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Kinanthropometry of Group I rugby players in Buenos Aires, Argentina

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Abstract

The large variability in size and structure between playing positions in rugby merits specific kinanthropometric profiling. We aim to report detailed descriptive anthropometric data of a sample of 133 rugby players stratified by field positions (age 24.3 ± 3.6 years, body mass 89.5 ± 13.2 kg, and stature 178.8 ± 7.3 cm) belonging to seven Group I teams competing in the Buenos Aires Rugby Union, and to find out if front row forwards (FR) have larger muscle and skeletal parameters. Body composition was analysed with the five-way fractionation method, expressing tissue masses in absolute terms, relative to weight as percentages and to stature as phantom z-scores. Furthermore, somatotype, body mass index, sum of six skinfolds, and muscle-to-bone ratio were calculated. Players were subsequently grouped into three positional clusters and muscular-skeletal elements compared, showing FR to have larger proportional muscle and skeletal structure than remaining forwards and backs ($P < 0.001$), albeit a similar muscle-to-bone ratio ($P = 0.060$). When compared to a sample of the top six teams at the 2003 Rugby World Cup, the Buenos Aires players were considerably smaller, measuring, on average, 3–11 cm less in height and 6–13 kg less in weight.

Keywords: *Muscle mass, somatotype, proportionality, body composition, muscle-to-bone ratio*

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Introduction

Descriptive anthropometric characteristics offer a unique wealth of information that can be used to analyse the size, proportionality, and body composition of athletes. This athlete profiling can be used by health and sports science practitioners in rugby for the design of exercise and nutrition interventions to improve health and performance (Ackland, Elliott, & Bloomfield, 2009), for talent detection purposes (Pienaar, Spamer, & Steyn, 1998; Spamer & De la Port, 2006), in the analysis and modelling of physical aptitude characteristics specific to the sport (Carlson et al., 1994; Quarrie & Wilson, 2000), work rate (Rienzi, Reilly, & Malkin, 1999), evolutionary trends (Olds, 2001), comparisons between countries (Doutreloux, Artigot, & Thon, 2000), and injuries (Babic, Misigoj-Durakovic, Matasic, & Jancic, 2001b; Lee, Myers, & Garraway, 1997; Quarrie, Handcock, Toomey, & Waller, 1996). Because of the game's physical requirements and its relatively recent professionalisation in 1995, the size of rugby players has increased substantially (Olds, 2001), most likely due to a combination of factors such as higher selection pressures and improved talent identification, nutritional, training, and perhaps pharmacological strategies (use of anabolic steroids and/or growth hormone). If the potential for muscle growth could be assessed from bone breadth dimensions, this information could also prove very valuable.

It is surprising to find a relative absence of detailed anthropometric information of this popular sport, specifically by playing position and at a senior level. Casual observation shows rugby union to be characterised by the high degree of variation in the size and morphology of its players according to position; second rows are very different to hookers among the forwards, as fullbacks are from scrum halves within the backline. Published anthropometric information usually groups players into forwards and backs (Nicholas, 1997; Scott, Roe, Coats, & Piepoli, 2002) or into front row forwards (FR), remaining forwards (RF), and backs (BK) (Dacres-Mannings, 1998), or into other positional clusters such as props, hookers, locks, loose forwards, inside, midfield, and outside backs (Quarrie et al., 1996). This practice of grouping players is understandably necessary to achieve sufficient statistical power for comparison

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tests. When position-specific information is found in the literature, it is of limited anthropometric scope: only proportionality scores (Wilders & de Ridder, 2001), height, weight, and chest-to-waist ratio (Lee et al., 1997), weight only (Maso & Robert, 1999) from less developed competition leagues (Babic, Misigoj-Durakovic, Matasic, & Jancic, 2001a; Carlson et al., 1994) or from tournament rosters, which cast doubts on the authenticity of the data. Moreover, when body composition was reported, it was either measured with expensive high-technology such as DEXA (Dual Energy X-ray Absorptometry) (Bell, Cobner, & Evans, 2000), which is excellent for research purposes but unavailable and impractical for most sports science practitioners, or limited to informing percent body fat (Scott et al., 2002).

In rugby, a strength and power contact sport, it is most useful to have data on muscle mass. The only study to report muscle mass (Rienzi et al., 1999) was on seven-a-side players, the selection criteria for whom may differ from that of fifteen-a-side players due to the differing nature of the seven-a-side game. Because of the unusual strain placed on players in the front row of the scrum, as well as the collisions involved in game situations, data on bone structure and skeletal proportions are also important. Some studies do provide somatotype rating information on players (Carlson et al., 1994; Dacres-Mannings, 1998), but none specific to each playing position. Somatotype, which is another helpful analytical tool, provides descriptive information on shape and form, albeit not size (Carter & Honeyman Heath, 1990), which makes it hard to quantify body composition changes in units of mass from a rating score. The stratagem of using an algorithm for the lean body mass of rugby players, the lean mass index (Duthie, Pyne, Hopkins, Livingstone, & Hooper, 2006), paradoxically does not include any girth nor breadth measures, which serve as proxies for muscle or bone structure, nor any assessment of body part regional tissue development, which makes inter-group comparisons difficult, and is conceptually complex for most practitioners to comprehend and apply. Thus, trends in anthropometric reductionism together with many journals' disinclination to publish anthropometric descriptive studies (Olds, 2004) have left a void of information in this aspect of the sport.

