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Does a novice technician produce results similar to that of an experienced DXA technician when assessing body composition and bone mineral density?

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Running title – Are novice DXA technicians results similar to experienced?

ABSTRACT

Dual energy X-ray absorptiometry is a commonly used clinical assessment tool for body composition and bone mineral density, which is gaining popularity in athletic cohorts. Results from body composition scans are useful for athletic populations to track training and nutritional interventions, whilst bone mineral density scans are valuable for athletes at risk of developing stress fractures due to low bone mineral density. However, no research has ascertained if a novice technician (accredited but not experienced) could produce similar results to an experienced technician. Two groups of recreational athletes were scanned, one by an experienced technician, one by a novice technician. All participants were scanned twice with repositioning between scans. The experienced technician's reliability (ICC 0.989 – 0.998, percentage change in mean -0.01 – 0.10), precision (typical error as CV% 0.01 to 0.47. standard error of measurement percentage 0.61% - 1.39%) and sensitivity to change (smallest real difference percentage 1.70% - 3.85%) were similar, however superior, to those of the novice technician. The novice technician results were: reliability (ICC 0.985 – 0.997, percentage change in mean -0.03 – 0.23), precision (typical error as CV% 0.03 – 0.75%, standard error of measurement percentage 1.06% - 2.12%) and sensitivity to change (smallest real difference percentage 2.73% - 5.86%). Extensive experience whilst valuable is not a necessary requirement to produce quality results when undertaking whole body dual energy X-ray absorptiometry scanning.

KEYWORDS

Reliability; Precision; sensitivity to change;

INTRODUCTION

Low bone mineral density (BMD) and associated conditions such as osteoporosis and osteopenia are health problems that annually costs over 830 million dollars in Australia and osteoporosis is a significant cause of morbidity and mortality (Johnell et al., 2006; Watts et al., 2013). The need to accurately and effectively measure whole body and segmental BMD led to the development of the DXA scanner, which is now considered the gold standard for BMD and body composition (Blake et al., 2007; Lewiecki, 2005). Low BMD (osteoporosis and osteopenia) is a concern for the general population as well as athletic population, as low BMD increases the risk of stress or fragility fractures while an athlete is actively training, competing and later in life (Kelsey et al., 2007; Scofield et al., 2012). Reduced cortical mass can predispose athletes to lower limb stress fractures, with the incidence rate being as high at 20% annually in track and field athletes (Bennell et al., 1996). Additionally, it is recognised that endurance athletes (female runners and swimmers, male cyclists) and athletes who did not partake in loaded and/or impact activities and sports as teens are at a higher risk of having low BMD and subsequently developing bony stress related conditions (Fredericson et al., 2005; Tenforde et al., 2015). This is due to factors including female athlete triad and excessive time spent in sport with low cortical stress leading to weakened bone strength (Chen et al., 2013; Fredericson et al., 2005; Tenforde et al., 2015). Therefore, screening these athletes via DXA can act as an injury prevention tool for early intervention. If stress fractures are not correctly treated and healed, they can result in a reduction in performance, an increase in pain, a loss of training time and medical expenses; subsequent development of a complete fracture, non-union, chronic pain, increased recovery time and possibly disability (Chen et al., 2013; Schnackenburg et al., 2011).

Additionally, DXA´s ability to assess whole body and segmental body composition (BC) including lean mass (LM), fat mass (FM) and bone mineral content (BMC) has become an important tool in the measurement of BC and is used in clinical, sporting and research settings and is considered the reference standard (Buckinx et al., 2018). In the sporting setting, it is known that LM and FM impact physical performance and the risk of injury and illness (Duthie, 2006; Georgeson et al., 2011; Hagmar et al., 2013; Stewart, 2001). Therefore, it is common practice among the professional sporting population to have regular BC assessments to track the effectiveness of training or nutritional interventions as any small change to BC can impact performance (Duthie, 2006).

