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A REVIEW OF THE PHYSIOLOGICAL AND ANTHROPOMETRICAL CHARACTERISTICS OF RUGBY LEAGUE PLAYERS

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ABSTRACT

To determine the anthropometric and physiologic characteristics of rugby league players based on a review of literature. Searches of PUBMED, CINHAL, OVID MEDLINE, SCOPUS, and SPORTDISCUS databases were performed for studies published in English from 1948 to May 2008. Terms utilized for the search of relevant research studies included anthropometric, physiologic, rugby league. Qualifying studies were mainly uncontrolled descriptive trials. Outcomes were body mass, sum of skinfolds, muscular power, speed, agility and estimated maximal aerobic power of rugby league players. Excess body fat has a detrimental effect on players' sporting performance. Forwards have a higher body mass than backs in most, but not in all published studies. Amateur forwards had a higher estimated body fat percentage (19.9%), lower body mass (90.8 kg), lower vertical jump height (38.1 cm) and lower estimated VO_{2MAX} (38.1 $ml{\cdot}kg^{-1}{\cdot}min^{-1}$) than semi-professional and professional players. Anthropometric and physiologic capacities of rugby league players and the physiologic demands of rugby league participation generally increase as the participation levels increase. However, there is evidence that player physiologic capacities may deteriorate as the season progresses. This has been shown to occur with increases in skin fold thickness and some decrement in players' maximal aerobic power and muscular power over a season.

Keywords: Rugby league; Anthropometric; Physiologic.

INTRODUCTION

Rugby league is an international team sport that consists of 13 players in each team. Junior and amateur rugby league matches are typically played under an unlimited interchange rule whereas professional/elite and semi-professional/sub-elite rugby league teams utilise up to 12 interchanges in competitions. Each team is permitted six tackles with the ball for a set of play and they must advance down the field into the opposition's territory and score a try (Gabbett, 2005f; Gabbett & Jenkins, 2008). The ball must be passed backwards but can be carried or kicked forward into the opposition's territory (Gissane *et al.*, 2002; Gabbett, 2005f). At the completion of the six tackles, the ball is immediately given to the opposition team to commence their set of six tackles (Gibbs, 1993; Gabbett, 2005f). The same players are therefore involved in both attack and defence.

The game is played under different rules depending upon player age. Children aged less than nine years play under mini-modified rules requiring play on a half sized field. There is no tackling, no kicking of the ball and no scrums contested in this age group (Corcoran, 1999). Children between 10 and 12 years old also participate in a modified rules version of the game that requires matches to be played on three-quarter sized fields. Tackles are allowed, there is limited kicking and they can contest for the ball in a scrum as in the full version of rugby league (Corcoran, 1999). For players over 13 years, the game is played under the international rules.

Similar to rugby union, the rugby league team consists of two main groups of players (six forwards and seven backs) on the field and four reserves that can be interchanged at the coach's discretion Meir *et al*., 2001b; Clark, 2002; Gabbett, 2005c). The demands on the players vary according to the specific positions played (Meir *et al*., 2001b; Gissane *et al*., 2001; Clark, 2002; Gabbett, 2005c) with forwards (prop n=2, hooker n=1, second row n=2 and lock n=1) more predominately involved in large numbers of physical collisions and tackles (Gabbett, 2004). Backs (half-back n=1, stand-off n=1, centre n=2, wing n=2 and fullback n=1) spent more time in free running but were also involved in tackles and collisions (Gabbett, 2004). There are four subgroups reflecting positional commonality are props, hookers and halves, back-rowers and outside backs Meir *et al*., 2001b; Clark, 2002; Gabbett & Jenkins, 2008).

As a result of the physical requirements and intense nature of the game, musculoskeletal injuries were common (Gabbett, 2003; Gabbett, 2005f; Gabbett & Jenkins, 2008). Player's competing in rugby league often undergo frequent bouts of high intensity activity (e.g. tackling, sprinting, running and passing) interspersed with short bouts of low intensity activity (e.g. jogging, walking and standing) (Meir *et al*., 1993; Brewer & Davis, 1995; Coutts *et al*., 2003a; Gabbett & Jenkins, 2008). As a result of the intermittent nature of the game, the physiologic demands of rugby league are complex. Players are required to have maximal aerobic power, speed, muscular strength and power and agility developed appropriately to be able to compete in the match environment (Meir *et al*., 1993; Brewer & Davis, 1995; Coutts *et al*., 2003a; Gabbett & Jenkins, 2008).

RATIONALE FOR REVIEW

Brewer and Davis (1995) originally published a review on the applied physiology of rugby league players in 1995. Since then there have been changes in the rules of rugby league, (Meir *et al*., 2001a; Orchard *et al*., 2003) development of new training techniques (Gabbett, 2002c) and more studies on the physiology of rugby league participants (Gabbett & Jenkins, 2008; Gabbett *et al*., 2008a; Gabbett *et al*., 2008b). The purpose of this paper was to present the available research in a comprehensive review further complimenting the already available studies on the applied physiology of rugby league.

OBJECTIVE

To investigate the anthropometric and physiologic characteristics of rugby league players based on a review of the current literature.

METHODS

Searches of PUBMED, CINHAL, OVID MEDLINE, SCOPUS, and SPORTDISCUS databases were performed for studies published in English up to and including May 2008. The computer databases provided access to sports-oriented and biomedical journals, serial publications, books, theses, conference papers, and related research published since 1948. Terms utilized for the search of relevant research studies included *anthropometric, physiologic, rugby league.* Qualifying studies were mainly uncontrolled trials. Outcomes were body mass, sum of skinfolds, muscular power, speed, agility, and estimated maximal aerobic power of rugby league players. All studies reported are on male rugby league participants unless otherwise stipulated.