The Buenos Aires Rugby Union (URBA) is composed of 80 clubs with 16,000 players, representing 45% of all players in Argentina (http://www.urba.org.ar/Acceso/nuevaimagen/historia.asp). About 2600 players are between the ages of 18 and 22 years, and a further 6125 make up the senior players in the URBA alone. Although still conserving its amateur status while the transition to professionalism is debated, the URBA Group I tournament encompasses 24 teams with about 800 players, and is the most competitive in the country. Raw estimates count a few hundred Argentine-born players playing professionally overseas, mainly in Europe, draining the local tournaments of its *prima-facie* talent, but also opening opportunities for talented younger players.

It was our goal to provide position-specific descriptive information on anthropometric characteristics as well as on size, shape, proportionality, and body fractionation of Group I rugby union players from the Buenos Aires, Argentina URBA championship. Second, we aimed to establish whether front FR have larger muscular–skeletal parameters than the other groups of players.

Methods

Subjects

Twenty-three anthropometric measurements were taken on 133 players from seven teams playing in Group I of the URBA championship during the 2003, 2004, and 2005 seasons. These teams finished in 2nd, 5th, 8th, 9th, 11th, 15th, and 21st places in the year they were measured. Subjects were informed of and agreed to the measurements as part of their routine evaluations, and approval was obtained from the respective club's medical authorities. In addition, the URBA Medical Ethics Committee oversaw and approved the study. The players were grouped by position into props, hookers, second rows (locks), and back rows (flankers plus number eights) in the forwards, and scrum halves, fly halves, centres, wings, and fullbacks in the backline. For the analysis of muscular-skeletal structure, players were subsequently grouped into task-specific clusters of FR (props and hookers), RF (locks and back rows), and BK. This subsequent grouping approach into three categories was necessary to obtain statistical power and minimise the number of analyses.

Anthropometry

Anthropometry was carried out by seven Level 2 and 3 anthropometrists, trained by the International Society for the Advancement of Kinanthropometry (ISAK), in accordance with the ISAK protocol (ISAK, 2001) immediately after pre-season training in March or during the first half of the tournament, when players tend to be leaner and more muscular (Holmyard & Hazeldine, 1993). Variables included body mass with portable strain gauge Aspen EB6571 scales (Zhongshan Jinli Electronic, China), height and sitting height with wall-mounted stadiometers and 50 cm high wooden boxes, large bone breadths with Campbell 20 sliding-branch calipers (Rosscraft SRL, Buenos Aires, Argentina), small bone breadth

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with Campbell 10 sliding-branch calipers (Rosscraft SRL), head, limb, and torso girths with metallic non-extendible tapes (Lufkin WP606, Rosscraft, Canada), and skinfolds with Harpenden calipers (Batty, UK). Skinfolds and torso girths (chest and waist), which normally carry a larger error in measurement, were measured in duplicate or triplicate (if the difference between the first two measures was greater than 1.0 mm in skinfolds, and 1.0 cm in girths) and the mean or median (for triplicate measures) value used. Time constraints limited other variables to single measurements.

Body composition, proportionality, somatotype, and derived indices

Body composition was calculated using the five-way fractionation method partitioning the body into anatomically defined adipose, muscle, residual, skeletal, and skin tissue masses (Kerr, 1988; Ross & Kerr, 1993); somatotype with the Heath-Carter Method (Carter & Honeyman Heath, 1990); and proportionality with the phantom stratagem (Ross & Marfell-Jones, 1991). The fractional masses of the five-way fractionation method were estimated from direct anthropometric measures, summed to yield a ''structured mass,'' and from which relative tissue percentages were calculated. The difference between ''structured mass'' and actual body mass, expressed in absolute terms and as a percentage of body mass, provided information on the error of the model. This difference was then proportionally adjusted to each tissue to yield a sum of individual tissue masses that was equal to the actual body mass. Indices calculated were body mass index (BMI) in $kg \cdot m^{-2}$, sum of six skinfolds (Σ 6 skf.) in mm, and muscle-to-bone ratio as kg muscle $\cdot$ kg bone^{-1}. The URBA sample was then compared to a sample of six of the top nine national squads (excluding Argentina) at the 2003 Rugby World Cup. Data on age, height, and weight per position were obtained from the tournament's roster (http://www.rwc2003.irb.com/EN/Tournament/Teams/index.htm). There was no description of how height and weight were measured in the national squads, nor are we certain that the data are entirely accurate.

Statistical analysis

Data were entered into Excel spreadsheets (Microsoft XP2000, Cupertino, USA), where body composition, somatotype and proportionality were calculated with the pertinent algorithms. Descriptive (mean $\pm$ s) and comparative statistics were calculated with SPSS software (version 11.5, Chicago, USA). Homogeneity of variance was tested with the Levene Test. An unpaired Student's *t*-test was used for the comparison between URBA and RWC2003 players, with statistical significance set at $P < 0.05$, and a one-way Analysis of Variance (ANOVA) with Tukey (Honestly Significant Difference) *post-hoc* Test for differences between the URBA players grouped as FR, RF, and BK in seven variables describing muscle and skeletal robustness. For the *post-hoc* comparisons, statistical significance was set at $P < 0.002$. The α level of 0.002 was arrived at by dividing the 0.05 α level by the number of comparisons carried out, as recommended by Dawson and Trapp (2001). Since three groups were compared for seven variables, an α level of 0.05 divided by 21 comparisons yielded an adjusted α level of 0.002.

