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Reliability of Bone Mineral Density and Body Composition using Dexa (Dual Energy X-Ray Absorptiometry) in Premenopausal Women

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Abstract

Purpose: The purpose of this study was to determine the precision and reliability of a dual energy x-ray absorptiometry (DEXA) device for assessing bone mineral density (BMD), hip geometry and body composition in premenopausal women. Test-retest reliability of DEXA was determined in conjunction with a 12-month bone health intervention to determine the reliability for measurements of key variables and therefore define the smallest worthwhile change.

Method: Seventeen woman (age, 32.3 ± 7.70y; body mass, 69.1 ± 23.2kg; height, 166.5 ± 5.90cm; body fat, 27.5 ± 6.70%) received two DEXA scans within a 7-day period using the same machine and performed by the same technician.

Results: Significant correlations ($p < 0.001$) were observed for all measures and reliability was excellent for all body composition measures (ICC's = 0.92 to 1.00; CV's = 0.32 to 1.23%). Significant correlations ($p < 0.001$) were observed for all measures and reliability was excellent for all left hip measures (ICC's = 0.83 to 1.00; CV's = 0.64 to 2.13%). Significant correlations ($p < 0.001$) were observed for all measures and reliability was excellent for all lumbar spine measures (ICC's = 0.94 to 1.00; CV's = 0.56 to 1.87).

Conclusion: The excellent reliability results reported for BMD, hip geometry and body composition support the use of DEXA to assess the therapeutic effectiveness of an exercise intervention to be used for osteoporosis prevention in premenopausal women.

Keywords: Reliability; Precision; Bone Health; Osteoporosis Prevention; Premenopausal Women

Introduction

Currently, Dual Energy X-Ray Absorptiometry (DEXA) is considered the 'gold standard' tool in the diagnosis and management of osteoporosis, and is used to define fracture risk using WHO T-score criteria [1] DEXA can provide measures of bone mineral density (BMD), bone mineral content (BMC), hip structural analysis (HSA) and body composition. With regards to understanding the utility of these measurements, it is important to quantify the variability associated with these assessments. Previous researchers reporting BMD in premenopausal women have reported coefficients of variation (CV's) ranging from 0.5% to 2.0% for femoral neck and lumbar spine [2-6] however these were not always reported [7-9]. A further limitation is that only one study has reported CV's for BMC, and this value was only presented for the femoral neck [2].

In addition, some of these studies [4,5] provided CV's which represented in-house precision error values, rather than establishing test-retest reliability of a particular technician quantifying the variability associated with a particular sample. Furthermore, only one study has reported test-retest reliability associated with hip structural analysis in premenopausal women, CV's for hip structural analysis variables (section modulus, Z, and minimal femoral neck width) were 4.1% and 1.4%, respectively [2]. However, no CVs were reported for cortical thickness or cross-sectional area. For a full understanding of the variability associated with measurements it is recommended that the measures of absolute (CV) and relative consistency (intra-class correlation coefficients - ICC) should be presented [11]. Given these limitations, the purpose of this study was to quantify both absolute and relative consistency for the variability associated with: a) BMD and BMC at the femoral neck and lumbar spine (L1 - L4); b) hip geometry variables (cortical thickness, cross-sectional area and section modulus) at the femoral neck using hip structural analysis software (HSA); and c) body composition variables (total mass, lean mass, fat mass and body fat percentage), for DEXA in premenopausal women.

Methods

Experimental Approach to the Problem

A test-retest design was utilised to quantify the reliability of the DEXA variables of interest (BMD, BMC, bone geometry variables and body composition). Data was collected using specialised hip structural analysis (HSA) software (Hologic Discovery QDR Series Bone Densitometer, Bedford, Massachusetts). Data was collected for each participant over two testing sessions separated by no more than seven days as recommended by the International Society for Clinical Densitometry.

Participants

Seventeen healthy premenopausal women (20 – 50 yr), volunteered to participate in this study (see Table 1). All participants were considered healthy as determined by a Physical Activity Readiness Questionnaire (PAR-Q) and inclusion criteria required participants to be younger than 51 years of age, in conjunction with the participants reporting a regular menstrual cycle, which was used to determine premenopausal status. All participants provided written informed consent after having being briefed on the potential risks associated with this research. The methods and procedures used in this study were approved by the New Zealand Health and Disability Ethics Committees (17/NTB/155).

