

# Relationships between Muscular Performance and Markers of Well-Being in Elite Rugby Union Players

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Regular testing can be used to track athletes' changes in performance over time. However, testing should not be limited to physiological characteristics alone, but also encompass perceived psychological status and well-being. Foster (1998) suggests monitoring of subjective well-being may serve to prevent deterioration in the practice of physical tasks. The relationship between psychological and physiological measures in professional team sport is not fully investigated. St Clair Gibson et al. (2003) proposed that fatigue may be the mental representation of physiological changes characterizing emotions. Therefore, the purpose of this study is to examine relationship between psychological self-assessment of well-being and physiological parameters related to muscular performance in a professional rugby union team. 15 male professional rugby union players ( $26.5 \pm 5.8$  years;  $102.6 \pm 13.4$  kg;  $186.1 \pm 9.5$  cm) participated. On a weekly basis over a competitive season players completed a perceived well-being questionnaire related to manifestations of fatigue, and 3 jump squats. Vertical displacement, velocity, power, force and force impulse were calculated for each jump. Time series analysis indicates no relationship between measures of well-being and muscular performance on an individual basis. However, analysis of mean team data does show the existence of a relationship in some cases.

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*Keywords:* rugby, muscular performance, physical fatigue.

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## Introduction

Rugby union is an intermittent high-intensity team sport of 80 min duration, consisting of two 40 min halves separated by 10 min break. Positional groups in rugby union can broadly be divided into 'forwards' and 'backs', with each group requiring specific physical preparation, such as highly developed speed,

agility, and maximal aerobic power (Duthie et al., 2003). Therefore, physiological demands of rugby union are very complex, but irrespective of playing position, one of the main physiological prerequisites for successful rugby performance is high levels of muscular strength and power (Gabbett et al., 2006).

However, an optimal performance does not rely only on highly developed physiological capacities, because psychological and emotional well-being status accounts for it, too. Such approach provides a unique opportunity to investigate the interaction between interdisciplinary variables and this could facilitate the development of theory-based knowledge that would be of potential relevance to elite athletes (Burwitz et al., 1994).

Testing and monitoring of the main physiological parameters in any given sport on a regular basis can help to track athletes' improvement over time and modify training programme according to the results obtained from the testing (Lambert, 2006). It is noteworthy, that regular testing should not be limited to only physiological characteristics, but also encompass perceived psychological and well-being status. As was proposed by Foster (1998) monitoring of subjective well-being status may serve as potential technique to prevent deterioration in the practice of physical tasks because long-term imbalance between stress (training, competition, and nontraining stress factors) and recovery can lead to a state of overtraining. Overtraining is an unexplained, sustained decrement in performance, usually accompanied by physiological and psychological changes reflecting maladaptation (Cureton, 2009).

Research has consistently focused on assessing the effectiveness of testing methods to monitor various changes in a single discipline rather than interdisciplinary. For example, the squat jump (SJ) exercise is known as a measure of power production in athletic population (Li et al., 2008; Cormie et al., 2008). Similarly, the Profile of Mood States (POMS) has been suggested as the primary psychological tool for monitoring training stress (Martin et al., 2000; Kenttä et al., 2006). However, the interdisciplinary relationship between measures in professional sport is not fully investigated (Kellmann, 2002).

To date very limited research has been done trying to establish relationship between physiology and psychology in order to identify if perceived well-being status, reflected by a short questionnaire, is sensitive to determine physiological changes, such as power output, in the professional team sports. However, it can be hypothesised that perceived levels of different mental and well-being measures may closely be related to the athlete's physiological performance. As an example, low levels of confidence on a particular day, may be reflected in a poor performance of the lower body muscles exercises, such as the SJ. In addition,

if despite seasonal variation in training load and competition requirements athlete consistently reports low scores on specific psychometric measures it may predict reduced performance or even indicate state of overtraining. According to Armstrong & Van Heest (2002) one of the recommendations for overtraining syndrome prevention and treatment was monitoring a subjective ratings of quality of sleep, fatigue, muscle soreness, and causes of stress other than training. Questionnaire has also been proposed as a simple/quick measure of assessing fatigue (Kellmann, 2002). Thus, self-reported questionnaire may help to monitor various sensations of fatigue and well-being associated with athletic performance on the day-to-day basis.

With regard to practical implications in the professional rugby union training, such approach could provide relatively non-invasive and valuable monitoring tool in order to examine the interaction of separate disciplines allowing to perform complex physiological processes, such as power production in lower body, required for successful rugby performance. It may also improve sport performance by minimizing fatigue effect on it, since feelings of fatigue have been proposed as the mental representations of the physiological changes which characterise these emotions (St Clair Gibson et al., 2003). Andreassi (2007) suggested that physiology and psychology are interrelated, since every physiological change is accompanied by a parallel change in the mental and/or emotional state. Such practical implications are, in particular, important for team-sport researches who face many challenges, such as training quantification and identification of physiological determinants (Mujika, 2007). Therefore, the main purpose of this study is to examine relationship between perceived well-being factors (as assessed by a 6-item self-report questionnaire) and muscular parameters (peak power output, maximum force, and force impulse) in professional rugby union players over the 19 weeks course of competitive season.

## **Physiological Demands of Rugby Union**

The nature of rugby sport requires energy for performance to be provided by both energy systems - anaerobic and aerobic, as well as well developed muscular strength and power, speed and agility (Duthie et al., 2003). A diverse range of physical attributes varies depending on the positional group differences between forwards and backs. However, with an application of two most sophisticated methods - time-motion analysis and Global Positioning System (GPS) tracking software, accurate and quantitative data on the physical demands of elite rugby union players is available.

