



UNIVERSITA' DEGLI STUDI DI VERONA

DIPARTIMENTO DI
SCIENZE NEUROLOGICHE, NEURO-PSICOLOGICHE, MORFOLOGICHE E MOTORIE

SCUOLA DI DOTTORATO DI
SCIENZE BIOMEDICHE TRASLAZIONALI

DOTTORATO DI RICERCA IN
SCIENZE DELL'ESERCIZIO FISICO E DEL MOVIMENTO UMANO

CICLO /ANNO (1° anno d'Iscrizione) XXIII/ 2008

TITOLO DELLA TESI DI DOTTORATO

**ELABORATION AND APPLICATION OF FUNCTIONAL EVALUATION
TECHNIQUES FOR RUGBY UNION**

S.S.D. BIO/09

Coordinatore: Prof. Federico Schena

Firma _____

Tutor: Prof.ssa Silvia Pogliaghi

Firma _____

Dottorando: Dott. Giorgio Da Lozzo

Firma _____

SUMMARY

SUMMARY	1
INTRODUCTION	2
GENERAL APPROACHES TO THE DEFINITION OF THE PERFORMANCE MODEL	2
PERFORMANCE MODEL IN RUGBY	3
AIMS OF THE PROJECT	4
REFERENCES.....	5
ANTHROPOMETRICS OF ELITE SENIOR MALE ITALIAN RUGBY UNION PLAYERS.	6
METHODS.....	6
RESULTS.....	7
DISCUSSION.....	7
REFERENCES.....	8
PHYSIOLOGICAL AND ANTHROPOMETRIC CHARACTERISTICS OF ELITE WOMEN UNION PLAYERS.....	9
ABSTRACT	9
METHODS.....	10
RESULTS.....	11
DISCUSSION.....	12
REFERENCES.....	13
WHAT IS THE WORK-LOAD DURING TRAINING SESSIONS IN RUGBY UNION?	14
ABSTRACT	14
METHODS.....	15
RESULTS.....	16
DISCUSSION.....	17
REFERENCES.....	18
INTERCHANGEABILITY OF OBJECTIVE AND SUBJECTIVE INDEXES OF WORK-LOAD IN RUGBY UNION	20
ABSTRACT	20
METHODS.....	22
RESULTS.....	23
DISCUSSION.....	25
REFERENCES.....	27
CONCLUSIONS	29

INTRODUCTION

General approaches to the definition of the performance model

The main goal of any training program, either technical-tactical or physical, is to produce medium/long-term adaptation aimed at stably and progressively increasing the performance levels. In order to rationally conduct such a project, it is necessary to define the characteristics of performance. The type of motor and technical tasks, the intensity, the volume and frequency of specific actions collectively define an ideal performance model (Weineck 2001). In accordance with the above mentioned model, ideal physical and technical characteristics of an athlete are defined; subsequently, necessary training strategies are performed to allow all his potential to be expressed. Furthermore, through a comparison between ideal performance characteristics, the coach or physical trainer is able to check the adequacy of the results obtained and thus of the whole training process he developed and realized.

The creation of a performance model is mainly based on three research typologies:

- a) Descriptive studies.
- b) Observational studies.
- c) Modeling studies.

Descriptive studies. They are based on the analysis of structural and functional characteristics, which are assumed to be relevant for a specific performance, such as the anthropometric measures (i.e. weight, height, corporal composition) and functional capacities (i.e. power and capacity of their aerobic and anaerobic energetic systems, muscular strength and power, agility and coordination, economy). Through the comparison with the data obtained in athletes competing in different disciplines inference can be made on the type and expression of structural and functional characteristics that may be relevant to the specific performance.

This kind of research can be further detailed through the comparison of the above-described characteristics between athletes of different competitive levels (i.e. international vs. national level athletes, professional vs. sub-professional). A higher expression level, in absolute terms or related to a specific position group, connected with a higher competition level, provide important information on the prominence of a certain parameter to finalize the performance.

Observational studies. Those studies take the research to a deeper level as they aim at describing and quantifying the characteristics of a real performance. Indeed, they measure the performance through the characterization of: *a*) movements and technical skills required (movement control complexity and coordination); *b*) quantity and type of muscles involved and characteristics of muscular contractions (expressions of strength, speed and endurance involved in the action); *c*) total length, frequency and duration of specific tasks, in order to define which energy pathway is mainly involved in the production of ATP during the action (aerobic or anaerobic, mixed component).

The direct observation can be performed by visual inspection or through specific research instruments. Through eye observation or video analysis instruments, are studied quality and accuracy as well as the repetition frequency of the actions defining the specific performance. New technologies such as the global positioning system (GPS) or the accelerometers lead to the definition of athletes' movements and the quantification of the distance covered. This kind of research helps defining the so-called objective or external load.

Another approach consists in observing the changing of some physiological parameters strictly connected to the physical effort and its intensity, such as the oxygen consumption (VO_2), the heart rate (HR), or the blood lactate accumulation (LA^-). The study of their evolution during the specific activity leads to the definition of the subjective or internal load.

Besides the definition of the performance during matches or general competition, observational studies can focus on specific training characteristics. Coaches have a great interest in quantifying the amount of work per session and the evaluation of its connection with the periodization of the training process.

Such a research helps to define precisely the individual training stimulus, to allow adequate time to recovery to the athletes and thus reducing over-training and injuries risks.

Modeling studies. Main aim of these studies is the creation of complex mathematical model that “explain” the performance. Through the characterization of performance indicators (a selection, or combination, of action variables that aims to define some or all aspects of performance, Hughes and Bartlett 2002), researchers attempt to create ideal performance profiles, in which every significant component of performance contribute to predict the final outcome. This approach appears extremely complex in team sports given the inherent variability in movement patters within and between the competitions, and because of the presence of different behaviours specific to the playing position and to the game situation (i.e. attacking or defending patterns).

Performance model in rugby

Since the declaration by the International Rugby Board in August 1995 that the game of rugby union would become professional, the sport has undergone considerable change both on and off the field (Mellalieu *et al.* 2008). In fact, the interest in rugby has increased exponentially with the development of international competitions as the Heineken Cup (Championship among the European most competitive teams), the Super 15 (a competition among professional franchise of the Southern Hemisphere) and the Rugby World Cup (the third largest sporting event after the Olympic games and the FIFA World Cup, attracting over two million spectators and viewed by a worldwide audience of over three billion people). Parallel to this development there was also a clear improvement of the game, characterized by an increasing level of competition and higher quality training programs, which induced noticeable changes on the players physical structure and on their levels of performance.

Despite the growth in the game itself, the development of the academic study on rugby union has been relatively slow compared with that in other sports, such as soccer, golf, cricket (Mellalieu *et al.* 2008).

Actually there is a considerable amount of rugby-related injury literature, from both epidemiological and medical case-study sources, but the rugby-specific sport science research is quite limited.

Descriptive studies investigated physical characteristics (body mass, stature, percentage of body fat, muscle fibre type) and physical capacities (maximal oxygen uptake, aerobic performance, muscle strength and power and speed) of rugby players of different competitive levels (for a review see Duthie *et al.* 2003). Research was mainly focused on adult male athletes of the Southern Hemisphere, while junior players and women were poorly studied (Kirby and Reilly 1993; Deutsch *et al.* 1998; Schick *et al.* 2008; Barr and Nolte 2011). These gender, geographical and age factors limit the availability/usefulness of the anthropometric and functional data for the comparison to different contests (i.e. male European players, women players). Moreover, due to the evolution of rugby in recent years, most of the data that are currently available might not be actual, so they probably need to be updated.

Observational studies were mainly addressed to define the physical demands and work-loads of rugby union by the quantification of frequency and/or duration of specific tasks by time-motion analysis (Duthie *et al.* 2005; Deutsch *et al.* 2007; Roberts *et al.* 2008) and by the determination of the acceleration-deceleration patterns using GPS tracking devices or accelerometers (Cunniffe *et al.* 2009). Not many researchers used measurement of physiological parameters (heart rate, blood lactate concentration, blood glucose, muscle glycogen) to establish the response to rugby-specific activities (Duthie *et al.* 2003). Heart rate monitoring method, that is widely used in individual and collective sports (Bot and Hollander 2000; Foster *et al.* 2001; Impellizzeri *et al.* 2004), has seldom be applied in rugby (Morton 1978; Deutsch *et al.* 1998; Doutreloux *et al.* 2002), probably due to the difficulty in obtaining reliable HR measures during highly vigorous contacts. Indeed this method of quantifying exercise intensity has many advantages compared to other methods as simplicity of use, relatively low cost, easy and transparent data handling and finally it allows the measurement of both absolute and relative loads. Furthermore, the availability of new, dependable HR monitors may allow the application of this approach on lager scale.

With the same purpose of finding an even simpler method to define exercise load, in recent years, many studies (Foster *et al.* 2001; Coutts *et al.* 2003; Impellizzeri *et al.* 2004; Coutts *et al.* 2009) investigated the

validity of the session-RPE method proposed by Foster et al. (2001) in team sport as soccer, basket and rugby league. However, to our knowledge, the applicability of the s-RPE method and the evaluation of its relationship with the HR-based methods, have not been yet studied in rugby union.

Most of the observational studies focused their attention on the determination of physical demands in rugby matches or competitions. Loads of training sessions were investigated only with reference to specific conditioning activities (Gamble 2004; Kennett *et al.* 2011) while entire sessions (including collective or unit technical and tactical elements) were not analyzed. So the knowledge on rugby-specific training load is quite limited.

Finally, the construction of a predictive model of performance in rugby (modeling approach) is still at the preliminary stages. Due to its complexity as a team sport, researchers focused their attention on clear definition of the key performance indicators, and after that they studied their relationship and influence on the definition of the final performance.(Hughes *et al.* 2001; Hughes and Bartlett 2002; Jones *et al.* 2004; James *et al.* 2005; Jones *et al.* 2008).

Aims of the project

The main aims of this project were:

- to extend the knowledge on structural and functional characteristics of rugby players, monitoring two populations, Elite male players of the southern European region (Italian national team) and Elite woman players (Italian national team), that have been poorly studied by the previous research. The definition of new normative database would be useful to assess comparisons and to evaluate athletes in our specific regional contest.

- to apply to the specific contest of rugby union a method of quantifying intensity and work-load that is widely used in other team sports but seldom in rugby: the heart rate (HR) recording method, and precisely to investigate the possibility to determine exercise intensity and work-load of two types of training session (Team Session and Unit Training) typically used in rugby union.

- to verify the applicability of the session-RPE method proposed by Foster (2001) to the specific contest of rugby union, analyzing the relationship between objective (HR-based) and subjective (s-RPE-based) indexes of training intensity and work-load.

