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Precision error in dual energy X-ray absorptiometry body composition measurements in elite male rugby league players

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Running title: DXA body composition precision in rugby players

Key Words: DXA; sport; reproducibility; fat mass; lean mass; bone mass

Abstract

Body composition analysis using dual energy X-ray absorptiometry (DXA) is becoming increasingly popular in both clinical and sports science settings. Obesity, characterised by high fat mass (FM), is associated with larger precision errors, however, precision error for athletic groups with high levels of lean mass (LM) are unclear. Total (TB) and regional (limbs and trunk) body composition were determined from two consecutive total body scans (GE Lunar iDXA) with re-positioning in 45 elite male rugby league players (age: 21.8 ±5.4 years BMI: 27.8 ±2.5 $kg.m^{-1}$). The root mean squared standard deviation (percentage co-efficient of variation) were TB bone mineral content (BMC): 24g (1.7%), TB LM: 321g (1.6%), and TB FM: 280g (2.3%). Regional precision values were superior for measurements of BMC: 4.7-16.3g (1.7-2.1%) and LM: 137-402g (2.0-2.4%), than for FM: 63-299g (3.1-4.1%). Precision error of DXA body composition measurements in elite male rugby players is higher than those reported elsewhere for normal adult populations and similar to those reported in those who are obese. It is advised that caution is applied when interpreting longitudinal DXA-derived body composition measurements in male rugby players and population-specific least significant change should be adopted.

Key Words: DXA; lean; fat; athletes; reproducibility

Introduction

The use of dual energy X-ray absorptiometry (DXA) for the evaluation of three compartment body composition is growing in popularity in both clinical and sports science settings. Clinically, DXA is valuable for decision-making in obese populations pre and post surgical or lifestyle interventions, and in sports science, DXA is proving invaluable for research into performance traits and athlete health status. Over the last decade, the use of DXA for research into rugby player populations has risen [1-5]. This is likely because DXA provides several advantages over field-based methods due to its ability to non-invasively evaluate three body composition components of non-osseous lean mass, fat mass and bone mass. An additional advantage is the provision of regional analysis of body composition through enhanced edge detection. This is of interest to sports scientists because the specific regional placement of mass may influence athletic performance or injury risk. For instance, greater mass proximal to a joint may improve biomechanical efficiency [4, 6].

In any Centre, it is important to determine *in-vivo* DXA precision specific to the population of interest to ensure interpretation of true change as opposed to discrepancies that may arise due to machine error. Previously, we and others have demonstrated excellent DXA body composition precision in non-athletic adults [7-10]. However, existing precision error values for DXA, determined from normal or clinical populations, may not be transferrable to athletes. Buehring and colleagues have reported useful body composition precision values for athletes in general, and concluded that precision values are needed for athletes of similar body size [11]. Rugby players differ markedly in body size compared to athletes from other sports, particularly those at elite level who are generally taller, heavier and possess greater levels of lean mass than the normal population. To date, no population-specific precision values have been reported for this population. Therefore the aim of this study was to ascertain short term precision of DXA total and regional body composition measurements in elite male rugby league players.

Methods

Forty five elite male rugby players from one UK professional Rugby League club participated in the study. Twenty one were First Team professional players (aged ≥20 years) and 24 were Academy level

players (aged 18-20 years). Each player provided signed informed consent to participate in the study, which was approved by the Institution's Research Ethics Committee and in accordance with the Declaration of Helsinki.

Subjects were measured wearing lightweight clothing, no shoes and with all jewelry removed. Height was measured with a free standing stadiometer (SECA, Birmingham UK) to the nearest millimeter, and body weight was recorded using calibrated electronic scales (SECA, Birmingham, UK) to the nearest 0.1kg. Body mass index (BMI) was calculated as body mass in kilograms/ height in metres squared. All participants were scanned in a euhydrated state[12].

DXA scans were conducted on a fan-beam GE Lunar iDXA (EnCore software version 15.0) using standard or thick mode depending on body size. The mode was automatically determined by the DXA software and based on BMI. Subjects were placed in the supine position on the scanning table with the body aligned with the central horizontal axis. Arms were positioned parallel to, but not touching the body, with hands flat on the table, legs fully extended and feet secured with a Nylon and Velcro support to avoid foot movement during the scan acquisition. Each participant was re-positioned between scans, after dismounting the scanning table. One skilled technologist led and analysed all scans following the manufacturer's guidelines for patient positioning, and identical scanning parameters were used for each scan. The regions of interest (ROI) were placed automatically by the machine, but manually checked by an ISCD certified clinical densitometrist and altered when necessary according to the manufacturer's instructions.