Roberts et al. (2008) match-play analysis on elite England rugby union players by using a time-motion analysis method has shown that backs travelled

more total distance than forwards, 6127 m and 5581 m, respectively. This difference can be attributed to the backs walking a greater distance and covering longer running distances at high intensities. However, in general forwards performed more high-intensity activities mainly because they spent longer periods involved in static exertion activities, such as scrums, rucks, and mauls. Percentage contribution of high- versus low-intensity activity for forwards were 12% and 88%, and backs – 4% and 96%. When the same study by Roberts et al. (2008) compared physiological differences in the first and second halves no differences were observed for total distance covered or high-intensity activities. Deutsch et al. (2007) conducted similar research using the time-motion analysis on professional rugby union players in Super 12 league in order to provide objective information on physiological demands. In contrast to Roberts et al. (2008), the analysed time of match-play was 70 min. Despite 10 min difference in the total game duration, the data derived from both studies were very similar. According to Deutsch et al. (2007), forwards spent significantly more time in high-intensity work (12% - 13%), while the corresponding value for backs was 4.5%. Maximum sprint duration for backs was in range between 5.2 s – 7.2 s, whereas forwards regularly sprinted between 3.2 s and 3.4 s. The mean work:rest ratio was significantly higher for backs 1:21.8 than forwards - 1:7.4. The higher work rate for forwards dictates a greater reliance on anaerobic glycolytic energy system in comparison to the creatine phosphate system likely to play an important role in energy production for backs.

Cunniffe et al. (2009) study used the GPS technology on two (1 forward, 1 back) elite rugby union players to get even more accurate than time-motion analysis data for the physiological requirements. However, the biggest limitation of this study remains a very small sample size. Similarly to the study by Roberts et al. (2008), data from the GPS tracking software has shown that backs travelled greater total distance (7227 m) during a game compared to their forwards counterparts (6680 m). Number of sprints ( $>20$  km/h) performed during the game was also higher for backs than forwards (34 vs. 19). Interestingly, in contrast to both time-motion analysis studies, the GPS revealed greater running distances to be covered in the second half of the game (6.7% backs; 10% forwards).

With regard to body fat percentage, backs tend to have lower values ( $10 \pm 2.3\%$ ) when compared to forwards ( $11.1 \pm 1\%$ ) (Duthie et al., 2003). Any increase in unnecessary players mass in the form of fat rather than lean tissue may be associated with a reduced power-to-weight ratio, increased energy expenditure during movement, and diminished horizontal and vertical acceleration.

Although, high-intensity of the game requires fuel for the performance to be predominantly provided by the anaerobic metabolism, development of

aerobic energy system is equally important to all rugby players. It has been shown by Deutsch et al. (1998) that improved aerobic capacity aids in recovery from high-intensity activity. As most of the physiological prerequisites the elite rugby players' VO<sub>2</sub>max values tend to support a variation by position. The backs demonstrated a larger VO<sub>2</sub>max than forwards when expressed relative to body mass, but a lower absolute aerobic power and ventilation rate (Nicholas, 1997).

Speed and acceleration are also crucial physiological assets for rugby players to enable them to make the position or sprint over extended distance. As Roberts et al. (2008) and Deutsch et al. (2007) studies showed, rugby players typically sprint between 10-20 m. However, it is difficult to measure maximal velocity over such short distances, therefore players are normally tested over longer distances (30 m, 40m, 50 m) with backs having faster times at all of them (Duthie et al., 2003).

An ability to generate muscular power and strength is considered to be similarly important, but used differently in the rugby union positions. As was denoted by Nicholas (1997), the forwards require power in the line-out and scrummage situations, whereas the back line players need the ability to accelerate over short distances and break tackles. With regard to muscular strength, it is required during the contact times, forwards, in particular, need to develop greater strength than backs, because during the game they more often get involved in scrums, rucks and mauls. Additionally, strength and power qualities are necessary for improving running velocity and the ability to change direction (Duthie, 2006). Therefore, the rugby union sport context dictates that forwards tend to produce greater force at low isokinetic speeds, whereas the backs produced greater force at the higher speeds.

In terms of the seasonal structure of the rugby union, it varies dependent on the competition level, the number of leagues (national and international) and teams (clubs and national teams) player has to play for. However, using the British Isle as an example, international players are expected to perform at a consistently high level for approximately 30 weeks (Nicholas, 1997). This may be even longer if players have to participate in major competitions, such as the World Cup.

## **Physical Fatigue**

Muscle fatigue can be defined as a reduction in maximal force-generating capacity and is believed to involve many factors at various sites, including both central and peripheral in origin (Cormack et al., 2008). Intense nature of the prolonged rugby union season places most of the players under great performance and physiological demands. This inevitably means that players will sustain a

fluctuation in their fitness levels over the course of the season. Although, the exact degree to which performance variation occurs may be related to genetic endowment and individual factors, periodizing - carefully planning manipulating training load (frequency, load and duration) and recovery, can help to avoid or reduce such fluctuation (Lambert, 2006).

The main goal of training, in any sport, is to maximize athlete's potential through specific training adaptations that determine performance level. Despite implementation of a well-periodized training programme and accurate management of training process, performance may suffer from prolonged underperformance and fatigue. However, enormous complexity and subjectivity of fatigue bring difficulties in order to find a single cause and preventive method for it.

Traditionally, peripheral model states that fatigue during physical activity occurs due to various limitations, such as inability to remove metabolic by-products like lactate, and substrate depletion, in peripheral organs (Noakes and St Clair Gibson, 2004). However, recent studies in exercise physiology refuted a long existed 'peripheral' model as the main cause of fatigue and proposed the central governor theory to explain occurrence of fatigue during various forms of exercise. According to Noakes et al. (2005), the central governor theory is formulated around the brain as a dominant regulator of exercise activity continuously taking into consideration numerous feedbacks from multiple peripheral physiological systems, such as muscles, in order to set the level of fatigue. In this model, the term 'fatigue' is considered to be a sensory perception that is regulated by the central nervous system to prevent the maximal capacity of any of the peripheral systems from being reached (St Clair Gibson et al., 2001).

Complexity of the human body and integration of numerous environmental factors, especially in the professional sport, makes an accurate and direct assessment of fatigue a very difficult task. Therefore, effectiveness of potential performance monitoring tools in professional sport environment has to be determined and can, partially, allow to analyse different causes of fatigue and well-being.