REFERENCES

- Barr, M. J. and V. W. Nolte, 2011. Which measure of drop jump performance best predicts sprinting speed? *J Strength Cond Res*, **25**(7) pp. 1976-82.
- Bot, S. D. and A. P. Hollander, 2000. The relationship between heart rate and oxygen uptake during non-steady state exercise. *Ergonomics*, **43**(10) pp. 1578-92.
- Coutts, A. J., E. Rampinini, et al., 2009. Heart rate and blood lactate correlates of perceived exertion during small-sided soccer games. *J Sci Med Sport*, **12**(1) pp. 79-84.
- Coutts, A. J., P. Reaburn, et al., 2003. Validity of the session-RPE method for determining training load in team sport athletes. *J Sci Med Sport*, **6** pp. 525.
- Cunniffe, B., W. Proctor, et al., 2009. An evaluation of the physiological demands of elite rugby union using Global Positioning System tracking software. *J Strength Cond Res*, **23**(4) pp. 1195-203.
- Deutsch, M. U., G. A. Kearney, et al., 2007. Time - motion analysis of professional rugby union players during match-play. *J Sports Sci*, **25**(4) pp. 461-72.
- Deutsch, M. U., G. J. Maw, et al., 1998. Heart rate, blood lactate and kinematic data of elite colts (under-19) rugby union players during competition. *J Sports Sci*, **16**(6) pp. 561-70.
- Doutreloux, J. P., P. Tepe, et al., 2002. Energy demands of playing positions in rugby union. *Exigences énergétiques estimées selon les postes de jeu en rugby*, **17**(4) pp. 189-197.
- Duthie, G., D. Pyne, et al., 2003. Applied physiology and game analysis of rugby union. *Sports Med*, **33**(13) pp. 973-91.
- Duthie, G., D. Pyne, et al., 2005. Time motion analysis of 2001 and 2002 super 12 rugby. *J Sports Sci*, **23**(5) pp. 523-30.
- Foster, C., J. A. Florhaug, et al., 2001. A new approach to monitoring exercise training. *J Strength Cond Res*, **15**(1) pp. 109-15.
- Gamble, P., 2004. A skill-based conditioning games approach to metabolic conditioning for elite rugby football players. *J Strength Cond Res*, **18**(3) pp. 491-7.
- Hughes, M. D. and R. M. Bartlett, 2002. The use of performance indicators in performance analysis. *J Sports Sci*, **20**(10) pp. 739-54.
- Hughes, M. D., S. Evans, et al., 2001. Establishing normative profiles in performance analysis. *International Journal of Performance Analysis in Sport*, **1**(1) pp. 1-26.
- Impellizzeri, F. M., E. Rampinini, et al., 2004. Use of RPE-based training load in soccer. *Med Sci Sports Exerc*, **36**(6) pp. 1042-7.
- James, N., S. D. Mellalieu, et al., 2005. The development of position-specific performance indicators in professional rugby union. *J Sports Sci*, **23**(1) pp. 63-72.
- Jones, N. M., N. James, et al., 2008. An objective method for depicting team performance in elite professional rugby union. *J Sports Sci*, **26**(7) pp. 691-700.
- Jones, N. M., S. Mellalieu, et al., 2004. Team performance indicators as a function of winning and losing in rugby union. *International Journal of Performance Analysis in Sport*, **4**(1) pp. 61-71.
- Kennett, D. C., T. Kempton, et al., 2011. Factors affecting exercise intensity in rugby-specific small-sided games. *J Strength Cond Res publish Ahead of Print*, pp. DOI 10.1519/JSC.0b013e31823a3b26.
- Kirby, W. J. and T. Reilly (1993). Anthropometric and fitness profile of elite female rugby union players. Science and Football II: Proceedings of the Second World congress of Science and Football, London.
- Mellalieu, S., G. Trewartha, et al., 2008. Science and rugby union. *J Sports Sci*, **26**(8) pp. 791-4.
- Morton, A. R., 1978. Applying physiological principles to rugby training. *Sports Coach* **2** pp. 4-9.
- Roberts, S. P., G. Trewartha, et al., 2008. The physical demands of elite English rugby union. *J Sports Sci*, **26**(8) pp. 825-33.
- Schick, D. M., M. G. Molloy, et al., 2008. Injuries during the 2006 Women's Rugby World Cup. *Br J Sports Med*, **42**(6) pp. 447-51.
- Weineck, J. (2001). L'allenamento ottimale. Perugia, Calzetti Marucci.

ANTHROPOMETRICS OF ELITE SENIOR MALE ITALIAN RUGBY UNION PLAYERS.

GIORGIO DA LOZZO, GABRIELA DE ROIA, SILVIA POGLIAGHI

Faculty of Human Movement Sciences, University of Verona, Italy

Rugby is a collision team sport, classified as an interval aerobic-anaerobic activity involving great muscle masses and force efforts of both upper and lower extremities (Duthie *et al.* 2003; Duthie *et al.* 2005; Duthie *et al.* 2006).

Game analysis and functional and anthropometric evaluation of players of different skill, gender and/or age are classical approaches to the understanding of the physical demands of rugby (Duthie *et al.* 2003; Reilly and Gilbourne 2003; Scott *et al.* 2003; Duthie *et al.* 2005; Deutsch *et al.* 2007). Anthropometric evaluation of athletes is essential to assist talent selection, guide training, monitor seasonal variations and quantify the evolving demands of the game. Evaluation requires a specific normative database that accounts for different geographical, technical and age contexts. Yet, while anthropometric evaluation is carried out on a regular basis by national federations as well as by individual clubs, data are kept confidential and/or are collected in a non standardized mode. Furthermore, scientific data on rugby union players are relatively scarce and mainly referred to the southern hemisphere (Duthie *et al.* 2003; Duthie *et al.* 2005; Duthie *et al.* 2006). Finally, due to the evolution of rugby union in the most recent years (Duthie *et al.* 2003), the data that are currently available might not be actual (Scott *et al.* 2003). All the above factors limit the availability/usefulness of anthropometric data to different contexts both in the sport and in the scientific community.

To fill in this gap, this descriptive study was aimed at providing reference data on anthropometric characteristics of elite senior male rugby players of the southern European region.

METHODS

To obtain an homogeneous sample of elite senior players we selected only subjects who were regularly engaged in elite training and international competitions. As a result, 127 male players from the National Senior and “A” Italian rugby union teams (60 forwards and 67 backs) were measured between 2006 and 2009, before the Six Nations Championship.

In the morning, before breakfast, body weight (digital scale, Seca 877, Seca, Leicester, UK) and stature (vertical stadiometer, Seca, Leicester, UK) were determined to the nearest 0,1 kg and 0,5 cm. Skin folds thickness was measured, in triplicate, by a single skilled investigator (pectoral, scapular, triceps, iliac, abdominal and thigh) using a pincer type caliper (Holtain T/W skinfold caliper, Holtain limited, UK). For each skinfold, an average value was calculated (after having discarded possible aberrant values, i.e. difference > 1 mm). Thereafter % body fat was estimated based on the sum of the 6 skin fold thicknesses (SS, in mm) with the formula (Golding *et al.* 1982):

$$\% \text{ body fat} = (0,2 * (SS)) - (0,0003 * SS^2) + (1,133 * \text{age}) - 5,7$$

and lean body mass was calculated as: LBM = body weight - (body weight * % body fat)

The within subject coefficient of variation of measures taken on the same day was 0,2 % for all parameters.

The Average and standard deviation (SD) were calculated in forwards (FW) and backs (BK) and in positional subgroups (Deutsch *et al.* 2007). Groups were compared using un-paired t-test followed by Bonferroni correction and the significant level was set at < 0,05.

TABLE 1. Anthropometric characteristics of forwards (FW) subgroup.

Role	FW			
	Props (#18)	Hooker (#6)	Locks (#14)	3 rd Row (#22)
Age (yrs)	27 ± 5	26 ± 3	24 ± 3	25 ± 3
Mass (kg)	116 ± 7	103 ± 1*	109 ± 6*°	103 ± 6*°§
Stature (cm)	185 ± 3	181 ± 1*	197 ± 2*°	190 ± 5*°§
Body fat (%)	20 ± 3	17 ± 2*	17 ± 3*	13 ± 3*°§
Fat Free Mass (kg)	93 ± 5	86 ± 3*	90 ± 4	90 ± 4*°
FFM/stature (kg•m ⁻¹)	50,3 ± 2,5	47,4 ± 1,5*	45,6 ± 2,4*	47,1 ± 1,9*°§

For each position group are reported mean ± SD values of age (in years), body mass (in kilograms), stature (in centimetres), percentage of body fat (%), free fat mass (in kilograms) and the ratio between free fat mass and stature (kg•m⁻¹).

*, ° and § indicate, respectively, a significant difference vs props, hookers and locks.

RESULTS

Athletes were 26±5 years old, with a rather homogeneous playing experience (16±5 years). Forwards (FW) were significantly heavier (108±8 vs 91±6 Kg), taller (190±7 vs 183±5 cm), had a larger % body fat (16±4 vs 11±4%) and fat free mass (91±5 vs 80±6 Kg) compared to backs (BK).

Significant differences in all the measured parameters were detected among FW subgroups (Table 1) yet not between BK subgroups (Table 2).

DISCUSSION

Our study provides a large and updated reference database for elite male rugby union players the southern European region.

TABLE 2. Anthropometric characteristics of backs (BK) subgroup.

Role	BK		
	half scrum (#10)	fly-half, centre (#30)	wings, full back (#27)
Age (yrs)	26 ± 5	24 ± 3	24 ± 3
Mass (kg)	87 ± 4	92 ± 6	90 ± 6
Stature (cm)	178 ± 3	183 ± 5	185 ± 5
Body fat (%)	12 ± 3	11 ± 4	11 ± 3
Fat Free Mass (kg)	77 ± 4	81 ± 5	80 ± 6
FFM/stature (kg•m ⁻¹)	43,2 ± 2,0	44,5 ± 2,0	43,5 ± 2,3

For each position group are reported mean ± SD values of age (in years), body mass (in kilograms), stature (in centimetres), percentage of body fat (%), free fat mass (in kilograms) and the ratio between free fat mass and stature (kg•m⁻¹).

BK subgroups are significantly different from FW yet no differences were detected among them.

In accordance with the literature, our data document significant role differences in anthropometric parameters between FW and BK and between FW subgroups and no differences within BK positional subgroups. This confirms the specificity in the physical requirements of rugby union in individual playing positions in senior males at the elite international level.

Furthermore, our data report very similar values in stature and lean body mass compared to the existing literature on southern (Duthie *et al.* 2003; Duthie *et al.* 2006) and northern hemisphere (Scott *et al.* 2003). On the contrary, our players, specially the first and second row FW, appear to have a larger fat mass compared to previous work. Such difference may be due to the fact the rugby players in this study were selected mainly based on their playing performance in a country where rugby is a minor sport and the physical characteristics required to play in first and second row are present in a very limited fraction of the population (>90^o percentile).

In conclusion, our study provides updated anthropometric data for elite professional rugby union players. This reference database can assist talent selection, addressing individual athletes to the role for which they are more gifted and guide individualized training to match the demands of the game. Furthermore, periodic monitoring of a variety of playing populations is necessary to quantify and compare the evolving demands of the game.

REFERENCES

- Deutsch, M. U., G. A. Kearney, et al., 2007. Time - motion analysis of professional rugby union players during match-play. *J Sports Sci*, **25**(4) pp. 461-72.
- Duthie, G., D. Pyne, et al., 2003. Applied physiology and game analysis of rugby union. *Sports Med*, **33**(13) pp. 973-91.
- Duthie, G., D. Pyne, et al., 2005. Time motion analysis of 2001 and 2002 super 12 rugby. *J Sports Sci*, **23**(5) pp. 523-30.
- Duthie, G. M., D. B. Pyne, et al., 2006. Anthropometry profiles of elite rugby players: quantifying changes in lean mass. *Br J Sports Med*, **40**(3) pp. 202-7.

- Golding, L., C. Meyers, et al. (1982). The Y's way to physical fitness. Rosemont, IL, National Board of YMCA.
- Reilly, T. and D. Gilbourne, 2003. Science and football: a review of applied research in the football codes. *J Sports Sci*, **21**(9) pp. 693-705.
- Scott, A. C., N. Roe, et al., 2003. Aerobic exercise physiology in a professional rugby union team. *Int J Cardiol*, **87**(2-3) pp. 173-7.

