



# The Upper and Lower Body Aerobic Fitness of Semi-elite Rugby League Players

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## Abstract

**Objectives:** The aim of this study was to measure the upper and lower body aerobic capacity of semi-elite Rugby League (RL) players.

**Methods:** Twenty-two semi-elite RL players and 24 physically active but untrained men completed a maximal oxygen consumption test (VO<sub>2</sub> max test) on a treadmill and electronic arm ergometer in a randomized order. Percent body fat was calculated from the sum of six skinfolds.

**Results:** Lower and upper body absolute (P=0.03 and P=0.02 respectively) but not relative VO<sub>2</sub> max was higher in the RL group compared to the control group. Upper body peak power (P=0.001), ventilation (P=0.05) and lactate concentration (P=0.03) were higher in the RL group compared to the control group. Maximum heart rate was lower during arm ergometry for both groups (P ≤ 0.001) compared to predicted and treadmill values.

**Conclusions:** The results show that while semi-elite RL players have above average lower body aerobic capacity their upper body aerobic capacity is not well developed and similar to untrained men. Coaches and players need to implement separate and dedicated training programs to enhance the development of the upper body aerobic system in RL players. Upper body training should be based on maximal heart rate values achieved during upper body maximal testing.

**Keywords:** Maximal oxygen consumption; Arm ergometry; Rugby; High-intensity; Game; Fitness

## Introduction

The game of rugby league (RL) is a physically demanding game with frequent bouts of high-intensity activity separate by periods of low-intensity activity or rest. Players may cover distances of over 6-km during a game with an average work-to-rest ratio of approximately 1:5 although players may be required to spend longer periods involved in high-intensity activity with limited rest periods [1].

As a result, considerable physiological stress is placed on both the lower and upper body during a game. A high aerobic capacity is therefore essential to successfully compete in RL and reduce the chances of injury [2]. Although the lower body aerobic capacity or maximal oxygen consumption (VO<sub>2</sub> max) of elite and semi-elite RL players is well established [3] no data presently exists on the upper body VO<sub>2</sub> max of RL players.

A well-developed upper body VO<sub>2</sub> max is an important physiological adaptation for the modern RL player. During a game, players are required to complete a series of tackles whereby a player will take hold of the opponent by grabbing at their upper body whilst physically trying to push and pull them to the ground.

A team may make over 300 tackles per game [4] with some individuals players completing over 40 tackles per game [5]. The entire

time a player is performing a tackle they are trying to minimize the forward momentum of the opposition player.

This is the very same objective in wrestling where each combatant is trying to wrestle/grapple the opponent to the floor via pushing and pulling techniques [6]. Such is the importance of the tackle that many professional teams are now seen to employ wrestling/grappling coaches to better prepare players for the physical demands of RL.

While little is known on the upper body VO<sub>2</sub> max of RL players other sports that involve the upper body musculature such as wrestling [6], sailing [7] and kayaking [8] have well developed upper body aerobic systems.

In particular wrestlers whose sport closely resembles the upper body aerobic demands of RL, have been reported to have higher upper body VO<sub>2</sub> max (40-41 ml·kg·min<sup>-1</sup>) [9,10] compared to untrained individuals and athletes from other sports (20-32 ml·kg·min<sup>-1</sup>) that do not extensively use the upper body musculature [11].

Therefore the aim of this study was to measure the upper body VO<sub>2</sub> max of semi-elite RL players and compare them with physically active but untrained men of a similar age. A second aim was to examine the relationship between upper and lower body VO<sub>2</sub> max in semi-elite RL players.

We hypothesized that RL players would have a greater developed upper body VO<sub>2</sub> max compared to untrained individuals and that

there would be a strong relationship between upper and lower body VO<sub>2</sub> max.

## Methods

### Experimental approach to the problem

It is well established that RL players require a well-developed aerobic system to cope with the physiological demands of the game. However, little data exists on the aerobic capacity of the upper body of elite and semi-elite RL players.