Table 1: Baseline characteristics of the participants (mean ± SD)

Demographics	All Participants (n = 17)
Age (yr)	32.3 ± 7.70
Height (cm)	166.5 ± 5.90
Body mass (kg) BMI (kg·m^{-2}) Body fat (%)	69.1 ± 23.2 24.6 ± 7.70 27.5 ± 6.70

Testing Protocol

During the first session participants filled in a pre-screening questionnaire prior to having their height (wall-mounted stadiometer to the nearest 0.1cm) and weight measured using Tanita electronic floor scales (Cloverdale, Western Australia). Prior to scanning, calibration was performed using a criterion phantom device in accordance with the manufacturer guidelines. Procedures were standardised according to the recommendations of the Australian and New Zealand Bone and Mineral Density Society, to minimise any scanning errors. The participants were all positioned within the scan range, with the leg position standardised, and secured with straps (hip scan only) to reduce positioning error. The participants removed metal objects or jewellery from their body prior to scanning and wore similar clothing for each scan. A fan beam DEXA (Hologic Discovery QDR Series Bone Densitometer, Bedford, Massachusetts) device was used, for both testing sessions, to perform the following scans; BMD and BMC at the proximal femur (neck and trochanter), and lumbar spine (L1 - L4); hip geometry (cortical thickness, cross-sectional area and section modulus) utilising specialised HSA software; and body composition (total mass, lean muscle mass, fat mass). Both DEXA testing sessions were performed using the same machine (see Figure 1) by the same technician, at a similar time of day and testing order was standardised for all participants.

Figure 1: Pictorial representation of the DEXA equipment utilised in this study

Statistical Analyses

Descriptive statistics were used to describe the cohort characteristics. Reliability of DEXA bone mineral density and body composition measures was evaluated by intraclass correlation coefficients (ICC) using a two-way random effects model, absolute agreement and average measures ICC [14]. ICCs were classified as follows: 'poor' (≤ 0.40), 'moderate' (0.41 - 0.60), 'good' (0.61 - 0.80), or 'excellent' (≥ 0.81) [10,14]. 95% confidence intervals (95% CI) were calculated to assess relative consistency for all reliability measures. Coefficients of variation (CV) were also calculated (CV = SD/mean * 100) for each dependant variable to assess absolute consistency. Although a CV < 10% is considered acceptable in clinical trials, the International Society for Clinical Densitometry guidelines indicate acceptable precision to be 1.9% at the lumbar spine and 2.5% at the femoral neck. Data analyses were conducted using SPSS 22.0 for Windows (SPSS Inc., Chicago, IL, USA). Significance was set at $p < 0.05$.

Results

Cohort Characteristics

There were 17 participants that completed the DEXA scanning twice over the seven-day period, with an average of 1.4 ± 2.0 days between testing sessions. Participants were between 20 and 50 years of age, with 59% also recruited for the 12-month jump-landing study (Table 1).

Bone Mineral Density and Bone Mineral Content

The test-retest reliability data for DEXA left hip and lumbar measures are reported in Table 2. Relative consistency (ICC) for all measures ranged between 0.98 to 1.00, the lowest ICC was associated with femoral neck BMC. Absolute consistency ranged between 0.70 to 2.01%, the greatest CV was also associated with femoral neck BMC.

Hip Structural Analysis

The test-retest reliability data for DEXA left hip structural analysis measures can be observed in Table 2. Relative consistency was excellent for all left hip structural analysis measures (ICC's = 0.91 to 0.99), the lowest ICC associated with narrow neck cross-sectional area. Absolute consistency ranged from 1.45 to 1.88%, the highest CV was associated with the narrow neck section modulus.

Body Composition

The test-retest reliability data for DEXA body composition measures are detailed in Table 2. Relative consistency for all measures was 1.00, and the absolute consistency ranged between 0.32 to 1.23%. The greatest CV was associated with total body mass and total body fat percentage femoral neck BMC (1.23%).

Please note that the variables reported in this results section are the principal variables of interest to this research and those reported the most in the literature. A full analysis of all variables can be observed in the supplementary material.

Table 2: Test-retest reliability of DEXA for left hip and lumbar spine (L1 - L4) BMD, BMC, hip structural analysis (left hip only) and total body composition measures