PHYSIOLOGICAL AND ANTHROPOMETRIC CHARACTERISTICS OF ELITE WOMEN UNION PLAYERS.

GIORGIO DA LOZZO¹, VERONICA CERADINI¹, CRISTINA TONNA², SILVIA POGLIAGHI¹

¹Faculty of Human Movement Sciences, University of Verona, Italy

²Federazione Italiana Rugby, Italy

ABSTRACT

The knowledge of the physical characteristics of women rugby union players, is scarce and, due to the evolution of this sport in the recent years, it is also dated. This study was aimed to provide up to date normative data on selected, laboratory-based, physiological and anthropometric characteristics of elite women players of the northern hemisphere.

A selection (i.e. only the players regularly engaged in elite training and international competitions) of the Italian national team was tested in March 2007, at the end of the Six Nations. Anthropometry (body mass, stature, % body fat and lean body mass determination by 5-site skin fold thickness), measurement of maximum oxygen consumption (VO_{2max} , incremental cycling test to exhaustion) and lower extremities strength by vertical jumping test (squat, SJ, and countermovement jump, CMJ, and elasticity index EI) were performed. Mean and standard deviation (SD) were calculated in FW and BK and in positional subgroups (i.e. front row FW: props, locks; back row FW: flankers, number eight, hooker; inside BK: fly-half, centre; outside BK: wings, full back). The half back was not included in the above subgroups due to its unique role). Data were compared by t test. Statistical significance was set at $p < 0.05$.

The athletes were 24 ± 4 years old and had a 9 ± 6 years playing experience. FW were significantly taller, heavier, had a larger fat free mass, absolute VO_{2max} and squat jump ability compared to BK. Front row FW were significantly taller, heavier, fatter and had a larger fat free mass compared to back row FW. No differences were detected in either anthropometric or functional parameters within BK positional subgroups.

This study provides normative functional and anthropometric data for elite female rugby union players, with special reference to positional role. In agreement with male data, role differences in the majority of the measured parameters appear between FW and BK and between FW subgroups, while no difference was measured within BK subgroups. This suggests that differences in the physical requirements of rugby union, in specific playing positions, are present in women as well as in man rugby. This normative database can provide coaching staff with a description of an individual athlete's strengths and weaknesses to assist talent selection and to guide training to match the demands of specific playing positions. Furthermore, periodic monitoring of a variety of playing populations is necessary to quantify and compare the rapidly evolving demands of this game.

Key words: female, collision sport, performance, functional evaluation, training

Rugby is a collision team sport, classified as an interval aerobic-anaerobic activity. It involves great muscle masses and force efforts of both upper and lower extremities (Duthie *et al.* 2003).

Rugby union has become a professional sport since 1995. The Italian national team has recently been included in the "6 Nations". This has contributed to an increased popularity of the sport and has primed improvements in the

quality of the game played by clubs of all levels. Since the first World Cup open to woman in 1991, this traditionally male sport is increasingly practiced, non-professionally, by female athletes.

This lack of investigation on the influence of intensity on training load is probably due to the complexity of its determination in a team sport Game analysis (Duthie *et al.* 2003; Duthie *et al.* 2005; Deutsch *et al.* 2007) and functional evaluation (Duthie *et al.* 2003; Scott *et al.* 2003) of players of different skill, gender and/or age are both classical approaches to the understanding of the physical demands of rugby (Reilly and Gilbourne 2003). However there appears to be limited scientific papers examining women's rugby at the elite level.

Schick *et al.* (2008), studying the rate of injuries in the 2006 Women's Rugby World Cup (WRWC) describe mean anthropometric characteristics (weight and height) of the 339 players involved in the tournament. Barr and Nolte (2011) investigating the relationship between drop jump performance and sprinting speed provide some functional data on Canadian of international level. Before these studies the only specific reference was a nineteen years old congress proceeding (Kirby and Reilly 1993).

The aim of this descriptive study was to integrate this limited knowledge on women rugby, providing normative data on laboratory-based, physiological and anthropometric variables in elite players of the northern hemisphere. These parameters can be useful to establish the physical requirements of women rugby union, to identify role differences and to support training decisions. It is also hoped that this study will stimulate further research in the field of women rugby union.

METHODS

This sample consisted of 22 female players (11 forwards (FW), 11 backs (BK)) from the Italian National rugby union senior team. During the competitive season the athletes played ~1 match/week with their club and had three 1,5-hour field and two 1-hour weight training sessions each week.

Tests were performed in the one testing session in March 2007, after the Six Nations championship. Body mass (digital scale, Seca 877, Seca, Leicester, UK) and stature (vertical stadiometer, Seca, Leicester, UK) were determined to the nearest 0,1 kg and 0.5 cm. Skin folds thickness was measured, in triplicate, by a single skilled investigator (scapular, triceps, iliac, abdominal and thigh) using a pincer type caliper (Holtain T/W skinfold caliper, Holtain limited, UK). For each skinfold, an average value was calculated and body fat percentage was estimated based on the sum of the 5 skin fold thicknesses (SS, in mm) with the following formula (Golding *et al.* 1982):

$$\% \text{ body fat} = (0,3 * (SS)) - (0,0005 * SS^2) + (0,03 * \text{age}) - 0,6$$

and lean body mass (LBM) was calculated as:

$$\text{LBM} = \text{body mass} - (\text{body mass} * \% \text{ body fat})$$

Next athletes underwent an incremental test to exhaustion on a magnetically braked cycle ergometer (3-min warm up at 50 watt +20 watt/min until voluntary exhaustion, at 60-70 revolutions per minute). During the test, ventilatory parameters were measured breath by breath (Quark b² Cosmed, Italy) and VO₂max was calculated as the average of the last 10 seconds of exercise prior to exhaustion if one of the following criteria was met: i) VO₂ plateau (VO₂ increase < 50% of the expected based on work load increment); ii) respiratory exchange ratio (R) > 1,15; iii) heart rate (HR) upon exhaustion > 90% of age predicted maximal HR (Tanaka *et al.* 2001).

Thirty minutes after the cycling test, athletes performed a total of 6 single jumps (3 squat jumps, SJ, and 3 counter movement jumps, CMJ), separated by 2-min resting intervals to determine leg power. The height of jumps was assessed based on flight time (t) (Optojump, Microgate, Italy).

Descriptive statistics (mean and standard deviation (SD) were calculated for forwards (FW) and backs (BK) as well as the following positional subgroups : *Front row forwards*: props and locks; *Back row forwards*: flankers, number eight and hooker; *Inside backs*: fly-half and centre; *Outside backs*: wings and full back (Deutsch *et al.* 2007). The only scrum half was not included in the above subgroups due to its unique role. Groups were compared using un-

TABLE 1, Anthropometric characteristics (mean \pm SD) of forwards (FW) and backs (BK) and subgroups

group	#	mass (kg)	stature (m)	fat (%)	lean mass (kg)
FW	11	71,2 \pm 11,6*	1,68 \pm 0,1*	24,4 \pm 5,5	53,3 \pm 4,5*
BK	11	62,5 \pm 5,7	1,63 \pm 0,1	24,3 \pm 4,0	47,2 \pm 3,8
FR FW	5	78,8 \pm 13,5§	1,71 \pm 0,1§	27,8 \pm 6,4§	56,2 \pm 4,6§
BR FW	6	65,0 \pm 4,5	1,64 \pm 0,0	21,6 \pm 2,6	50,9 \pm 2,9
I BK	6	64,0 \pm 5,6	1,63 \pm 0,1	25,8 \pm 3,6	47,4 \pm 3,2
O BK	4	61,0 \pm 6,5	1,63 \pm 0,1	22,0 \pm 4,1	47,5 \pm 5,3

Number of subjects (#), Body mass (in kg), stature (in meters), percentage of fat mass (%) and lean mass (in kg) are reported for positional groups (FW and BK) and for positional subgroups: Front Row Forwards (FR FW) Back Row Forwards (BR FW), Inside Backs (I BK), Outside Backs (O BK),

* and § indicate a significant difference from BK and within positional subgroups ($p < 0,05$),

paired *t*-test followed by Bonferroni correction and the significant level was set at $< 0,05$.

RESULTS

Athletes were 24 ± 4 years old, with an average playing experience of 9 years ($SD = 6$ years). Table 1 indicates that FW were significantly heavier and taller compared to BK and had a larger fat free mass. No difference in body fat

percentage was detected between the groups. Front row FW were significantly heavier and taller and had a larger body fat percentage and fat free mass than back row FW. On the contrary, no difference was found within BKs. All the athletes completed the incremental test to exhaustion meeting the criteria for definition of maximal effort. Average HR_{max} was $93 \pm 6\%$ of predicted maximal (Tanaka *et al.* 2001), while

TABLE 2, Functional data (mean \pm SD) of forwards (FW) and backs (BK) and subgroups

group	#	VO_{2max} ($l \cdot min^{-1}$)	VO_{2max} ($ml \cdot Kg^{-1} \cdot min^{-1}$)	SJ (cm)	CMJ (cm)
FW	11	3,0 \pm 0,4*	42,6 \pm 5,3	26,4 \pm 4,3*	29,2 \pm 3,3
BK	11	2,7 \pm 0,5	43,1 \pm 5,3	23,8 \pm 2,9	28,5 \pm 3,5
FR FW	5	3,1 \pm 0,3	40,7 \pm 5,9	25,4 \pm 2,3	28,0 \pm 1,9
BR FW	6	2,9 \pm 0,4	44,3 \pm 4,7	27,3 \pm 5,5	30,2 \pm 4,0
I BK	6	2,8 \pm 0,5	42,7 \pm 6,6	23,6 \pm 2,7	28,7 \pm 3,0
O BK	4	2,6 \pm 0,3	42,4 \pm 1,8	24,0 \pm 3,6	28,8 \pm 4,6

Number of subjects (#), Oxygen consumption (absolute, in $l \cdot min^{-1}$ and relative, $ml \cdot Kg^{-1} \cdot min^{-1}$), Squat Jump (SJ) height (in cm) and Counter Movement Jump (CMJ) height (in cm) values are reported for positional groups (FW and BK) and for positional subgroups: Front Row Forwards (FR FW) Back Row Forwards (BR FW), Inside Backs (I BK), Outside Backs (O BK),

* and § indicate a significant difference from BK and within positional subgroups ($p < 0,05$),

R was $1,12 \pm 0,02$ for all playing group. The FW recorded significantly larger absolute VO_{2max} compared to BK (Table 2). However, this difference disappeared when data were expressed relative to body mass.

With regard to leg power FW performed significantly higher squat jumps compared to BK. However, counter movement jump height was not significantly different between FW and BK and there was no difference in leg power between the FW and BK subgroups.

DISCUSSION

This descriptive study provides, normative data on laboratory-based, physiological and anthropometric variables in elite European women rugby union players, with special reference to positional groups.

In accordance with male studies, significant role differences in the majority of the measured parameters were detected between forwards and backs and between FW subgroups and no differences were detected in either anthropometric or physiological parameters within BK positional subgroups. This suggests that specificity in the physical requirements of rugby union in individual playing positions is present in women as well as in males playing at the international level.

The national athletes in this study were younger in comparison with the international players that took part at the 2006 World Cup (Schick *et al.* 2008). Height and body mass appear lower ($\sim 6-9$ kg, $\sim 2-4$ cm) both for FW than for BK. Stature and fat free mass of the forwards and backs were comparable to those in the Kirby study (1993), but they recorded higher levels of body fat (i.e. 3,5-4% of body fat) compared to their British colleagues. A high percent body fat can provide protection against physical collision and represents a static advantage over opponents in scrums. However it also increases the physiological demands of playing during both training and matches. It could be speculated that the high body fat may reflect a low training volume in these athletes.

