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Precision of the GE Lunar total body-less head scan for the measurement of three-compartment body composition in athletes

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Abstract

*Introduction:*Dual energy X-ray absorptiometry (DXA) is widely used for the assessment of lean mass (LM), fat mass (FM) and bone mineral content (BMC). When observing standardised protocols, DXA has a high level of precision for the assessment of total body composition, including the head region. However, including the head region may have limited relevance in athletes and can be problematic when positioning taller athletes who exceed scan boundaries. This study investigated the precision of a new total-body-less-head (TBLH) DXA scan for three-compartment body composition measurement in athletes, with outcomes compared to the standard total-body DXA scan. *Methods:* Precision errors were calculated from two consecutive scans with re-positioning (Lunar iDXA, GE Healthcare, Madison, WI), in male and female athletes from a range of sports. TBLH precision was determined from repeat scans in 95 athletes (male n = 55; female n = 40; age: 26.0 ± 8.5 y; body mass: 81.2 ± 20.5 kg; stature: 1.77 ± 0.11 m), and standard total-body scan precision was derived from a sub-sample of 58 athletes (male n = 19; female n = 39; age: 27.6 ± 9.9 y; body mass: 69.6 ± 14.8 kg; stature: 1.72 ± 0.94 m). Data from the sub-sample were also used to compare precision error and 3-compartment body composition outcomes between the standard total-body scan and the TBLH scan. *Results:*: TBLH precision errors [root mean squared-standard deviation, RMS-SD (coefficient of variation, %CV)] were bone mineral content (BMC): 15.6 g (0.5%), lean mass (LM): 254.3 g (0.4%) and fat mass (FM): 199.4 g (1.3%). These outcomes compared favourably to the precision errors derived from the standard total-body scan [BMC: 12.4 g (0.4%), LM: 202.2 g (0.4%), and FM: 160.8 g (1.1%)]. The TBLH scan resulted in lower BMC (-19.5%), LM (-6.6%), and FM (-4.5%) compared to the total-body scan (BMC: 2,308 vs. 2,865 g; LM: 46,954 vs. 50,276 g; FM: 15,183 vs. 15,888 g, all $p<0.005$). *Conclusion*The TBLH scan demonstrates high in-vivo precision comparable to that of the standard total-body scan in a heterogeneous cohort of athletes. Given the impact of head exclusion on total body composition outcomes, TBLH scans should not be used interchangeably with the standard total-body scan.

Keywords: DXA; Lean mass; Fat mass; Bone mass; Sport; Reproducibility.

Introduction

Dual energy X-ray absorptiometry (DXA) is a quantitative imaging method that has been used for over three decades for the measurement of bone mineral density (BMD) and the diagnosis of osteoporosis *(1)*.

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Technological advances have seen DXA become the method of choice for body composition assessment in athletes given its ability to concurrently measure bone, lean and fat mass (2-4), at high resolution and in around 6 to 15 minutes depending on body thickness (5). In athletes, this can be useful to inform on athlete health and injury management plans, as well as physical conditioning (6,7). To date, DXA has been used for body composition profiling of athletes from different sports (8), by ethnicity (9), to monitor body composition across an intensive competitive season (10,11), and to evaluate risk and recovery from injury (12-14).

Standard DXA body composition scans include the head region and start two sweeps above the cranium. This can pose challenges when scanning taller athletes, in terms of positioning athletes within the upper and lower horizontal scan boundaries, and is common in sports such as basketball, rowing, volleyball, cricket and netball where larger stature creates a competitive advantage (15). Best practice for the assessment of taller athletes requires the combination of two separate scans, for one total body assessment (16). This takes additional time and increases exposure to ionising radiation, albeit small. In recognition of this, GE Healthcare have recently introduced a new total-body-less-head (TBLH) DXA scan which provides an assessment of 3-compartment body composition without including the head. This scan starts at the mandible and excludes the head from the analysis, that exceeds the scan region (GE Healthcare, Madison, WI; Encore software version 18.0).

Knowledge of precision is essential to inform on what constitutes a true meaningful change in tissue composition (or ’least significant change’)(17,18). In-vivo precision of the standard total body DXA scan has been investigated in various populations, including athletes from different sports (9,19,20) and non-athletes (21,22). However, given the relative infancy of the TBLH, no study has yet investigated the precision of this approach. In addition, no study to date has investigated the relative contribution of the head region to total body composition DXA assessments. Therefore, the aims of this study were first, to determine same-day, in-vivo precision of the TBLH scan for the assessment of body composition in athletes and second, to explore differences in total body composition with and without the head.