FINDINGS

Twenty-six published studies have reported anthropometric and physiologic aspects of rugby league players (see table 1). Changes in the rules of rugby league have resulted in changes in the physiologic demands placed on players (Orchard *et al*., 2003; Gabbett, 2005d). Changes such as the move from a five metre (5-m) to a 10-m defensive line following each tackle (Meir *et al*., 2001a) and the introduction of the limited interchange replacement rule (Orchard *et al*., 2003; Gabbett, 2005d) have required different training techniques and increased aerobic, strength, endurance and anaerobic requirements (Meir *et al.,* 2001a).

TABLE 1: **ANTHROPOMETRIC AND/OR PHYSIOLOGIC ASSESSMENTS OF RUGBY LEAGUE PLAYERS BY PARTICIPATION LEVEL AND COUNTRY**

Playing population	Pre-season	Season duration
Professional	• England (Atkins, 2006) • Australia (O'Connor, 1992; Baker & Nance, 1999; Baker, 2001a; Baker, 2001b; Baker, 2001c; Baker, 2002; Baker & Newton, 2006; Gabbett, 2009)	• None
Female teams	• Australia (Gabbett, 2007)	• None
Semi-professional teams	• England (Atkins, 2006) • Australia (Brewer *et al*., 1994; Gabbett, 2002a; Coutts *et al.,* 2003a; Gabbett, 2009; Gabbett *et al*., 2008b) • New Zealand (King, 2007)	• None
Sub-elite teams	• Australia (Gabbett, 2000; Baker, 2001a; Baker, 2001b; Baker, 2002; Gabbett, 2002b; Gabbett, 2006a; Gabbett, 2006b; Gabbett, 2006c; Gabbett *et al*., 2008a)	• None
Amateur teams	• Australia (Gabbett, 2000)	• Australia (Gabbett, 2005a)
Masters teams	• None	• None
School-boy teams	• Australia (Baker, 2002)	• None
School-girl teams	• None	• None
Junior elite	• Australia (Gabbett, 2002b; Gabbett & Herzig, 2004; Gabbett, 2006a; Gabbett *et al*., 2009)	• None
Junior	• Australia (Baker, 2002; Gabbett, 2005b)	• Australia (Gabbett, 2005e)
Reviews	• Australia (Brewer & Davis, 1995; Gabbett, 2005f; Gabbett & Jenkins, 2008)	• None

Body composition

Meir *et al.* (2001b) showed that excess body fat and body mass had a detrimental effect on player sporting performance in areas such as aerobic capacity, thermoregulation and power to body mass ratio (Meir *et al*., 2001b). When comparing rugby league players to other team sports players from Australian football, soccer and rugby union, rugby league players had a higher body mass and percentage of body fat (Gabbett & Jenkins, 2008).

Although amateur level players had a percentage of body fat 31% higher than professional level players, (Gabbett, 2005f; Gabbett & Jenkins, 2008) the estimated percentage of body fat (calculated using the sum of four skinfolds (Durnin & Womersley, 1974)) and mean body mass measurements between forwards and backs were similar at all levels of participation (Brewer *et al*., 1994; Gabbett, 2000; Gabbett, 2005b). Although amateur players' body mass has varied, (Gabbett, 2005f; Gabbett & Jenkins, 2008) when comparing the different participation levels there have been no significant differences observed in the mean body mass between forwards and backs (see table 2).

TABLE 2: **COMPARISON OF ESTIMATED BODY FAT PERCENTAGES (± SD) AND BODY MASS (± SD OR 95% CI) AMONGST DIFFERENT PARTICIPATION LEVELS IN RUGBY LEAGUE**

	Estimated body fat (%)				Body mass (kg)			
	Forwards		Backs		Forwards		Backs	
	Mean	(±SD)	Mean	(±SD)	Mean	±SD or 95% CI	Mean	±SD or 95% CI
Professional (Brewer *et al*., 1994)	15.2	3.4	12.6	3.2	92.1	10.4	79.8	8
Semi-professional (Gabbett, 2005b)	17.6	4.4	15.2	4.1	-	-	-	-
Semi-professional 1st grade (Gabbett, 2002a)	-	-	-	-	97	10	88.7	7
Semi-professional 2nd grade (Gabbett, 2002a)	-	-	-	-	89	13	84	7
Female elite (Gabbett, 2007)	-	-	-	-	75.5	12.5	64.7	7.6
Amateur (Gabbett, 2000)	19.9	3.7	17.5	5	90.8	86.2-95.4	79.7	74.7-84.7
Junior elite (Gabbett & Herzig, 2004)	-	-	-	-	85.4	82.3-88.5	73.3	70.3-76.3
Junior sub-elite (Gabbett & Herzig, 2004)	-	-	-	-	78.1	74.3-81.9	66.5	63.8-69.2

CI: Confidence Interval

Forwards had a higher body mass than backs in most, (Larder, 1992; Stephenson *et al*., 1996) but not all (Meir *et al*., 1993) published studies. Body mass was the only physical characteristic that predicted selection into a first grade team (Gabbett, 2005f; Gabbett & Jenkins, 2008) or to be a forward or back (Gabbett, 2005f; Gabbett & Jenkins, 2008). The requirement for forwards to spend more time involved in physical collisions (Gabbett, 2005f) and tackles (Gabbett, 2005f; Gabbett & Jenkins, 2008) than backs may be reflective of the higher body mass and percentage of body fat recorded in this group (Ramsbottom *et al*., 1998).

A higher body mass may also assist forwards in the development of greater impact forces associated with match participation (Gabbett, 2002b) and may act as a means of protection

from impact injuries (Gabbett & Herzig, 2004). However, no scientific evidence exists to refute or support this (Gabbett, 2007). There have been no studies evaluating body compartment models for body composition characteristics (i.e., bone mass, fat mass, muscle mass, and residual mass), nor proportional anthropometric characteristics using the Phantom stratagem and predication of performance.