The International Society for Clinical Densitometry (ISCD) recommends precise measures during preparation and positioning of the participant of a DXA BC scan (ISCD, 2015). For whole body analysis of BC it has been shown that sources of biological error in DXA results include hydration, stomach content and food consumption, time of day of scanning and pre-scan physical activity (Hangartner et al., 2013; Nana et al., 2012, 2013). Furthermore sources of technical error include artifacts such as clothing, number of technicians used to complete scans and position of participant (Hangartner et al., 2013; Kiebzak et al., 2000; Kerr et al., 2016; Nana et al., 2012). Given the importance of positioning, it is crucial the DXA technician adheres to established best practice to ensure the most accurate and reliable results.

It has been reported that up to 64% of scans were deemed inadequate as they did not provide sufficient accuracy when automatic analysis was applied and that manual analysis should be undertaken, therefore the skill of the DXA scanning technician is vitally important (Baniak et al., 2014). However, to date no research has focused on whether the experience of the DXA scanner influences BC and BMD results. Kim et al. (2014) suggest a DXA technologist is sufficiently experienced after performing repeated training in which the technologist undertakes adjusting patient positioning, device manipulation and result analysis on 100 patients.

The increasing popularity to use DXA to assess and track change in BC and BMD over time has created a larger need for qualified DXA technicians. As such, Australian (Kerr et al., 2016) and USA universities (Standorth et al., 2016; Trexler et al., 2018) possess DXA scanners to conduct research assessing BC and BMD in athletic/non-athletic and clinical (Newton et al., 2009) populations. However, the demand for scanning may lead to novice technicians being utilised and even though these technicians are accredited, they may not have the extended training and experience using the device to attain accurate and reliable results.

As such, the rationale for this study was that the DXA data being collected by a novice technician was showing high quality results. The question was then asked, how close were the results of a novice technician to those already obtained by an experienced technician utilising the same DXA scanner?

Therefore, the aim of this study is to ascertain if a novice technician can produce whole body BC and BMD DXA scanning results similar to that of an experienced technician when scanning recreational athletes.

METHODS

Study Design

In order to assess the novice and experienced technicians' reliability, precision and sensitivity to change individuals were assigned to a group (experienced or novice). Individuals total body

BC and BMD were scanned twice on the same day, minutes apart with repositioning between each scan. Scanning took place in accordance with positioning protocols developed by Alisa Nana as illustrated in Figure 1. (Nana et al., 2012). The study had ethical approval Bond University Human Research Ethics Committee (RO15221, RO1655).

Participants

A total of 38 participants were included in this two-part pilot study. Eight participants formed the experienced technicians' group, which was a convenience sample. These eight participants were scanned twice by the same experienced technician to establish their own reliability. The second group (novice technician's group), which consisted of 30 participants, was scanned twice by the same novice technician to determine his reliability. Ethical approval was only granted for individual's to be scanned twice due to concerns over radiation exposure.

All participants recruited were aged over eighteen, recreational athletes and were from the local geographical area. To be eligible for the study, participants must have been willing to meet scanning stipulations (fasted, bladder voided, removal of metal, abstained from exercise on day of scan and undertake anthropometric assessment). Participants were excluded from the study; if the participant competed in collegiate or professional sport, suspected they were pregnant and or were non-healthy: inclusive of osteoporosis, current fractures, hemiarthroplasty and total joint replacements, rheumatoid or osteoarthritis, current cardiac or pulmonary conditions, diabetes or if they were unable to maintain the required position for the duration of the scans. To reduce the likelihood of artifacts, male participants wore underwear during scanning while female participants wore underwear, sports bra or two-piece bathers. Participants initially were informed of all testing procedures and questions were answered at that time prior to signing the voluntary consent form. No participants who were invited to participate in the study declined to participate. Participants were assessed for height (to the nearest 1.0 cm) using a stadiometer (Harpenden, Holtain Limited, Crymych, UK) and mass (to the nearest 100 grams) using calibrated scales (WM202, Wedderburn, Bilinga, Australia) prior to scanning.

Technicians

Both technicians were accredited and trained through the Australia and New Zealand Bone Mineral Society (ANZBMS). The ANZBMS accreditation is the only certification course available which satisfies the requirements of radiation safety legislation in Australia, leading to licensure. Both technicians undertook the same accreditation process. The accreditation course consists of theoretical knowledge and practical skills involved with DXA usage, including bone pathology, device usage, manipulation and the analysis of results. Prior to this study the novice technician's previous experience was approximately 25 DXA scans. The experienced technician was deemed so, as they had completion of more than 100 scans as well as having a five-year history as a DXA technician (Kim et al., 2014).