Materials and methods

The study sample comprised male and female university athletes, from a range of sporting disciplines (team sports: rugby, soccer, hockey and lacrosse; individual sports: distance running, rowing and cross-fit). Inclusion criteria were non-injured athletes who had been competing in their primary sport for at least 3 months, with representation at club level or above. Exclusion criteria were injury, pregnancy and orthopaedic metal devices. Due to horizontal boundary limits, only athletes with a stature of up to 1.98 m were included in the standard total body composition measurements. All participants provided signed informed consent prior to starting the study and ethical approval was granted by the regional NHS research ethics committee.

Participant characteristics are presented in (Table 1). Ninety-five participants received two consecutive TBLH scans, 58 participants received two consecutive standard total-body, and from these two groups a total of 57 participants received both at least one TBLH and one standard total body scan (STB).

Prior to the appointment, participants were asked to follow the standardised pre-scan protocols outlined by Nana et al. (23) to reduce biological variation. Specifically, the protocol advised that participants present in an overnight fasted and euhydrated state, with voided bladder, to minimise variation in tissue hydration and gastrointestinal tract contents. For appointments commencing later than 11:00 am, participants were advised to fast for 5 h and limit water intake for 3 h prior to the scan. Before the scan, stature was measured to the nearest millimetre using a free-standing stadiometer (SECA, UK), and body mass was measured to the nearest gram using calibrated scales (SECA, Birmingham, UK). Stature and body mass were used to determine body mass index (BMI, kg/m2). During the scan, participants wore lightweight clothing and removed shoes and jewellery. DXA scans were performed on a narrow fan-beam GE Lunar iDXA (GE Healthcare, Madison, WI) with Encore software version 18.0. Scan mode (standard = 16 - 25 cm, thick = >25 cm) was automatically determined based on estimation of body thickness from BMI data (24).

For each scan, athletes were positioned supine on the DXA bed with the hands in a mid-prone position and without contact to the body (24). The participants’ feet assumed a dorsiflexion position and Velcro straps were secured around the ankles to support consistent positioning. Upon completion of the first scan, the participant dismounted the DXA bed and was then re-positioned in the same manner. The standard total body scan commenced

Table 1
Participant characteristics.

	Precision study		
	TBLH	**STB**	**TBLH & STB**
Male (*n*)	55	19	17
Female (*n*)	40	39	40
Total (*n*)	95	58	57
Age (y)	26.0 ± 8.5	27.6 ± 9.9	28.0 ± 9.9
Body Mass (kg)	81.2 ± 20.5	69.6 ± 14.8	68.7 ± 14.0
Height (m)	1.77 ± 0.11	1.72 ± 0.94	1.71 ± 0.09

TBLH, Total Body Less Head; STB, Standard Total Body; *n*, number; yrs, years; kg, kilograms; m, metres.

1-2 sweeps above the cranium (Fig. 1). For the TBLH scan, the starting position of the scanner arm was manually positioned at the mandible to exclude the head region from the measurement, head position was standardised using a Frankfort plane (Fig. 2).

Data analysis was performed using Microsoft Excel (Version 16.5, Microsoft Inc, Redmond, WA) and IBM SPSS Statistics (Version 27.0, SPSS Inc, US). Descriptive data were normally distributed and are presented as the mean and standard deviation. Precision error is reported as the root mean square standard deviation (RMS-SD) and percentage coefficient of variation (%CV; SD/mean * 100), calculated using the International Society For Clinical Densitometry advanced precision calculator tool (https://iscd.org/). Least significant change (LSC) was calculated from the precision errors (LSC = RMS-SD * 2.77). Differences in three-compartment body composition outcomes between the standard total body scan and the TBLH scan were determined using an independent T-test and significance was denoted at $p < 0.05$.