Due to the high number of repetitive upper body muscular efforts in the game of RL, a well-developed upper body aerobic system is essential for performance and injury prevention. This study compared the upper and lower body aerobic capacity of semi-elite RL players with physically active males of a similar age. It was hypothesized that the semi-elite RL players would have significantly higher upper and lower body aerobic capacity compared to their physically active counterparts.

### Subjects

Twenty-two semi-professional rugby league players ( $21.6 \pm 2.5$  years, height  $182.2 \pm 6.1$  cm and weight  $92.6 \pm 7.7$  kg) and 24 physically active but untrained men (age  $22.1 \pm 2.4$  years; height  $174 \pm 8$  cm; weight  $75 \pm 11.5$  kg) volunteered to participate in the study. Following the screening procedure and the completion of a medical history questionnaire all participants were healthy and free from any cardiovascular or neuromuscular irregularities.

Prior to participation, the experimental procedures and potential risks were explained to the participants and all provided written informed consent. The study was approved by the University of the Sunshine Coast Ethics Committee and performed in accordance with the ethical standards of Harris and Atkinson [12].

### Procedures

The study adopted a randomized counter-balanced protocol in which half the participants completed the upper body VO<sub>2</sub> max while the other half completed the lower body VO<sub>2</sub> max. Four days following the initial testing this procedure was then reversed for the second VO<sub>2</sub> max.

All participants were familiarized with the testing procedures before the commencement of the study to reduce learning effects. All tests were conducted at the same time of the day with participants asked to avoid exhaustive exercise 48 h prior to testing and to avoid food and caffeine 3 h prior to testing.

### Maximal aerobic test

The upper body VO<sub>2</sub> max test was conducted on a modified electromagnetically braked cycle ergometer (EE) (Excalibur Sport, Lode B.V., Netherlands). The EE was fixed to a table with the table fixed to the ground to prevent any movement in the EE during the VO<sub>2</sub> max test.

Participants sat in a chair (also fixed to the ground) and were advised to keep their feet flat on the ground and remain seated throughout the VO<sub>2</sub> max test.

The seat height and back rest were adjusted so that with the crank position on the opposite side to the body and the hand grasping the

handles, the elbow joint was almost in full extension ( $165\text{-}175^\circ$ ) and the shoulders in line with the centre of the ergometers shaft.

After an initial warm-up of two minutes at 45 Watts, the test began at 60 Watts and increased one Watt every five seconds until volitional exhaustion or until fly wheel revolutions dropped below 60 rpm.

Lower body VO<sub>2</sub> max was assessed during a graded exercise test on a treadmill (Woodway, Waukesha, USA). After an initial warm-up of three minutes at  $6 \text{ km h}^{-1}$ , the test began at  $8 \text{ km h}^{-1}$  and speed increased by  $1 \text{ km h}^{-1}$  every 1 min until  $16 \text{ km h}^{-1}$  with grade increasing thereafter until exhaustion.

Cardiorespiratory-metabolic variables were measured using open circuit spirometry (Parvo-Medics True One<sup>®</sup> 2400 Metabolic Measurement System, Sandy, UT). Heart rate (HR) was measured via a HR monitor (Polar S610 HR Monitor, Polar Electro Oy, Kempele, Finland) strapped against the participant's chest.

During the progressive exercise test, each participant was encouraged to give a maximal effort. Maximal values for oxygen consumption were calculated from the average of the last minute of exercise before volitional fatigue.

VO<sub>2</sub> max was confirmed when three or more of the following criteria were met: (1) a plateau in VO<sub>2</sub> despite an increase in running speed/grade or ergometer power; (2) a respiratory exchange ratio (RER) higher than 1.20; (3) a heart rate within 10 bpm of its predicted maximum; (4) a lactate concentration higher than  $8 \text{ mmol l}^{-1}$ .