Test – retest reliability	Mean ±SD		ICC	95% CI	CV	Qualitative Inference
	Test 1	Test 2	AvgMea		%	
Femoral Neck						
Neck BMC (g)	4.74 ±0.63	4.70 ±0.76	0.98^{s}	0.94 to 0.99	2.01	Excellent
Neck BMD (g/cm^2)	0.95 ±0.11	0.96 ±0.11	0.99^{s}	0.97 to 1.00	1.12	Excellent
Total BMC (g)	37.2 ±6.25	37.2 ±6.27	1.00^{s}	0.99 to 1.00	1.12	Excellent
Total BMD (g/cm^2)	1.07 ±0.12	1.07 ±0.12	1.00^{s}	0.99 to 1.00	0.64	Excellent
Lumbar Spine (L1 - L4)						
Total BMC (g)	72.2 ±8.91	73.5 ±9.02	1.00^{s}	0.99 to 1.00	0.70	Excellent
Total BMD (g/cm^2)	1.16 ±0.15	1.15 ±0.15	0.99^{s}	0.98 to 1.00	1.08	Excellent
Hip Structural Analysis						
Narrow Neck CSA (cm^2)	3.50 ±0.51	3.52 ±0.58	0.91^{s}	0.98 to 1.00	1.56	Excellent
Narrow Neck Z (cm^3)	1.64 ±0.32	1.64 ±0.31	0.99^{s}	0.97 to 1.00	1.88	Excellent
Narrow Neck Cort. Thick. (cm)	0.23 ±0.03	0.23 ±0.03	0.99^{s}	0.95 to 1.00	1.45	Excellent
Body Composition						
Total Body Fat Mass (g)	20630 ±9019	20409 ±9107	1.00^{s}	0.99 to 1.00	1.23	Excellent
Total Body Lean + BMC (g)	52021 ±7793	52179 ±7837	1.00^{s}	0.99 to 1.00	0.69	Excellent
Total Body Mass (g)	72586 ±15343	72588 ±15441	1.00^{s}	1.00 to 1.00	0.32	Excellent
Total Body Fat (%)	27.5 ±6.70	27.2 ±6.77	1.00^{s}	0.99 to 1.00	1.23	Excellent

Key: ICC Intraclass correlation coefficient; AvgMea Average measures; ^{s} $p < 0.001$; CV Coefficient of Variation; BMC Bone mineral content; BMD Bone mineral density; CSA Cross sectional area; Z Section modulus; Cort Cortical; Thick Thickness

Discussion

The purpose of this study was to present a full understanding of the variability associated with DEXA measurements of interest for premenopausal women, by providing measures of absolute (CV) and relative consistency (ICC). Previously these values have not been reported for femoral neck and lumbar spine BMC, bone geometry variables and body composition in this population. In addition, test-retest reliability has not previously achieved the rigour associated with presenting absolute and relative consistency values for these measures, and these values can represent generic in-house values rather than that of a specific technician using a study-specific population. The main findings of this study were that reliability was excellent for all DEXA measures (ICC's = 0.91 to 1.00; CV's = 0.32 to 2.01%).

The test-retest reliability data for DEXA left hip and lumbar BMD and BMC measures were excellent, and relative consistency ranged between 0.98 to 1.00. Absolute consistency for BMD ranged between 0.64 to 1.12%, which is comparable to values (1.0 to 1.4%) reported by researchers who utilised a sub-sample of the premenopausal participants in their intervention [2,3,6]. Absolute consistency ranged between 0.70 to 2.01% for BMC with the greatest CV associated with femoral neck. As only one study has presented test-retest reliability for BMC in premenopausal women [2] and only at the femoral neck (CV = 1.7%), future studies need to report on this variable.

The DEXA left hip structural analysis reliability data was excellent for all measures (ICC's = 0.91 to 0.99; CV's = 1.45 to 1.88%). Any variability may have arisen from technical error generated by the failure to standardise the positioning of the participant in exactly the same position to replicate the rotation at the hip joint, however our results are favourable in comparison to values previously presented (1.4 and 4.1%; for femoral neck width and section modulus respectively) [2]. Further research is required to gain a better understanding about the variability associated with HSA, as currently only one study to our knowledge has presented such data in premenopausal women [2].

Participant positioning has also been suggested to influence DEXA estimates for body composition in addition to biological variation, including hydration status and the effects of diet, exercise, food and fluid in the hours prior to the [13]. However, the test-retest procedures used for determining DEXA body composition measures of premenopausal women produced stable data over two testing occasions. Relative consistency for all measures was 1.00, and the absolute consistency ranged between 0.32 to 1.23%. Although CV values for body composition were either not assessed or not presented for most DEXA studies involving premenopausal women [6] reported absolute consistency values of <1.5% which are similar to our results, all CVs < 1.25%.

As previously only measures of absolute consistency have been presented for the variability associated with DEXA measurements, the purpose of this study was to improve the rigour of test-retest reliability by presenting both absolute and relative consistency values for these measures in premenopausal women. It is therefore recommended that both CV and ICC values should be presented to describe a full understanding of the variability associated with DEXA measurements in this specific population. In addition, it is recommended that test-retest reliability values presented must represent the error associated with a specific technician using a study-specific population, rather than generic in-house values.

Conclusion

We have provided a comprehensive description of the reliability (relative and absolute consistency) associated with DEXA measurements not previously presented for premenopausal women. In addition, we have reported excellent reliability results for BMC, HSA and body composition, which are values not reported in previous studies. It is therefore recommended that future research using DEXA should provide precision error values for these variables to enable acceptable precision ranges to be established for this population. Furthermore, it is advised that test-retest reliability should represent the variability associated with a specific technician utilising a specific population rather than in-house precision error values.

Conflict of Interest

The authors declare that they have no conflict of interest.

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