Anaerobic endurance

As rugby league is characterised by intermitted efforts of low to high-intensity activity that uses both the aerobic and anaerobic pathways (Brewer & Davis, 1995) these are important criteria for performance in rugby league (Atkins, 2006) and are utilised during repeated short-term explosive efforts such as tackling, sprinting and scrummaging (Brewer & Davis, 1995; Meir *et al*., 2001a). The demands of completing repetitive 10-m movements up and back, and tackling the opposition player to either a standstill or wrestling them to the ground, for six or more tackles in rugby league can place a high demand on the players' anaerobic glycolytic system (Holloway *et al*., 2008). Despite the requirements of anaerobic capacity in rugby league, anaerobic endurance is not currently systematically assessed in rugby league players (Holloway *et al.,* 2008).

Video analysis has identified that the mean (±SD) number of tackles made per defensive set in a match ranged from 3.7 ±1.5 to 4.0 ±1.2 for professional players and 3.3 ±1.8 to 3.4±1.5 for semi-professional players (Holloway *et al*., 2008). The mean time spent in a defensive set range from 37.0 to 47.0 seconds (professional 38.1 ±15.3 s to 46.9 ±13.6 s, and semi-professional 37.1 ±15.1 s to 38.3 ±18.5 s) (Holloway *et al.,* 2008).

Based on these performance demands, the triple 120-m shuttle test (T120S) was designed to evaluate the anaerobic system by mimicking the action of a defensive set (Holloway *et al*., 2008). The test requires completion of a set of six 10-m sprints combined with three simulated tackles. This test enables assessment of anaerobic endurance simulating tackles without the actual potential for injuries associated with tackling. The results were similar to video analysis of match data indicating that the average time in a defensive set was 42.5 ±1.7 s to 49.5 ±2.1 s (Holloway *et al*., 2008).

Maximal aerobic power

Maximal aerobic power (VO_{2MAX}) was reflective of the level of "cardiorespiratory" or "endurance fitness" of the participant (Tumilty & Darby, 1992; Tumilty, 2000). VO_{2MAX} of professional players is higher than that of other participation levels and is obvious when considering that professional players train upwards of five to six times a week and may perform multiple training sessions per day.

TABLE 3: **ESTIMATED MAXIMAL AEROBIC POWER (VO_{2MAX}) COMPARISONS OF FORWARDS AND BACKS BETWEEN DIFFERENT PARTICIPATION LEVELS**

	Forwards		Backs	
	VO^{2MAX}	± SD	VO_{2MAX}	± SD
Professional (Gabbett, 2002b)	56.4	-	55.4	-
Semi-professional 1st grade (Gabbett, 2002b)	45.8	4.4	48.0	3.6
Semi-professional 2nd grade (Gabbett, 2002b)	45.6	4.9	44.9	4.2
Semi-professional (Gabbett, 2005b)	50.5	4.8	54.1	4.3
Elite female (Gabbett, 2007)	32.2	4.4	35.3	3.4
Sub-elite 1st Grade (Gabbett, 2002b)	50.0	2.4	50.1	2.7
Sub-elite 2nd Grade (Gabbett, 2002b)	45.5	2.7	45.0	3.5
Sub-elite U19 (Gabbett, 2002b)	43.9	3.6	46.1	3.8
Sub-elite U16 (Gabbett, 2002b)	42.9	2.8	49.5	3.1
Sub-elite U15 (Gabbett, 2002b)	38.5	3.0	41.4	2.7
Sub-elite U14 (Gabbett, 2002b)	40.5	5.0	40.8	3.8
Sub-elite U13 (Gabbett, 2002b)	32.1	2.5	36.2	2.4
Amateur (Gabbett, 2002b)	38.1	2.7	40.0	2.2

VO_{2MAX} expressed as ml.kg-1.min-1

Amateur players had a poorly developed maximal aerobic power (O'Connor, 1995) - between 20 to 42% lower than professional rugby league players' estimated mean VO_{2MAX}, (Brewer *et al*., 1994) and was attributed to a low playing intensity, infrequent matches of short duration and an inadequate training stimulus (Gabbett, 2002a). A higher percentage body fat may also contribute to the lower estimated mean VO_{2MAX} at this level of participation (Gabbett, 2000). When comparing positional VO_{2MAX} differences of rugby league players, backs and forwards were similar suggesting that positional fitness training was similar for all playing positions (see table 3). A study on sub-elite under 16 year-old rugby league players identified that backs had a significantly higher mean VO_{2MAX} (49.5 ml.kg-1.min-1) than forwards (42.9 ml.kg-1.min-1) (Gabbett, 2002b) and the volume and intensity of training differed between forwards and backs in this age group of players (Gabbett, 2002b). Despite the similarities between forwards and backs at amateur, semi-professional and professional levels of participation, when different positional groups in rugby league were compared, they had significantly different estimated mean VO_{2MAX} scores (see table 4).

TABLE 4: **ESTIMATED MAXIMAL AEROBIC POWER (VO_{2MAX}) COMPARISONS BETWEEN DIFFERENT PLAYING POSITIONS IN RUGBY LEAGUE**

Level	Prop		Hooker		Second Row		Lock		Half-Back		Five-eighth		Centre		Wing		Fullback	
	VO_{2MAX}	Range	VO_{2MAX}	Range	VO_{2MAX}	Range	VO_{2MAX}	Range	VO_{2MAX}	Range	VO_{2MAX}	Range	VO_{2MAX}	Range	VO_{2MAX}	Range	VO_{2MAX}	Range
Semi-Professional (King, 2007)	48.33	-	48.94	-	55.42	-	51.44	-	55.42	-	51.73	-	55.14	-	54.57	-	55.42	-
Sub-elite (Gabbett, 2006a)	42.6	(± 6.5)	46.7	(± 7.0)	44.4	(± 6.9)	46.1	(± 5.4)	47.3	(± 6.2)	45.5	(± 5.3)	46.6	(± 6.2)	45.2	(± 6.7)	47.0	(± 5.8)
Junior (Gabbett, 2005b)	42.2	-	46.9	-	45.1	-	44.6	-	50.5	-	48.3	-	47.1	-	45.7	-	47.8	-

VO_{2MAX} expressed as ml.kg-1.min-1

Only a few studies have documented changes in VO_{2MAX} of characteristics over a competitive season (see table 5) and have shown that the greatest improvements occurred in the early stages of the season but deteriorated towards the end of the season (Gabbett, 2005a; Gabbett, 2005e). This deterioration has been suggested as a result of decreased training loads, increased match loads and high injury rates, (Pyne *et al*., 2003; Gabbett, 2005a) along with a high overall playing intensity and residual fatigue associated with limited recovery time between matches (Gabbett, 2005a).