Equipment

All scans were performed using a narrow angle fan beam Lunar Prodigy DXA scanner (GE Healthcare, Madison, WI). Scans were analysed automatically by the GE enCORE 2016 software (GE Healthcare). Scans were then analysed by the DXA technician and region of interest lines adjusted accordingly, if needed, relative to the ANZBMS guidelines. The DXA scanner was calibrated daily using a whole body phantom as per manufacturer's guidelines prior to any scans.

Statistical Analysis

All data was analysed using IBM statistical package for the social sciences (SPSS, version 24) or via a customised reliability spreadsheet from sportsci.org. To analyse test re-test reliability the recommended Intraclass Correlation Coefficient (3,1) with 95% confidence intervals was performed using SPSS (Ionan et al., 2014; Trevethan, 2016). The ICC results were interpreted as indicators of reliability as follows: ICC of 0.00–0.29, very low reliability; 0.30–0.49, low reliability; 0.50–0.69, moderate reliability; 0.70–0.89, high reliability; and 0.90–1.00, very high reliability (Munro et al., 2005). Additionally, SPSS was used to calculate the standard error of measurement percentage (SEM%) (Equation 1) and smallest real difference percentage (SRD%) (Equation 2) (Lexell et al., 2005). Acceptable precision of results has been previously set by ISCD at 2% for LM and 2% for FM respectively (ISCD, 2015).

$$SEM = ((\sqrt{\text{mean square error from ANOVA}})/\text{mean}) \times 100, \quad (1)$$

$$SRD\% = ((1.96 \times SEM \times \sqrt{2})/\text{mean}) \times 100, \quad (2)$$

A customised spreadsheet from Sportscience website (www.sportsci.org) was utilised to calculate and analyse percentage change in mean and the accompanying typical error (coefficient of variation (CV%) percentage) as recommended (Hopkins, 2000; Hopkins et al., 2009).

RESULTS

Anthropometrical data (mean + SD) of the participants are presented in Table 1. Independent T-tests for age, height, weight, BMI, whole body FM percentage, whole body LM percentage, whole body BMC percentage and whole body BMD revealed no significant differences between the novice and experienced groups (p = 0.96, 0.45, 0.21, 0.35, 0.13, 0.06, 0.01, 0.49 respectively) except for BMC.

All the collated results from the experience and novice technicians' reliability, precision and sensitivity to change are presented in Table 2. Both technicians ICC reliability values were within the high to very high range (Munro et al., 2005)

Experienced technician

Scan 1 produced the following absolute values: FM 23.01%, LM 73.69%, BMC % 3.30%, BMD 1.275 g.cm^{-2}. Scan 2 produced the following 23.13%, 73.65%, 3.31%, 1.274 g/cm^{2}, difference of 0.12%, 0.04%, 0.01% and 0.001 g/cm^{2} which was evident in the high reliability scores.

Novice technician

Scan 1 produced the following absolute values: FM 25.91%, LM 70.21%, BMC % 3.87, BMD 1.312 g/cm^{-2}. Scan 2 produced the following 25.96%, 70.38%, 3.89%, 1.308 g/cm^{2}, difference of 0.05%, 0.18%, 0.02% and 0.004 g/cm^{2} which was evident in the high reliability scores.

DISCUSSION

The purpose of this study was to ascertain if a novice but accredited DXA technician could produce results similar to that of an experienced DXA technician. DXA reliability has been studied extensively in both the facets of whole body and segmental BC (Bilsborough et al., 2014; Kerr et al., 2016; Nana et al., 2012, 2013) and region specific BMD (Fuller et al., 2016; Lohman et al., 2009). To our knowledge, there is no study to date that has assessed the reliability, precision or sensitivity to change of BC or BMD scanning when completed by a novice technician. Our results indicated that when an accredited, but novice technician uses the Lunar DXA scanner to assess BC and BMD they produce results that are similar, yet slightly inferior to that of an experienced technician.