The outcomes of interest include bone mineral content (BMC), lean mass (LM) and fat mass (FM) of the total body, arms, legs and trunk. DXA does not facilitate separate left and right side measurements in participants whose body width exceeds that of the designated scanning boundaries. In such cases, the software will apply results from the arm that fits within the boundary, and estimate the size and composition of the arm which is outside of the boundary. This could be either left or right. In this study, there were 13 subjects who did not fully fit within the scanning boundaries, with the arms being affected. These subjects were excluded from the precision analyses of the arm region so as not to provide false-positive results. Thus, precision analyses were computed on 32 subjects for the arms, and 45 subjects for the legs and trunk.

Data analysis was performed using Microsoft Excel 2007. The study group descriptive data are reported as the mean and standard deviation (S). Precision is reported as the root-mean-square standard deviation (RMS-SD) and %CV (RMS-CV) and the resulting least significant changes (LSC) were calculated using the ISCD's precision calculation tool (www.isced.org). The %CV was derived from the equation: *%CV =(SD/mean value) * 100.* The effect of age and BMI on the SD and %CV between the two measurements was evaluated using repeated measures regression analysis. Regression parameters were calculated with Measurement 1 as the dependent variable and Measurement 2 as the independent variable. The computed slope and intercept values for each measurement site were assessed for difference to'0' and'1',by assessment in relation to 95% confidence intervals.

Results

Players ranged in age from 16.3 to 36.3 years, and mean age was 21.8 ±5.4 years. Height was 180.6 ±6.8cm, body weight 90.8 ±10.8kg, and BMI was 27.8 ±2.5 $kg.m^{-2}$. Table 1 gives the total body composition results from the paired DXA measurements, and Table 2 gives the paired regional body composition results.

Table 1 near here

Table 2 near here

The precision error is represented as the square root of the mean of the sum of differences between Measurement 1 and Measurement 2 (RMS-SD) and the % CV (Table 3). The least significant change (LSC) by both the RMS-SD and %CV are given at 95% confidence intervals. Precision error (%CV) was less than 3% for lean mass and BMC in all regions. All %CV regional values for regional fat mass were greater than 3%. The relationships between the paired fat and lean mass measurements are presented in figures 1 and 2 respectively. The slope of the regression for the fat masses was Fat Mass 2 = -31.6(373 to -436) + 1.010 (0.987 to 1.033)*Fat Mass 1, r^2 = 0.99 SEE = 374g. The slope of the regression for the lean masses was Lean Mass 2 = -287(-1488 to 913) + 1.002 (0.985 to 1.019)*Lean Mass 1, r^2 =

0.99 SEE = 447g. The slopes of the regression and lines of equality are almost identical. The intercepts and slopes were not significantly different from zero and one.

Figure 1 near here

Figure 2 near here

Table 3 near here*

Table 4 near here

Given the variation in age of the study group, separate precision errors were calculated for fat and lean mass measurements in academy players (age: 17.8 ±0.9 years; height: 179.2 ±5.7cm; weight: 85.4 ± 9.1kg) and senior players (age: 26.5 ±4.5 years; height: 182.2 ±7.6 cm; weight: 97.0 ±9.4 kg). RMS-SD and %CV results are given in Table 4.

Discussion

We determined short term precision for DXA body composition measurements in elite male rugby players. Precision errors for all outcomes were acceptable but noticeably larger compared to values reported for normal adult populations, and varied somewhat by type of soft tissue. Our findings also demonstrate that precision error and LSC did not vary between younger and older aged rugby players. Body weight is known to modify precision error [13]. In comparison to precision error for non-athletic subjects on the same machine [7,8] and elsewhere [10], machine error for measurements on our male rugby player subjects are larger (Table 5). Precision and LSC are similar to those reported by Knapp et al [9] in obese subjects. We found that error associated with the measurement of BMC was greater in rugby players compared to our previous work in normal adults, and elsewhere it has been shown in situ that larger volumes of soft tissue decrease DXA bone measurement performance [14]. Larger error was also observed with lean mass and fat mass measurements. In subjects with greater BMI, the greater soft tissue thickness might attenuate the X-rays, influencing precision of repeat measurements. There is also the possibility that repositioning of larger subjects can cause variation in displacement of the soft tissue

around the bone from one measurement to the next. Our results in conjunction with those in normal [8, 10] and obese subjects [9],indicate that greater BMI and soft tissue, regardless of whether this is primarily composed of fat or lean mass, increases DXA error of total body measurements.