TABLE 5: **ESTIMATED MAXIMAL AEROBIC POWER (VO_{2MAX}) CHANGES OVER A COMPETITIVE SEASON FOR AMATEUR AND JUNIOR PLAYERS**

	Amateur (Gabbett, 2005a) Training		Junior (Gabbett, 2005e) Training	
	VO_{2MAX}	95% CI	VO_{2MAX}	95% CI
Off season	42.0	(38.8-45.1)	43.7	(39.9-47.5)
Pre season	48.5	(46.1-50.9)	50.6	(48.5-52.8)
Mid season	51.3	(49.6-52.9)	53.5	(51.7-55.3)
End season	49.6	(47.5-51.7)	52.1	(50.5-53.8)

VO_{2MAX} expressed as ml.kg-1.min-1

Speed and sprint ability

The requirement to move quickly to reposition themselves in attack and defence is essential for rugby league players (Gabbett & Herzig, 2004). Professional rugby league studies have identified that forwards rarely sprint further than 10-m and all players rarely sprint distances greater than 40-m in a single bout of intense activity (Gabbett, 2000). Although there were no significant differences between forwards and backs for 10-m speed, forwards were consistently slower over 40-m than backs (Gabbett, 2002a). This was similar for junior sub-elite players where there were no significant differences for 10-, 20- and 40-m sprint speeds (Gabbett, 2002a; Gabbett 2002b; Gabbett & Herzig, 2004) but, like other studies, forwards were consistently slower than backs (Gabbett & Herzig, 2004).

Amateur rugby league players (Gabbett, 2007) were predictably slower in sprint speeds than semi-professional (Clark, 2002) and professional (O'Connor, 1996) levels of participation. Female players (Gabbett, 2006a) recorded even lower sprint speeds. Backs were predictably faster than forwards at all participation levels (see table 6).

TABLE 6: **SPRINT SPEED OF FORWARDS AND BACKS BY PARTICIPATION LEVEL**

Level	Position	Sprint distance							
		10-M	95% CI	20-M	95% CI	30-M	95% CI	40-M	95% CI
Professional (Meir *et al*., 2001b)	Forward	-	-	-	-	-	-	5.27	-
	Back	-	-	-	-	-	-	5.08	-
Professional (Meir, 1993)	Forward	-	-	-	-	-	-	5.04	-
	Back	-	-	-	-	-	-	4.88	-
Professional (Clark, 2002)	Forward	1.88	-	3.18	-	4.39	-	5.57	-
	Back	1.79	-	3.07	-	4.14	-	5.28	-
Semi-professional 1st grade (Gabbett, 2002a)	Forward	2.19	-	3.56	-	4.94	-	6.12	-
	Back	2.09	-	3.38	-	4.68	-	5.86	-
Semi-professional 2nd grade (Gabbett, 2002a)	Forward	2.20	-	3.56	-	4.80	-	6.12	-
	Back	2.18	-	3.52	-	4.80	-	6.02	-
Elite (Gabbett & Herzig, 2004)	Forward	1.88	(1.85-1.91)	-	-	-	-	5.64	(5.53-5.75)
	Back	1.82	(1.79-1.85)	-	-	-	-	5.45	(5.38-5.52)
Sub-elite (Gabbett & Herzig, 2004)	Forward	2.19	(2.14-2.24)	-	-	-	-	6.25	(6.10-6.40)
	Back	2.12	(2.06-2.18)	-	-	-	-	5.98	(5.88-6.08)
Sub-elite 1st grade (Gabbett, 2002b)	Forward	2.05	(1.97-2.13)	3.38	(3.28-3.48)	-	-	5.86	(5.76-5.96)
	Back	1.98	(1.93-2.03)	3.28	(3.21-3.35)	-	-	5.69	(5.58-5.80)
Sub-Elite 2nd grade (Gabbett, 2002b)	Forward	2.14	(2.09-2.19)	3.50	(3.43-3.57)	-	-	6.09	(5.94-6.24)
	Back	2.08	(1.97-2.19)	3.34	(3.22-3.46)	-	-	5.81	(5.64-5.98)
Sub-elite U19 (Gabbett, 2002b)	Forward	2.19	(2.10-2.28)	3.57	(3.46-3.68)	-	-	6.20	(6.01-6.39)
	Back	2.19	(2.09-2.29)	3.53	(3.41-3.65)	-	-	6.01	(5.85-6.17)
Sub-elite U16 (Gabbett, 2002b)	Forward	2.22	(2.15-2.29)	3.61	(3.51-3.71)	-	-	6.17	(6.00-6.34)
	Back	2.17	(2.10-2.24)	3.55	(3.46-3.64)	-	-	6.00	(5.87-6.13)