### **Physiological Muscular Measures**

Despite different positional roles on a pitch similar principles of physiological assessment and testing apply to all rugby players (McLead, 1992).

Although, a number of techniques and protocols, such as contact mat, yardstick, optimal encoders, accelerometers, and force platforms, can be used to assess athlete's lower-body jump performance, inaccuracy and limited practicality may prevent from using them on a regular basis. In addition, muscular performance



values may be dependent on the data collection and analysis procedures used. There are 4 commonly used methods to measure power output during the SJ: i) utilization of only displacement data ii) use of the vertical ground reaction force (VGRF) data obtained from a force platform iii) use of combination of VGRF and displacement data iv) utilization of an accelerometer system (Dugan et al., 2004). Therefore, different methods may cause potential discrepancies in results values. For example, a force platform is considered to be a 'gold standard' for force measurement, however it requires costly equipment with an assessment normally taking place in a laboratory (Cronin et al., 2004). Therefore, cost-effective, portable alternative has to be sought for a regular force and power field-testing. Cronin et al. (2004) study has found a linear position transducer (LPT) to be a valid and reliable method to calculate peak force and peak power with calculations derived from the LPT being very similar to those of the force platform. In contrast to the Cronin et al. (2004), study by Cormie et al. (2007) has found two LPTs and a force platform to be advantageous to the single LPT technique by tracking displacement in the vertical and the horizontal planes and, therefore, allowing for a more accurate calculation of peak power and peak force. Newell et al. (2005) has lent further support to the fact that the LPT was invalid testing device for measuring power output during the free standing SJ, because of its inability to distinguish between vertical and horizontal displacement. Despite discrepancies in peak power, peak force and force impulse values whilst using different methods of testing, all three parameters derived from the LPT have been proven to have an acceptable range of reliability and validity and, therefore, may be practical tool of regular muscular performance assessment for practitioners working with athletes (Cronin et al., 2004).

As aforementioned, muscular strength, power and force impulse are important physical attributes in the rugby union game. According to Stone et al. (2003), power generation during sports performance is generally considered to be the major factor for separating successful participants. Practical example of muscular strength and power importance during the rugby game has been provided by Quarrie and Wilson (2000), who reported correlation between forwards' power and scrummaging force. Although needs analyses of the rugby union reveal that backs and forwards lie on various points of maximum strength/speed-strength continuum, training for these physical attributes is equally important regardless of positional roles (Gamble, 2004). For example, forwards rely more on maximal strength in order to contest possession at the restart phases, such as scrum and lineout.

The squat jump (SJ) is a popular form of exercise for improving power production, as well as testing method for power production among various athletic populations (Dugan et al., 2004). In addition, McBride et al. (2002)

proposed the SJ power as one of the criterion measures to evaluate different training interventions and athlete's performance status. The SJ was found to be a valid and reliable jumping test for the estimation of power of the lower limbs (Markovic et al., 2004). In recent years, many investigations have attempted to assess optimal loading and variety of techniques to determine maximal power output during the SJ (Li et al., 2008; Cormie et al., 2008). However, no consensus has been achieved with loading values ranging from 0% to 80% of 1 repetition maximum (1RM). For example, Stone and colleagues (2003) reported 10% of 1RM for maximal power output during the SJ. In contrast, Sleivert et al. (2002) suggested much higher loading range 50%-80% 1RM. More recently, study conducted by Cormie et al. (2008) has found that body mass only (i.e. 0% 1RM) maximized peak power output displaying a significant greater value than 40, 60, and 80 kg loading conditions. Furthermore, the work of Kilduff et al. (2007) has shown that various exercises require different rate of load in order to achieve maximal power output. Hence, the optimal load for peak power output (PPO) may greatly differ during traditional upper (bench press or ballistic bench press) and lower (squat and jump squats) body resistance-training exercises.

Due to its high complexity it is hard to fully understand the muscular performance, however a close relationship between some of its parameters can be explained. Strength is the maximal force produced by a muscle or muscle group at a specified velocity (Harman, 2008). Mechanical power can be defined as the rate at which force is applied ( $P = \text{force} \times \text{velocity}$ ) (Kawamori and Haff, 2004). Impulse is the product of the average force over a given time ( $I = F \times \text{time}$ ) and represents the area under the force-time curve (Schilling et al., 2008). Because power is the product of force and velocity any increases in force can increase power production. Similarly, as impulse describes the application of force relative to time it may be of interest in the strength diagnosis process (Hansen et al., 2010).

It is logical to assume that fluctuation in any of the above mentioned muscular characteristics may occur due to different phases of the training, for example, an increase of power and strength in the early stages of the season, where high training loads are predominant, and deterioration as the season continues (Gabbett and Domrow, 2007). However, such changes in muscular performance values throughout the season may not only occur due to different phases of periodization programme and/or competition demands, but may also be dependent on athlete's perceived well-being and fatigue status.

## **Psychological Well-being and Fatigue Measures**

Subjective information about potential causes of fatigue may help coaches to evaluate and, if needed, modify training programmes accordingly, which



consequently enable athletes to receive the best intervention to benefit their health and athletic performance (Dickinson and Hanrahan, 2009). According to Swain (2000), fatigue measurement scales typically involve the development and application of a series of questions in the form of self-assessment questionnaires which attempt to measure a subject's perception and severity of fatigue. Although, there are several questionnaires generally used in clinical population settings, it is important to seek for alternative psychometric measures appropriate for monitoring elite athletes. As was emphasized by Dickinson and Hanrahan (2009) measures with strong psychometric properties and brevity may be useful in the search for an appropriate way to subjectively measure elite athletes' fatigue and overall well-being.