Precision error varies by the type of soft tissue. With studies consistently reporting better machine performance for measurements of lean mass than of fat mass [7,8,9,10]. In agreement, we report lean mass precision (%CV) of 1.6% (LSC: 4.5%) and fat mass precision of 2.3% (LSC: 6.4%).

Table 5 near here

Our findings have shown that precision of regional body composition measurements were consistently poorer than for total body measurements, particularly for fat mass of the arms and trunk which demonstrated a CV of 4.2% and 4.1% respectively (over 1.5 greater than the CV for total body fat mass). This agrees with reports elsewhere where the greatest variability was observed at the trunk [15, 16]. The risk for error is greater for regional measurements due risks of inconsistent placement of ROI markers and limitations in software edge detection, particularly in larger subjects. In mesomorphic rugby players, the arm region is greater than in normal subjects and difficulties can arise in ensuring the body fits within the scan boundaries. Further, in larger subjects, displacement of soft tissue around the bone on repeat measurements may also influence precision.

We conclude that the Lunar iDXA provides acceptable precision for repeat measurements of body composition in elite male rugby players, performing better for measurements of lean than fat mass, and for measurements of the total body as opposed to regional analysis. We highlight the importance of not relying on precision errors derived from non-athletic subject groups because LSC will be larger and erroneous conclusions may be made. Precision errors and the corresponding LSC are larger than those reported for normal subjects elsewhere and this should be considered when performing serial measurements. Finally, our findings should not be generalised to other athletic populations, female rugby players or rugby players at amateur levels. Instead, separate precision studies for these groups should be implemented.

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Figure 1

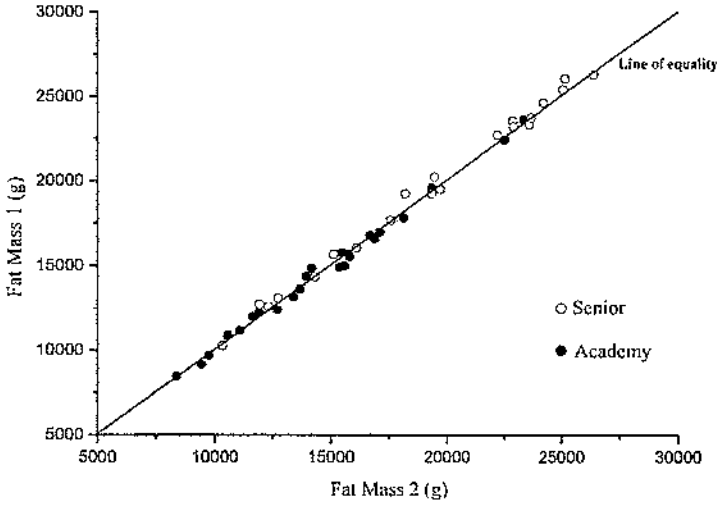

Figure 1. The regression between measures 1 and 2 of the Fat Mass.

Figure 2

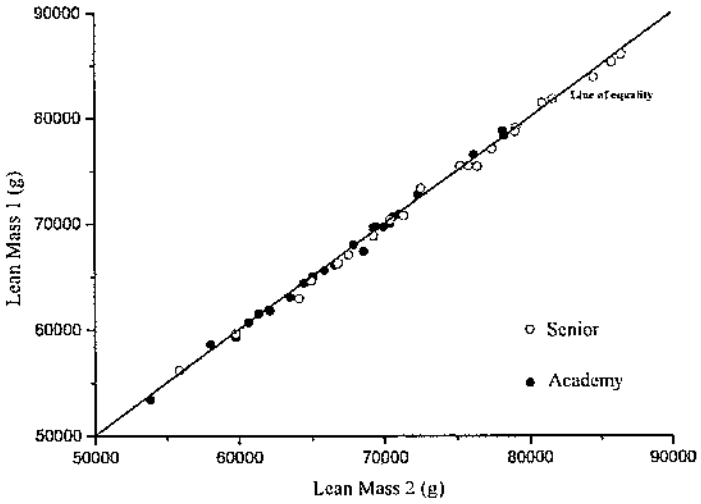

Figure 2. The regression between measures 1 and 2 of the Lean Mass.