Level	Position	Sprint distance							
		10-M	95% CI	20-M	95% CI	30-M	95% CI	40-M	95% CI
Sub-elite U15 (Gabbett, 2002b)	Forward	2.25	(2.20-2.30)	3.72	(3.61-3.83)	-	-	6.58	(6.32-6.84)
	Back	2.21	(2.13-2.29)	3.62	(3.53-3.71)	-	-	6.26	(6.14-6.38)
Sub-elite U14 (Gabbett, 2002b)	Forward	2.44	(2.34-2.54)	3.99	(3.79-4.19)	-	-	7.00	(6.40-7.60)
	Back	2.24	(2.15-2.33)	3.70	(3.51-3.89)	-	-	6.47	(6.08-6.86)
Sub-elite U13 (Gabbett, 2002b)	Forward	2.60	(2.53-2.67)	4.24	(4.14-4.34)	-	-	7.50	(7.29-7.71)
	Back	2.46	(2.38-2.54)	4.04	(3.92-4.16)	-	-	7.11	(6.87-7.35)
Elite females (Gabbett, 2007)	Forward	2.04	-	3.60	-	-	-	6.59	-
	Back	1.96	-	3.44	-	-	-	6.33	-
Amateur (Gabbett, 2000)	Forward	2.62	(2.57-2.67)	-	-	-	-	6.79	(6.69-6.89)
	Back	2.53	(2.43-2.63)	-	-	-	-	6.45	(6.35-6.55)

Data reported as means. CI Confidence Interval

Given that repeat-sprint ability is important in rugby league it is surprising that relatively few studies have investigated the repeated-sprint ability of rugby league players. Players were often required to sprint from the defensive line, make a tackle, chase from marker defence, and then recover to enable a repeat of these activities. The repeated sprint ability test is specifically designed to test the athlete's ability to perform in short bursts of high intensity exercise over a series of multiple efforts (O'Connor, 1996; Clark, 2002). Of the two studies (O'Connor, 1996; Clark, 2002) published on repeat-sprint ability, one (Clark, 2002) used a 8 x 40-m repeat sprint test while the other study (O'Connor, 1996) used a 6 x 40-m repeat sprint test. There were no significant differences between player positions in professional rugby league players with the 8 x 40-m sprints test (Clark, 2002) but when compared with the 6 x 40-m sprint test there were significant differences amongst the different playing positions (Webb & Lander, 1983). Props had the highest speed decrement (7.1%) followed by outside backs (6.2%), back-rowers (6.2%) (Meir, 1993). Halves and hookers recorded the lowest speed decrement at 5.1% (Roozen, 2004).

Although forwards recorded a slower total time to complete the repeat-sprint ability test than backs (35.02 vs. 33.65 s) they recorded a lower speed decrement than backs (5.8% vs. 6.4%) (O'Connor, 1996; Clark, 2002). A limitation to conducting this test is that repeated sprint efforts in rugby league can vary in distance and recovery duration (O'Connor, 1996). Meir *et al.'s* (1993) study on time-motion activities of professional rugby league players identified that for every four seconds of high-intensity activity, approximately 30–80 seconds of low-intensity followed. However, further research is required to provide information on the repeated demand of rugby league at all levels of participation (O'Connor, 1996).

Agility

Described as "a rapid whole body movement with change of velocity or direction in response to a stimulus", (Sheppard *et al*., 2006) agility is an essential component for rugby league. Players are required to rapidly accelerate, decelerate and change direction (Meir *et al*., 1993).

There are several agility tests (Gabbett *et al*., 2008b) such as the Illinois agility (see table 7), 'L' agility (see table 8), 505 test (see table 9), Modified 505 test, glycolytic agility (see table 10) and the reactive agility test (Gabbett *et al*., 2008b) and other 'novel' (Baker & Newton, 2008) tests. Inter-study comparisons were difficult to undertake because of the different tests utilised, and a further limitation of the current studies is that none of the tests assess perceptual components of agility, (Gabbett *et al*., 2008b) a key component of rugby league.

TABLE 7: **ILLINOIS AGILITY PUBLISHED RESULTS BY PARTICIPATION LEVEL**

	Forwards		Backs		All Players	
	Mean	95% CI	Mean	95% CI	Mean	95% CI
First grade (Gabbett, 2002a)	17.2 ±1.0[a]	-	16.6 ±0.7[a]	-	16.9 ±0.9[a]	-
First grade (Gabbett, 2002b)	17.2[b]	(16.6-17.8)	17.4[b]	(16.7-18.1)	-	-
Second grade (Gabbett, 2002a)	17.2 ±1.2[a]	-	17.5 ±1.4[a]	-	17.4 ±1.3[a]	-
Second grade (Gabbett, 2002b)	18.1[b]	(17.6-18.6)	17.7[b]	(17.3-18.1)	-	-
Under 19 (Gabbett, 2002b)	18.3[b]	(17.5-19.1)	17.9[b]	(17.2-18.6)	-	-
Under 16 (Gabbett, 2002b)	19.4[b]	(18.5-20.3)	19.1[b]	(18.4-19.8)	-	-
Under 15 (Gabbett, 2002b)	19.5[b]	(18.5-20.5)	19.5[b]	(18.9-20.1)	-	-
Under 14 (Gabbett, 2002b)	21.1[b]	(19.4-22.8)	20.3[b]	(19.4-21.2)	-	-
Under 13 (Gabbett, 2002b)	22.0[b]	(21.5-22.5)	21.5[b]	(20.9-22.1)	-	-

All data reported in seconds (s). **a=** Data reported as mean (±SD). **b=** Data reported as mean (95% CI). CI = Confidence Interval

TABLE 8: **'L' AGILITY TEST PUBLISHED RESULTS BY PARTICIPATION LEVEL**

	Professional (Meir, 1993)		Sub-elite (Gabbett, 2006a)		Junior (Gabbett, 2005b)		1st grade (Gabbett *et al*., 2008b)		2nd grade (Gabbett, 2008b)	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Total[a]	-	-	-	-	-	-	6.36	±0.53	6.49	±0.40
Forwards[a]	5.46	±0.21	6.04a	±0.54a	5.99[c]	±0.31a	-	-	-	-
Backs[b]	5.37	±0.22	5.98a	±0.52a	5.90[c]	±0.12a	-	-	-	-
Prop[b]	-	-	6.36	±0.48	6.37	(6.21-6.52)	-	-	-	-
Hooker[b]	-	-	5.83	±0.60	5.86	(5.61-6.11)	-	-	-	-
Second row[b]	-	-	6.11	±0.60	6.10	(5.91-6.30)	-	-	-	-
Lock[b]	-	-	5.84	±0.47	5.64	(5.35-5.94)	-	-	-	-
Half-back[b]	-	-	5.93	±0.47	6.01	(5.79-6.24)	-	-	-	-
Five-eighth[b]	-	-	6.16	±0.64	5.71	(5.34-6.08)	-	-	-	-
Centre[b]	-	-	5.94	±0.44	5.89	(5.68-6.09)	-	-	-	-
Wing[b]	-	-	5.96	±0.54	5.98	(5.85-6.12)	-	-	-	-
Fullback[b]			5.89	±0.50	5.90	(5.72-6.08)	-	-	-	-