Self-assessment questionnaires, such as the Profile of Mood States (POMS), measuring athletes' emotional state and mood, are widely used in sport environment (Kellmann, 2002). The Profile of Mood States (POMS, McNair et al., 1971) is a 65-item scale questionnaire which has been the primary psychological tool for monitoring training stress (Martin et al., 2000). Since its introduction the POMS has become one of the most commonly used tools for psychology and training assessment among sport psychologists. Berning (1998) reported that monitoring the POMS can help to predict athletic success and prevent overtraining in several types of athletes. In contrast, Martin et al. (2000) who studied high-intensity interval training stress in cycling athletes, showed that the POMS was not able to distinguish, at an individual level, athletes who are not responding well to a high-intensity training intervention from those who are. Furthermore, the POMS can also be used to rate daily, weekly, or habitual feelings (i.e., "during the past week, including today") (Buckworth and Dishman, 2002). This means that an integration of the POMS as a tool of assessment can be used accordingly to the training schedule. However, it is important to note that the POMS is not the only questionnaire used in the world of sport to assess athletes' psychological status and perceived well-being, thus other questionnaires also hold promise (Eichner, 1995).

In professional sport settings where time constraints are high, the length and complexity of the POMS questionnaire makes regular use of it very impractical. Therefore, simpler, shorter and more practical psychological measurement tools are required in order to maximize compliance from athletes. If proved appropriate of perceived well-being assessment in the professional team sports, the modified and shorter psychometric questionnaire could be a potential instrument for daily monitoring. Cox (2003) study provides an example of successful monitoring of overall athlete's physical and psychological health by using a questionnaire, which was primarily designed for swimmers, however can be easily modified to suit the needs of other sports, such as rugby. A questionnaire is called "early warning

response sheet” (EWRS), because it is designed to show an early warnings of unusual signs for a particular athlete. The questionnaire consisted of 20 different questions including general fitness, health, and appetite, quality of sleep, all-round muscular strength, stiffness or soreness from training, with 3 optional answers. Furthermore, Neville et al. (2008) examined the relationship between salivary immunoglobulin A (s-IgA) and upper respiratory infections (URI) in elite yacht racing athletes while successfully incorporating a subjective fatigue questionnaire. Neville et al. (2008) used a very simple three-scale subjective fatigue rating questionnaire, asking a question: “How rested do you feel?” with three potential answers: “worse than normal”, “normal”, and “better than normal”. Most importantly, it was the first study to report association between subjective fatigue and relative s-IgA concentration. Thus, it can be concluded that a simple fatigue rating reflects immune status to some extent and appears to validate the use of a simple subjective questionnaire in monitoring underlying fatigue and recovery of athletes (Neville et al., 2008). Dickinson and Hanrahan (2009) investigated elite athletes from a range of sports using self-report questionnaires to measure subjective sleep quality and found them to be valid and reliable for such population. Therefore, subjective measures provides the most cost-effective method of sleep monitoring and the data derived might be sufficient for accurate sleep assessment. Another study by Jürimäe et al. (2004) conducted on rowers established a close relationship between self-rated fatigue and muscle soreness scores.

Although, some of the evidence from above studies may be lacking reliability, it appears that self-reported perceived well-being questionnaire may be linked with changes in muscular performance and provide some useful information for the coach. However, it is important to note that some of the limitations of using self-assessment questionnaires in the professional sport environment do exist and have to be taken into consideration by the people responsible for testing.

Firstly, individual’s interpretation of actual psychological testing procedure may greatly influence the outcome of a whole study. In other words, players may not accurately report their current perceived well-being status, because of the associated danger not to be selected for the team’s next game or some drastic adjustments in their individual training programme/exercise prescription. One of the biggest disadvantages of using self-report psychological assessments is possible dishonesty in answers (Weinberg and Williams, 2001).

Secondly, players’ answers in the questionnaire may be based on other factors, such as environmental and family matters, which are not necessarily related to the actual question being asked (Dickinson and Hanrahan, 2009).

Finally, an interpretation of the psychometric data/scores and ability to differentiate between important/unimportant changes is very much dependent on the coach (Jürimäe et al., 2004).

## Methods

**Participants.** 15 male ( $26.5 \pm 5.8$  years;  $102.6 \pm 13.4$  kg;  $186.1 \pm 9.5$  cm), professional rugby union players volunteered to participate in this study. All participants were informed of the risks and benefits of participation in the research and were required to sign informed consent forms. This was followed by the additional verbal familiarization of the study, emphasizing to participants that they could withdraw from the study at any time. Finally, all the data were kept confidentially with only researchers having access to it. Prior to the research all procedures undertaken were approved by the University of Worcester Ethics Committee.

**Procedure.** At the beginning of each week (exact day depending on a weekly training schedule and the day game was played over the past weekend), during the course of 19 weeks of competitive season, after arrival at the team's sport centre all players were required to fill in a 6-item perceived scaled questionnaire pertaining to well-being. Questions included in the questionnaire were: 'sleep quality', 'food quality/appetite', 'stress levels/confidence', 'lower body muscle soreness', 'upper body muscle soreness', 'energy level/fatigue'. This was followed by a standardised warm-up and players reporting to the club's training gym to undertake 3 jump squats without an external load (i.e., body mass only) using a technique identical to that described by Hori et al. (2007). This involved participants standing at a self-selected foot width with the right side of the unweighted (plastic) barbell attached to a linear position transducer attachment (LPT) and placed on their upper trapezius. The participant then performed a maximal jump squat to a self-selected depth. During testing participants were instructed to keep the depth of jump squat consistent between jumps and "jump for maximum height" on each repetition. All participants were familiar with the jump squat movement as a regular part of both training and testing programs. In addition, a National Strength and Conditioning Association (NSCA) certified strength and conditioning specialists ensured that all participants adhered to proper technique during their testing session. It is noteworthy, that testing order when completion of questionnaire preceded the SJs was selected in order to avoid any negative training impact on psychometric answers. A LPT (HX-VPA-200, Unimeasure, Oregon – mean sensitivity 0.499mV/V/mm, linearity 0.05% full scale) which measured vertical displacement with an accuracy of 0.01cm was attached to the plastic pole placed on the participant's back. The LPT was calibrated to a known distance (1 m) prior to data collection. Displacement

data were sampled at 500 Hz via an analogue to digital converter (16-Bit, 250 kS/s National Instruments, Austin, TX.) and collected by a laptop computer using custom-built data acquisition and analysis software (Labview 8.2, National Instruments, Austin, TX.).