Results

Descriptive characteristics of URBA Group I players per position

In Table I information on specific anthropometric variables is provided by position of play and as a whole. Table II provides information on body fractionation both relative to body mass (%) and in absolute terms (kg). There is also information on the proportionality of tissue masses, somatotype components, and indices such as sum of six skinfolds, body mass index, and muscle-to-bone ratio. Professionals and researchers in sports medicine might find this information useful for comparison purposes.

Differences with international 2003 Rugby World Cup players

When compared to a sample of six of the top nine teams competing at the 2003 Rugby World Cup (Table III), the URBA props, hookers, second rows, scrum halves, and fly halves were younger in age ($P < 0.024$ and less). There were no statistically significant differences in age for centres ($P = 0.614$), wings ($P = 0.099$), nor fullbacks ($P = 0.674$). URBA players had less weight at all positions ($P < 0.015$ and less), and were also shorter in height at all positions ($P < 0.001$) except for fly halves ($P = 0.108$) and fullbacks ($P = 0.114$). The BMI was not statistically significantly different for props ($P = 0.524$), hookers ($P = 0.918$), second rows ($P = 0.510$), scrum halves ($P = 0.639$), fly halves ($P = 0.074$), and centres ($P = 0.241$), but different for back rows ($P = 0.009$), wings ($P = 0.018$), and fullbacks ($P = 0.028$).

Differences among grouped playing positions

In Table IV, one-way ANOVA revealed statistically significant differences between the three groups in all muscular-skeletal structure variables ($P < 0.001$), except for muscle-to-bone ratio ($P = 0.060$).

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Table I. Descriptive anthropometry of URBA players by position (mean ± *s*).

	Prop ($n=22$)	Hooker ($n=10$)	Second row ($n=16$)	Back row ($n=22$)	Scrum half ($n=12$)	Fly half ($n=13$)	Centre ($n=18$)	Wing ($n=13$)	Fullback ($n=7$)	Total ($n=133$)
Basics										
Age (years)	24.5 ± 4.1	25.2 ± 3.2	23.9 ± 2.8	24.6 ± 3.6	24.2 ± 3.1	23.3 ± 3.5	25.2 ± 4.0	23.7 ± 3.9	24.2 ± 3.3	24.3 ± 3.6
Body mass (kg)	105.0 ± 10.0	94.6 ± 5.4	101.6 ± 8.2	90.4 ± 9.4	73.1 ± 5.7	81.5 ± 7.2	84.0 ± 7.1	78.2 ± 10.2	80.7 ± 4.6	89.5 ± 13.2
Stature (cm)	179.2 ± 3.2	173.7 ± 4.2	189.3 ± 4.4	181.8 ± 6.1	167.3 ± 3.9	177.4 ± 5.8	178.2 ± 4.5	175.9 ± 6.9	180.7 ± 4.4	178.8 ± 7.3
Sitting height (cm)	95.6 ± 2.5	93.1 ± 1.6	99.1 ± 2.5	96.1 ± 3.9	90.9 ± 2.3	95.0 ± 3.0	93.7 ± 2.8	93.4 ± 3.5	96.8 ± 2.3	95.0 ± 3.6
