Fisioterapia & Saúde Funcional

Original Article

# Dual energy X-ray absorptiometry (DXA) reliability of women's pelvic body composition measurements: a cross-section study

Confiabilidade da absorciometria por dupla emissão de raios X (DXA) nas medidas de composição corporal pélvica de mulheres: um estudo transversal

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**ABSTRACT**

Objective: To verify the intra and inter reliability of young adults women's pelvic body composition measurements with the dual x-ray absorptiometry images. Materials and methods: This was a cross-section study of reliability composed by 68 women (35.79 ±14.02 years). Two examiners (Examiner 1 and Examiner 2) performed the measurement from pelvic region through dual energy x-ray absorptiometry (DXA) images. The Examiner 1 performed all the DXA body composition exams. For intra-rater reliability, the Examiner 1 analyzed the image in 2 days separated by 1-week interval. For inter-rater reliability, the Examiner 2 analyzed the images on a different day than Examiner 1. The pelvis was the region of interest (ROI) of this study that was selected manually giving the results from local body mass, lean mass, fat mass, and % fat. Intraclass correlation coefficient (ICC) was calculated considering ICC≥0.75 excellent; 0.40≤ ICC <0.75 satisfactory; and ICC <0.40 poor, with a level significance of 5% and a 95% confidence interval. Results: The intra-rater reliability of Examiner 1 was considered excellent, with ICC above 0.86(p<0.0001). The inter-rater reliability was considering excellent between examiners, with ICC above 0.97(p<0.0001). Conclusion: The intra and inter-rater reliability of Pelvis ROI shows great reliability from pelvic region measurement by DXA images.

**Keywords:** Musculoskeletal System. Densitometry. Reproducibility of Results. Pelvis. Body Fat.

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## INTRODUCTION

The musculoskeletal structure of the pelvic region is responsible for stabilize the movements of the hips and lower limbs, support the load of visceral organs, regulating the rectal and urogenital opening, and maintain urinary and fecal continence [1]. Evidence indicates that structural changes in body composition (distribution of muscle, fat and bone mass) in this region may be related to the development of chronic diseases [2–4].

The deterioration of muscle fibers and the accumulation of intramuscular adipose tissue in the pelvic region predispose to musculoskeletal disease, such as hip osteoarthritis [2], and neuromuscular disorders [3,4]. As well, there is also the hypothesis that the accumulation of adipose tissue in the pelvic region may develop symptoms of the lower urinary tract [5].

Although these dysfunctions are presented in the literature, the methodologies to measure the body composition are too expensive, such as MRI [2], or too basic and not specific as body mass index (BMI) [6]. Recent studies have used dual energy x-ray absorptiometry (DXA) in order to measure body composition in whole body [7] and body segments 8, with great results for reliability and reproducibility. However, there are still no studies that present a reliable method to measure body composition in the pelvic region by DXA.

A reliable method of pelvic segmentation from a body composition exam can improve the understanding of how changes in body composition can influence musculoskeletal disorders in this region [9]. In addition, DXA can generate important and accurate measurements of the body composition of the pelvic region, so that it broadens the assessment of risk factors and research related to chronic diseases.

Considering the importance of body composition analyses in different body segments, particularly in the pelvic region, this present study aims to evaluate the intra and inter-examiner reliability of young women's pelvic body composition measurements, obtained from a manually selected region of interest from dual-energy X-ray absorptiometry (DXA) images, and to introduce a standardized method to evaluate and analyze a segmental body composition of this region.

## MATERIALS AND METHODS

### *Study design*

This cross-section study of reliability was conducted according to the guidelines recommended by The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) [10], by the Consensus for the Selection of Health Measurement Instruments (COSMIN) [11] and by the Guidelines for Reporting Reliability and Agreement Studies (GRRAS) [12].

This study respected the ethical standards established by Resolution CNS 466/2012, which advocates ethical care in research with human beings. The study was approved by the by (CAEE 25632619.6.0000.5504, from the Federal University of São Carlos Ethics Committee on Human Research). All participants who participated in the research received the necessary clarifications regarding the health risks and the objectives of the study, and subsequently signed two copies of the Informed Consent Form.