All data reported in seconds (s) **a=**Data reported as mean (±SD). **b=**Data reported as mean (95% CI). CI = Confidence Interval. c= calculated mean (±SD) of 'L' agility scores

TABLE 9: **505 AGILITY TEST PUBLISHED RESULTS BY PARTICIPATION LEVEL**

	Total	
	Mean	**SD or 95% CI**
Junior elite (Gabbett *et al*., 2009)	2.30 [a]	±0.13
Junior sub-elite (Gabbett *et al*., 2009)	2.38 [a]	±0.16
Elite Under 17 (Gabbett & Herzig, 2004)	2.36 [b]	(2.28-2.44)
Elite Under 16 (Gabbett & Herzig, 2004)	2.40 [b]	(2.35-2.45)
Elite Under 15 (Gabbett & Herzig, 2004)	2.45 [b]	(2.41-2.49)
Sub-elite Under 17 (Gabbett & Herzig, 2004)	2.68 [b]	(2.60-2.76)
Sub-elite Under 16 (Gabbett & Herzig, 2004)	2.85 [b]	(2.80-2.90)
Sub-elite Under 15 (Gabbett & Herzig, 2004)	2.89 [b]	(2.85-2.93)
Sub-elite forward (Gabbett & Herzig, 2004)	2.77 [b]	(2.72-2.82)
Sub-elite backs (Gabbett & Herzig, 2004)	2.76 [b]	(2.61-2.91)
Elite forwards (Gabbett & Herzig, 2004)	2.45 [b]	(2.41-2.49)
Elite backs (Gabbett & Herzig, 2004)	2.38 [b]	(2.34-2.42)
First grade (Gabbett *et al.,* 2008b)	2.34 [a]	±0.20
Second grade (Gabbett *et al*., 2008b)	2.39 [a]	±0.15

All data reported in seconds (s)
a= Data reported as mean (±SD). **b=** Data reported as mean (95% CI).
CI = Confidence Interval.

TABLE 10: **GLYCOLITIC AGILITY TEST PUBLISHED RESULTS BY PARTICIPATION LEVEL**

		Mean	SD or Range
Professional (O'Connor, 1996)	Backs [a1]	45.3	±3.33
	Halves [a2]	45.89	±3.03
	Back row [a3]	46.55	±2.73
	Props	46.71	±2.89
	Hookers	46.20	±2.84
Professional (O'Connor, 1992)	Backs	44.92	(40.20-51.90)
	Forwards	46.67	(41.83-52.32)
	Under 21	46.01	(40.27-51.90)
	Reserve grade	46.00	(40.20-52.32)
	First grade	45.09	(40.20-52.30)
Elite women (Gabbett, 2007)	Forwards	53.1	±2.6
	Backs	51.6	±3.7
	Hit-up forwards	53.5	±2.9
	Adjustables	51.9	±1.7
	Outside backs	51.2	±5.1

All data reported in seconds (s) a1= Fullback, wing, centre; a2= five eight/stand-off, half-back; a3= lock, second row

More recently other agility tests more specific to rugby league have appeared in the literature. A 'novel' test used on professional and semi-professional players required a 40-m distance to be covered incorporating two 45º and a single 135º turns to be made (Baker & Newton, 2008). It was thought that this would mimic some aspects of movement when players were defending (Baker & Newton, 2008) although no results have been presented. The Reactive Agility Test (RAT) initially utilised in netball, (Farrow *et al*., 2005) has been compared with change of direction speed and sprint speed (Sheppard *et al*., 2006; Gabbett *et al*., 2008c) and with other agility tests (Gabbett *et al*., 2008c) and appears relevant to rugby league. Superior movement speed (2.48 ±0.17 s vs. 2.60 ±0.16 s), decision times (55.3 ±43.6 ms vs. 78.2 ±40.4 ms) and response accuracy (89.3 ±13.9% vs. 84.0 ±17.3%) have been reported in first grade compared with second grade players (Gabbett *et al*., 2008c). There is practical utility of the RAT for assessment of perceptual components of agility in players (Gabbett *et al*., 2008 c).

Muscular strength and power

For rugby league players to be successful, one of the key characteristics is their capacity to generate high levels of muscular force (Meir *et al*., 2001b) to effectively tackle, lift, pull, and push opponents during match activities. Muscular strength and power are also essential requirements to enable leg drive to occur in the tackle (Gabbett & Jenkins, 2008).

There were many studies that have examined strength characteristics of rugby league players (O'Connor, 1996; Meir *et al*., 2001b; Baker, 2001a; Baker, 2001b; Baker, 2002). For example, Meir (1993) reported significant differences between forwards and backs for bench press (119 vs. 113 kg) and one-repetition maximum (1-RM) squat (188 vs. 168 kg). O'Connor (1996) confirmed these findings by reporting significantly greater three-repetition maximum (3-RM) squat, power-clean and bench-press in props (149.3 kg, 92.5 kg, 123.4 kg) and back rowers (143.5 kg, 86.8 kg, 112.4 kg) when compared with hookers (130.0 kg, 76.0 kg, 99.7 kg), halves (131.0 kg, 78.8 kg, 100.1 kg) and outside backs (135.6 kg, 81.4 kg, 106.0 kg) respectively.

