Training load (AU) for these competitive fixtures was calculated through playing minutes x 10 (sRPE). It has been demonstrated by Lovell at al. (2013) [12] that sRPE can accurately quantify athlete load in collision sports. It has been shown to have statistical significance with GPS metrics within-individual. Therefore, dependent on the individual match play demands and work performed by players, sRPE values provided by the player would be the most accurate measurement of load. It is suggested that in order to increase the validity of any statistical testing to determine the correlation between load and neuromuscular performance using the PUSH band 2.0, the methodology for sRPE data collection be more robust.

Results from this study indicated that CMJ peak velocity had it's greatest decrement in week to week neuromuscular performance following the week of highest training load (AU), with week 1 representing the highest load (2994 ± 321 AU). Following this load, CMJ peak velocity dropped by -0.0532 m/s in week 2. Reduced training loads in week 2 (2339 ± 621 AU) and week 3 (1933 ± 326 AU) respectively were accompanied by CMJ m/s increase of 0.068 m/s from week 2 to week 3 and by another 0.0305 m/s from week 3 to week 4. This data would suggest that while statistical significance was not found, there is a relationship between reducing total load and an increase in neuromuscular performance. In the second block of in-season weeks following the recovery week (week 5 - Christmas week), the 2nd highest period of training load (2632 ± 387) represents another decrement in neuromuscular performance dropping by -0.0637 m/s when compared to week 1. It is worth noting that the following week which represents a reduction in training load (2217 ± 392) and coming off a weekend of no competitive fixtures, there was increase in CMJ peak velocity of +.0128 m/s. Week 8 increased in load (2592 ± 426) and was accompanied by a subsequent reduction in weekly CMJ peak velocity of -.0163 m/s. Prevailing theories of training periodisation suggest that removal of a fatigue-inducing training stressor and associated recovery period allow for the manifestation of improvements in physical performance [38]. Consideration for the nature of the recovery/off week within the 8-week period being Christmas and New Year's, it is plausible that optimal recovery modalities (sleep, dietary intake, no alcohol consumption) were not a priority and therefore had an effect on CMJ peak velocity output in week 6.

It is suggested by Boyas & Guevel (2011) [39] that neuromuscular fatigue is multi-factorial with considerations for central and peripheral fatigue being contributory, given the role each plays in performing muscular work. Research by Roe et al. (2016) [23] found that changes in CMJ mean force during an 11-week pre-season period were trivial even with increasing training loads, suggesting this metric was not sensitive enough to detect changes in neuromuscular fatigue. It is suggested that system fatigue induced by training resulted in changes in movement velocity rather than force lending more support for the usage of CMJ peak velocity (m/s) to detect neuromuscular fatigue using the PUSH band 2.0.

As demonstrated in previous research into the effect of load on neuromuscular performance, the CMJ has been shown to be a sensitive measure of lower limb output. Enoka (1995) [40] stated there to be a task dependent nature to fatigue with factors such as muscular type and duration as well as movement speed all contributing factors. Given the nature of rugby union competition and training involving activities with long ground contact times and slow SSC components for actions such as acceleration, deceleration and collisions, the CMJ represent a relevant test of neuromuscular performance.

However, consideration must be given for the most appropriate metric through which we may determine changes in neuromuscular performance given the underlying physiological responses which take place following training and competition stress. Eccentric muscle action and associated muscular damage as discussed earlier in this study, can lead to reduction in eccentric contractile capabilities and affect SSC of CMJ performance. With a reduction in eccentric force production due to fatigue, subsequent concentric muscular action, as a result of the stretch-reflex, and movement velocity will be affected in the upward phase of the CMJ. This has been demonstrated by Nicol et al. (2006) [41] in their assessment of the stretch-shortening cycle and naturally occurring neuromuscular fatigue. With decrements in CMJ peak velocity seen throughout the study period, the PUSH band 2.0 may be able to detect such acute and longitudinal changes in neuromuscular performance.

5. Conclusion & Practical Applications

The in-season 8-week competition phase for elite level male rugby union athletes resulted in longitudinal changes in neuromuscular performance when assessed through CMJ performance, measured by the PUSH band 2.0 velocity-based training device. While statistically significant results were not found for the group across the study period, the PUSH band 2.0 did appear to be sensitive in its ability to detect changes in load and subsequent neuromuscular performance response. That is, that higher loads resulted in decreased neuromuscular performance and CMJ peak velocity with reduced loads resulting in improvements in neuromuscular performance. In order to improve validity of the sRPE weekly load data collection, it is suggested that competition loads, and training loads be collected in with robust methodologies ensuring accuracy with respect to timing and player education in the process.

While not a statistically significant method of neuromuscular performance assessment, the use of the PUSH band 2.0 to assess lower limb neuromuscular performance in professional rugby union athletes offers a reliable and cost-effective measure to track athlete responses in season with potential sensitivity to detect responses to load adjustments. This should assist in the practitioners ongoing professional practice of fatigue monitoring and its role in training prescription with repect to schedule demands and athlete management during a competitive season.