### *Setting*

All procedures were performed at the OMMITED FOR BLINDED PURPOSES, in the laboratory where the DXA (Horizon® DXA System, Hologic Discovery A, Bendford, MA, USA) is located. This study was conducted from March 2020 to March 2021. Each participant was evaluated once. The Examiners had a prior 20-hour practical training given by a team qualified to handle the equipment and performed all exams. This training aimed to standardize the positioning during the evaluation and acquisition of images.

### *Participants*

Female biological participants aged 18 years or older were eligible for the study. The exclusion criteria were pregnancy, lack of understanding of the proposed procedures, metallic implant, and/or women who underwent bariatric surgery. The sample size was determined by Bonett's study data [13], considering the number of raters (n = 2), a significance level of .05, and intraclass correlation of 0.90. The calculation estimated the correct sample size at 21 individuals. In total, 50 participants participate in the study.

*Procedures*

Prior to the exam, the participants were asked to not perform any physical exercise in the 24 hours preceding the exam and to be at least 4 hours fasting during the exam time. To perform the exam, the participants had to be wearing clothes that did not contain any type of metallic material (zipper or accessories).

The assessment consisted of the identification of the participant, measurement of anthropometric data (weight, height, and body mass index) and the DXA scan for whole body. The measurement of the BMI was performed using an anthropometric scale, applying the formula of the divided mass over the height squared (BMI = $Kg/m^2$).

The procedures for obtaining the images were performed according to the manufacturer's recommendations 14,15:

I. The participant was positioned supine, in the center of the table, with the head at 3 cm from the top marking of the table.

II. The arms were placed resting alongside the trunk (without touching the trunk or pelvis).

III. The legs remained extended and set apart in the hip width, in order to not touch each other. The hallux fingers were taped together.

IV. The participant was asked to remain immobile during the assessment.

After collecting all the images, two independent examiners (Examiner 1 and Examiner 2) were responsible for analyses the specific pelvic region, cropping the images of the region of interest (ROI) (Figure 1). Both examiners received 20-hour theoretical-practical training with a team of physiotherapists trained to perform this analysis. The cutout of the pelvis ROI followed the following parameters:

I. Select the participant's exam.

II. Adjust the contrast of the image to highlighting the bone structures.

III. Boundary cutout edges:

1. Upper border superimposed on the iliac crests.

2. Edge juxtaposed to the right and left acetabulum.

3. Edge between the right and left ischial tuberosity and the coccyx.

The ROI of the pelvis was extracted in the shape of a polygon as in Figure 1, so that it covered the entire pelvic region, avoiding selecting tissues from the abdominal region and thighs. At the end of the ROI selection, the DXA device software provided data on bone mass (g), lean mass (g), fat mass (g) and% fat of the selected polygon.

Each participant perfermed the DXA scan only once, and the images were stored on the equipment's computer. Subsequently, each examinador, on different days and independently, accessed the scans, made a copy. The analyses of the pelvic region were performed using these copies. For intra-rater reliability, the Examiner 1 performed the image analysis in 2 days (day 1 and day 2) separated by 1-week interval. For inter-rater reliability, a second rater (Examiner 2) analyzed the images on a different day than Examiner 1. The examiners did not have access to each other's measurement data during the data analysis. As the examiners did not have access to each other's assessments and worked in a blinded and independent manner, randomization among them was not applicable in this context.

The process of selection, evaluation of participants and analysis of images is represented in Figure 2 through an explanatory flowchart.

*Statistical analysis*

The statistical analysis was performed using SPSS software (IBM company, version 22.0., Armonk, NY, USA). The normality of the data was checked by the Shapiro – Wilk test. The variability of intra and inter-rater measures was assessed using the coefficient of variation (CV), as described by Glüer et al [16] and the International Society for Clinical Densitometry-ISCD [15].

To identify the intra-class correlations (ICC) intra and inter-examiners, the Hulley's 17,18 classification was used, which proposes an excellent ICC when the values are ≥ 0.75, 0.40 ≤ ICC <0.75 a satisfactory result and ICC <0.40 being weak. For all evaluations, it was adopted a significance level of 5%. In addition, the agreement intra and inter-rater evaluated by Bland-Altman plots, with a 95% confidence interval. These plots presented the difference between measurements (y-axis) against the mean of measurements (x-axis).