Breadths (cm)										
Biacromiale	42.5 ± 1.7	42.5 ± 1.9	43.1 ± 2.1	41.9 ± 2.0	38.4 ± 2.7	40.8 ± 2.3	41.8 ± 1.4	40.9 ± 2.1	40.7 ± 2.0	41.6 ± 2.3
Transverse chest	33.8 ± 1.5	32.1 ± 1.7	32.0 ± 1.5	31.4 ± 2.3	28.6 ± 1.3	30.6 ± 1.9	30.6 ± 1.4	29.9 ± 1.3	29.7 ± 1.1	31.2 ± 2.2
Antero-post. chest	24.2 ± 1.6	22.6 ± 2.1	22.3 ± 1.8	21.3 ± 1.5	20.2 ± 1.9	20.7 ± 1.3	20.8 ± 1.3	20.7 ± 2.3	19.5 ± 1.7	21.6 ± 2.1
Bi-cristale	31.0 ± 1.6	29.5 ± 2.0	30.9 ± 1.7	30.2 ± 1.9	26.9 ± 1.3	29.0 ± 1.7	29.2 ± 1.2	28.4 ± 1.0	28.9 ± 1.5	29.5 ± 2.0
Humerus	7.6 ± 0.4	7.4 ± 0.3	7.7 ± 0.5	7.5 ± 0.5	7.0 ± 0.3	7.2 ± 0.4	7.4 ± 0.3	7.2 ± 0.3	7.3 ± 0.2	7.4 ± 0.4
Fémur	10.9 ± 0.6	10.7 ± 0.3	10.9 ± 0.5	10.4 ± 0.5	9.8 ± 0.4	10.2 ± 0.4	10.2 ± 1.6	10.1 ± 0.5	10.2 ± 0.5	10.4 ± 0.6
Girths (cm)										
Head	58.8 ± 1.2	58.0 ± 1.4	58.9 ± 1.4	58.3 ± 1.7	56.5 ± 1.5	57.6 ± 1.6	57.6 ± 0.9	57.2 ± 1.4	57.3 ± 1.4	58.0 ± 1.6
Arm, relaxed	38.2 ± 1.8	36.8 ± 1.4	36.0 ± 2.5	34.2 ± 2.2	32.1 ± 1.7	33.1 ± 2.1	33.6 ± 1.6	32.3 ± 2.3	33.1 ± 1.3	34.6 ± 2.8
Arm, flexed	40.3 ± 1.9	38.7 ± 1.6	38.6 ± 2.7	36.9 ± 2.2	34.3 ± 2.0	35.5 ± 2.0	36.5 ± 1.6	35.3 ± 1.9	35.1 ± 1.0	37.1 ± 2.7
Forearm	31.5 ± 1.3	30.1 ± 1.3	31.0 ± 1.8	29.6 ± 1.3	27.8 ± 1.0	28.5 ± 1.2	29.6 ± 1.3	28.7 ± 1.4	28.5 ± 0.7	29.7 ± 1.7
Chest	113.8 ± 5.6	109.1 ± 4.2	109.0 ± 5.0	105.3 ± 4.7	97.5 ± 5.7	101.8 ± 4.6	102.4 ± 2.5	99.0 ± 5.6	101.3 ± 3.2	105.2 ± 7.0
Waist (min)	97.9 ± 6.3	92.9 ± 5.0	90.4 ± 5.8	87.1 ± 4.4	81.0 ± 4.2	84.0 ± 5.0	85.4 ± 3.8	80.4 ± 5.8	82.9 ± 2.8	87.8 ± 7.5
Upper thigh	68.2 ± 3.4	65.1 ± 3.8	65.1 ± 3.2	62.5 ± 3.8	57.9 ± 2.9	61.1 ± 3.1	60.8 ± 3.1	58.7 ± 3.6	59.6 ± 2.0	62.6 ± 4.6
Mid-thigh	63.3 ± 3.8	60.6 ± 3.2	59.7 ± 3.1	57.9 ± 3.8	54.9 ± 3.0	56.8 ± 3.3	55.9 ± 3.0	54.9 ± 3.4	54.8 ± 1.4	58.2 ± 4.4
Calf (max)	43.1 ± 2.5	41.3 ± 1.8	41.9 ± 2.1	40.0 ± 2.7	37.1 ± 1.5	38.4 ± 2.1	39.0 ± 1.9	38.3 ± 2.3	37.7 ± 2.2	40.0 ± 2.9
Skinfolds (mm)										
Triceps	15.4 ± 5.2	13.7 ± 3.6	12.3 ± 4.1	12.2 ± 5.3	8.9 ± 3.5	11.0 ± 3.2	9.3 ± 3.5	8.4 ± 3.1	9.2 ± 4.7	11.5 ± 4.7
Subscapulare	18.9 ± 5.7	15.5 ± 4.6	12.6 ± 4.9	11.5 ± 4.1	9.5 ± 1.9	11.3 ± 2.8	10.4 ± 2.5	9.4 ± 2.0	8.8 ± 2.0	12.5 ± 5.0
Supraspinale	18.0 ± 5.2	13.1 ± 4.2	10.8 ± 5.2	10.1 ± 3.5	7.9 ± 3.6	9.1 ± 3.2	8.2 ± 2.7	6.3 ± 1.7	6.7 ± 1.6	10.6 ± 5.3
Abdominale	31.4 ± 7.0	27.5 ± 7.1	21.6 ± 10.2	18.5 ± 6.6	14.9 ± 6.5	18.6 ± 7.4	18.7 ± 7.8	12.7 ± 5.5	14.4 ± 7.3	20.6 ± 9.3
Front thigh	17.6 ± 6.4	14.7 ± 3.0	14.2 ± 4.5	14.4 ± 7.5	13.6 ± 4.6	13.5 ± 3.8	10.8 ± 2.9	10.8 ± 4.3	12.6 ± 4.7	13.8 ± 5.5
Medial calf	12.8 ± 3.9	12.5 ± 2.6	12.1 ± 4.8	9.8 ± 3.3	8.4 ± 3.0	10.0 ± 3.1	7.6 ± 2.7	6.7 ± 2.2	7.2 ± 3.1	9.9 ± 4.0