**Data Analysis.** Displacement time data was filtered using a 4th order dual pass digital filter with a cut-off frequency of 4Hz (Hansen et al., 2010). Filtered displacement-time data was used to calculate velocity and acceleration using a finite difference technique (Hori et al., 2007). The summation of system acceleration and acceleration due to gravity, multiplied by the system mass was then used to calculate force. To obtain power applied to the plastic pole placed on player's upper back, the force applied to the plastic pole was multiplied by the velocity of the plastic pole at each time point. These procedures are similar to those reported in previous research using displacement data to calculate power, force, and force impulse variables (Hori et al., 2007).

**Statistical Analyses.** Although, a whole rugby union team undertook the same testing procedures, due to various factors, predominantly injuries or competition requirements, some of the players had been tested more times than others. Consequently, criteria were set to exclude players who had missed more than a half of testing days or had not completed either psychometric or squat jumps testing procedures for more than 3 consecutive weeks, leaving only 15 out of total 42 players acting as participants throughout the course of 19 weeks of testing. Therefore, when referring to 'team results/data/values' in below sections, in particular Results, only the same 15 players' data were used for calculations. However, even such a clear establishment of criteria did not prevent from a high volume of missing data, with exact percentages of missing values for each variable alongside likely causes, being provided in the Discussion section.

All statistical calculations were performed on the mean of trials two and three with the first trial excluded from analysis (Hopkins et al., 2001). Therefore, collecting three trials and excluding the first, related to the familiarization effect, may increase reliability during data collection. Due to a high volume of missing data over the long period of testing, data set in this study could not be treated with conventional statistical techniques (Foster et al., 1996). Current SPSS 17.0 guidelines (2007) for missing values offer statistical methods for high volume data imputation, however studies with less than 5% of the total number of cases missing can be considered to be 'safe' for statistical analyses. Otherwise missing data may cause misleading results as well as reduction in the precision of calculated statistics. Despite a high volume of missing data in this study, the relationship between all perceived well-being status questions and muscular performance parameters was plotted. This allowed to make some preliminary

attempts to model the relationship between markers of perceived well-being and muscular performance (Foster et al., 1996). All graphs were drawn using Microsoft Excel with standard error bars removed for the clarity reasons.

## Results

**Team Results.** Relationships between 6 different perceived well-being status questions, together with an extra total well-being score (calculated as a sum score of all questions) and 3 physiological parameters (peak power, peak force, and force impulse) have been established. Since this resulted in a large quantity of graphs, only 8 of them have been presented for the illustration purposes in this study. In order to emphasise the difference between individual and team results each of the section contained 4 graphs demonstrating relationships between exactly the same measures (the peak power and 3 well-being questions).

Although when presented on a team basis some of the questions ‘sleep quality’ (Figure 1) have shown better correlation with the peak power than the others ‘lower body muscle soreness’ (Figure 2), ‘energy level/fatigue’ (Figure 3), ‘total well-being score’ (Figure 4), an establishment of accurate relationship between any of the measures remains a very subjective and indefinite process. Figure 1. may have demonstrated the best relationship between physiological and psychometric measures of all the graphs presented, but even such relationship was not consistent over all 19 weeks of testing period, with a clearer pattern of relationship starting to emerge only from the week 8 onwards. Thus, none of the presented graphs indicated a clear relationship between team’s psychometric questions/total well-being score and the peak power, with the same tendency apparent in all other graphs between the rest of psychometric and muscular performance parameters measured.

Figure 1. Relationship between team mean values of sleep quality and the peak power over the course of 19 weeks.

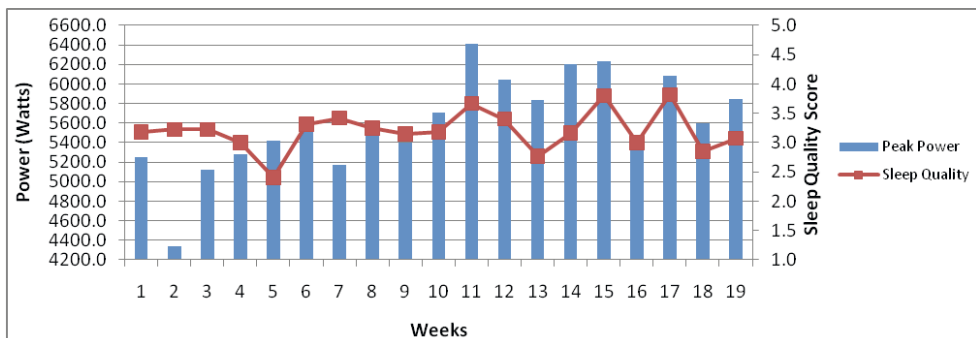


Figure 2. Changes in team mean values of the lower body muscle soreness score in relation to the peak power over 19 weeks' duration.

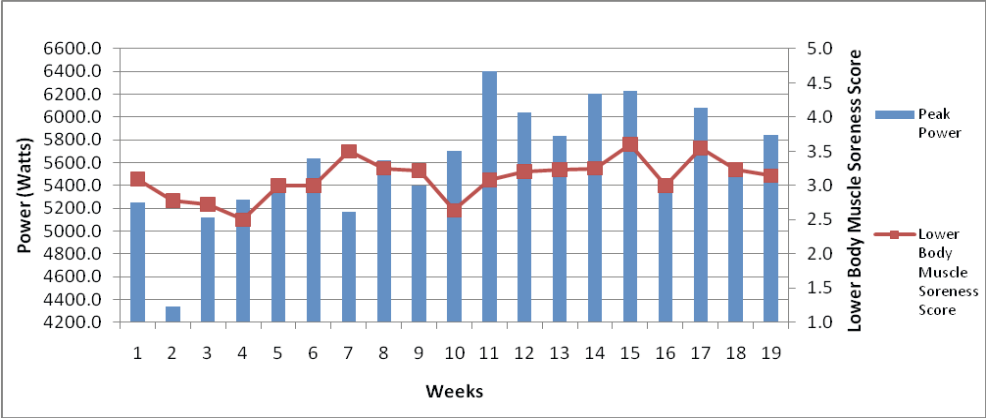


Figure 3. Relative changes in individual player's mean values of sleep quality and the peak power over the course of 19 weeks.