In other studies (O'Connor, 1996; Baker & Nance, 1999; Baker 2001a; Baker, 2002) professional rugby league players had a 3-RM squat of 157.9 ±18.8 kg, a 3-RM bench press of 124.0 ±13.0 kg and a 3-RM power clean of 102.2 ±13.4 kg. Professional rugby league players, w hen compared with college aged, (Baker, 2001a) and junior high school aged rugby league players, (Baker 2002) had significantly greater maximal strength and power. This was attributed, in part, to the neural adaptations that have occurred with long-term periodised strength and power training that professional players undertake in their training regime (Gabbett & Herzig, 2004).

Some studies that have examined strength in rugby league players have used the vertical jump test to assess leg muscular power (Gabbett & Herzig, 2004). There is a progressive improvement in the muscular power as the participation level increased (see table 11), and one study (Gabbett *et al.,* 2009) identified that players that were selected to start in the first match of the season had a greater mean vertical jump score than the non-starters for both junior elite (52.6 ±7.8 vs. 49.4 ±7.5 cm) and junior sub-elite (46.8 ±7.3 vs. 45.9 ±7.7 cm) players.

TABLE 11: **VERTICAL JUMP SCORES OF FORWARDS AND BACKS BY PARTICIPATION LEVEL**

Study	Forwards		Backs	
	VJ (cms)	95% CI	VJ (cms)	95% CI
Semi-professional 1st grade (Gabbett, 2002a)	40.7	-	46.7	-
Semi-professional 2nd grade (Gabbett, 2002a)	43.7	-	40.2	-
Elite (Gabbett & Herzig, 2004)	51.1	(48.9-53.3)	54.1	(51.5-56.7)
Sub-elite (Gabbett & Herzig, 2004)	38.2	(35.2-41.2)	40.6	(38.0-43.2)
Sub-elite 1st grade (Gabbett, 2002b)	48.7	(42.1-55.3)	50.9	(47.5-54.3)
Sub-elite 2nd grade (Gabbett, 2002b)	41.0	(37.8-44.2)	42.9	(39.3-46.5)
Sub-elite Under 19 (Gabbett, 2002b)	37.9	(33.1-42.7)	40.0	(35.1-44.9)
Sub-elite Under 16 (Gabbett, 2002b)	38.0	(34.4-41.6)	41.2	(37.7-44.7)
Sub-elite Under 15 (Gabbett, 2002b)	34.7	(29.2-40.2)	37.1	(34.3-39.9)
Sub-elite Under 14 (Gabbett, 2002b)	33.1	(26.8-39.4)	38.5	(32.7-44.3)
Sub-elite Under 13 (Gabbett, 2002b)	28.2	(21.7-34.7)	30.8	(38.2-33.4)
Elite females (Gabbett, 2007)	35.1	-	35.7	-
Amateur (Gabbett, 2000)	37.1	(33.7-40.5)	39.3	(36.1-42.5)

Data reported as mean scores. CI = Confidence Interval. VJ = Vertical Jump.

Comparison of muscular strength positional groups using the vertical jump is limited as different authors have used either different positional group combinations (Gabbett, 2000; Gabbett, 2002a; Gabbett, 2005b; Gabbett, 2006a; Gabbett *et al.,* 2009) with either standard deviations (Gabbett, 2006a) or 95% confidence intervals (Gabbett, 2005b) for player positions (see table 12) and either standard deviations (Gabbett, 2006a) or 95% confidence intervals (Gabbett, 2005b) (see table 13) or a mean score for all players (Gabbett, 2000; Gabbett, 2002a; Gabbett *et al*., 2009) (see table 14). Different participation levels have varying results with no playing group or position recording greater vertical jump scores throughout all participation levels.

TABLE 12: **VERTICAL JUMP SCORES OF RUGBY LEAGUE POSITIONAL BY PARTICIPATION LEVEL**

Participation level	Positional group	Mean (cms)	(±SD)	(95% CI)
Professional (O'Connor, 1996)	Backs[a1]	45.3	3.3	-
	Halves[a2]	45.9	3.0	-
	Back row[a3]	46.6	2.7	-
	Props	47.6	2.9	-
	Hookers	46.2	2.8	-
Sub-elite (Gabbett, 2006a)	Props	43.4	9.0	-
	Hooker/Halves[b1]	47.7	10.3	-
	Back row[b2]	46.0	11.1	-
	Outside backs[b3]	48.3	10.6	-

Participation level	Positional group	Mean (cms)	(±SD)	(95% CI)
Elite Female (Gabbett, 2007)	Hit up forwards[c1]	34.3	8.6	-
	Adjustables[c2]	35.6	5.5	-
	Outside backs[c3]	37.0	7.0	-
Junior (Gabbett, 2005b)	Props	44.0	-	(41.6-46.4)
	Hooker/Halves[b1]	49.0	-	(46.2-51.7)
	Back row[b2]	48.2	-	(45.1-51.3)
	Outside backs[b3]	47.1	-	(45.1-49.1)

a1= Fullback, wing, centre; a2= five eight/stand-off, half-back; a3= lock, second row
b1= Hooker, halfback, five-eight/stand-off; b2= second row, lock; b3= centre, wing, fullback
c1= second row, prop; c2= hooker, half-back, five-eight/stand-off, lock; c3= centre, wing, fullback

TABLE 13: **VERTICAL JUMP HEIGHT SCORES OF RUGBY LEAGUE SPECIFIC POSITIONS BY PARTICIPATION LEVEL**

	Sub-Elite (Gabbett, 2006a)		Junior (Gabbett, 2005b)	
Playing position	**cm**	**(±SD)**	**cm**	**(95% CI)**
Prop	43.4	9.0	44.0	(41.6-46.4)
Hooker	50.9	10.5	47.9	(44.3-52.0)
Second row	45.7	10.5	49.0	(45.5-52.6)
Lock	46.6	12.4	45.2	(38.6-51.8)
Halfback	48.4	9.0	50.4	(45.8-54.0)
Five-eight	41.0	7.7	48.5	(43.0-54.0)
Centre	50.0	8.8	50.4	(46.9-53.9)
Wing	46.5	12.0	45.4	(42.6-48.2)
Fullback	47.4	11.9	42.8	(38.2-47.3)