The novice and the experienced technician produced very similar fat percentage results. Both technicians achieved very high test-retest reliability (ICC 0.995 and 0.996, and 0.996, 0.10 and 0.23 percentage change in mean) and the results are similar to previously published data (ICC 0.98 to 0.99, percentage change in mean 0.0 to 0.4) (Bilsborough et al., 2014; Kerr et al., 2016; Nana et al., 2012, 2013). However, the percentage fat parameter produced the worst precision (SEM%) and poorest sensitivity to change (SRD%) statistics compared with the parameters of bone and LM. This is due to the fat parameter producing the largest variance (error rate) of the parameters. This finding of fat tissue producing poorer reliability results is consistent across several BC studies (Bilsborough et al., 2014; Kerr et al., 2016; Nana et al., 2012, 2013), which is then exacerbated when calculating SEM and SRD. Additionally, the novice technicians group had a larger fluctuation in stature of participants with some (n-7) only just fitting within the scanning field, which would have increased the statistical variance. This increase in statistical variance contributed to the experienced technician having better precision (CV% 0.33 vs 0.36, SEM% 1.39% vs 2.12) and sensitivity to change (SRD% 3.85% vs 5.86%). However, the precision results (CV%) (0.36% and 0.33% respectively) of the novice and experienced technicians falls well below the range of previously published CV% data of 1.3 to 5.9% (Bilsborough et al., 2014; Kerr et al., 2016; Nana et al., 2012, 2013). It should be noted that the sensitivity to change (SEM%) of the experienced technician (1.39%) is well below the ISCD recommend precision (2%) (ISCD, 2015), indicating superior precision, however the SEM% (2.12%) of the novice is just above the recommend precision illustrating that the novice’s precision was slightly worse than recommended and may be due to inexperience in positioning and assessing scans, or the larger fluctuation of stature creating higher statistical variance.

The novice technician had slightly better reliability results when assessing the lean mass parameter (ICC 0.996 vs 0.989, percentage change in mean -0.03 vs -0.10) however the experienced technician demonstrated better precision (CV% 0.47 vs CV% 0.75, SEM% 0.61 vs 1.46%) and sensitivity to change (SRD% 1.70 vs 4.05). The reliability of the novice and experienced technician is slightly lower than previously published data when using the ICC statistic (0.996 and 0.989 vs 1.00), however all results are deemed as very high reliability (Munro et al., 2005). When using the percentage change in mean statistic the results are very similar (-0.03 and -0.10 vs range of 0.0 to 0.3.) This fluctuation in reliability results may be due to the type of athlete scanned in the previous studies (professional athletes versus recreational) and the variances in the statistical analysis. When assessing precision the novice and experienced technicians results (CV% 0.75 and 0.47) fall into the lower end of the published data range (0.3 to 1.5%) and the SEM% (0.61 to 1.46%) is well within the ISCD recommendations (2%) (ISCD, 2015), indicating high precision by the technicians in this study.

When assessing the reliability of BMC% the novice technician produced a slightly higher ICC (0.997 vs 0.994), both of which are deemed as very high (Munro et al., 2005). When comparing the experienced and novice technicians the reliability, when using the ICC statistic is very similar to previously published data (Bilsborough et al., 2014), and at the lower end of the published percentage change in mean (0.02 vs 0.00 – 1.9%). The precision of both technicians is very good with the experienced technician producing slightly better SEM% (0.88% vs 1.1%), which may be due to the smaller sample size of the experienced technician. The precision when expressed as CV% is very low (0.03) in comparison to the large range displayed in previous studies (0.06 – 5.2%) (Bilsborough et al., 2014; Kerr et al., 2016; Nana et al., 2012, 2013), indicating that both the experienced and novice technicians in this study produced very precise results when assessing BMC%. The sensitivity to change of the experienced technician is also lower than the novice technician (2.44% vs 3.10%) indicating better results.