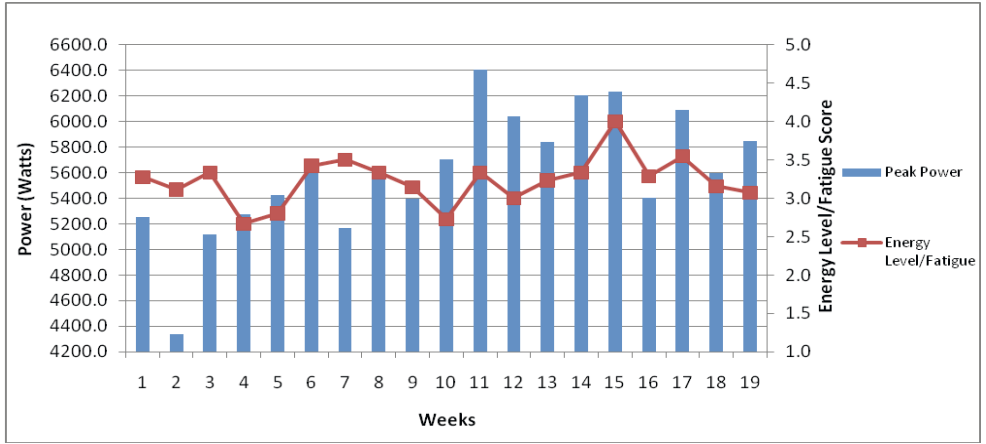
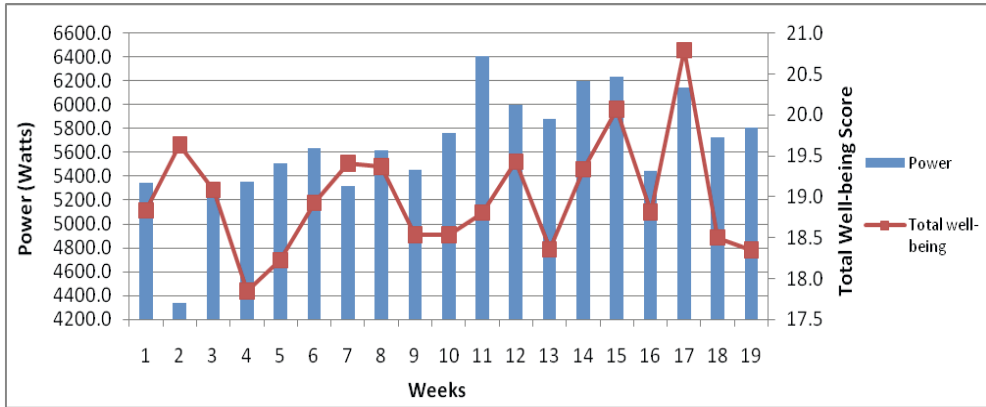




Figure 4. Relationship between team mean values of total well-being score and the peak power over the course of 19 weeks.



**Individual Results.** Although, the fullest individual player's data set out of all 15 players tested in this study was selected for the illustration purpose in this section, no clear relationship between perceived well-being markers and the peak power has been identified at any point on an individual basis. It is important to note that gaps between blue bars and discontinuity in red solid line represent missing data values.

Figure 5. Relative changes in individual player's mean values of sleep quality and the peak power over the course of 19 weeks.

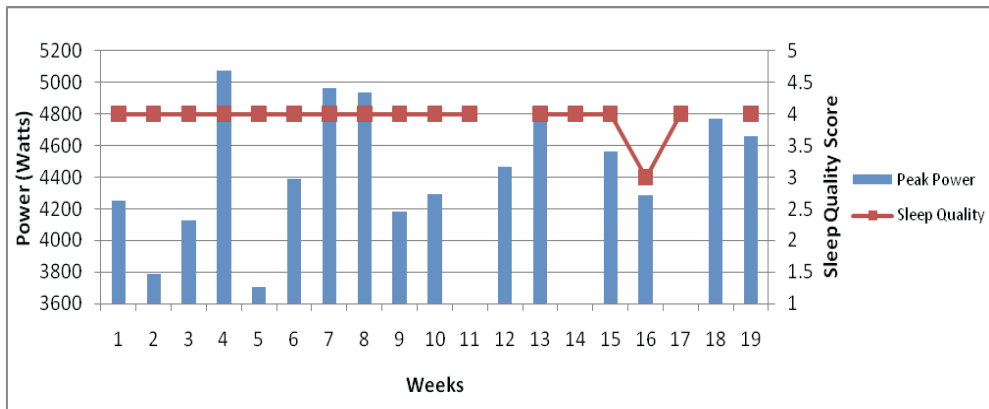


Figure 6. Changes in a relationship between the individual player's mean values of lower body muscle soreness and the peak power over 19 weeks.

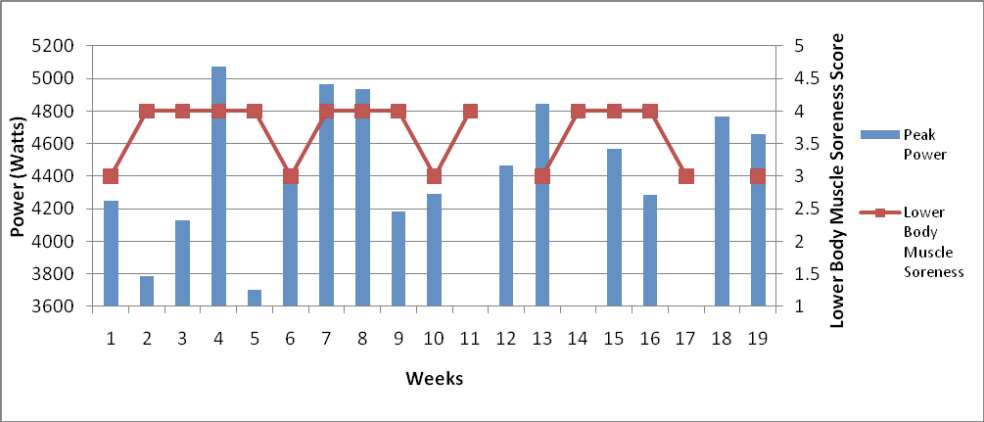


Figure 7. Relationship between the individual player's mean values of energy level/fatigue and the peak power over the course of 19 weeks.