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Table II. Body composition, somatotype, and selected indices (mean ± *s*) of URBA players by position.

	Prop ($n=22$)	Hooker ($n=10$)	Second row ($n=16$)	Back row ($n=22$)	Scrum half ($n=12$)	Fly half ($n=13$)	Centre ($n=18$)	Wing ($n=13$)	Fullback ($n=7$)	Total ($n=133$)
Fractionation										
Adipose										
(%)	25.6 ± 3.1	23.9 ± 1.4	24.3 ± 3.9	23.5 ± 3.5	21.6 ± 2.4	23.7 ± 3.0	21.7 ± 3.0	20.7 ± 2.8	21.9 ± 3.5	23.2 ± 3.4
(kg)	26.9 ± 4.3	22.6 ± 2.0	24.8 ± 5.4	21.4 ± 5.0	15.8 ± 2.7	19.2 ± 2.9	18.3 ± 3.3	16.3 ± 3.8	17.7 ± 3.2	21.0 ± 5.4
Phantom Z	−0.23 ± 0.65	−0.61 ± 0.48	−1.18 ± 0.75	−1.29 ± 0.67	−1.50 ± 0.62	−1.32 ± 0.53	−1.56 ± 0.47	−1.84 ± 0.42	−1.75 ± 0.58	−1.19 ± 0.78
Muscle										
(%)	48.2 ± 2.8	49.1 ± 1.6	49.2 ± 3.8	49.1 ± 2.7	50.3 ± 1.9	48.8 ± 2.8	50.5 ± 2.4	50.9 ± 2.1	50.3 ± 2.5	49.5 ± 2.7
(kg)	50.6 ± 5.4	46.4 ± 3.0	49.9 ± 4.7	44.3 ± 4.1	36.7 ± 2.7	39.8 ± 4.4	42.4 ± 3.9	39.8 ± 5.2	40.6 ± 3.1	44.1 ± 6.2
Phantom Z	3.90 ± 0.78	3.81 ± 0.82	2.38 ± 0.64	2.41 ± 0.60	2.67 ± 0.69	2.27 ± 0.62	2.54 ± 0.53	2.25 ± 0.89	1.95 ± 0.54	2.75 ± 0.93
Residual										
(%)	11.9 ± 0.8	11.9 ± 0.8	11.3 ± 0.7	11.3 ± 0.7	12.1 ± 0.9	11.6 ± 0.8	11.6 ± 0.8	11.8 ± 0.5	11.6 ± 1.1	11.7 ± 0.8
(kg)	12.6 ± 1.6	11.2 ± 0.9	11.5 ± 1.0	10.6 ± 1.2	8.8 ± 0.9	9.5 ± 1.2	9.8 ± 1.1	9.2 ± 1.3	9.3 ± 1.1	10.5 ± 1.7
Phantom Z	3.97 ± 1.17	3.52 ± 0.99	2.24 ± 0.87	2.28 ± 0.51	2.03 ± 0.86	1.87 ± 0.67	2.31 ± 0.87	1.82 ± 0.81	1.29 ± 0.62	2.49 ± 1.15
Skeletal										
(%)	10.1 ± 0.5	10.7 ± 0.5	10.6 ± 1.1	11.0 ± 1.1	10.9 ± 1.0	11.0 ± 0.7	11.4 ± 0.8	11.6 ± 1.3	11.2 ± 1.2	10.9 ± 1.0
(kg)	10.6 ± 1.1	10.1 ± 0.8	10.8 ± 1.1	9.9 ± 1.3	8.0 ± 0.9	9.0 ± 1.1	9.5 ± 0.6	9.0 ± 0.9	9.0 ± 0.9	9.7 ± 1.3
Phantom Z	1.12 ± 0.59	1.31 ± 0.76	0.21 ± 0.84	0.35 ± 0.72	0.33 ± 0.76	0.28 ± 0.43	0.51 ± 0.44	0.31 ± 0.93	−0.06 ± 0.54	0.52 ± 0.77
Skin										
(%)	4.2 ± 0.2	4.4 ± 0.3	4.5 ± 0.3	4.7 ± 0.3	5.1 ± 0.4	4.8 ± 0.3	4.8 ± 0.2	5.1 ± 0.3	5.0 ± 0.2	4.7 ± 0.4
(kg)	4.4 ± 0.3	4.2 ± 0.3	4.6 ± 0.2	4.2 ± 0.3	3.7 ± 0.2	3.9 ± 0.3	4.0 ± 0.3	4.0 ± 0.3	4.0 ± 0.3	4.2 ± 0.4
Error										
(%)	5.3 ± 4.0	3.1 ± 5.5	3.1 ± 4.2	3.2 ± 3.3	0.6 ± 5.1	4.8 ± 4.2	3.6 ± 3.1	1.7 ± 3.5	3.2 ± 3.5	3.4 ± 4.1
(kg)	5.4 ± 4.2	2.9 ± 5.3	3.3 ± 4.2	2.9 ± 3.1	0.5 ± 3.9	3.9 ± 3.5	2.9 ± 2.7	1.3 ± 2.8	2.5 ± 2.8	3.1 ± 3.8
Somatotype										
Endomorphy	4.9 ± 1.1	4.2 ± 1.0	3.2 ± 1.2	3.2 ± 1.0	2.7 ± 0.9	3.0 ± 0.8	2.7 ± 0.8	2.3 ± 0.6	2.3 ± 0.8	3.3 ± 1.3
Mesomorphy	8.1 ± 0.2	7.9 ± 0.7	6.5 ± 1.1	6.4 ± 1.0	6.6 ± 0.8	6.1 ± 1.0	6.5 ± 0.8	6.2 ± 1.0	5.6 ± 0.8	6.8 ± 1.2
Ectomorphy	0.2 ± 0.2	0.3 ± 0.2	1.3 ± 0.6	1.3 ± 0.6	1.0 ± 0.5	1.5 ± 0.6	1.3 ± 0.6	1.7 ± 0.9	2.0 ± 0.6	1.1 ± 0.8
Indices										
BMI ($kg \cdot m^{-2}$)	32.7 ± 2.9	31.3 ± 1.8	28.3 ± 1.9	27.3 ± 2.0	26.1 ± 1.9	25.9 ± 1.7	26.5 ± 1.9	25.2 ± 2.5	24.7 ± 1.2	27.9 ± 3.4
Σ 6 skinfolds (mm)	114.2 ± 23.5	96.9 ± 15.7	83.6 ± 29.0	76.5 ± 25.1	63.2 ± 21.3	73.4 ± 18.9	65.1 ± 17.2	54.3 ± 16.1	58.8 ± 20.6	79.0 ± 28.6
Muscle · bone ratio^{-1}	4.79 ± 0.33	4.60 ± 0.33	4.68 ± 0.71	4.53 ± 0.57	4.65 ± 0.57	4.44 ± 0.42	4.45 ± 0.33	4.45 ± 0.51	4.55 ± 0.54	4.58 ± 0.49

Table III. Comparison of URBA sample with RWC2003[1] by position (mean ± *s*).