The standard error of measurement (SEM), minimum detectable difference (MDD), and descriptive statistics (minimum, mean, median, maximum, standard deviation, and coefficient of variation) were also calculated. The SEM is a measure of response stability, which makes it possible to quantify the size of the error in relation to the size of the measurement differences, it is usually used with ICC in reproducibility studies. Through SEM it is possible to obtain MDD, an important index that presents the necessary difference between the measures of two different evaluators for this difference to be considered real [19,20]

**Figure 1.** Dual-energy X-ray absorptiometry (DXA) report with pelvic ROI – R1 (Source: DXA image from one exam, provided by the researchers from this study).

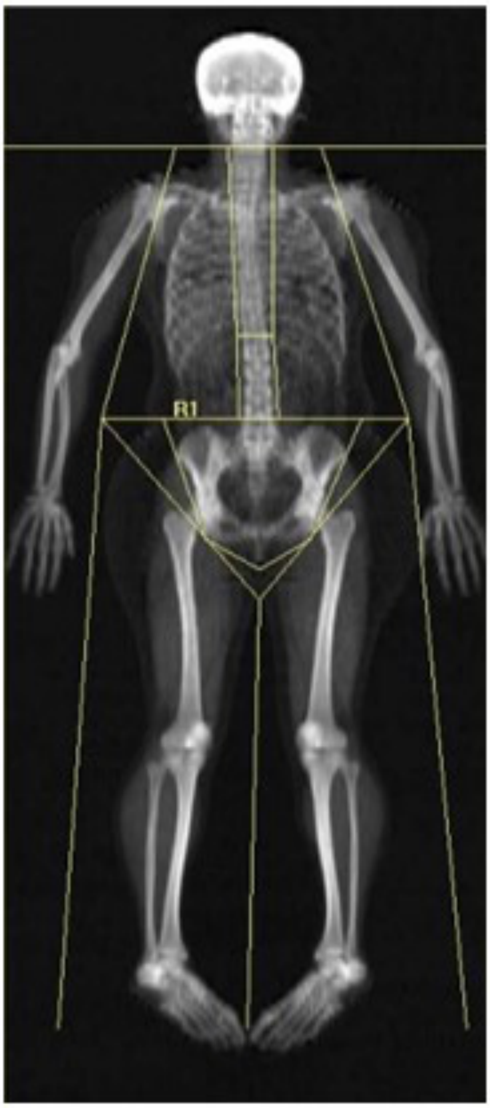
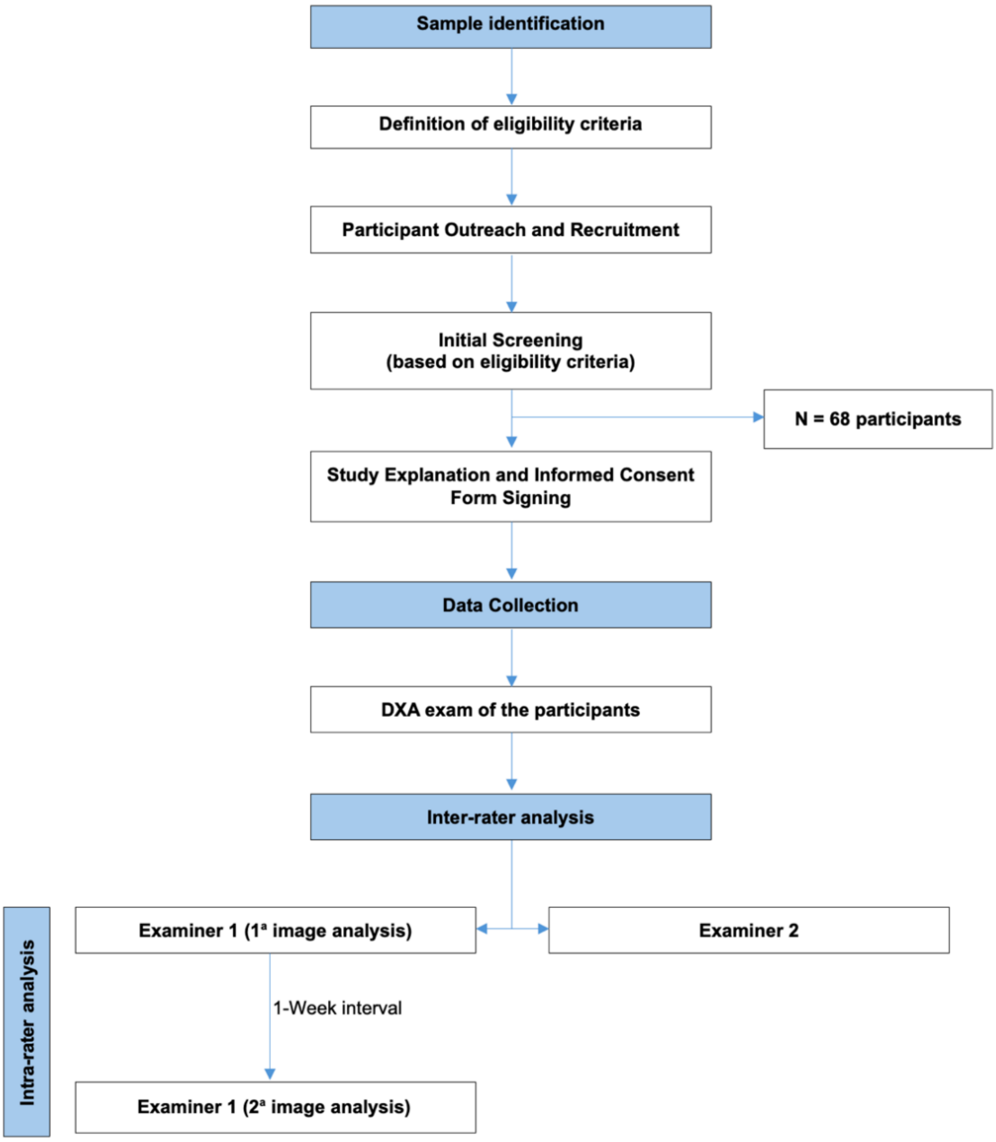