Functional evaluation of aerobic performance was also performed in our study. Compared to different field-based team sports our data are comparable with those of college level lacrosse and soccer athletes (Enemark-Miller *et al.* 2009),

yet lower than those of international level soccer (-15%) (Krustrup *et al.* 2005) and field hockey (-7%) (Hinrichs *et al.*) athletes. In these sports, a high VO_{2max} facilitates the repetition of and the recovery from high intensity anaerobic efforts inherent to both training and competition. Furthermore, in rugby league, VO_{2max} has been demonstrated to be positively related to different indexes of players' performance during the actual game and to be associated with lower injury rates (Gabbett 2007). Yet, VO_{2max} is only one component of the several requirements of the overall fitness profile and rugby union players normally do not include specific sessions to develop VO_{2max} in their training regimen. Therefore, the relatively low VO_{2max} observed in our study could be ascribed to both a low exercise volume and to the fact that training is normally not addressed at improving this functional parameter, despite its potential importance for fatigue resistance and injury prevention.

Rugby performance requires high levels of muscular strength and power for success, with the forwards requiring more strength and the backs requiring more speed (Duthie *et al.* 2003). The force produced during a vertical jump has been shown to be related to scrum force (Duthie *et al.* 2003). Direct comparison of studies is difficult due to difference in test protocols and to the rapid evolution of the game, especially over the last decade, yet, our subjects appear to have a lower level of muscular power compared both to international rugby players (Barr and Nolte 2011), both to international level athletes of different team sports (Enemark-Miller *et al.* 2009).

Collectively these results suggest that, although the women rugby players in this study had adequate playing performance to warrant selection into the national team, they are nonetheless characterized by fitness levels that are lower than those reported in the literature for team sports. Furthermore, FW and BK appear to be less differentiated compared to male rugby players. This may be influenced by the following factors: *i)* the recent exposure to high level international competition; *ii)* suboptimal training regimens in terms of training volume and specificity in these non-professional athletes; *iii)* less competition for selection based on lower participant numbers.

Furthermore, due to a less organized team structure and a smaller playing population compared to professional male rugby, the role assignment in Italian women's rugby is quite diverse. It is common for a player to have a different role when competing in international competitions compared to national club competitions. Consequently female players are less likely than male players to conform to the physical requirements of specific roles. It must be noted however, that our small sample size and the high between-subject variability of our group, may reduce the likelihood to identify significant differences among positional subgroups.

In conclusion, this study provides physiological and anthropometric data for elite women rugby union players. Only by increasing the number of published studies can we gain a better understanding of this specific athletic population. These findings may assist in talent selection, addressing individual athletes to the role for which they are more suited and guide individualized training to match the demands of the game. Finally, we hope to stimulate further research in this rather unexplored field.

REFERENCES.

- Barr, M. J. and V. W. Nolte, 2011. Which measure of drop jump performance best predicts sprinting speed? *J Strength Cond Res*, **25**(7) pp. 1976-82.
- Deutsch, M. U., G. A. Kearney, et al., 2007. Time - motion analysis of professional rugby union players during match-play. *J Sports Sci*, **25**(4) pp. 461-72.
- Duthie, G., D. Pyne, et al., 2003. Applied physiology and game analysis of rugby union. *Sports Med*, **33**(13) pp. 973-91.
- Duthie, G., D. Pyne, et al., 2005. Time motion analysis of 2001 and 2002 super 12 rugby. *J Sports Sci*, **23**(5) pp. 523-30.
- Enemark-Miller, E. A., J. G. Seegmiller, et al., 2009. Physiological profile of women's Lacrosse players. *J Strength Cond Res*, **23**(1) pp. 39-43.
- Gabbett, T. J., 2007. Physiological and anthropometric characteristics of elite women rugby league players. *J Strength Cond Res*, **21**(3) pp. 875-81.
- Golding, L., C. Meyers, et al. (1982). The Y's way to physical fitness. Rosemont, IL, National Board of YMCA.
- Hinrichs, T., J. Franke, et al., Total hemoglobin mass, iron status, and endurance capacity in elite field hockey players. *J Strength Cond Res*, **24**(3) pp. 629-38.
- Kirby, W. J. and T. Reilly (1993). Anthropometric and fitness profile of elite female rugby union players. Science and Football II: Proceedings of the Second World congress of Science and Football, London.
- Krustrup, P., M. Mohr, et al., 2005. Physical demands during an elite female soccer game: importance of training status. *Med Sci Sports Exerc*, **37**(7) pp. 1242-8.
- Reilly, T. and D. Gilbourne, 2003. Science and football: a review of applied research in the football codes. *J Sports Sci*, **21**(9) pp. 693-705.
- Schick, D. M., M. G. Molloy, et al., 2008. Injuries during the 2006 Women's Rugby World Cup. *Br J Sports Med*, **42**(6) pp. 447-51.
- Scott, A. C., N. Roe, et al., 2003. Aerobic exercise physiology in a professional rugby union team. *Int J Cardiol*, **87**(2-3) pp. 173-7.
- Tanaka, H., K. D. Monahan, et al., 2001. Age-predicted maximal heart rate revisited. *J Am Coll Cardiol*, **37**(1) pp. 153-6.

WHAT IS THE WORK-LOAD DURING TRAINING SESSIONS IN RUGBY UNION?

GIORGIO DA LOZZO, SILVIA POGLIAGHI

Faculty of Human Movement Sciences, University of Verona, Italy

ABSTRACT

There is a great interest in coaches and fitness trainers to define the physical demands of training, in order to optimize the training process, to evaluate the players' performance and provide suitable recovery time and nutrition. The determination of training load can be particularly challenging in Rugby Union, a team sport played by 15 players of highly variable build, that is characterized by short, high intensity efforts (struggle, impacts, sprinting) and longer, low intensity activities (standing still, walking, jogging). Our study aimed at applying a heart rate based approach to measure absolute and relative work-loads in two typologies of training session, typically used in rugby union: team session (TS) and unit training (UT).

Methods. 8 forwards (FW) and 7 backs (BK) from an Italian 1st Division rugby team undertook an incremental test to exhaustion on the treadmill to determine individual VO_{2max} , heart rate (HR) at max and HR/ VO_2 relationship. Furthermore, within the following month, HR was continuously monitored during 12 training sessions (6 TS and 6 UT). For each training session, we determined absolute ($Kcal \cdot Kg^{-1} \cdot min^{-1}$) and relative intensity (%HRmax) and a cumulative index of work-load (Lucia's TRIMP). Mean and standard deviation were calculated in FW and BK for TS and UT sessions and compared by t test ($p < 0,05$).

Results. The athletes were 24 ± 3 years old, with a 12 ± 3 years playing experience and a VO_{2max} of 47 ± 5 $ml \cdot kg^{-1} \cdot min^{-1}$. FW and BK weight and height were: 108 ± 8 and 92 ± 12 Kg; 187 ± 1 and 181 ± 1 cm respectively. Training sessions had similar duration (mean 55 ± 15 min). TS were conducted at a higher relative intensity and caused a higher energy expenditure compared to UT in both FW and BK. Accordingly, TS had a higher training-load (i.e. TRIMP) compared to UT. Furthermore in unit training sessions BK reached a significantly lower ($p < 0,05$) level of absolute and relative intensity compared to FW.

Discussion. Our study successfully determined absolute and relative work-load during specific training sessions in rugby union players. In this group of senior players of a national level, the overall work-load of both TS and UT was within the moderate intensity domain.

Conclusions. A further investigation on these parameters would be useful to establish the physical requirements of both training and match-play, to identify role differences and to support training decisions.

The determination of the work-load related to specific activities is essential to design training programs with adequate volume and intensity and to plan the optimal sequence of load and recovery (Borresen and Lambert 2009). This allows reaching the highest levels of performance

while minimizing the risk of injuries and overtraining. Furthermore, the monitoring of the individual effort allows the evaluation of the players' performance and commitment and can be used to reinforce motivation (Coutts *et al.* 2009). Finally, this information is essential to quantify the athletes' energy requirements and

the prevalent energy substrate involved in the training activity and to customize the dietary regime.

Three main components determine the training load: *Frequency*, which is the number of sessions that take place in a given time; *Volume*, which is the total length of training sessions; *Intensity*, which is the degree of effort that the athletes exert in each session (Weineck 2001). This last component is the most elusive in team sports (Duthie *et al.* 2003). In rugby, the quantification of exercise intensity is further complicated by the variability of tasks, in the whole team and in positional groups, and by the high variability in players' somatotype. Differences in playing ability, age and gender pose additional challenges to the determination of exercise intensity at the team and individual level.

Possible approaches to the characterization of the physical demands of rugby are the quantification of frequency and/or duration of specific tasks by video movement analysis ((Duthie *et al.* 2005; Deutsch *et al.* 2007) and the determination of the accelerations/ decelerations using GPS tracking devices or accelerometers (Cunniffe *et al.* 2009). Along with the high costs, a number of validity issues may limit the usefulness of the above approaches: i) estimation of exercise intensity based on absolute load (also called external load); ii) simplification of movement patterns into categories (while the actual play involves a dynamic combination of tasks, skills and tactics); iii) limitations of accuracy and reliability, especially for high intensity activities ((Duthie *et al.* 2003; Coutts and Duffield 2010); iv) the dedicated software supplied by the vendors, often provide an output (e.g. the number of collisions during rugby) rather than raw data and do not allow to act upon their calculated algorithms or criteria (i.e. the black box model).

An alternative approach to the quantification of exercise intensity is based on the well-known linear relationship between heart rate (HR) and oxygen uptake (VO_2). The advantages of this approach are: simplicity of use; relatively low cost; easy and transparent data handling; measurement of both absolute and relative loads. Within some limitations (i.e. potential

perturbation of HR by ambient and internal confounders; overestimation of HR during high-intensity isometric activities; inability of HR to account for the anaerobic component of exercise intensity; relatively slow adaptation of HR at the onset and offset of changes in work rate), the HR method provides satisfactory average estimates of exercise intensity for a group (Achten and Jeukendrup 2003) and it has been widely used in individual and team sports (Foster *et al.* 2001; Impellizzeri *et al.* 2004).

Based on the determination of individual HR/ VO_2 relationship, a number of indexes of absolute (VO_2 , caloric expenditure) and relative exercise intensity ($\%\text{HR}_{\text{max}}$, $\%\text{VO}_{2\text{max}}$) can be determined. Furthermore, based on the knowledge of the athlete's ventilatory thresholds, the individual work load can be quantified (Lucia *et al.* 2003).

HR-based quantification of exercise intensity has seldom been applied in rugby (Deutsch *et al.* 1998; Duthie *et al.* 2003) due to the difficulty in obtaining reliable HR measures during highly vigorous contacts (Duthie *et al.* 2003). The availability of new, dependable HR monitors may allow the application of this approach on a large scale.

The few previous studies focused their attention on the determination of work-load in competitive matches (Deutsch *et al.* 1998; Duthie *et al.* 2005; Deutsch *et al.* 2007). Regarding training sessions, the influence of duration and frequency on injuries was evaluated (Brooks *et al.* 2008), but the component of intensity wasn't investigated. The lack of knowledge on specific training sessions' loads surely limits the accuracy of the training process' design and control.