Position	Variable	URBAREF	RWC2003	Diff.	*P*
Prop	*n*	22	31		
	Age, years.	24.5 ± 4.1	28.2 ± 3.6	−3.8*	0.001
	Weight, kg	105.0 ± 10.0	113.6 ± 6.1	−8.6*	0.001
	Height, cm	179.2 ± 3.2	185.3 ± 4.9	−6.1*	<0.001
	BMI, kg · m^{-2}	32.7 ± 2.9	33.1 ± 1.9	−0.4	0.524
Hooker	*n*	10	17		
	Age, years.	25.2 ± 3.2	28.5 ± 3.5	−3.2*	0.024
	Weight, kg	94.6 ± 5.4	105.5 ± 6.2	−11.0*	<0.001
	Height, cm	173.7 ± 4.2	183.2 ± 3.0	−9.5*	<0.001
	BMI, kg · m^{-2}	31.3 ± 1.8	31.4 ± 1.3	−0.1	0.918
Second row	*n*	16	24		
	Age, years.	23.9 ± 2.8	27.2 ± 3.1	−3.3*	0.001
	Weight, kg	101.6 ± 8.2	111.1 ± 5.2	−9.5*	<0.001
	Height, cm	189.3 ± 4.4	199.3 ± 2.5	−10.0*	<0.001
	BMI, kg · m^{-2}	28.3 ± 1.9	28.0 ± 1.4	0.3	0.510
Back row	*n*	22	42		
	Age, years.	24.6 ± 3.6	27.1 ± 3.7	−2.5*	0.013
	Weight, kg	90.4 ± 9.4	102.7 ± 6.7	−12.3*	<0.001
	Height, cm	181.8 ± 6.1	189.6 ± 5.5	−7.9*	<0.001
	BMI, kg · m^{-2}	27.3 ± 2.0	28.6 ± 1.6	−1.3*	0.009
Scrum half	*n*	12	17		
	Age, years.	24.2 ± 3.1	28.8 ± 3.2	−4.7*	0.001
	Weight, kg	73.1 ± 5.7	84.5 ± 6.1	−11.4*	<0.001
	Height, cm	167.3 ± 3.9	178.6 ± 3.6	−11.4*	<0.001
	BMI, kg · m^{-2}	26.1 ± 1.9	26.5 ± 2.0	−0.3	0.639
Fly half	*n*	13	17		
	Age, years.	23.3 ± 3.5	27.2 ± 3.6	−3.9*	0.006
	Weight, kg	81.5 ± 7.2	87.5 ± 5.5	−6.0*	0.015
	Height, cm	177.4 ± 5.8	180.5 ± 4.5	−3.1	0.108
	BMI, kg · m^{-2}	25.9 ± 1.7	26.9 ± 1.2	−1.0	0.074
Centre	*n*	18	24		
	Age, years.	25.2 ± 4.0	25.7 ± 2.8	−0.5	0.614
	Weight, kg	84.0 ± 7.1	91.6 ± 5.9	−7.6*	<0.001
	Height, cm	178.2 ± 4.5	184.0 ± 5.1	−5.8*	<0.001
	BMI, kg · m^{-2}	26.5 ± 1.9	27.1 ± 1.5	−0.6	0.241
Wing	*n*	13	24		
	Age, years.	23.7 ± 3.9	25.6 ± 2.8	−1.9	0.099
	Weight, kg	78.2 ± 10.2	91.3 ± 7.7	−13.1*	<0.001
	Height, cm	175.9 ± 6.9	184.7 ± 6.4	−8.7*	<0.001
	BMI, kg · m^{-2}	25.2 ± 2.5	26.7 ± 1.3	−1.5*	0.018
Fullback	*n*	7	13		
	Age, years.	24.2 ± 3.3	24.9 ± 3.1	−0.6	0.674
	Weight, kg	80.7 ± 4.6	89.6 ± 5.9	−8.9*	0.003
	Height, cm	180.7 ± 4.4	184.5 ± 5.2	−3.9	0.114
	BMI, kg · m^{-2}	24.7 ± 1.2	26.3 ± 1.5	−1.6*	0.028

Note: [1]RWC2003. source: http://www.rwc2003.irb.com/EN/Tournament/Teams/index.htm
*statistically significant difference ($P < 0.05$).

The Tukey HSD *post-hoc* analysis revealed that RF were taller than both FR and BK ($P < 0.001$), with no statistically significant difference between the latter two ($P = 0.328$). Relative to stature, FR had more proportional muscle and bone than both other groups ($P < 0.001$), which in turn did not differ between themselves ($P = 0.995$). FR did not differ from RF in absolute muscle ($P = 0.056$) and bone ($P < 0.930$) masses, but BK had less of these tissues than both other groups of forwards ($P < 0.001$). Finally, FR had more mesomorphy than the other two groups ($P < 0.001$), which in turn showed no differences among them ($P = 0.756$).

Discussion

This sample of rugby players is very heterogeneous in size, composition, proportionality, and shape, with marked differences among playing positions (Tables I–III, Figure 1). Therefore it is useful to report descriptive results by position rather than to group the players into forwards and backs or any

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Table IV. ANOVA results for muscular-skeletal structure parameters between three groups of URBA players. (mean $\pm$ *s*).

	ANOVA				
	Front row (FR)	Remaining forwards (RF)	Backs (BK)	*F*(2, 130)	*P*
n	32	38	63		
Height cm	177.5 $\pm$ 4.3	184.9 $\pm$ 6.6	175.7 $\pm$ 6.7	27.2*	$<$0.001
Z-Muscle	3.87 $\pm$ 0.78	2.4 $\pm$ 0.61	2.39 $\pm$ 0.69	55.6*	$<$0.001
Z-Skeletal	1.18 $\pm$ 0.64	0.34 $\pm$ 0.67	0.32 $\pm$ 0.64	20.7*	$<$0.001
Muscle mass kg	49.3 $\pm$ 5.1	46.6 $\pm$ 5.1	40 $\pm$ 4.4	46.9*	$<$0.001
Skeletal mass kg	10.4 $\pm$ 1.0	10.3 $\pm$ 1.2	9.0 $\pm$ 1.0	30.9*	$<$0.001
Muscle-bone ratio	4.73 $\pm$ 0.34	4.54 $\pm$ 0.54	4.5 $\pm$ 0.46	2.9	0.060
Mesomorphy	8.0 $\pm$ 0.9	6.4 $\pm$ 1.0	6.3 $\pm$ 0.9	39.7*	$<$0.001

*statistically significant difference.