**Figure 2.** Flowchart of the process of sample selection, evaluation and analysis of DXA images.




## RESULTS

This study included 68 women participants. The anthropometric variables are shown in Table 1.

**Table 1.** Anthropometric data.

| Variable | Min-Max | Median | Mean ± SD | CV% |
|---|---|---|---|---|
| Age (years) | 20 - 64 | 29.00 | 35.79± 14.02 | 0.39 |
| Body mass (kg) | 44.00 - 115.00 | 68.95 | 70.31 ± 13.91 | 0.19 |
| Height (m) | 1.46 - 1.79 | 1.63 | 1.62 ± 0.07 | 0.04 |
| Body mass index (kg/m$^2$) | 19.00-44.60 | 26.55 | 26.62 ± 4.76 | 0.17 |

**Legend:** Min-Max: Minimum-Maximum; SD: Standard Deviation, CV: Coefficient of variation.

The intra reliability was considered excellent for all measures assessed with low CV (<0.28%) and high ICC (ICC≥0.75). The ICC values for bone mass, lean mass, fat mass and % fat was 0.99 (p <0.0001); 0.98 (p <0.0001); 0.86 (p <0.0001); and 0.99 (p <0.0001), respectively (Table 2). Table 3 shows the distribution of results CV (<0.28%) and ICC (ICC≥0.75) of the inter-reproducibility of the variables evaluated. The ICC of bone mass, lean mass, fat mass and % fat, of the pelvic ROI, were equal or greater than 0.97 (p <0.0001).

**Table 2.** Results of intra-rater reliability from Pelvis region of interest (ROI) measurement at first evaluation versus second evaluation (Examiner 1).

| **Measures** | **Min-Max** | **Mean** | **SD** | **CV (%)** | **ICC** | **p-value** | **CI95% ICC** | **SEM** | **MDD** |
|---|---|---|---|---|---|---|---|---|---|
| Bone mass (kg) | 0.12-0.47 | 0.23 | 0.07 | 0.27 | 0.99 | <0.0001 | 0.99-0.99 | 0.01 | 0.02 |
| Lean mass (kg) | 3.83-9.28 | 6.01 | 1.03 | 0.16 | 0.98 | <0.0001 | 0.98-0.99 | 0.12 | 0.34 |
| Fat mass (kg) | 1.49-5.66 | 3.35 | 0.83 | 0.25 | 0.86 | <0.0001 | 0.78-0.91 | 0.10 | 0.28 |
| Fat mass (%) | 21.70-47.15 | 35.34 | 4.79 | 0.13 | 0.99 | <0.0001 | 0.99-0.99 | 0.58 | 1.61 |

**Legend:** Min-Max: Minimum-Maximum; SD: Standard Deviation; CV: coefficient of variation ICC: intraclass correlation coefficient CI95%ICC: Confidence Intervals of 95% for Intraclass Correlation. SEM: Standard error of measurement; MDD: Minimum detectable difference.