The aim of this study was to investigate the possibility to determine exercise intensity and work-load of two types of training session (Team Session and Unit Training) typically used in rugby union, based on the session HR, the individual HR/ VO_2 relationship and the knowledge of individual ventilatory thresholds.

METHODS

Subjects. Fifteen rugby players (8 forwards and 7 backs) from the same Italian 1st Division

TABLE 1. Anthropometric and functional characteristics of forwards (FW) and backs (BK),

GROUP	Age (y)	Mass (kg)	Stature (cm)	Fat mass (%)	Lean body mass (kg)	VO _{2max} (ml·kg ⁻¹ ·min ⁻¹)
FW (8)	25 ± 4	106 ± 10	188 ± 9	18 ± 6	87 ± 4	47 ± 5
BK (7)	24 ± 3	92 ± 12*	181 ± 11*	14 ± 6	79 ± 6*	47 ± 3

For each positional groups are reported mean ± SD values of age (in years), body mass (in kilograms), stature 8 in centimetres), percentage of fat mass, lean body mass (in kilograms) and oxygen consumption (in ml·kg⁻¹·min⁻¹).

* indicate a significant (p<0,05) difference from FW,

rugby team were involved in the study (Table 1).

Laboratory Tests. Body mass (digital scale, Seca 877, Seca, Leicester, UK), stature (vertical stadiometer, Seca, Leicester, UK) and % body fat (plicometry, Holtain T/W skinfold caliper, Holtain limited, UK) were measured. Thereafter, athletes performed an incremental treadmill test to exhaustion (RunRace Technogym, Italy): after one minute standing still, subjects started running at 6.0 Km h⁻¹ at an inclination of 1%. After three minutes, the treadmill speed was increased to 8.0 Km h⁻¹ and then by 0.5 Km h⁻¹ every minute until exhaustion. Throughout the test, respiratory variables and HR were measured breath-by-breath (Quark b² Cosmed, Italy).

Field tests. 12 afternoon training sessions (6 Team Sessions (TS) and 6 Unit Trainings (UT)) were monitored within a 4-week period, during the mid-season competition break (January-February). During TS all the players were involved in similar activities: attack and defence movements on narrow or wide spaces, breakdown plays, pattern plays. During UT, Forwards were trained mainly on scrums and lineouts; Backs performed 3vs2 and 4vs2 attack and defence patterns, kicking game and counterattack movements. Throughout the sessions HR was measured every 10 seconds (Memory Belt, Suunto, Finland).

Calculations. Based on the laboratory test, the sub-maximal and maximal values of HR and VO₂ were calculated as the average of the last 10s of each work-load and of the last 10s before exhaustion, respectively. Furthermore the ventilatory thresholds were detected with standard technique (Wasserman *et al.* 1973) and

the individual HR/VO₂ relationship was determined by linear regression. Based on the ventilatory thresholds, three intensity zones were defined: Light Intensity Zone (LI zone): below the first ventilatory threshold (VT₁); b) Moderate Intensity Zone (MI zone): between VT₁ and the second ventilatory threshold (VT₂ or respiratory compensation point); c) High Intensity Zone (HI zone): over VT₂ (Lucia *et al.* 2003).

Regarding the field tests, the training duration and the HR data were evaluated after the removal of the initial, standardised warm-up phase (~15min). HR data were expressed as percentage of maximum heart rate (%HR_{max}) and the energy expenditure (Kcal·Kg⁻¹·min⁻¹) was calculated, after conversion of individual HR into VO₂ data, based on a caloric equivalent of oxygen of 5 Kcal l⁻¹. Furthermore, the training impulse (TRIMP), a cumulative indicator of work-load, was calculated as the sum of the minutes spent in the three different intensity zones, each multiplied by a specific coefficient equal to 1 for LI zone, 2 for MI zone and 3 for HI zone (Lucia *et al.* 2003).

Statistics

Mean and standard deviation were calculated for all parameters and data were compared by t test.

RESULTS

Players had 12±3 years playing experience and their anthropometrical and functional characteristics (Table 1) are representative of the Italian 1st Division championship. As it can be expected, FW were taller, heavier and had a larger fat free mass compared to BK, yet the

TABLE 2, Average \pm standard deviation of the duration (min), intensity (% of maximal heart rate $-\%HR_{max}$ - and energy expenditure - $Kcal \cdot kg^{-1} \cdot min^{-1}$ -) and work-load (training impulse or TRIMP and % of time spent in each intensity zone during training sessions) of team (TS) and in unit (UT) training sessions, in positional groups: forwards (FW) and backs (BK),

	Team session training (TS)		Unit training (UT)	
	FW	BK	FW	BK
Duration (min)	59 \pm 12	59 \pm 12	56 \pm 17	51 \pm 17§
HR ($\%HR_{max}$)	72 \pm 8	74 \pm 6	63 \pm 7 §	70 \pm 5 *§
Energy Expenditure ($Kcal \cdot kg^{-1} \cdot min^{-1}$)	0,13 \pm 0,03	0,14 \pm 0,02	0,11 \pm 0,03 §	0,12 \pm 0,03 *§
TRIMP (Au)	69,4 \pm 16,0	67,4 \pm 21,2	58,5 \pm 23,5 §	55,5 \pm 23,6 §
Time in zone 1 (%)	88 \pm 14	89 \pm 15	91 \pm 8	89 \pm 10
Time in zone 2 (%)	8 \pm 9	6 \pm 8	6 \pm 5	8 \pm 7
Time in zone 3 (%)	4 \pm 8	5 \pm 8	3 \pm 5	3 \pm 5

* and § indicate, respectively, a significant ($p < 0,05$) difference vs FW and vs TS,

aerobic fitness was not different between groups.

Regarding the monitoring of training sessions, a minimal data loss was experienced (11 measures out of the initially programmed 180 were lost, 8 due to athlete's absence, 3 due to malfunction of the heart rate monitor).

The characteristics of the training sessions are summarized in Table 2. TS and UT had similar overall duration. TS were conducted at a higher relative intensity and caused a higher energy expenditure compared to UT in both FW and BK. Accordingly, TS had a higher training-load (i.e. TRIMP) compared to UT.

DISCUSSION

The present study was the first to determine exercise intensity and work-load of two types of training sessions (Team Session and Unit Training) typically performed in rugby union, based on the session HR, the individual HR/ VO_2 relationship and the knowledge of individual ventilatory thresholds.

In this team of senior, semi-professional players, the absolute and relative intensity and the work-load of training sessions were successfully determined.

TS, during which all the players were involved in similar, mostly dynamic, activities (attack and defence movements on narrow or wide spaces, breakdown plays, pattern plays), were performed in the moderate intensity domain and produced a relatively low energy expenditure.

During UT forwards performed high-intensity activities with a large isometric component (i.e. scrums and lineouts), interspersed by complete recovery periods while backs performed dynamic activities (3vs2 and 4vs2 attack and defence patterns, kicking game and counterattack movements). Surprisingly, UT were characterised by lower absolute and relative exercise intensity and by a lower work-load compared to TS for both FW and BK.

During both types of activity, yet specially so for UT, the ability of HR to accurately track exercise intensity may be reduced due to the following: *a*) an overestimation of HR of about 10 bmin^{-1} has been documented in mixed, static-dynamic activities compared to only dynamic activities (Patterson *et al.* 1985). In the present study, this would have caused a 10% overestimation of energy expenditure; *b*) HR does not account for the anaerobic component of exercise, therefore potentially causing an

underestimation of caloric expenditure of highly intense, intermittent activities. In the present study, average intensity was relatively low ($\sim 70\% \text{HR}_{\text{max}}$) and homogeneous (average within session coefficient of variation $<10\%$), suggesting a rather small contribution of the anaerobic metabolism to the overall energy production; *c*) at exercise onset and offset, both HR and VO_2 adapt to the changes in work rate with a 30s to 1 min delay in trained individuals. Particularly so for highly intermittent exercise, this may cause an underestimation of exercise intensity in the on-transient that is mirrored by (and therefore can be dampened by) an overestimation during the off-transient.

Notwithstanding the above potential limitations the HR method provides satisfactory average estimates of exercise intensity for a group of athletes (Achten and Jeukendrup 2003) that has been widely used in individual and team sports (Foster *et al.* 2001; Impellizzeri *et al.* 2004) in which a direct VO_2 determination cannot be performed.

In accordance with the literature (Duthie *et al.* 2003; Scott *et al.* 2003; Duthie *et al.* 2006), our data document significant role differences in anthropometric parameters between FW and BK. This confirms the specificity in the physical requirements of rugby union in individual playing positions. Our players appear shorter, lighter, with a lower fat free mass and a larger fat mass compared to elite Italian and international players. Such differences may reflect the lower playing ability, selection and training work-load that is typical of our semi-professional national championship.

Functional evaluation of aerobic performance was also performed in our study. $\text{VO}_{2\text{max}}$ values in both FW and BK appear lower than indicated in previous studies (Duthie *et al.* 2003). The importance of $\text{VO}_{2\text{max}}$ is controversial in rugby union. Although, as in many other team-sports, a high $\text{VO}_{2\text{max}}$ facilitates the repetition of high intensity anaerobic efforts, it is not usually considered a fundamental component of the rugby player's fitness profile. Therefore the low $\text{VO}_{2\text{max}}$ observed in our study could be ascribed to both a low work-load and to the fact that training is

normally not addressed at improving this functional parameter.

In summary, this is the first study to evaluate the absolute and relative intensity and the work-load during specific training sessions in rugby union. These parameters can be useful to establish the physical requirements of both training and match-play, to identify role differences and to support training decisions. Only by increasing the number of published data in the scientific literature, can we have reliable reference data on this small and poorly understood subject. Furthermore, periodic monitoring of a variety of playing populations is necessary to quantify and compare the evolving demands of rugby union.

REFERENCES

- Achten, J. and A. E. Jeukendrup, 2003. Heart rate monitoring: applications and limitations. *Sports Med*, **33**(7) pp. 517-38.
- Borresen, J. and M. I. Lambert, 2009. The quantification of training load, the training response and the effect on performance. *Sports Med*, **39**(9) pp. 779-95.
- Brooks, J. H., C. W. Fuller, et al., 2008. An assessment of training volume in professional rugby union and its impact on the incidence, severity, and nature of match and training injuries. *J Sports Sci*, **26**(8) pp. 863-73.
- Coutts, A. J. and R. Duffield, 2010. Validity and reliability of GPS devices for measuring movement demands of team sports. *J Sci Med Sport*, **13**(1) pp. 133-5.
- Coutts, A. J., E. Rampinini, et al., 2009. Heart rate and blood lactate correlates of perceived exertion during small-sided soccer games. *J Sci Med Sport*, **12**(1) pp. 79-84.
- Cunniffe, B., W. Proctor, et al., 2009. An evaluation of the physiological demands of elite rugby union using Global Positioning System tracking software. *J Strength Cond Res*, **23**(4) pp. 1195-203.
- Deutsch, M. U., G. A. Kearney, et al., 2007. Time - motion analysis of professional

- rugby union players during match-play. *J Sports Sci*, **25**(4) pp. 461-72.
- Deutsch, M. U., G. J. Maw, et al., 1998. Heart rate, blood lactate and kinematic data of elite colts (under-19) rugby union players during competition. *J Sports Sci*, **16**(6) pp. 561-70.
- Duthie, G., D. Pyne, et al., 2003. Applied physiology and game analysis of rugby union. *Sports Med*, **33**(13) pp. 973-91.
- Duthie, G., D. Pyne, et al., 2005. Time motion analysis of 2001 and 2002 super 12 rugby. *J Sports Sci*, **23**(5) pp. 523-30.
- Duthie, G. M., D. B. Pyne, et al., 2006. Anthropometry profiles of elite rugby players: quantifying changes in lean mass. *Br J Sports Med*, **40**(3) pp. 202-7.
- Foster, C., J. A. Florhaug, et al., 2001. A new approach to monitoring exercise training. *J Strength Cond Res*, **15**(1) pp. 109-15.
- Impellizzeri, F. M., E. Rampinini, et al., 2004. Use of RPE-based training load in soccer. *Med Sci Sports Exerc*, **36**(6) pp. 1042-7.
- Lucia, A., J. Hoyos, et al., 2003. Tour de France versus Vuelta a Espana: which is harder? *Med Sci Sports Exerc*, **35**(5) pp. 872-8.
- Patterson, R. P., J. Pearson, et al., 1985. Work-rest periods: their effects on normal physiologic response to isometric and dynamic work. *Arch Phys Med Rehabil*, **66**(6) pp. 348-52.
- Scott, A. C., N. Roe, et al., 2003. Aerobic exercise physiology in a professional rugby union team. *Int J Cardiol*, **87**(2-3) pp. 173-7.
- Wasserman, K., B. J. Whipp, et al., 1973. Anaerobic threshold and respiratory gas exchange during exercise. *J Appl Physiol*, **35**(2) pp. 236-43.
- Weineck, J. (2001). L'allenamento ottimale. Perugia, Calzetti Marucci.