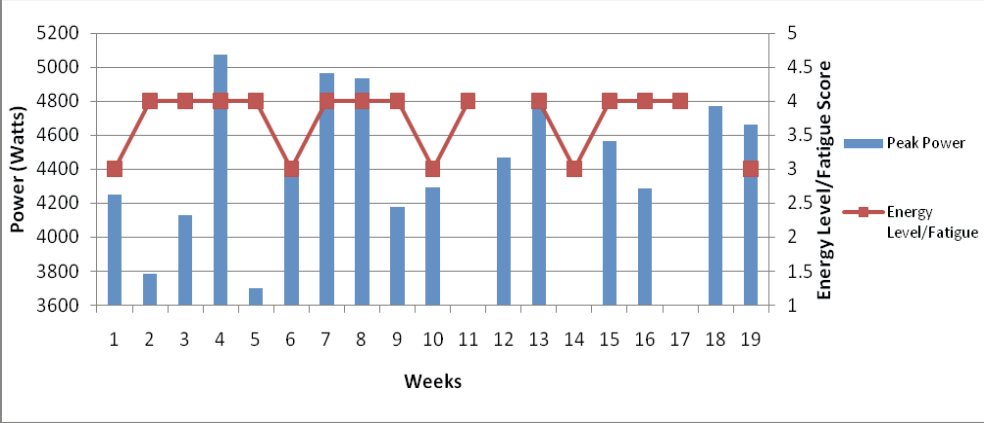
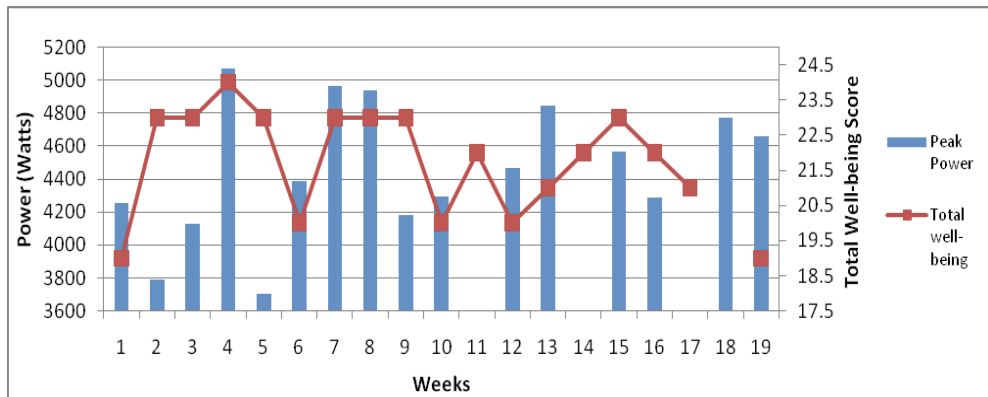


Figure 8. Relationship between individual player's mean values of total well-being score and the peak power over 19 weeks of testing period.



## Discussion

This study identified relationship between various markers of perceived well-being status, as reflected by the short questionnaire, and physiological parameters, related to the muscular performance, in a professional rugby union team. No previous research, examining direct association between self-report psychometric well-being questionnaires and muscular performance in the professional team-sport environment, has been reported in the literature.

Results of the current study were presented as relative changes between the peak power and 4 measures associated with the perceived well-being over the course of 19 weeks. However, a clear relationship could not be identified between any of the tested measures. Furthermore, individual and team mean values were selected as two separate methods for data representation in order to assess differences and similarities of graphical correlations generated by both methods. Interestingly, such comparison has showed a clear distinction in correlation patterns between team (Figures 1-4) and individual (Figures 5-8) data. Despite the fact that some team mean parameters (Figure 1) correlated better than others (Figure 2-4), this was not consistent throughout a whole period of testing, hence unequivocal existence of relationships between any tested measures could not be established. In contrast to the team results, none of the parameters reflected visual correlations at any instances throughout the course of 19 weeks on an individual basis.

It could be argued that descriptive time-series analysis is a very subjective and inappropriate technique for assessment of correlations, especially when

relatively complicated physiological variables, such as power output, are measured. Hence, graphical time-series analysis may not allow to identify any type of correlations with the same accuracy as sophisticated statistical techniques. Morley and Adams (1991) recommended to conduct graphical analysis together with statistical analysis in order to increase accuracy of results. However, due to a high volume of missing data in the current study no conventional statistical analysis could be run, making time-series analysis, which demonstrated changes in psychological and physiological measures with time, the only practical way to present the data.

The lack of obvious and consistent correlations between perceived well-being status markers and muscular performance parameters either on team or individual player's bases could be also strongly associated with several causes, mainly inherited in the team-sport research.

**Complexities in Team Research.** Firstly, most of the research in the sport science is based on individual sports, such as cycling, running, or rowing, because contrary to the team-sport research it is easier to conduct. Mujika (2007) addressed 4 main challenges team-sport researchers are faced with: i) physiological determinants of team-sport are not clearly understood ii) performance concept itself is a difficult concept to define iii) complicated training quantification due to a vast range of contributing variables iv) inability to carry out longitudinal investigations because of the long competitive seasons and high levels of stress it places on team-sport athletes. With regard to complexities of training quantification, Hopkins (1998) has lent further support, emphasizing difficulties in measuring of training process, as training itself is a complex behaviour. As aforementioned, the biggest limitation of this study was a high volume of missing data – 26.7% and 23.2% of muscular performance and psychometric scores, respectively. Most of the data have been missed due to players unavailability for testing as result of injury or competitive requirements. In contact sports, such as rugby union, players often sustain various injuries, making it almost impossible to test the same players on a regular basis over extended period of time.