**Table 3.** Results of inter-rater reliability from Pelvis region of interest (ROI) measurement at first evaluation.

| **Measures** | **Min-Max** | **Mean** | **SD** | **CV (%)** | **ICC** | **p-value** | **CI95% ICC** | **SEM** | **MDD** |
|---|---|---|---|---|---|---|---|---|---|
| Bone mass (kg) | 0.12-0.47 | 0.23 | 0.06 | 0.27 | 0.99 | <0.0001 | 0.99-0.99 | 0.01 | 0.02 |
| Lean mass (kg) | 3.90-9.61 | 6.15 | 1.04 | 0.17 | 0.98 | <0.0001 | 0.97-0.98 | 0.12 | 0.35 |
| Fat mass (kg) | 1.51-5.91 | 3.36 | 0.86 | 0.25 | 0.97 | <0.0001 | 0.96-0.98 | 0.10 | 0.28 |
| Fat mass (%) | 21.80-47.25 | 34.51 | 4.82 | 0.13 | 0.99 | <0.0001 | 0.98-0.99 | 0.58 | 1.62 |

**Legend:** Min-Max: Minimum-Maximum; SD: Standard Deviation; CV: coefficient of variation ICC: intraclass correlation coefficient CI95%ICC: Confidence Intervals of 95% for Intraclass Correlation. SEM: Standard error of measurement; MDD: Minimum detectable difference.

The Bland-Altman plots show that there is no heteroscedasticity between the intra-rater (Figure 3) and inter-rater (Figure 4) values. Thus, the data indicate excellent agreement in the test-retest (first versus second assessment by rater 1) and between the raters, with values within the 95% confidence limits.