INTERCHANGEABILITY OF OBJECTIVE AND SUBJECTIVE INDEXES OF WORK-LOAD IN RUGBY UNION

GIORGIO DA LOZZO, GIOVANNI CROTTI, SILVIA POGLIAGHI

Faculty of Human Movement Sciences, University of Verona, Italy

ABSTRACT

The ability to determine work-load in team sports is essential to design the training process during the competitive season. The aim of this study was to verify the applicability of the session-RPE method proposed by Foster to the specific contest of rugby union, analyzing the relationship between objective (HR-based) and subjective (s-RPE-based) indexes of training intensity and work-load.

Methods: 24 professional rugby players, 12 Forwards (mean \pm SD: age $28,8 \pm 6,5$ yr, stature $1,87 \pm 0,05$ m, body mass $106,1 \pm 11,2$ kg, body fat $20,0 \pm 5,0$ %) and 12 Backs (mean \pm SD: age $27,1 \pm 5,8$ yr, stature $1,82 \pm 0,05$ m, body mass $89,8 \pm 9,3$ kg, body fat $14,2 \pm 5,8$ %) were involved in the study. Objective (mean HR, %HR_{max}) and subjective (s-RPE) indexes of intensity were recorded in 9 specific training sessions. Objective index of work-load was settled as proposed by Edwards, through the identification of five zones of increasing intensity (Summated heart rate zone index, SHRZ). Training load (TL) was calculated by multiplying s-RPE for the duration of the session. Pearson product-moment correlations were performed to assess the relationship between %HR_{max} and s-RPE, between s-RPE and duration, and between SHRZ and TL. Furthermore multiple linear regressions were calculated to investigate the influence of duration, %HR_{max} and time spent in the different heart rate zones on the s-RPE parameter. Statistical significance was set at $p < 0,05$.

Results: Average training intensity was moderate (mean \pm SD: %HR_{max} 66 ± 4 %, s-RPE $4,3 \pm 0,7$ Au). Correlations, considering, respectively, all the individual data and session team-averages were: %HR_{max} and s-RPE: $r=0,41$, $r=0,80$; s-RPE and duration: $r=0,47$, $r=0,94$; SHRZ and TL: $r=0,55$, $r=0,92$. All these correlations were significant ($p < 0,05$). The applied multiple linear regressions described significant ($p < 0,05$) influence of duration and time in the lowest (Z_1) and in the higher HR intensity zones (Z_4 , Z_5).

Discussion: Our study applied and compared subjective and objective indexes of exercise intensity and training load and came to the conclusion that such indexes are highly correlated and therefore interchangeable when team average data are considered. On the contrary, interchangeability between these indexes is not sufficiently reliable to allow avoidance of the monitoring of objective parameters in individual subjects. Furthermore, our study suggests a possible independent effect of duration on the perception of effort during typical and specific rugby union training sessions. More research is needed to clear if duration may be an integrated component of s-RPE and may independently predict training load and overtraining in team sports.

The determination of the work-load related to specific activities is essential to design training programs with adequate volume and intensity and to plan the optimal sequence of load and recovery (Borresen and Lambert 2009). This allows the athletes to reach the highest levels of performance while minimizing the risk of injury or overtraining. Furthermore, monitoring individual effort allows the evaluation of performance and commitment and can be used to give feedback to the players and to reinforce their motivation (Coutts *et al.* 2009).

The physical work-load can be defined by three elements: *Frequency* (number of sessions carried out in a given time), *Volume* (total duration of the sessions) and *Intensity* (the degree of effort that the athletes exert in each session, Weineck 2001). Previous studies on rugby Union focused their attention on the determination of work-load only in competitive matches mainly investigating the components of frequency and volume and indirectly estimating intensity through the enumeration of the different types of activity (Deutsch *et al.* 1998; Duthie *et al.* 2005; Deutsch *et al.* 2007). Brooks *et al.* (2008) studied the work-load of training sessions investigating the possible relationship between the risk of injuries and training volume and frequency. Intensity was not considered.

This lack of investigation on the influence of intensity on training load is probably due to the complexity of its determination in a team sport as rugby (Duthie *et al.* 2003). In fact, a wide range of physical and technical tasks accompanied by significant differences in the players' characteristics (in terms of somatotype, positional role, playing ability, age and/or gender) make it difficult to accurately define the individual effort in rugby-specific activities.

As mentioned previously, one approach to describe the physical demand of rugby is to deduce the exercise intensity based on the so called external load (i.e. absolute load) by the quantification of frequency and/or duration of specific tasks by video movement analysis (Duthie *et al.* 2005; Deutsch *et al.* 2007) or by the determination of the acceleration-deceleration patterns using GPS tracking devices or accelerometers (Cunniffe *et al.* 2009).

Along with the high costs, two main issues may limit the usefulness of these methods: *i)* the estimation of exercise intensity based on absolute load (also called external load); *ii)* the simplification of movement patterns into categories (while the actual game involves a dynamic combination of tasks, skills and tactics); *iii)* the presence of limitations in accuracy and reliability, especially so for activities performed at a high speed (Duthie *et al.* 2003; Barbero-Alvarez *et al.* 2010; Coutts and Duffield 2010).

An alternative approach to define exercise intensity that could overcome some of these issues is the monitoring of HR during training sessions. This method, that is based on the linear relationship that exists between HR and oxygen uptake, has been widely used in individual and collective sports (Bot and Hollander 2000; Foster *et al.* 2001; Impellizzeri *et al.* 2004), yet seldom in rugby (Deutsch *et al.* 1998; Doutreloux *et al.* 2002; Duthie *et al.* 2003), probably due to the difficulty in obtaining reliable HR measures during highly vigorous contacts. Simpler and more affordable than other methods (time motion analysis, measure of blood lactate), it allows the determination of relative (also called internal) loads and, if the individual HR/VO₂ relationship is known, even of absolute loads (Åstrand and Rodahl 1986). Furthermore, the combination of HR-based indexes of exercise intensity and the session duration has been used to quantify the exercise load in highly variable activities and in rugby (Banister 1991; Edwards 1993; Lucia *et al.* 2003). Among these, the Edwards' summated heart rate zone index (SHRZ), that identifies five HR-zones of increasing intensity and multiplies the time spent in each zone by a coefficient (from 1, for the lower intensity zones, to 5 for the higher intensity zones), might facilitate the quantification of the exercise load.

With the same purpose of finding an even simpler method to define exercise load, in recent years, many studies (Foster *et al.* 2001; Coutts *et al.* 2003; Impellizzeri *et al.* 2004; Coutts *et al.* 2009) investigated the validity of the session-RPE method proposed by Foster *et al.* (2001) in team sport as soccer, basket and

TABLE 1. Subject characteristics (mean \pm SD)

GROUP	Age (y)	Stature (m)	Body Mass (kg)	Fat Mass (%)
Forwards (12)	28,2 \pm 6,5	1,87 \pm 0,05	106,1 \pm 11,2	20,0 \pm 5,0
Backs (12)	27,1 \pm 5,8	1,82 \pm 0,05*	89,8 \pm 9,3*	14,2 \pm 5,8*

* indicate a significant ($p < 0,05$) difference from FW

rugby league. Yet, the relationship between subjective (RPE-based) and objective (HR-based) methods has never been verified in rugby union.

The aim of this study was to determine if both indexes, that are based on assumptions and contain some degree of uncertainty, hold the same type of information and therefore to verify their interchangeability.

METHODS

Subjects. Twenty-four professional players (12 Forwards and 12 Backs) form a single Italian First Division Team were involved in the study (Table 1). All participants were informed of the aims and procedures of the study and gave a written consent.

Field data collection. Training data were collected on 9 specific training sessions during the competitive period of the 2010-11 season. A random selection of 15 players from the main group, 8 FW and 7 BK, was monitored for each training session, excluding the injured athletes.

The training weekly program consisted on 4 rugby specific field sessions, which were held in the afternoon (Monday, Tuesday, Thursday, Friday. Duration: 40-80 mins); 2 gym sessions of 50 minutes of duration were planned on Monday and Thursday morning, while on Tuesday morning athletes underwent a 50 minutes long specific speed session. Rugby match was scheduled on Saturday afternoon.

For this study, we chose to monitor Monday training sessions, characterized by a specific standardized warm-up phase, followed by a main or central phase consisting of technical-tactical tasks. Sessions were concluded by a specific physical conditioning phase, defined as

“rugby fitness”, characterized by pre-defined sequences of competitive play with low or moderate presence of impacts.

HR was recorded every 10 seconds during each training session with individual HR monitor devices with an integrated memory chip (Memory Belt, Suunto, Finland). Data were downloaded after exercise on a PC by a specific USB docking station. In addition, every training session was video-recorded (Samsung Electronics Co. Ltd, South Korea).

Session Rating of Perceived Exertion (s-RPE) data were collected, as proposed by Foster (2001), 30 minutes after each training. In this study was used the Italian translation of the Borg CR-10 scale, modified by Foster. All the players involved had been familiarized with this scale for rating perceived exertion before the beginning of the study.

Calculations and Training load indices determination. Maximal heart rate (HR_{max}) was indirectly calculated with Tanaka’s formula ($208 - age \times 0,7$; (Tanaka *et al.* 2001) for every player. Training session HR data were expressed both as mean values \pm SD and as percentage of the assessed HR_{max} value ($\%HR_{max}$).

Objective (HR-based) index of training load was determined with the method proposed by Edwards (1993). The accumulated duration (minutes) in each of five heart rate zones (i.e. 50-60%, 60-70%, 70-80%, 80-90% and 90-100% of HR_{max}) was calculated and then multiplied by a specific coefficient for each zone (50-60%=1, 60-70%=2, 70-80%=3, 80-90% =4, 90-100%=5). The results were then summated in a cumulative score (Summated Heart Rate Zones Index – SHRZ).