Table 1

Table 1.Total body composition in elite male rugby players *(n=45)*, from two consecutive measurements on the GE Lunar iDXA with re-positioning

	Total body–Lunar iDXA			
	%Fat tissue mass	Fat mass (g)	Lean mass (g)	BMC (g)
Measurement 1	19.1 ±4.4	16,787 ±4,906	69,995 ±7,981	4,019 ±540
Range	*12.2 – 28.2*	*8,355 – 26,375*	*53,831 – 86,446*	*2,653 – 5,083*
Measurement 2	19.3 ±4.4	16,930 ±4,971	69,877 ±8,012	4,022 ±538
Range	*11.9 – 29.3*	*8,474 – 26,272*	*53,420 – 86,017*	*2,684 – 5,056*

Table 2

Table 2.Regional body composition in elite male rugby players (arms, n=32; legs and trunk, *n=45),* from two consecutive measurements on the GE Lunar iDXA with re-positioning

	Regional –Lunar iDXA		
	Fat mass (g)	**Lean mass (g)**	**BMC (g)**
Arms M1	1,568 ±373	8,680 ±1,340	542 ±84
Range	928-2189	62,62-12187	349-737
Arms M2	1,568 ±393	8,735 ±1,377	540 ±86
Range	911-2454	64,40-12535	398-749
Legs M1	6,019±1711	25,074 ±3,167	1,529 ±224
Range	3,185-11171	18,204-30958	974-1992
Legs M2	5,974 ±1732	25,088 ±3,292	1,527±224
Range	3,160-11219	18,069-31286	971-1992
Trunk M1	8,337 ±3211	32,140±3,577	1,350 ±196
Range	3,689-14619	25,830-39167	914-1722
Trunk M2	8,327±3162	32,196±3,485	1,351±196
Range	3,380-14164	25,420-38949	886-1734

M1= measurement 1; M2= measurement 2

Table 3.Short term precision of total and regional body composition parameters acquired using the GE Lunar iDXA in elite male rugby players*(arms n=32; legs and trunk n=45)*

			LSC – 95%CI	
	RMS -SD	**%CV**	**RMS -SD**	**%CV**
Total %fat mass	0.32	2.3	0.89	6.4
Total fat mass (g)	280	2.3	775	6.4
Total LM (g)	321	1.6	888	4.5
Total BMC (g)	24	1.7	65	4.6
Arms fat mass (g)	63	4.2	175	11.5
Arms LM (g)	137	2.4	380	6.7
Arms BMC (g)	4.7	2.1	13	5.7
Legs fat mass (g)	145	3.1	403	8.7
Legs LM (g)	369	2.1	1023	6.0
Legs BMC (g)	9.5	1.7	26.6	4.6
Trunk fat mass (g)	299	4.1	828	11.5
Trunk LM (g)	402	2.0	1115	5.5
Trunk BMC (g)	16.3	2.0	45.3	5.6

LM- lean mass; BMC=bone mineral content; RMS-SD=root mean squared SD; CV=co-efficient of variation; LSC= least significant change

Table 4. Short term precision of total fat mass and lean mass measurements acquired using the GE Lunar iDXA in elite Academy and First Team male rugby players

	Fat Mass			Lean Mass		
	RMS-SD (g)	**%CV**	**LSC%**	**RMS-SD (g)**	**%CV**	**LSC%**
Academy Rugby Players	221	2.7	7.5	285	2.2	6.1
Senior Rugby Players	334	2.9	8.0	356	2.4	6.7

RMS-SD=root mean squared SD; CV=co-efficient of variation;

Table 5

Table 5. Precision error and LSC for body composition measurements in elite rugby players (current study) and previously published for normal adults (Hind et al, 2011).

	RMS-SD		CV%		LSC (95% CI) RMS-SD		CV%	
	Hind et al. (2011)	Current study	Hind et al. (2011)	Current study	Hind et al. (2011)	Current study	Hind et al. (2011)	Current study
BMC (g)	15	24.0	0.6	1.7	41	65	1.7	4.6
Fat mass (g)	187	280	0.8	2.3	519	775	2.3	6.4
Lean mass (g)	244	321	0.5	1.6	677	888	1.4	4.5