**Figure 3.** Bland-Altman graphs of the intra-rater reliability at the first and second evaluation of the Examiner 1.

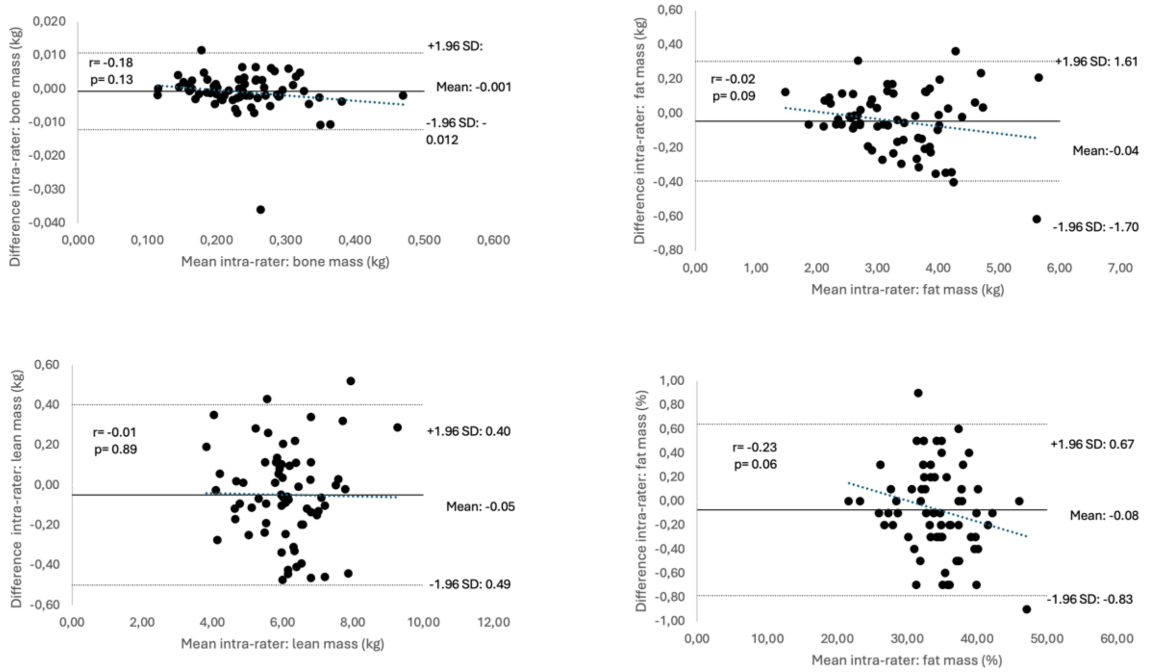
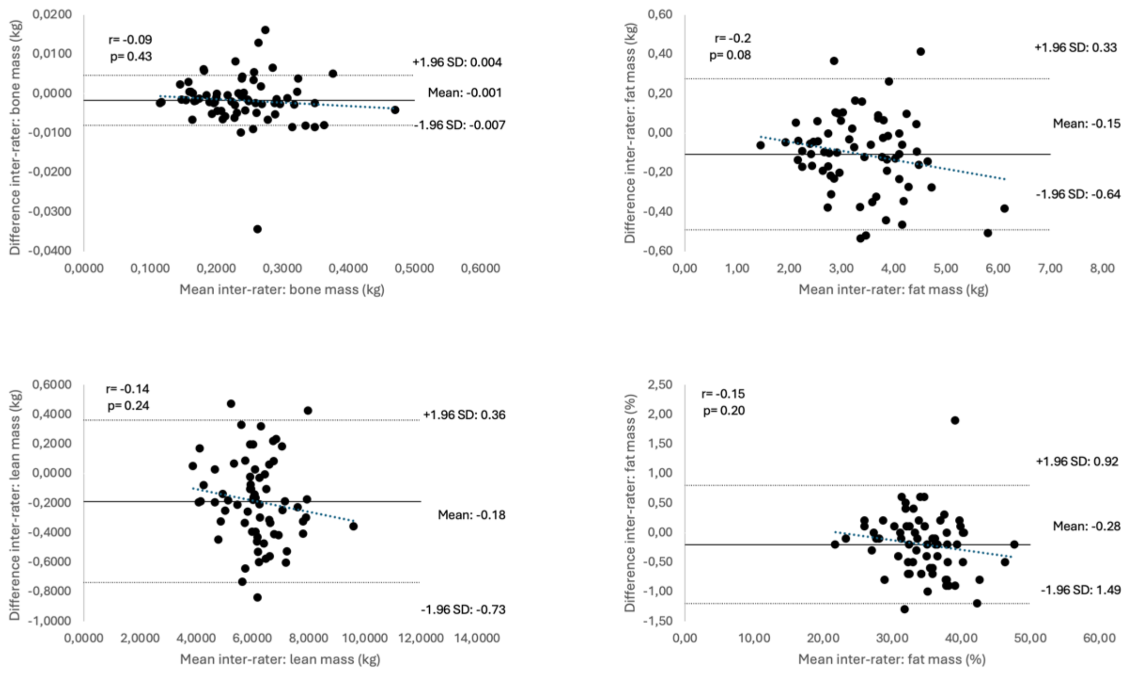



**Figure 4.** Bland-Altman graphs of the inter-rater reliability between Examiner 1 and Examiner 2 at the first evaluations.




## DISCUSSION

This is the first study to report the results of intra- and inter-examiner reliability of measuring pelvis ROI assessed by DXA images. In addition, the analysis was based on a specific guideline to report the intra-reproducibility of an examiner and the inter-reproducibility of two different examiners, who performed the measurements at two different times. Our study shows that the intra and inter reproducibility for the pelvis composition using the DXA images were excellent.

To our knowledge, only one previous study evaluated the ROI of the pelvis by DXA images, however the sample was male and the authors reported only intra-examiner reliability [7]. As observed in our study, Moreira et al. obtained high reproducibility (ICC of 0.98) when measuring the composition of the pelvis in men [7]. Due the lack of inter-examiner reliability, these results are not sufficient to conclude whether the method adopted by the authors is reproducible with different evaluators. The inclusion of the inter-examiner analysis of the present study was important to clarify the consistency and reproducibility of the different evaluators of the adopted method, adding important scientific information about DXA in the segmental assessment of body composition in the pelvic region. In addition, our sample was female only, showing the reproducibility from pelvic analysis in women with different BMI.

Furthermore, the method of pelvic ROI, adopted by the previously cited study, must be carefully analyzed, once the edges of the pelvic ROI were positioned so that the area of analysis of body composition exceeded the pelvic region [7]. In order to avoid other regions inside the ROI of the pelvis, our study used anatomical references to create a polygon that covered the pelvis area with minimum of interference from nearby tissues.