Subjective, s-RPE-based, training load (TL) index, was calculated as proposed

TABLE 2. Objective and subjective indexes of intensity

TRAINING SESSION	DURATION (min)	HR (bpm)	%HR _{max}	s-RPE (Au)
07-12-10	67,2	119 ± 12	63 ± 6	3,3 ± 0,8
14-12-10	95,1	130 ± 11	68 ± 5	5,5 ± 1,3
28-02-11	84,2	137 ± 11	73 ± 5	4,9 ± 1,2
07-03-11	88,2	132 ± 15	70 ± 7	4,9 ± 1,1
15-03-11	80,2	129 ± 16	68 ± 8	4,3 ± 1,9
22-03-11	65,7	115 ± 14	61 ± 6	3,3 ± 1,3
29-03-11	71,2	121 ± 10	65 ± 4	4,1 ± 1,0
05-04-11	78,2	127 ± 12	67 ± 6	4,2 ± 0,7
12-04-11	83,2	117 ± 15	62 ± 7	4,0 ± 1,1

In table are reported duration (in minutes), heart rate parameters as mean heart rate (HR, in beat per minute) and the percentage of maximal heart rate (%HR_{max}) and session rating of perceived exertion (s-RPE, in arbitrary units). Data are expressed as mean ± SD.

by Foster et al. (2001) by multiplying the whole session rating of perceived exertion by the session duration in minutes.

Statistical analysis.

Homogeneity of training load within and between training sessions at the individual and the team level was calculated: a) homogeneity of training intensity within individual players in a single training session was determined by the average coefficient of variation (CV) of individual HR data; b) homogeneity of training intensity within the team in a single training session was calculated based on the CV of average HR data; c) homogeneity of training intensity among the 9 training sessions was calculated as the average of the individual between-sessions CV of HR data.

Pearson product-moment correlations were performed to assess the relationship between the objective (%HR_{max}) and the subjective (s-RPE) indexes of intensity, based on individual data and on pooled team data for each session. Relationship between s-RPE and duration of the sessions was evaluated, too. Furthermore multiple linear regressions were calculated to investigate the influence of duration, %HR_{max} and time spent in the different heart rate zones on the s-RPE parameter, considering the individual data. Finally Pearson's correlations were also determined between the objective (SHRZ) and subjective (Foster TL) methods of quantifying training load, based on individual

data and on pooled team data for each session. Statistical significance was set at $p < 0,05$ for all comparisons.

RESULTS

The duration of the 9 training sessions ranged between 65 to 95 minutes (Table 2) with an average length of 79 ± 10 minutes.

Average training intensity was moderate as express by HR data (mean HR: 125 ± 8 bpm; mean %HR_{max}: 66 ± 4 %). Similar indications emerged by the analysis of the average values of session rating of perceived exertion: mean s-RPE was $4,3 \pm 0,7$, confirming a moderate intensity domain.

The average coefficient of variation of within individual HR data within training sessions was $17,9 \pm 1,0$ %, indicative of a low variability of the training intensity throughout the session.

A mean CV of within-session, between-subjects HR data equal to $10,3 \pm 1,6$ % is suggestive of a high homogeneity of training intensity within the team. No differences were detected in CV between playing subgroups or positions.

Finally, a $9,0 \pm 5,1$ % CV of HR among-sessions suggests a very low variability of training intensity among the 9 training days.

The correlation between s-RPE and %HR_{max}, based on 118 individual surveys, was significant yet moderate ($r = 0,41$, $p < 0,05$, Figure 1). A larger and significant correlation was found

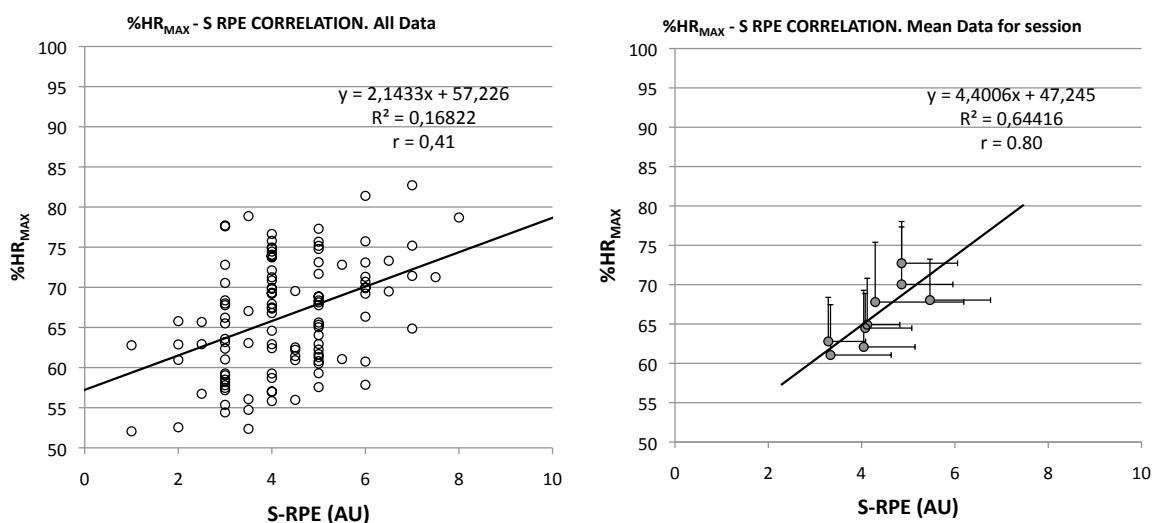


FIGURE 1. Relationship between objective (%Hr_{max}) and subjective (s-RPE) indexes of intensity. In the graph on the left are reported all the individual data recorded in the 9 training sessions. In the graph on the right, indexes are expressed as session team-averages.

between the session rating of perceived exertion and the duration of the sessions ($r=0,47$, $p<0,05$). When session team-averages rather than individual values were considered, significant and higher correlations were detected between %HR_{max} and duration and s-RPE ($r=0,80$, $p<0,01$ and $r=0,94$, $p<0,01$ respectively).

In order to investigate how much of the variability of the s-RPE index could be cumulatively explained by these two parameters (objective intensity and volume) a multiple

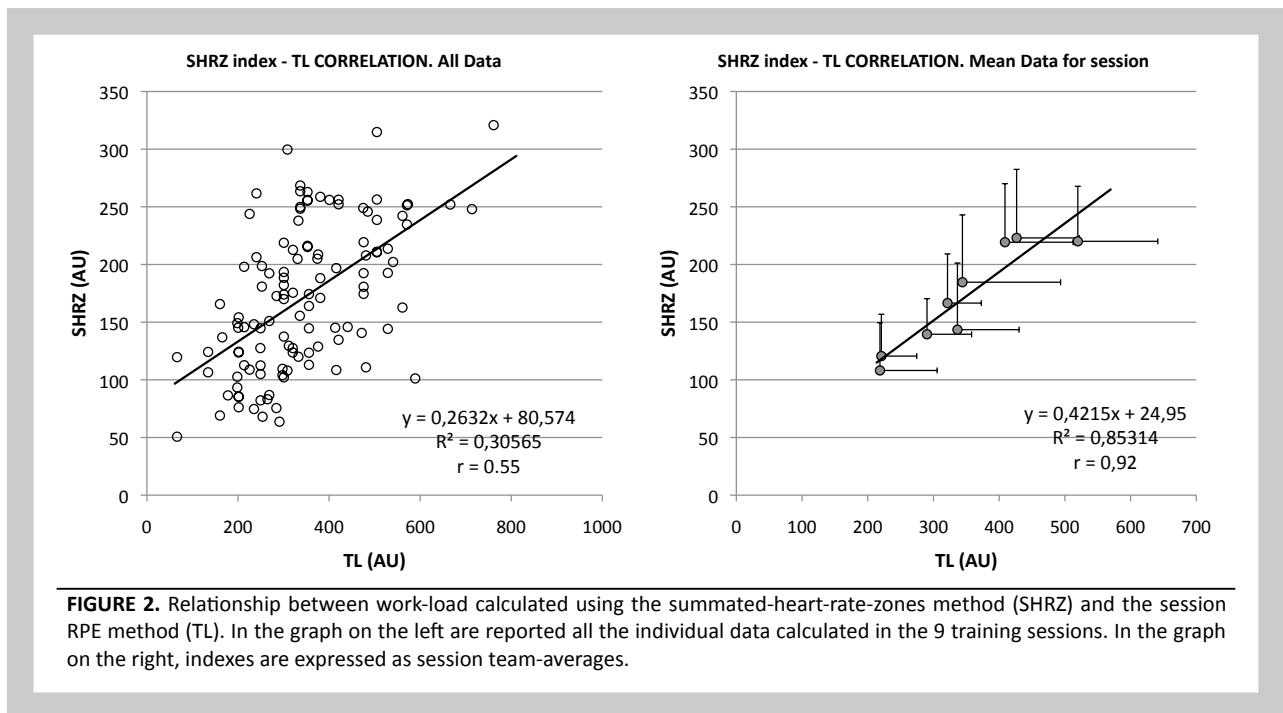
linear regression was calculated. All the independent variables significantly affect s-RPE ($r=0,54$, $p<0,05$) with the following equation: $s-RPE = -3,318 + (0,0535 \cdot \%HR_{max}) + (0,0514 \cdot \text{duration})$. These data suggest that exercise volume as well as of the objective intensity significantly affect the subjective perception of effort.

To investigate the possible differential contribution of the time spent in different intensity zones to the rating of perceived

TABLE 3. Objective and subjective indexes of work-load. Training sessions data

TRAINING SESSION	LENGHT (min)	SHRZ index (Au)	TL (Au)
07-12-10	67,2	121 ± 36	221 ± 54
14-12-10	95,1	220 ± 48	520 ± 122
28-02-11	84,2	219 ± 51	409 ± 104
07-03-11	88,2	223 ± 59	427 ± 95
15-03-11	80,2	185 ± 58	344 ± 149
22-03-11	65,7	108 ± 41	219 ± 87
29-03-11	71,2	140 ± 31	290 ± 68
05-04-11	78,2	167 ± 43	310 ± 51
12-04-11	83,2	144 ± 58	336 ± 94

In table are reported duration (in minutes), Edwards' Summated-heart-rate-zone index (SHRRZ, in arbitrary units) and Foster's Training load (TL, in arbitrary units). Data are expressed as mean ± SD.



exertion, a second multiple linear regression was performed with the time spent in the 5 Edward's zones as independent variables and the s-RPE as dependent variable. Only the time spent in the lowest (Z_1) and in the higher intensity zones (Z_4, Z_5) contributed significantly to predict the perceived exertion ($p < 0,05$). Objective (SHRZ) and subjective (TL) indexes of training load are reported in Table 3. SHRZ ranged from 122 to 231 Au with an average value of 180 ± 43 Au. Foster's training load (TL) had a mean value of 342 ± 98 Au. SHRZ and TL were significantly correlated ($r = 0,55$, $p < 0,01$ when individual data were considered; $r = 0,92$, $p < 0,01$ when session team-averages were used, Figure 2).

DISCUSSION

The aim of this study was to verify the applicability of the session-RPE method proposed by Foster to the specific contest of rugby union, analyzing the relationship between objective (HR-based) and subjective (s-RPE-based) indexes of training intensity and work-load.

Our findings confirm that the Foster's method can effectively be applied to define the load of rugby training sessions. In fact s-RPE and TL provide indexes strongly correlated with

subjective parameters, especially so with team averages.

There are a few studies that characterized the exercise load, during rugby matches (Morton 1978; Doutreloux *et al.* 2002; Cunniffe *et al.* 2009), in rugby-specific small-sided games (Kennett *et al.* 2011), and in rugby league training sessions (Gabbett 2006). On the contrary, this study is the first that investigated cumulative work-load of entire rugby union training sessions (including collective technical and tactical elements), applying both HR-based and s-RPE-based methods.