### Anthropometric measurements

The participants' height was measured with a wall-mounted stadiometer (Holtain Ltd, Crymych, and Wales). Body mass was measured with a beam balance scale (Avery Ltd, Fairmont, MN) with the participants wearing shorts only.

Skinfold thickness was measured by a highly qualified observer on the right side of the body at appropriately marked sites and recorded to the nearest 0.2 mm with a Harpenden caliper (range: 0.00-50.00 mm; minimum graduation: 0.20 mm; accuracy: 99.00%).

Skinfold thickness was measured at six sites (triceps, abdominal, subscapular, supraspinale, front thigh, medial calf) according to standardized anatomic locations and methods [13].

From the sum of skinfolds, body density was calculated using the formula for males aged 20-29 years of Durnin and Womersley [14] and percentage body fat estimated using the Yuhasz equation [15].

### Statistical analysis

The Standard descriptive statistics were obtained (mean and standard deviation) for all variables using SPSS (16.0, Chicago). Independent t tests were conducted to determine differences between groups for physiological parameters. Pearson r correlation was used to determine the relationship between upper and lower body VO<sub>2</sub> max. Significance was accepted at  $P \leq 0.05$ .

### Results

The RL players body mass and height were significantly ( $P \leq 0.001$ ) higher than the control group but there was no difference in the sum of six skinfolds and percent body fat between the two groups (Table 1). Lower and upper body absolute ( $P=0.03$  and  $P=0.02$  respectively) but

not relative VO<sub>2</sub> max was higher in the RL group compared to the control group.

|  | Rugby League Group (n=22) | Control Group (n=24) |
|--|---------------------------|----------------------|
| Age (yr)   | 21.6 ± 2.5                | 22.1 ± 2.4           |
| Body mass (kg)   | 92.6 ± 7.7*               | 75 ± 8.5             |
| Height (cm)  | 182.2 ± 6.1*              | 174 ± 8.2            |
| Sum of six skinfolds (mm)                                    | 106.5 ± 15                | 114.2 ± 22           |
| Percent body fat   | ± 3.7                     | 14.70 ± 4.1          |
| Data are mean ± SD; *Significantly different at p < 0.001.tT |                           |                      |

**Table 1:** Anthropometric measurements.

Upper body peak power (P=0.001), ventilation (P=0.05) and lactate concentration (P=0.03) were higher in the RL group compared to the control group. For the lower body only ventilation (P=0.04) was higher in the RL group compared to the control group (Table 2).

| Variable   | Rugby League Group | Control Group |
|--|--------------------|---------------|
| <b>Upper body</b>  |                    |               |
| VO <sub>2</sub> max  |                    |               |
| L·min <sup>-1</sup>  | 2.79 ± 0.37 *      | 2.38 ± 0.53   |
| ml·kg·min <sup>-1</sup>  | 31.1 ± 4.3         | 28.7 ± 4.7    |
| Peak power (W)   | 158 ± 13 **        | 135 ± 15      |
| Ventilation (L·min <sup>-1</sup> )   | 132.7 ± 29.1 *     | 111.6 ± 27.6  |
| RER  | 1.25 ± 0.04        | 1.27 ± 0.08   |
| Lactate (mmol l <sup>-1</sup> )  | 11.2 ± 1.3 *       | 9.3 ± 0.8     |
| <b>Lower body</b>  |                    |               |
| VO <sub>2</sub> max  |                    |               |
| L·min <sup>-1</sup>  | 4.53 ± 0.34 *      | 4.11 ± 0.51   |
| ml·kg·min <sup>-1</sup>  | 50.4 ± 4.2         | 48.7 ± 4.5    |
| Duration (min)   | 11:40 ± 1:30       | 11:15 ± 1:10  |
| Ventilation (L·min <sup>-1</sup> )   | 154.8 ± 19.8 *     | 135.5 ± 23.1  |
| RER  | 1.20 ± 0.04        | 1.22 ± 0.05   |
| Lactate (mmol l <sup>-1</sup> )  | 15.7 ± 1.8         | 16.5 ± 1.6    |
| VO <sub>2</sub> max: Maximal Oxygen Consumption; RER: Respiratory Exchange Ratio; *significantly different at p<0.05; **Significantly different at p<0.001 |                    |               |