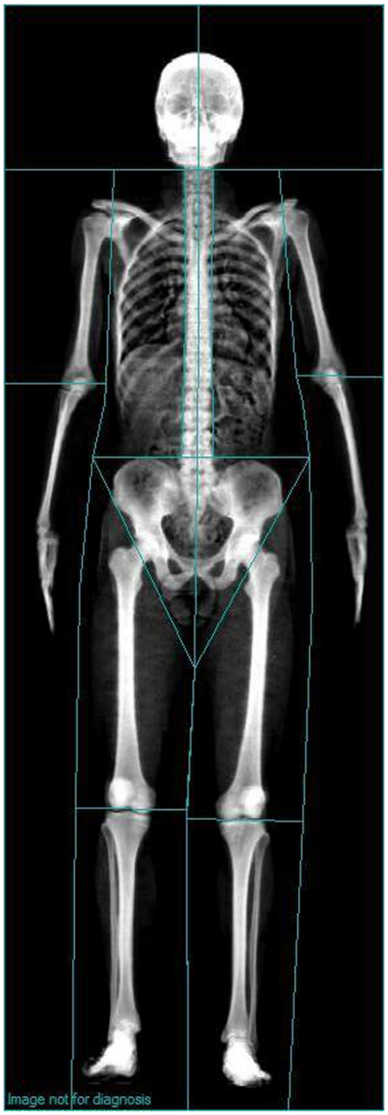

Fig. 1. GE Lunar iDXA standard total body scan.

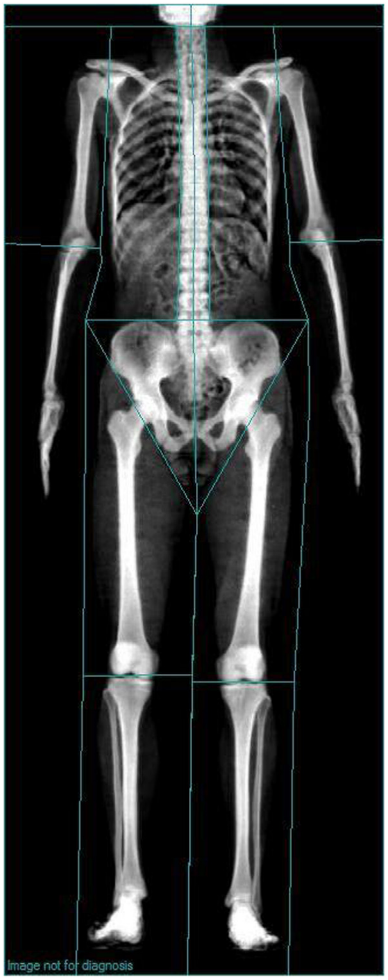

Fig. 2. GE Lunar iDXA total body less-head scan.

Results

Body composition data from the repeat TBLH and standard total-body measurements are presented in (Table 2). TBLH scan precision errors ranged from 0.39 to 1.28 %CV and the standard total body scan precision errors ranged 0.38 to 1.15 %CV. Precision errors were less than 1 %CV for all body composition outcomes, except for %BF and FM which were 1.19 and 1.28 %CV for the TBLH scan and 1.15 and 1.13 %CV for the standard total body scan respectively (Table 3).

Bone and body composition outcomes from the standard total-body scan and the TBLH scan (first measurement) were compared (Table 4). Reflecting exclusion of the head region, total mass, LM, FFM, FM and bone outcomes were significantly lower with the TBLH scan compared to the standard scan ($p < 0.001$).

Table 2

Total-body composition in athletes from two consecutive total body less head and two consecutive standard total body GE Lunar iDXA scans, with re-positioning.

	Measurement 1		Measurement 2	
Body Composition Outcome	**Mean ± SD**	**Range**	**Mean ± SD**	**Range**
TBLH				
Body Fat (%)	21.5 ± 6.5	8.5 - 38.5	21.45 ± 6.48	8.76 - 38.15
Fat Mass (g)	16,493 ± 5,995	5,727 - 32,004	16,444 ± 5,969	5661 - 31,004
Lean Mass (g)	57,414 ± 16,604	26,878 - 92,474	57,487 ± 16,619	26,745 - 93,539
Fat Free Mass (g)	60,298 ± 17,457	28,262 - 97,037	60,368 ± 17,469	28,135 - 98,079
Bone Mineral Content (g)	2,884 ± 884	1,355 - 5,281	2,882 ± 882	1358 - 5,253
Bone Mineral Density (g/cm^2)	1.32 ± 0.21	0.83, 1.87	1.32 ± 0.21	0.82 - 1.83
Bone Area (cm^2)	2,131 ± 349	1,522 - 2,888	2,132 ± 355	1,509 - 2,894
STB				
Body Fat (%)	23.1 ± 6.9	8.5 - 38.2	23.1 ± 6.9	8.6 - 38.4
Fat Mass (g)	16,046 ± 5,594	6,429 - 31,154	16,057 ± 5,560	6,408 - 30,649
Lean Mass (g)	50,998 ± 12,608	29,596 - 83,838	50,978 ± 12,630	29,714 - 83,880
Fat Free Mass (g)	53,898 ± 13,201	31,413 - 88,236	53,879 ± 13,220	31,530 - 88,278
Bone Mineral Content (g)	2,901 ± 641	1,817 - 4,466	2,900.61 ± 637.94	1,816 - 4,435
Bone Mineral Density (g/cm^2)	1.33 ± 0.15	1.02 - 1.69	1.33 ± 0.15	1.01 - 1.69
Bone Area (cm^2)	2,157 ± 269	1,732 - 2,741	2,158 ± 269	1,733 - 2,726