Training sessions were designed to elicit a work-load in the moderate-high range, with short resting periods and therefore a lower variability in exercise intensity compared to the actual game. Furthermore, the physical coach aimed at eliciting a homogeneous intensity among subjects and a high consistency in the training stimulus among the 9 sessions. The results corroborate these assumptions. In fact, during each session and between sessions, players experienced a homogeneous effort (within the team CV 10%, between sessions CV 9%) with no significant differences related to playing position.

Heart rate and s-RPE data confirm that, in our study, the mean training intensity was moderate and therefore much lower than that reported

for rugby union matches (Morton 1978; Doutreloux *et al.* 2002; Cunniffe *et al.* 2009) and for small-side rugby games (Kennett *et al.* 2011). The latter is not surprising due to the peculiarity of these training activities (limits on number of players and on field sizes, short duration). On the other hand, the intensity recorded was similar to that reported in a study on rugby league training sessions with analogue characteristics in terms of duration and contents (Gabbett 2006).

In summary, relative to duration, structure, content and intensity, the studied training sessions were representative of a typical session in rugby union for senior national-level players.

Regarding the comparison between indexes (subjective and objective) of exercise intensity, two issues arise from our data: a) correlations between HR and s-RPE are larger when session team-averages are considered;

b) s-RPE appears to be affected by exercise duration *per se* as well as by exercise relative intensity. When a multiple linear regression is applied, time and intensity both significantly affect s-RPE, with a similar coefficient. Furthermore, our data indicate that the time spent at the lowest (Z_1) and that spent at the higher exercise intensities (Z_4 and Z_5) mostly affect effort perception. This is somewhat surprising, since in the literature s-RPE has been proposed as an index of intensity (Seiler and Kjerland 2006). Two studies tested the effect of task duration and recovery time on RPE during interval training in the moderate and high intensity domain (Seiler and Sjørusen 2004; Seiler and Hetlelid 2005). These studies did not directly address the possible effect of exercise duration *per se* on the perceived intensity. Yet, they both clearly demonstrate a linear influence of task duration on RPE, at invariant absolute and relative intensity. The same studies exclude a modulation of recovery time and work-to-rest ratio on RPE. Few studies that examined the possible effect of duration on s-RPE during moderate intensity sessions. The above studies confirmed a small drift of RPE as a linear function of exercise duration and a non-significant yet visible effect on s-RPE. The studies concluded that the effect of duration on effort perception was negligible;

yet they speculated that such effect could be amplified for exercises of longer durations, intermittent near-maximal intensity and under inadequate recovery and/or glycogen depletion (i.e. under a paradigm that is more similar to the typical training session in team sports and to the conditions of our study).

Our study examined a relatively narrow range of exercise intensities. Therefore, we cannot exclude that, if a larger span of intensities would be evaluated, HR would have a stronger relationship with s-RPE; furthermore, intensity, as opposed to duration, could be the main determinant of effort perception. Yet, in the “ecological” setup evaluated in our study, s-RPE appears to be affected as much by intensity as by exercise duration.

In conclusion, our data suggest that: a) s-RPE may not be a valid method to substitute objective indexes of exercise intensity on an individual bases, while it is confirmed a good indicator at the team level; b) while more research is required to determine whether duration has an independent influence on s-RPE, our data suggest that a direct comparison of s-RPE of individual training sessions can be made when session durations are equal.

In agreement with the literature, our study shows that subjective (TL) and objective (SHRZ) indexes of training load are significantly correlated, for individual data and even more so for session team-averages. The correlation coefficients between objective and subjective indicators of training load are significantly higher compared to those observed for intensity indexes. It would seem that, when time is incorporated in a cumulative training load score, the strength of the association between objective and subjective indicators is improved. Yet, only if s-RPE were independent of duration, support would be provided for the concept of training load index. Otherwise, the effect of time in this model could be related to the fact that it is a common factor on both parameters.

In summary, our study applied and compared subjective and objective indexes of exercise intensity and training load and came to the conclusion that such indexes are highly correlated and therefore interchangeable when

team average data are considered. On the contrary, interchangeability between these indexes is not sufficiently reliable to allow avoidance of the monitoring of objective parameters in individual subjects. Furthermore, our study suggests a possible independent effect of duration on the perception of effort during typical and specific rugby union training sessions. More research is needed to clear if duration may be an integrated component of s-RPE and may independently predict training load and overtraining in team sports.

REFERENCES.

- Åstrand, P.-O. and K. Rodahl (1986). Textbook of work physiology : physiological bases of exercise. New York, McGraw Hill.
- Banister, E. W. (1991). Modeling elite athletic performance. In J.D. MacDougal, H.A. Wenger, & H.J. Green (Eds.), Physiological testing of the high-performance athlete. Campaign (IL), Human Kinetics Books.
- Barbero-Alvarez, J. C., A. Coutts, et al., 2010. The validity and reliability of a global positioning satellite system device to assess speed and repeated sprint ability (RSA) in athletes. *J Sci Med Sport*, **13**(2) pp. 232-5.
- Borresen, J. and M. I. Lambert, 2009. The quantification of training load, the training response and the effect on performance. *Sports Med*, **39**(9) pp. 779-95.
- Bot, S. D. and A. P. Hollander, 2000. The relationship between heart rate and oxygen uptake during non-steady state exercise. *Ergonomics*, **43**(10) pp. 1578-92.
- Brooks, J. H., C. W. Fuller, et al., 2008. An assessment of training volume in professional rugby union and its impact on the incidence, severity, and nature of match and training injuries. *J Sports Sci*, **26**(8) pp. 863-73.
- Coutts, A. J. and R. Duffield, 2010. Validity and reliability of GPS devices for measuring movement demands of team sports. *J Sci Med Sport*, **13**(1) pp. 133-5.
- Coutts, A. J., E. Rampinini, et al., 2009. Heart rate and blood lactate correlates of perceived exertion during small-sided soccer games. *J Sci Med Sport*, **12**(1) pp. 79-84.
- Coutts, A. J., P. Reaburn, et al., 2003. Validity of the session-RPE method for determining training load in team sport athletes. *J Sci Med Sport*, **6** pp. 525.
- Cunniffe, B., W. Proctor, et al., 2009. An evaluation of the physiological demands of elite rugby union using Global Positioning System tracking software. *J Strength Cond Res*, **23**(4) pp. 1195-203.
- Deutsch, M. U., G. A. Kearney, et al., 2007. Time - motion analysis of professional rugby union players during match-play. *J Sports Sci*, **25**(4) pp. 461-72.
- Deutsch, M. U., G. J. Maw, et al., 1998. Heart rate, blood lactate and kinematic data of elite colts (under-19) rugby union players during competition. *J Sports Sci*, **16**(6) pp. 561-70.
- Duthie, G., D. Pyne, et al., 2003. Applied physiology and game analysis of rugby union. *Sports Med*, **33**(13) pp. 973-91.
- Duthie, G., D. Pyne, et al., 2005. Time motion analysis of 2001 and 2002 super 12 rugby. *J Sports Sci*, **23**(5) pp. 523-30.
- Edwards, S. (1993). High performance training and rancing. Sacramento, CA, Feet Fleet Press.
- Foster, C., J. A. Florhaug, et al., 2001. A new approach to monitoring exercise training. *J Strength Cond Res*, **15**(1) pp. 109-15.
- Gabbett, T. J., 2006. A comparison of physiological and anthropometric characteristics among playing positions in sub-elite rugby league players. *J Sports Sci*, **24**(12) pp. 1273-80.
- Gabbett, T. J., 2006. Skill-based conditioning games as an alternative to traditional conditioning for rugby league players. *J Strength Cond Res*, **20**(2) pp. 309-15.
- Hughes, M. D. and R. M. Bartlett, 2002. The use of performance indicators in

- performance analysis. *J Sports Sci*, **20**(10) pp. 739-54.
- Impellizzeri, F. M., E. Rampinini, et al., 2004. Use of RPE-based training load in soccer. *Med Sci Sports Exerc*, **36**(6) pp. 1042-7.
- Kennett, D. C., T. Kempton, et al., 2011. Factors affecting exercise intensity in rugby-specific small-sided games. *J Strength Cond Res publish Ahead of Print*, pp. DOI 10.1519/JSC.0b013e31823a3b26.
- Lucia, A., J. Hoyos, et al., 2003. Tour de France versus Vuelta a Espana: which is harder? *Med Sci Sports Exerc*, **35**(5) pp. 872-8.
- Seiler, K. S. and G. O. Kjerland, 2006. Quantifying training intensity distribution in elite endurance athletes: is there evidence for an "optimal" distribution? *Scand J Med Sci Sports*, **16**(1) pp. 49-56.
- Seiler, S. and K. J. Hetlelid, 2005. The impact of rest duration on work intensity and RPE during interval training. *Med Sci Sports Exerc*, **37**(9) pp. 1601-7.
- Seiler, S. and J. E. Sjursen, 2004. Effect of work duration on physiological and rating scale of perceived exertion responses during self-paced interval training. *Scand J Med Sci Sports*, **14**(5) pp. 318-25.
- Tanaka, H., K. D. Monahan, et al., 2001. Age-predicted maximal heart rate revisited. *J Am Coll Cardiol*, **37**(1) pp. 153-6.
- Weineck, J. (2001). L'allenamento ottimale. Perugia, Calzetti Marucci.

CONCLUSIONS

The main aims of this project were:

a) to extend the knowledge on structural and functional characteristics of rugby players, monitoring two populations, Elite male players of the southern European region (Italian national team) and Elite woman players (Italian national team), that have been poorly studied by the previous research. The definition of new normative database would be useful to assess comparisons and to evaluate athletes in our specific regional contest.

b) to apply to the specific contest of rugby union a method of quantifying intensity and work-load that is widely used in other team sports but seldom in rugby: the heart rate (HR) recording method, and precisely to investigate the possibility to determine exercise intensity and work-load of two types of training session (Team Session and Unit Training) typically used in rugby union.

c) to verify the applicability of the session-RPE method proposed by Foster to the specific contest of rugby union, analyzing the relationship between objective (HR-based) and subjective (s-RPE-based) indexes of training intensity and work-load.

Our studies on anthropometric characteristics of elite male players and structural and functional characteristics of elite female rugby players provide update database for the referenced populations. The findings of the research on male athletes were similar to that reported in the literature for elite athletes of the Southern Hemisphere, confirming the improvements, at least under the physical point of view, of the Italian rugby from its entrance in the Six Nations Championship. Women results appear lower than reported in the scarce specific literature. This is probably due to the recent exposure to high-level international competition, and also to the still low number of players in a country where rugby is a minor sport. These findings may assist coaches of our specific regional contest in talent selection, addressing individual athletes to the role for which they are more suited and guide individualized training to match the demands of the game.

The study on the determination of work-load using the HR monitoring was the first to define exercise intensity of two types of typical rugby training sessions. The HR-based method of measuring exercise intensity proved to be useful and effective to determine the players physical effort on that rugby specific sessions. Furthermore, these parameters can be useful to establish the physical requirements of both training and match play, to identify role differences and to support training decisions.

The last study applied and compared subjective and objective indexes of exercise intensity and training load and came to the conclusion that such indexes are highly correlated and therefore interchangeable when team average data are considered. On the contrary, interchangeability between these indexes is not sufficiently reliable to allow avoidance of the monitoring of objective parameters in individual subjects. Furthermore, our study suggests a possible independent effect of duration on the perception of effort during typical and specific rugby union training sessions. More research is needed to clear if duration may be an integrated component of s-RPE and may independently predict training load and overtraining in team sports.