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other sub-cluster. Subsequent analysis requiring greater statistical power from a larger sample size might then cluster positions into fewer categories (Table IV). The descriptive results follow the logic of position specificity, showing that in the forwards second rows require height for line out operations, props and hookers, a large bone and muscle structure for scrums, and back rows less size and adiposity to facilitate greater mobility on the field (Deutsch, Kearney, & Rehrer, 2007). The current tendency is for hookers to be more involved in the loose play, akin to back rows. However, in this URBA sample, hookers carried as much adipose mass as props. Among the backs, scrum halves' agility requirements possibly benefit from having a smaller size, as is the case with sports requiring a high-skill component, such as gymnastics or diving, (Samaras, 2007) or it may well be the case that the reduced need for contact of this position caters to individuals who have less size. Centres are more mesomorphic than other back line players (Figure 1), save for scrum halves, their position requiring a stronger bone and muscle structure for tackling and powering through the opposition at high speed. In Argentina, centres also have the highest injury incidence of all backline players (Bottini, Poggi, Luzuriaga, & Secin, 2000). Wings are the leanest and least muscular of all players, catering to their need for speed.

Together with position-specificity, the anthropometric characteristics of these rugby players, particularly those concerning height and bone structure, are delimited by the gene pool availability in the local population. What stands out in these results is the proportional skeletal structure of props and hookers, which, at 1.12 $\pm$ 0.59 and 1.31 $\pm$ 0.76 phantom *z*-scores (Table II), is far beyond that of other players and a Buenos Aires normal sample adult male population average of 0.06 $\pm$ 0.57 (http://www.nutrinfo.com/pagina/info/argoref.pdf). It is perhaps harder to find individuals with the bone structure to play front row than it is to find those tall enough to play second row. It is little wonder then, given the

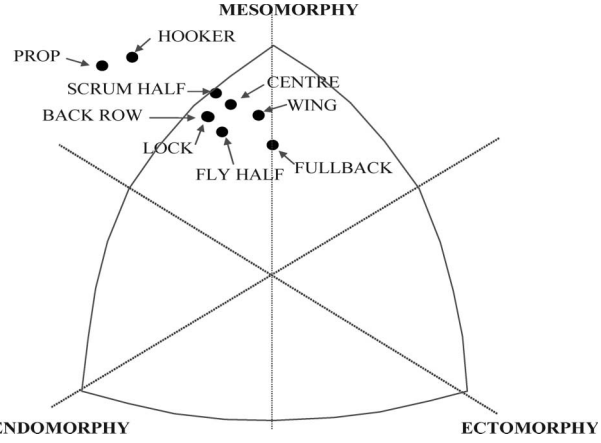

Figure 1. Somatochart of URBA players showing field positions.

uncommonness of certain positional physique requirements, that the inclusion of foreign players from other ethnic groups has become common practice in most leading rugby nations seeking to optimise performance. When compared to a sample of six of the top nine national squads at the 2003 Rugby World Cup (RWC2003), the average height of the Buenos Aires players was significantly lower for all positions, except for fly halves ($P = 0.108$) and fullbacks ($P = 0.114$). This fact illustrates the importance of height (and size) in rugby union, where more competitive teams are taller and bigger (Duthie, Pyne, & Hooper, 2003). Whereas data in team rosters and popular press releases might be exaggerated, nevertheless, the difference in height and weight between these two playing levels is noteworthy. Contrary to what we see in the URBA sample, where wings were among the shortest players (175.9 $\pm$ 6.9 cm), in the RWC2003, sample wings were, together with fullbacks and centres, the tallest players in the backline (184.7 $\pm$ 6.4 cm). This relative height difference might be due to different playing strategies, to the effect of selection pressures at the elite, professional level, or because of a lack of tallness in the Argentine population, when compared

to European, South African, Oceanic, or Pacific Island rugby-playing nations. Since Argentina is a two-time Olympic medal-winner in both basketball and volleyball in the last 20 years, it is quite likely that tall sports-talented individuals are preferentially recruited into other sports.

The five-way fractionation model has several advantages over the traditional two-component hydrodensitometry-based chemical models: (a) it provides more information, particularly on the sports-important components of lean body mass, muscle, and bone; (b) it is based on mathematical equations instead of multiple-regression equations, thereby hurdling the sample-specificity problem; (c) it considers the dimensionality of tissues – for instance, two people with similar skinfolds but different heights will have different adipose tissue masses; and (d) it is validated with cadaver dissection analysis (Kerr, 1988; Ross & Kerr, 1990). The adiposity values estimated by this model, when compared to percent body fat of the chemical models, often awake skepticism by their ''high'' values. It is a little understood fact that this model estimates the anatomically defined adipose tissue, as opposed to the more familiar chemically defined fat (lipids). Adipose tissue is a larger entity comprising a lipid fraction (Martin, Daniel, Drinkwater, & Clarys, 1994), and also water, proteins, and electrolytes. This lipid fraction of adipose tissue is variable, comprising about 50% in lean subjects to 90% in fatter ones. With the two-compartment chemical model, fat-free mass engulfs the non-fat portion of the body, including fat-free-adipose-tissue (Heymsfield et al., 2002), resulting in a smaller value for fat mass as opposed to adipose tissue. Using the same five-way fractionation model, for instance, Landers and colleagues (2000) found elite male triathletes at the 1997 World Championships to have a lean composition, with 20.1 ± 2.1% adipose tissue. The URBA rugby players ranged from 20.7 ± 2.8% for wings to 25.6 ± 3.1% in props.