SD, Standard Deviation; TBLH, Total Body Less Head; STB, Standard Total Body; %, percentage; g, grams; g/cm^2, grams per centimetre squared; cm^2, centimetres squared.

Discussion

The purpose of this study was to determine precision and least significant change of the TBLH scan application for the measurement of body composition in athletes in-vivo, and to evaluate differences in body composition outcomes when the head is excluded. The results highlight that precision for body composition outcomes from the paired measurements for both the standard total-body and the TBLH scans, were comparable. The results also demonstrate a significant effect of head exclusion on total body composition outcomes and therefore, TBLH scans should not be used interchangeably with the standard total-body scan.

All precision errors were within ISCD acceptable limits (<3%, <2%, and <2% for FM, %BF, and LM, respectively) (Hangartner et al., 2013) for both the standard total-body and TBLH scan methods. Therefore, both DXA methods are considered valid for the assessment of body composition in athlete populations when standardised protocols are followed. In agreement with previous research *(19-21,25-27)*, we report that precision error was lowest for FFM measurements, irrespective of scan method. As such, in athletes, changes in FFM during dietary and/or training interventions are likely to be minimally influenced by technical error. The greatest difference in precision error between the two scan methods was found for FM, which also presented the highest error when using the TBLH method. The precision error for FM using the TBLH application, was similar to that reported by Beuhring et al. *(25)* also using a GE Lunar iDXA in athletes from mixed sports (1.3%CV vs 1.5%CV). Despite being within the ISCD acceptable limits, the higher risk of error when measuring FM over other body composition outcomes should be considered, especially if change in FM is the primary goal of the athlete.

Precision assessments of DXA outcomes may be influenced by the physical characteristics of the athletes studied, mainly mass and composition. The present sample of multi-discipline athletes is alike to the sample studied by Beuhring et al. *(25)*, who reported comparable precision errors for LM (0.3%CV) and FM (0.6 - 1.5%CV) using a standard total-body scan method. In contrast, our precision errors are lower than those reported for high performance, male rugby players (LM = 1.6 %, FM = 2.3 %, and BMC = 1.7 %) measured using standard DXA methods on a GE Lunar iDXA densitometer *(19)*. It is also apparent that there is greater variability across populations for FM precision error, than precision error for other body composition outcomes. In mixed discipline athletes, Santos et al. *(28)* reported a FM precision error of 3.7%CV, which was higher than reported for Australian football players (2.5%CV) *(26)*, and more so compared to non-athlete populations (1.0%CV) *(22)*. Precision errors for LM and BMC among these diverse samples were less varied (CV range = 0.3 - 1.6% and 0.6 - 1.7% for LM and BMC, respectively) *(19,22,25,26,29)* and comparable to

Table 3

. Precision error for total-body less head and standard total body GE Lunar iDXA scans in athletes.

			LSC – 95%CI	
	%CV	**RMS-SD**	**%CV**	**RMS-SD**
TBLH				
Body Fat (%)	1.19	0.22	3.31	0.62
Fat Mass (g)	1.28	199.41	3.53	552.38
Lean Mass (g)	0.41	254.30	1.14	704.42
Fat Free Mass (g)	0.39	251.08	1.07	695.49
Bone Mineral Content (g)	0.49	15.57	1.37	43.14
Bone Mineral Density (g/cm^2)	0.71	0.01	1.98	0.03
Bone Area (cm^2)	0.86	19.20	2.38	53.18
STB				
Body Fat (%)	1.15	0.25	3.19	0.68
Fat Mass (g)	1.13	160.78	3.12	445.35
Lean Mass (g)	0.42	202.15	1.15	559.94
Fat Free Mass (g)	0.38	194.45	1.05	538.61
Bone Mineral Content (g)	0.44	12.38	1.21	34.29
Bone Mineral Density (g/cm^2)	0.69	0.01	1.90	0.03
Bone Area (cm^2)	0.72	15.35	2.00	42.51

LSC, Least Significant Change; %, percentage; CI, Confidence Interval; CV, Coefficient Variation; RMS-SD, Root Mean Square – Successive Differences; TBLH, Total Body Less Head; STB, Standard Total Body; g, grams; g/cm^2, grams per centimetre squared; cm^2, centimetres squared.

the present study. As such, the precision of body composition assessments with DXA may vary depending on participant characteristics (for example, body mass, which may be predisposed by sporting discipline) and this should be considered when comparing precision error data between studies.