Other studies present excellent intra- and inter- examiner reproducibility of ROI measures from other lower limb regions. Bakkum et al. (2014) obtained an excellent intra and inter-rater agreement in the measurement of the proximal region of the tibia and distal of the femur with ICC of 0.97 and 0.98, respectively [21]. Another study also showed excellent inter-reproducibility in metatarsal measurement (ICC 0.86) [22]. Such results demonstrate that reproducibility studies using DXA images to analyze specific regions of the lower limbs are widely performed to expand the assessment of body composition in particular region.

In addition, the intra and inter-rater variability was calculated, by CV, in order to ensure that the measurements had a low precision error [16,23]. The International Society for Clinical Densitometry 15 establishes that the precision error values do not exceed 3% to determine that there is reproducibility. The present study reached values below 1%, therefore, there are high precision was achieved in intra and inter-rater measurements. Such results are in accordance with a study of segmental analyzes by DXA of upper and lower body in which an intra-tester (CV ≤ 2.0%; ICC ≥ 0.888) and inter-tester (CV ≤ 2.0, 4%; ICC ≥ 0. 980) very high and almost perfect [24].

Although ICC and CV are often reported as the only ones statistical analysis in reproducibility studies, it is recommended that SEM and MDD analyzes be performed to also estimate the accuracy and stability of measurements [19,20]. The present study obtained good results, minimum values, after performing the SEM and MDD analyzes of the studied measures. Such results suggest that the clipping method adopted by the authors can be performed in a reliable and precision way to assess the composition of the pelvic region. We did not find studies of reproducibility of body composition in the pelvic region by DXA that analyzed SEM and MDD. Furthermore, the graphs indicate that this method is reliable and without error variance in assessing bone mass, fat mass and lean mass in the pelvic region. Thus, this is the first study to report the results of intra and inter-rater reproducibility of women's pelvic composition using DXA, following the recommendations for carrying out the appropriate statistical analyzes.

The computed tomography exam is widely recommended in clinical analysis from pelvis region with great reproducibility [25–27]. However, the computed tomography exam has limitations as high radiation dose, high costs and requires a specialized professional. Therefore, it is important to search for other exams that are more accessible, low cost and with a lower radiation dose, as DXA scan [28]. The high ICC values found in the analysis of intra- and inter-examiner reliability in this study indicate that measuring pelvis ROI by DXA is an alternative for assessment of women's body composition by segmentation in the pelvic region, can be implemented in clinical assessments and further research.

It is known that sex and age can influence body composition due to the amount of fat and morphological changes during the aging process, which can cause variations in DXA measurements [29,30]. In order to include different body compositions, our sample was diversified among age and BMI. However, this study was carried out by a sample composed exclusively of women, which indicates that the results obtained must be carefully applied in a different population. Therefore, further research is recommended to assess the reproducibility of the measurement of pelvis ROI from men in different age and BMI groups.

We did not find difficulties in defining the ROIs, despite the diverse sample analyzed. We believe that having a standardized image acquisition protocol in the literature [14, 15] ensured adequate body position and pelvic region alignment. Furthermore, adopting an analysis of a specific region based on bone anatomical bone points facilitates the definition of the ROI, regardless of the weight or biotype of the analyzed individual. Even in images in which the hip was not perfectly aligned, the use of anatomical points as reference allows ROI delimitation.

The present study has as limitation the population included in the study, that evaluate only a sample of women. The sex can influence the fat concentration and body composition [31] thus is recommended new research that investigate the possible differences in segmental body composition between genders male and female.

These results indicate that the segmental assessment presented technical practicity to daily clinical. The findings of the ROI measurements of the pelvis show excellent intra-examiner and inter-examiner reproducibility for two independent examiners. Such results indicate that the segmental assessment presented in this study is a standardized and reproducible method to quantify a body composition in the pelvic region using DXA. Thus, this evaluation may help understanding the repercussions caused by the increase of fat in this region on the health of the woman. However, we emphasize that to obtain a high confidence and a low error in the reproduction of the presented evaluation protocol, we recommend that there is prior training of the professional who will carry out the evaluations.

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**DECLARATIONS**

**Ethics approval:** This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by CAEE 25632619.6.0000.5504, from the Federal University of São Carlos Ethics Committee on Human Research.

**Consent to participate:** Written informed consent was obtained from the parents.

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