**Table 2:** Upper and lower body maximal oxygen consumption data.

Maximum heart rate was lower during arm ergometry for both groups (P ≤ 0.001) compared to predicted and treadmill values. No correlation was found between the upper and lower body VO<sub>2</sub> max in either group.

## Discussion

Rugby League is a physically demanding game with frequent bouts of upper and lower body high-intensity activity requiring players to have a well-developed aerobic system. However little data exists on the upper body aerobic capabilities of RL players. Therefore the purpose of this study was to measure the upper body VO<sub>2</sub> max of semi-elite RL players and examine its relationship with lower body VO<sub>2</sub> max.

The present study found no difference in the upper body relative VO<sub>2</sub> max of RL players compared to the men of the control group. This was an unexpected result as the RL players participating in this study regularly train the upper body as part of their RL training. Their upper body training consists of boxing, rowing, arm grinding and various local muscular endurance exercises such as pull-ups and pushups. The upper body relative VO<sub>2</sub> max of the RL players in the present study (31 ± 4.3 ml·kg·min<sup>-1</sup>) is also similar to untrained men of a similar age (31-33 ml·kg·min<sup>-1</sup>) reported in other studies [16,17]. Therefore our evidence suggests that the upper body training by the RL players lacked sufficient stimulus to create adaptations in the upper body and improve their VO<sub>2</sub> max. Our study also further highlights the lack of transfer of training effects from the lower body to the upper body. Although the RL players may have had central cardiovascular changes due to large volumes of lower body aerobic training resulting in above average lower body VO<sub>2</sub> max (50 ± 4.2 ml·kg·min<sup>-1</sup>), changes in upper body VO<sub>2</sub> max have been shown to be primarily the result of peripheral adaptations in the trained muscle [18]. In support of these findings we found no correlation (data not shown) between upper and lower body VO<sub>2</sub> max in either the RL players or the control group. Furthermore the ratio of upper-to-lower body VO<sub>2</sub> max (62%) was similar to untrained men (56%) [17] and other sports that predominately use the lower body such as athletics (60%) [19] but lower than sports such as rowing and wrestling (69-75%) [6,20] that typically use both the upper and lower body aerobic systems.

A significant (p < 0.05) difference was found in the absolute VO<sub>2</sub> max of the upper and lower body of the RL players compared to the control group. The main reason for a difference in absolute but not relative VO<sub>2</sub> max is the larger body mass and in particular muscle mass of the RL players compared to the control group. Anthropometric data (Table 1) revealed higher body mass and height in the RL compared to the control group but no difference in the sum of six skinfolds and consequently per cent body fat. Although not measured directly we can assume from the anthropometric data that the RL players would have greater muscle mass (higher body mass with similar per cent body fat) compared to the control group which is consistent with previous research [21,22]. The higher muscle mass in the upper body of the RL players may also be the primary reason for the higher peak power and lactate achieved during their VO<sub>2</sub> max test.

While the lower body VO<sub>2</sub> max values achieved by the RL players in the present study are consistent with previous data [3], comparisons with upper body VO<sub>2</sub> max values are not possible due to a lack of studies in this area. Compared with other sports that have similar upper body aerobic demands as RL [6,9,20], the upper body VO<sub>2</sub> max (31 ± 4.3 ml·kg·min<sup>-1</sup>) of the RL players of the present study was not as high as expected. This may be due to the semi-elite players not being as aerobically fit as professional RL players with the fitness of players shown to increase as the level of playing competition increases [3]. In agreement with this, Baker et al. [23] also found that strength endurance of the upper body was a strong predictor of elite level RL players. Or as previously mentioned the RL players may not have completed sufficient upper body training to improve their VO<sub>2</sub> max.