References

[1] Halson, S. (2014). Monitoring Training Load to Understand Fatigue in Athletes. Sports Medicine, 44(2), 139-147.

[2] Cunniffe, B., Proctor, W., Baker, J.S. and Davies, B., 2009. An evaluation of the physiological demands of elite rugby union using global positioning system tracking software. *The Journal of Strength & Conditioning Research*, *23*(4), pp.1195-1203.

[3] Duthie, G., Pyne, D. and Hooper, S., 2003. Applied physiology and game analysis of rugby union. *Sports medicine*, *33*(13), pp.973-991.

[4] McLean, B.D., Coutts, A.J., Kelly, V., McGuigan, M.R. and Cormack, S.J., 2010. Neuromuscular, endocrine, and perceptual fatigue responses during different length between-match microcycles in professional rugby league players. *International journal of sports physiology and performance*, *5*(3), pp.367-383.

[5] Quarrie, K.L., Raftery, M., Blackie, J., Cook, C.J., Fuller, C.W., Gabbett, T.J., Gray, A.J., Gill, N., Hennessy, L., Kemp, S., Lambert, M., Nichol, R., Mellalieu, S.D., Piscione, J., Stadelmann, J., Tucker, R. (2016). Managing Player Load in Professional Rugby Union: A Review of Current Knowledge and Practices. *British Journal of Sports Medicine.* 0:1-8

[6] Impellezzeri, F.M., Rampinini, E., Marcora, S.M. (2005). Physiological Assessment of Aerobic Training in Soccer. *Journal of Sports Sciences.* 23(6):583- 692

[7] Comyns, T. and Flanagan, E.P., 2013. Applications of the session rating of perceived exertion system in professional rugby union. *Strength & Conditioning Journal*, *35*(6), pp.78-85.

[8] Coutts, A., Reaburn, P. and Abt, G., 2003. Hearth rate, blood lactate concetration and estimated energy expediture in a semi-profesional rugby league team during a match: case study. *Journal of Sports Sciences*, *21*(2), pp.97-103.

[9] Handziski, Z., Maleska, V., Petrovska, S., Nikolik, S., Mickoska, E., Dalip, M., Kostova, E. (2006). The Changes of ACTHM Cortisol, Testosterone and Testosterone/Cortisol Ratio in Professional Soccer Players during a Competition Half-Season. *Sports Medicine.* 107(6-7):259-263

[10] Bourdon, P.C., Cardinale, M., Murray, A., Gastin, P., Kellmann, M., Varley, M.C., Gabbett, T.J., Coutts, A.J., Burgess, D.J., Gregson, W. and Cable, N.T., 2017. Monitoring athlete training loads: consensus statement. *International journal of sports physiology and performance*, *12*(s2), pp S2-161.

[11] Foster C, Daines E, Hector L, et al. Athletic performance in relation to training load. Wis Med J 1996; 95:370-4.

[12] Lovell, T.W., Sirotic, A.C., Impellizzeri, F.M. and Coutts, A.J., 2013. Factors affecting perception of effort session rating of perceived exertion) during rugby league training. *International journal of sports physiology and performance*, *8*(1), pp.62-69.

[13] Herman, L., Foster, C., Maher, M.A., Mikat, R.P. and Porcari, J.P., 2006. Validity and reliability of the session RPE method for monitoring exercise training intensity. *South African Journal of Sports Medicine*, *18*(1), pp.14-17.

[14] Lambert MI, Borrensen J. Measuring training load in sports, *lnt J Sports Physiol Perform.* 2010;5(3):406-411. PubMed

[15] Austin d, Gabbett T, Jenkins d. The physical demands of Super 14 rugby union. J Sci Med Sport 2011;14:259–63.

[16] Coutts AJ, Reaburn p, piva TJ, Rowsell GJ. Monitoring for over- reaching in rugby league players. eur J appl physiol 2007;99:313–24.

[17] West, D. J., Finn, C. V., Cunningham, D. J., Shearer, D. A., Jones, M. R., Harrington, B. J., Kilduff, L. P. (2014). Neuromuscular function, hormonal, and mood responses to a professional rugby union match. J Strength Cond Res, 28(1), 194-200.

[18] Macintyre dl, reid Wd, McKenzie dc. delayed muscle soreness. The inflammatory response to muscle injury and its clinical implications. Sports Med 1995;20:24–40.

[19] Johnston rd, Gibson NV, Twist c, Gabbett TJ, MacNay Sa, Macfar- lane NG. Physiological responses to an intensified period of rugby league competition. J Strength cond res 2013;27:643–54.

[20] Webb NP, Harris NK, Cronin JB, Walker C. The relative efficacy of three recovery modalities after professional rugby league matches. J Strength cond res 2013;27:2449–55.