**No Psychophysiological Relationship.** According to Kellmann (2002), an interdisciplinary approach by using all objective and subjective physiological and psychological data from training as well as performance, is the key factor to optimise athlete's performance. The importance of an interdisciplinary approach was, in particular, emphasized in the testing of strength/power, overtraining and fatigue in multiple-sprint sports (Burwitz et al., 1994). Despite large complexities in each subdiscipline, which may cause difficulties in establishing interdisciplinary relationships, there is a recent evidence in the literature indicating close associations between very complex systems, such as

endocrine and psychology, in high-level rugby players. Elloumi et al. (2008) have demonstrated parallelism between testosterone/cortisol (T/C) ratio and questions related to the overtraining syndrome in male Tunisian rugby players during an international competitive season. Similarly, a study by Maso et al. (2004) has found a relationship between testosterone and 'overtraining' questionnaire scores in young international rugby players. Although, both studies were not directly related to the current study in terms of parameters measured, body's endocrine system may be as complicated as muscular performance, thus, showing a great potential to establish psychophysiological relationship in the professional rugby players. Furthermore, Beedie et al. (2000) study presented some evidence of a relationship between perceived fatigue at pre-competition (as measured with the POMS) and performance outcomes. As was proposed by Elloumi et al. (2008) highly trained athletes are faced with a delicate and complex psychophysiological process in order to maintain and improve their physical performance.

**An Inappropriate Questionnaire.** The second limitation in this study was related to the use of perceived well-being questionnaire. It was a modified and adopted version of other questionnaires, without a previously tested validity and reliability, which may have led to some of the questions asked in the questionnaire being incorrectly formulated. One of the questions in the questionnaire was "sleep quality", which has been suggested as an important variable to be measured in elite athletes, because it may have implications for athletic performance and overall well-being (Dickinson and Hanrahan, 2009). Conversely, another question in the questionnaire was ambiguous because of a combination of relatively distinct psychological measures - "Stress levels/Confidence". Furthermore, an answer scale for each question was provided in numerical as well as verbal descriptions, however as a result of actual scale format, differentiation between possible answer numbers was reported as being problematic. In other words, participants would frequently enquire about accurate differentiation between adjacent numbers on the scale. This also made data analyses more complicated, because the magnitude and effect each of the numbers may have had on the final findings and comparisons was unclear. Therefore, sensitivity of the questionnaire utilised in this study to monitor important changes in highly-trained rugby players well-being status remains unknown and it also emphasizes the importance for practitioners/coaches/sport scientists to use appropriate psychometric questionnaires for their testing. Jürimäe et al. (2004) denoted that rather than using full self-assessment questionnaires to monitor the effect and recovery of high-volume training loads, it is more important to focus on identifying specific inquiries to be monitored on a daily basis. Further, psychological assessment, in particular questionnaires, should be measured on a longitudinal basis, which raises the scientific value and provides a better foundation for feedback (Kellmann, 2002).

**Dishonesty in Questionnaire Answers.** Collecting psychometric data is not without controversy, because most of the time athletes find it unreliable and test results have never been proven to be accurate predictors of success (Smith et al., 2002). Therefore, players may have had a negative attitude towards psychometric testing process, which consequently have led to dishonest answers, devaluation of actual testing process or even reluctance to complete the questionnaire. As Weinberg and Williams (2001) noted, on a negative side of using self-report psychological assessments lies possible dishonesty in answers, misinterpretation of the findings, and inappropriate validity, reliability and suitability of the actual psychological measure used for the investigation. However, when based on sound scientific knowledge and controlled delivery, psychological assessment can be a valuable tool for performance enhancement (Kellmann, 2002).

**Disparity in Team and Individual Results.** This study has revealed obvious differences in individual and team results, which may indicate team mean values as inappropriate method for illustration of individual player's data. Hence, team/group mean data may mask important changes and variations of individual data, which is of critical importance when trying to establish an interdisciplinary relationship, because each player has a distinctive profile. Renfree et al. (2009) study has found that the RPE mean data from a self-paced 20 km cycle time trial was unrepresentative of any individual participant's responses. This shows that in the field of human perceptions analyses, it is inadequate to make assumptions about the general population based upon group analysis.

## Further Research

The lack of research in team-sports environment, particularly in professional sports, may be result of all aforementioned limitations encountered in this study, which prevent more sport scientists and practitioners from regular attempts to conduct team-sport research. Further, numerous environmental and internal factors play role in determining the sporting outcome, whose complex interactions among one another, reduce ability to ascertain cause-effect relationship. Therefore, longitudinal case-study experimental design studies could be proposed as one of the alternatives to the team-sport research. Such approach would allow to minimize or eliminate challenges experienced in the team-research by making environmental and other influential factors more controllable. On the other hand, findings of the case-studies could not be applied to the overall sport population or even different positional groups because of each individual player's uniqueness (Renfree et al., 2009). Finally, scientifically validated questionnaire and better methods, such as the use of force platform alongside the LPT, for muscular performance testing, could be used in the future research



to maximize accuracy of the data for determination of psychology and physiology relationship in the professional team-sport players.

## **Conclusion**

In summary, this study has not established an apparent psychophysiological relationship between muscular performance measures, in particular peak power output, and markers of perceived well-being status, as assessed by using a 6-item questionnaire, in the professional rugby union players. Although, descriptive time-series analysis has indicated a slight distinction between team and individual results, with team mean values better correlated than individual mean values, such findings may be closely related to the actual data analysis method used, when the team values possibly mask the uniqueness of individual player's responses, and other inherited problems in a long-term team-research. Based on the present findings, more conventional statistical analysis to test physiology and psychology correlations in a professional team settings can only be used if all the associated team-sport research challenges are kept to minimum.

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