Maximum heart rates were similar during the arm ergometer and treadmill VO<sub>2</sub> max tests for both the RL players and control groups.

As expected maximum heart rates were lower for both groups during arm compared to leg VO<sub>2</sub> max tests and predicted values (Figure 1).

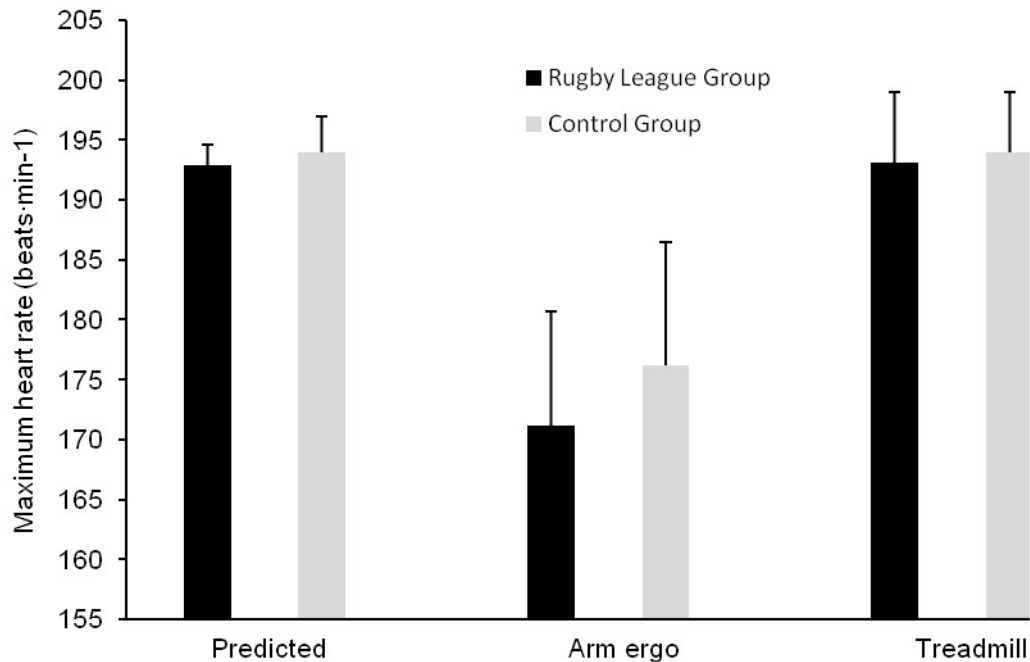


Figure 1: Comparison of maximum heart rate values from maximal exercise tests and predicted maximum values.

The ~20 beats·min<sup>-1</sup> difference is similar to other studies of trained and untrained men [11,20]. The difference in maximum heart between the upper and lower body VO<sub>2</sub> max tests highlights the need for exercise prescription for the upper body to be based on values achieved during arm ergometer and not predicted or maximal treadmill tests. Arm exercise based on the chronotropic response to treadmill testing or from predicted values may result in an improper target heart rate for arm training [11,24].

In conclusion, the high-intensity intermittent nature of professional Rugby League requires players to have a well-developed aerobic system to cope with the physiological demands of the game. A well-developed aerobic capacity is required for both the lower and upper body due to the large amount of running and wrestling/tackling. The results of our study show that while semi-elite Rugby League players have above average lower body aerobic capacity their upper body aerobic capacity is not well developed and similar to untrained men. Coaches and players need to implement separate and dedicated training programs to enhance the development of the upper body aerobic system in Rugby League players. Furthermore upper body training prescription should be based on maximal heart rate values achieved during upper body maximal testing. Future studies should examine the upper body aerobic capacity of elite Rugby League players and other sports that have similar upper body metabolic demands.

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