The quantification of muscle mass in rugby players is of interest since specific training and dietary regimens are often undertaken by players to increase muscle mass, this sport requiring an amount that is considerably above that which the average person carries. In a sample of recreational-fitness individuals from the Buenos Aires area (the ARGOREF sample: http://www.nutrinfo.com/pagina/info/argoref.pdf), males had an average of 36.0 ± 5.0 kg muscle mass, whereas the URBA forwards ranged from 44.3 ± 4.1 kg in the back row, to 50.6 ± 5.4 kg in the props. These rugby players had on average a muscle-to-bone ratio of 4.58 ± 0.49, with forwards above this average and backs below it, again coinciding with game positional-role specificity (Figure 2). This ratio is also affected by a skeletal size, and a large value could either mean a high muscular development or a small skeleton.

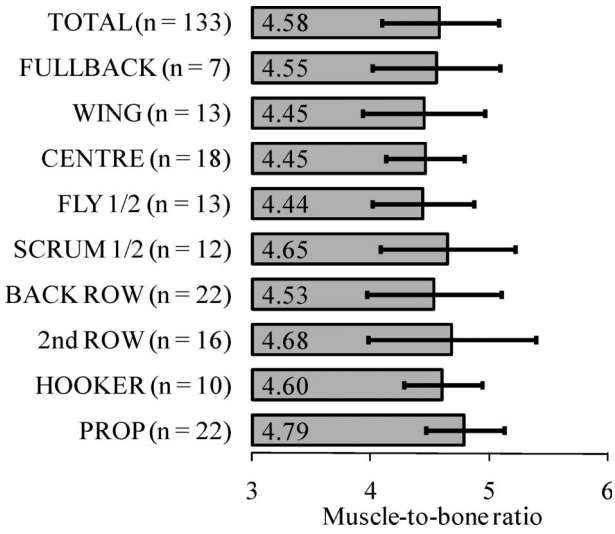

Figure 2. Muscle-to-bone ratio of URBA players per position. (Error bars are mean ± *s*).

When the players were grouped into three clusters (FR, RF, and BK, Table IV) to analyse whether FR had larger muscular–skeletal structure, differences in height must be considered. For instance, there was no significant difference ($P = 0.930$) in absolute skeletal mass between FR and RF, with both groups having 10.4 ± 1.0 kg and 10.3 ± 1.2 kg, respectively, but relative to height, the proportionality score for skeletal mass was significantly different (FR 1.18 ± 0.64 and RF 0.34 ± 0.67, $P < 0.001$). Mesomorphy rating, although solely calculated from appendicular measures (flexed arm and calf girths, and humerus and femur breadths) also shows this difference (FR 8.03 ± 0.94, RF 6.43 ± 0.99, $P < 0.001$). The muscle-to-bone ratio did not show statistically significant differences among playing position groups ($P = 0.060$). This is explained in part from the fact that in this ratio, a larger muscle mass divided by a larger skeletal mass will produce a similar index, as can be seen from the comparison between FR and BK.

Residual mass, composed of organs, viscera, and intra-abdominal adipose tissue, and skin mass attract the least attention by sports scientists, but constitute part of the ''dead weight'' that athletes have to carry. These two tissues varied proportionally to body mass, with props having the largest residual mass (12.6 ± 1.6 kg) and scrum halves the least (8.8 ± 0.9 kg).

Limitations and further studies

This study describes anthropometric data by playing position to a detailed extent. Splitting back row

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forwards into flankers and number eights might have been better, but we did not do this as many teams alternate these players between both positions. It might have been helpful to have measured neck girth in FR, an important indicator of neck muscle mass necessary for scrimmaging. The error in body mass prediction from the five-way fractionation method can be seen as an element of internal validity if the predicted structured body mass comes to within 5% of actual body mass (Ross & Kerr, 1993). This error goal was met in most instances, except in props, where it was $5.3 \pm 4.0\%$, perhaps because of the extreme muscularity of these players. Kerr (1988), analysing this error component of the model in 11 human groups differing in morphology, found the largest error (8.0%) in a group of body-builders. The data on international players available in the RWC2003 tournament roster might not be accurate, and some of the values for height and weight might have been exaggerated. Finally, it would have been better to have been able to measure teams during the same period of the season, to have included more teams in the study, and also those pertaining to dissimilar playing levels.

Conclusions

The large variability in the size, composition, proportion, and shape between field positions of URBA rugby players highlights the importance of kinanthropometric profiling to better understand the needs of each specific position, although statistical analysis may require clustering positions into fewer groups to attain statistical power. Compared to elite international caliber players, the URBA sample was considerably smaller in height and weight. The game's demands on high muscularity and skeletal robustness, particularly in the FR, make the assessment of both muscle mass and skeletal structure important elements in player evaluation and selection. As this study shows, Kerr's five-way fractionation method (1988), together with height-proportionality phantom z-scores are useful analytical tools for the assessment of body components in rugby players.

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