[21] Gathercole, R., Sporer, B. and Stellingwerff, T., 2015. Countermovement jump performance with increased training loads in elite female rugby athletes. *International journal of sports medicine*, *36*(09), pp.722-728.

[22] Oliver, J.L., Lloyd, R.S. and Whitney, A., 2015. Monitoring of in-season neuromuscular and perceptual fatigue in youth rugby players. *European journal of sport science*, *15*(6), pp.514-522.

[23] Roe, G.A., Darrall-Jones, J.D., Till, K. and Jones, B., 2016. Preseason changes in markers of lower body fatigue and performance in young professional rugby union players. *European Journal of Sport Science*, *16*(8), pp.981-988.

[24] Twist, C. and Highton, J., 2013. Monitoring fatigue and recovery in rugby league players. *International Journal of sports physiology and performance*, *8*(5), pp.467-474.

[25] Jovanović, M. and Flanagan, E.P., 2014. Researched applications of velocity-based strength training. *J Aust Strength Cond*, *22*(2), pp.58-69.

[26] Wadhi, T., Rauch, J.T., Tamulevicius, N., Andersen, J.C. and De Souza, E.O., 2018. Validity and Reliability of the GymAware Linear Position Transducer for Squat Jump and Counter-Movement Jump Height. *Sports*, *6*(4), p.177.

[27] O'Donnell, S., Tavares, F., McMaster, D., Chambers, S. and Driller, M., 2018. The validity and reliability of the GymAware linear position transducer for measuring counter-movement jump performance in female athletes. *Measurement in Physical Education and Exercise Science*, *22*(1), pp.101-107.

[28] Ripley, N. and McMahon, J., 2016, July. Validity and reliability of the PUSH wearable device to measure velocity and power during loaded countermovement jumps. In *Proceedings of the National Strength and Conditioning Association National Conference, New Orleans, LA, USA* (pp. 6-9).

[29] Lake, J.P., Augustus, S., Austin, K., Mundy, P., McMahon, J.J., Comfort, P. and Haff, G.G., 2018. The validity of the Push Band 2.0 during vertical jump performance. *Sports*, *6*(4), p.140.

[30] Kennedy, R., Drake, D. (2015). The effect of acute fatigue on countermovement jump performance in rugby union players during preseason training. *Journal of Sports Sciences*. 33 (1), p44-59.

[31] Roe, G.A., Darrall-Jones, J.D., Till, K. and Jones, B., 2016. Preseason changes in markers of lower body fatigue and performance in young professional rugby union players. *European Journal of Sport Science*, *16*(8), pp.981-988.

[32] Bradley, W.J., Cavanagh, B.P., Douglas, W., Donovan, T.F., Morton, J.P. and Close, G.L., 2015. Quantification of training load, energy intake, and physiological adaptations during a rugby preseason: a case study from an elite European rugby union squad. *The Journal of Strength & Conditioning Research*, *29*(2), pp.534-544.

[33] Gathercole, R., Sporer, B. and Stellingwerff, T., 2015. Countermovement jump performance with increased training loads in elite female rugby athletes. *International journal of sports medicine*, *36*(09), pp.722-728.

[34] Oliver, J.L., Lloyd, R.S. and Whitney, A., 2015. Monitoring of in-season neuromuscular and perceptual fatigue in youth rugby players. *European journal of sport science*, *15*(6), pp.514-522.

[35] Tavares, Francisco, Phil Healey, Tiaki B. Smith, and Matthew Driller. "The effect of training load on neuromuscular performance, muscle soreness and wellness during an in-season non-competitive week in elite rugby athletes." *The Journal of sports medicine and physical fitness* 58, no. 11 (2018): 1565-1571.

[36] Turner, A., Brazier, J., Bishop, C., Chavda, S., Cree, J., & Read, P. (2015). Data Analysis for Strength and Conditioning Coaches. *Strength And Conditioning Journal*, *37*, 76-83.

[37] Cross, M. J., Williams, S., Trewartha, G., Kemp, S. P., & Stokes, K. A. (2015). The Influence of In-Season Training Loads on Injury Risk in Professional Rugby Union. Int J Sports Physiol Perform.

[38] Hausswirth, C. and Mujika, I., 2013. Recovery for performance in sport. Human Kinetics. (2013). Overtraining Prevention. In: Human Kinetics *Recovery for Performance in Sport*. 107 Bradford Rd, Stanningley, Pudsey LS28 6AT: Human Kinetics. p27.

[39] Boyas, S., & Guével, A. (2011). Neuromuscular fatigue in healthy muscle: Underlying factors and adaptation mechanisms. Annals Phys Rehabil Med, 54(2), 88-108.

[40] Enoka, R. M. (1995). Mechanisms of muscle fatigue: Central factors and task dependency. Journal of Electromyography and Kinesiology, 5, 141–149.

[41] *Nicol C, Avela J, Komi PV*. The stretch-shortening cycle: a model to study naturally occurring neuromuscular fatigue. Sports Med 2006; 36: 977–999

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