The reliability of the experienced technician (ICC 0.998) is very high and is clearly more superior to the novice technician's high reliability (0.985) (Munro et al., 2005). Not surprisingly the precision of the experienced technician is also more superior to that of the novice (CV% 0.01 vs 0.14, SEM% 0.70 vs 1.06%). Previously, BMD analysis has been used on site-specific basis i.e. lumbar spine, hip to assess for changes after the occurrence of symptoms, however for this study it was assessed for the entire body as it was being utilised as a screening tool for those at risk of developing bony stress related injuries. As such there has been no reliability data published, however the results of this study (experienced 1.27 + 0.20 g.cm^2 $\pm$ 0.11, inexperienced 1.31 + 0.11 g.cm^2) in terms of grams per centimeter squared are similar to those of previously published data (1.04 $\pm$ 0.07 to 1.31 $\pm$ 0.08 g/cm^2) of athletes who are involved in sports that are deemed high risk for stress reactions due to low BMD (Andreoli et al., 2001; Ferry et al., 2011).

One identified limitation was the use of whole-body BMD measurement as opposed to site-specific BMD measurements because the technology embedded in the BC scan allows for whole body BMD analysis, subsequently reducing the levels of exposure to radiation. For this reason, professional athletes who routinely have BC scan should include a whole-body BMD assessment from the BC scans. The authors recommend that if the whole-body BMD scans results were to show a cause for concern, a segmental site specific BMD can then be undertaken.

Furthermore, this study only assessed one experienced technician and one novice technician, using two different sample groups of different sizes, as significant multiple scanning and exposure to radiation was an ethical consideration. Ideally, future research should include multiple technicians scanning large participant cohorts in a cross-sectional design to further validate the findings of this study and minimise the impact of a single technician. To be able to further generalise the findings the sample population should include both recreational and professional athletes.

In summary, the high to very high reliability results of DXA scanning for both technicians compared with previously published data illustrates that extensive experience whilst valuable is not necessarily a requirement to produce quality results. In a climate where DXA use is becoming a more common place, the results of this study will provide the novice technician with more confidence when completing DXA scanning.

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TABLES

Table 1. Demographical Data

	Age (years)	Height (cm)	Mass (kgs)	BMI (range)	FM %	LM %	BMC%	BMD (g/cm^2)
Experienced	29.2 ± 11.5	175.8 ± 2.6	78.75 ± 6.9	23.0 to 29.2	23.07 ± 4.49	73.62 ± 4.30	3.31 ± 0.51	1.27 ± 0.19
Novice	29.6 ± 10.0	171.7 ± 10.7	70.6 ± 12.4	19.4 to 31.7	26.03 ± 7.29	70.07 ± 7.03	3.89 ± 0.45	1.31 ± 0.11

cm – centrimetres, kgs – kilograms, FM % - Fat mass perecentage, LM % - Lean mass percentage, BMC% - bone mineral content percentage, BMD – bone mineral density, g/cm^2 – grams per centimetre squared

Table 2. Reliability, precision and sensitivity to change results for experienced and novice technicians.

		ICC	CI	% Δ in Mean	CV%	SEM%	SRD%
Experienced	Fat %	0.995	0.976 – 0.999	0.10	0.33	1.39%	3.85%
	Lean %	0.989	0.949 – 0.998	-0.10	0.47	0.61%	1.70%
	BMC (g)	0.994	0.973 – 0.999	0.02	0.03	0.88%	2.44%
	BMD g/cm^2	0.998	0.991 – 1.000	-0.01	0.01	0.70%	1.90%
Novice	Fat %	0.996	0.990 – 0.998	0.23	0.36	2.12%	5.86%
	Lean %	0.996	0.991 – 0.998	-0.03	0.75	1.46%	4.05%
	BMC (g)	0.997	0.993 – 0.999	0.02	0.03	1.10%	3.10%
	BMD g/cm^2	0.985	0.970 – 0.993	-0.04	0.14	1.06%	2.73%

g/cm^2 – grams per centimetre squared, % Δ in Mean – percentage change in mean, CV- confidence variance (typical error), ICC – intraclass correlation coefficient, CI – confidence interval, SEM% - percentage standard error of measurement, SRD% - percentage smallest real difference

FIGURES

Figure 1. Positioning Protocol.