TABLE 14: **VERTICAL JUMP HEIGHT SCORES OF RUGBY LEAGUE PLAYERS BY PARTICIPATION LEVEL**

	cm	**(±SD)**
Junior Elite (Gabbett *et al*., 2007)	51.6	7.7
Junior Sub-Elite (Gabbett *et al*., 2009)	46.9	6.8
Amateur (Gabbett, 2000)	38.1	7.1
Semi-Professional (Gabbett, 2002a)	42.5	8.8

Changes over a season

All but a few (Pyne *et al.,* 2003; Gabbett, 2005a) studies examining the physiologic and anthropometric characteristics of rugby league players have utilised cross sectional analysis. The studies that undertook a longitudinal review of the physiologic and anthropometric changes of rugby league players have highlighted the changes that occur as the season progresses for amateur (Gabbett, 2005a), semi-professional (Coutts *et al.,* 2003b) and junior elite (Gabbett, 2005e) rugby league. The early part of the season is where the greatest improvements occur (Gabbett, 2005e) but performance reportedly deteriorates as the season

progresses (see table 15). Early season improvements were attributed to high training loads that players underwent in preparation for the competition season whereas the deterioration of the players' fitness improvements was attributed to reductions in training loads throughout the season (Gabbett, 2005e).

TABLE 15: **BODY MASS, SUM OF SKINFOLDS, MUSCULAR POWER, SPEED, AGILITY AND ESTIMATED MAXIMAL AEROBIC POWER OF RUGBY LEAGUE PLAYERS DURING A COMPETITIVE SEASON BY PARTICIPATION LEVEL**

		Off-Season		Pre-Season		Mid-Season		End-Season	
		mean	95% CI	mean	95% CI	mean	95% CI	mean	95% CI
Body Mass (kg)	Amateur (Gabbett, 2005a)	84.2	(78.3-90.0)	82.0	(76.4-87.5)	84.5	(79.0-90.1)	86.2	(80.7-91.7)
	Junior (Gabbett, 2005e)	83.3	(72.2-94.3)	79.9	(74.1-85.8)	78.2	(72.8-83.7)	79.0	(73.7-84.4)
Sum of Skinfolds (mm)	Amateur (Gabbett, 2005a) [a]	90.7	(78.1-103.2)	84.7	(73.2-96.2)	84.3	(71.2-97.4)	93.4	(82.1-104.7)
	Junior (Gabbett, 2005e) [b]	93.9	(71.4-116.4)	85.2	(72.8-97.7)	83.6	(72.1-95.0)	84.4	(73.4-95.4)
10-m Sprint (s)	Amateur (Gabbett, 2005a)	1.83	(1.78-1.89)	1.85	(1.81-1.89)	1.80	(1.77-1.83)	1.80	(1.77-1.83)
	Junior (Gabbett, 2005e)	1.82	(1.75-1.90)	1.85	(1.81-1.88)	1.82	(1.78-1.86)	1.79	(1.76-1.82)
20-m Sprint (s)	Amateur (Gabbett, 2005a)	3.15	(3.05-3.24)	3.12	(3.06-3.19)	3.13	(3.08-3.18)	3.10	(3.06-3.14)
	Junior (Gabbett, 2005e)	3.12	(2.99-3.25)	3.11	(3.05-3.17)	3.13	(3.06-3.19)	3.09	(3.05-3.13)
40-m Sprint (s)	Amateur (Gabbett, 2005a)	5.61	(5.43-5.79)	5.61	(5.48-5.74)	5.62	(5.52-5.72)	5.53	(5.46-5.61)
	Junior (Gabbett, 2005e)	5.56	(5.30-5.82)	5.58	(5.76-5.92)	5.64	(5.51-5.77)	5.52	(5.45-5.58)
Agility (s)	Amateur (Gabbett, 2005a)	6.03	(5.88-6.18)	5.92	(4.82-5.02)	5.95	(5.74-6.16)	5.94	(5.82-6.06)
	Junior (Gabbett, 2005e)	5.93	(5.71-6.14)	5.84	(5.76-5.92)	5.55	(5.28-5.81)	5.82	(5.70-5.94)
Vertical Jump (cm)	Amateur (Gabbett, 2005a)	55.4	(52.1-58.8)	58.6	(56.0-61.2)	55.7	(53.2-58.1)	55.5	(53.6-57.4)
	Junior (Gabbett, 2005e)	54.8	(50.4-59.2)	58.2	(56.0-60.3)	56.8	(54.2-59.5)	57.8	(55.7-60.0)
VO_{2MAX} (ml.kg-1.min-1)	Amateur (Gabbett, 2005a)	42.0	(38.8-45.1)	48.5	(46.1-50.9)	51.3	(49.6-52.9)	49.6	(47.5-51.7)
	Junior (Gabbett, 2005e)	43.7	(39.9-47.5)	50.6	(48.5-52.8)	53.5	(51.7-55.3)	52.1	(50.5-53.8)

Data reported as means (95% confidence interval). VO_{2MAX} = estimated maximal aerobic power; a= sum of 7 skinfolds (Biceps, triceps, subscapular, supraspinale, abdomen, thigh, and calf on the right side); b= sum of four skinfolds (biceps, triceps, subscapular, and suprailiac).

CONCLUSION

This review summarised the available published data of anthropometric and physiologic characteristics of rugby league players. Physiological aspects of rugby league players can change during matches and over the participation season in regards to muscular power,

maximal aerobic capacity and skin-fold thickness. The resulting fatigue combined with the playing intensity has been suggested as a contributor to the incidence of injuries in rugby league players. More research is warranted on the physiologic aspects of amateur, junior and female players. Although there were some established data available this is typically from single teams at one level of participation and predominately for male players.

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