The present study was the first to directly compare body composition outcomes derived from the standard total-body DXA scan and the TBLH DXA scan in athletes. The data indicate that on average, the head region accounts for 4.4% (705 g) FM, 6.6% (3,321 g) LM, 7.3% (3,878 g) FFM and 19.4% (557 g) BMC of the total body. Due to these differences, repeat DXA scans conducted in athletes should utilise consistent methods (TBLH or standard total-body) and comparison between results obtained from these methods is not feasible.

The TBLH application has several advantages over the standard total-body application, which may benefit athletic populations. First, the TBLH method exposes the athlete to a lower radiation dose, due to a shorter scan duration relative to the standard total-body method. While a standard total-body DXA scan has a low effective dose of radiation (~2 μSv), any reduction in radiation exposure is advantageous to align with the 'as low as reasonably practicable' (ALARP) guidance for radiation protection. Second, the TBLH application enables inclusivity of taller

Table 4

Differences between GE Lunar iDXA standard total body and total body-less head body composition measurements in athletes (n=57).

	STB	**TBLH**	**Mean difference**	***P***
Body Fat (%)	23.17 ± 6.93	23.30 ± 7.00	0.13	0.008
Fat Mass (g)	15,888 ± 5,485	15,183 ± 5,491	-705	<0.001
Lean Mass (g)	50,276 ± 12,109	46,954 ± 11,783	-3321	<0.001
Fat Free Mass (g)	53,141 ± 12,671	49,263 ± 12,297	-3878	<0.001
Bone Mineral Content (g)	2,865 ± 610	2,308 ± 552	-557	<0.001
Bone Mineral Density (g/cm^2)	1.33 ± 0.15	1.19 ± 0.16	-0.14	<0.001
Bone Area (cm^2)	2,140 ± 254	1,914 ± 236	-226	<0.001

Data are presented as mean ± standard deviation. STB, Standard Total Body scan; TBLH, Total Body Less Head scan; *p*, *p*-value statistic; %, percentage; g, grams; g/cm^2, grams per centimetre squared; cm^2, centimetres squared.

(>1.98 m) athletes, for example, basketball and rugby players, who may otherwise exceed the DXA scan boundaries when using the standard total-body application. Previously, conducting total-body DXA scans with taller individuals necessitated the combination of two-to-three partial scans *(28,29)* which is more time-demanding and which increases ionising radiation dose. Third, the TBLH method may be more appropriate than the standard total-body method for measuring longitudinal change in body composition with repeat scans. While there is limited research evaluating the change in composition of the head region over time, it is plausible to hypothesise that the head region is unlikely to adapt to dietary and/or training interventions comparably to the rest of the body. Therefore, with exclusion of the head region, repeat DXA scans may have greater sensitivity for detecting relative change, particularly in bone mass outcomes. Standard total body BMD is not currently used for diagnosis and does not correlate well with BMD at the clinical sites of the lumbar spine or hip. Future research should explore the efficacy of the TBLH scan for predicting BMD at the spine and hip. This would have relevance for the clinical utility of total body densitometry in athletes at risk for low bone density, in that both body composition and bone density screening might be achievable in one scan instead of separate total body, spine and hip scans.

In this study, precision error assessment and inter-method comparisons were conducted at one time point. Future research could examine the relative change in body composition outcomes across a sporting season or with targeted interventions using the TBLH compared to the standard total-body scan methods, and applying least significant change. Such research could help further determine efficacy of the TBLH method over the standard total-body application for athletic populations. It is also noteworthy that the current study implemented a standardised protocol to limit the influence of biological variation from exercise, food and fluid intake, which would also be relevant when monitoring body composition in athletes over time *(17,29)*.

In conclusion, we report comparable precision error for body composition outcomes using the new TBLH application and the standard total-body application with DXA, well within ISCD recommended limits. As such, TBLH DXA scans can be used for the assessment of body composition in multi-discipline athletes when following standardised protocols, with excellent precision. Given the exclusion of the head region, the TBLH method should not be used interchangeably with the standard total-body method.

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