Nutrición Hospitalaria

Trabajo Original

Valoración nutricional

Dual energy X-ray absorptiometry (DXA) reliability and intraobserver reproducibility for segmental body composition measuring

Reproducibilidad de la absorciometría dual de rayos X (DXA) y la reproducibilidad intraobservador para la medición de la composición corporal segmentaria

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Abstract

Background: the measurement precision of body composition can interfere on the diagnosis and prescription of diseases' treatment. Furthermore, with regard to dual energy X-rays absorptiometry (DXA), there may be important differences between the measures of regions of interest (ROI) automatically performed by DXA or manually by an evaluator, which can cause measurement error and influence the evaluation or diagnosis.

Aim: thus, this study aimed to evaluate the measurement reliability of body composition by DXA and intraobserver reproducibility for the ROI measurement.

Methods: a total of 15 young adults were subjected to two full-body scans by DXA, under the same conditions. The first scan of all volunteers was chosen and the extent of the ROI was performed, in two stages, separated by a period of 2 weeks, by a single trained evaluator. The coefficient of variation (CV) and intraclass correlation coefficient (ICC) were calculated with a significance level of $p < 0.05$.

Results: high-precision measurements of DXA for whole body mass (ICC = 0.999; CV = 2.3%), fat mass (ICC = 0.998; CV = 1.6%), lean mass (ICC = 0.995; CV = 0.3%) and bone mineral content (ICC = 0.996; CV < 0.1%) were obtained. Further, it was observed high intraobserver reproducibility for ROI measurement, with ICC values ranging between 0.952 and 0.999.

Conclusion: body composition measurement by DXA presents high reproducibility for whole body mass, fat mass, lean mass and bone mineral content and also high intraobserver reproducibility for the ROI measurement.

Resumen

Introducción: la precisión de las medidas de la composición corporal puede interferir en el diagnóstico y prescripción del tratamiento de las enfermedades. Además, con respecto a la absorciometría dual de rayos X (DXA), pueden existir diferencias importantes entre las medidas de regiones de interés (ROI) realizadas automáticamente por DXA o manualmente por un evaluador, lo que puede causar error de medición e influir en la evaluación o diagnóstico.

Objetivo: evaluar la reproducibilidad de la medida de la composición corporal por DXA y la reproducibilidad intraobservador para la medición de las ROI.

Métodos: quince adultos jóvenes fueron sometidos a dos exploraciones de cuerpo completo por DXA, en las mismas condiciones. Se escogió la primera exploración de los voluntarios y se realizó la extensión de las ROI en dos etapas, separadas por un periodo de 2 semanas, por un solo evaluador capacitado. El coeficiente de variación (CV) y el coeficiente de correlación intraclase (ICC) se calcularon con un nivel de significación de $p < 0.05$.

Resultados: la DXA presentó alta precisión para las medidas de la masa corporal total (ICC = 0.999, CV = 2.3%), masa grasa (ICC = 0.998, CV = 1.6%), masa magra (ICC = 0.995, CV = 0.3%) y hueso (ICC = 0,996, CV < 0,1%). Además, se observó una alta reproducibilidad intraobservador para la medida de las ROI, con valores de ICC entre 0,952 y 0,999.

Conclusión: la medida de la composición corporal por DXA presenta alta reproducibilidad para todos los componentes y también alta reproducibilidad intraobservador para la medida de las ROI.

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INTRODUCTION

Body composition, admittedly plays a key role in the health/
disease process, since its components have, among others, met-
abolic functions that may be involved in the prevention or genesis
of various diseases (1-5). In this sense, the precise measurement
or monitoring of fat mass (FM), lean mass (LM) or bone mineral
content (BMC) can have significant clinical application, once can
interfere in the diagnosis and prescription of drug or non-drug
treatment (6,7).

Based on this premise, a recent systematic review (8) indi-
cates that the dual energy X-ray absorptiometry (DXA) is being
considered the new gold standard for measuring body composi-
tion, due to its high correlation with the methods of the MRI and
computed tomography and present better cost benefit compared
to these methods. This is making to engage yourself in some
studies to analyze the reliability of measurements of the apparatus
for body composition assessment (9-14). However, these studies
only analyze the data relating to measures total body and not
providing accurate information about DXA to measure segmental
body composition.

Segmental body composition is measured by DXA defining
regions of interest (ROI) (15), which can be automatically set by
the apparatus or manually by the observer. Both definitions can
lead to errors which, in turn, can interfere with the measurement
result. In this sense, none of the studies reviewed had dedicated
to analyze if assessing the measurements of ROI made by the
same evaluator are accurate or not.

Therefore, this study aimed to evaluate the reliability of the
measurement of body composition by DXA and intraobserver
reproducibility for the measurement of ROI.

METHODS

SAMPLE

The sample included 15 young adults, males, apparently
healthy and physically active who volunteered for the study. None
of the volunteers reported use of drugs or any substance that
could interfere with the results of the measures.

Before any test, all volunteers were informed of the possible risks
and objectives of the study and signed informed consent to partic-
ipate. All assessment procedures were done in the Exercise Phys-
iology Laboratory of the Department of Biomedical Sciences at the
University of León. The procedures used in this work were approved
by the Ethics Committee of the University of León, in accordance
with the ethical principles expressed in the Declaration of Helsinki.

PROCEDURES

To set the measurements precision, both the apparatus used
and the evaluator who performed the measurements of the ROI,
was conducted the design presented in figure 1.

To check the reproducibility of DXA to measure body composi-
tion, the volunteers were subjected to two full-body scans by DXA
using a densitometer General Electric, model Lunar Prodigy and
the software Encore 2009, version 13.0. Before conducting the
exploration, the equipment has been calibrated.

The two scans of each volunteer were done after stand by for
30 minutes and under the same conditions. In the first whole
body scan (S1) by DXA, the volunteer laid in supine position on the
device, with upper limbs extended and parallel to the trunk, hands
pronated and supported on the device. The lower limbs were also
extended, with standard separation at hip width and secured by
a tape that held his ankles. They were instructed to remain as
still as possible for the duration of the scan (10,15,16). After the
end of the first scan, it was requested to the volunteer stands up
and lies down again on device, keeping the same body position
of the first scan. From there, the second exploration proceeded
with another whole body scan (S2) by DXA. Each scan took about
seven minutes and from S1 and S2, an automatic calculation of
DXA outcome parameters (TBM, FM, LM, BMC) was achieved. For
each subject, the following outcome parameters were obtained:
TBM_{S1}, FM_{S1}, LM_{S1}, BMC_{S1}, TBM_{S2}, FM_{S2}, LM_{S2}, BMC_{S2}. Using these
outcome parameters, were calculated the coefficient of variation
(CV), the interclass correlation coefficient (ICC) and its 95% con-
fidence interval (CI95%).

To measure the intraobserver reproducibility for ROI measures,
in two different days (D1 and D2, seven to twenty days between
both readings), one expert manually defined ROIs on the S1. Then,
the body was divided into 16 ROI, determined based in some
anatomical points, as follows:

– *Foot:* it was considered as part of the bottom edge of the
   distal phalanx of the hallux to the line drawn on the medial

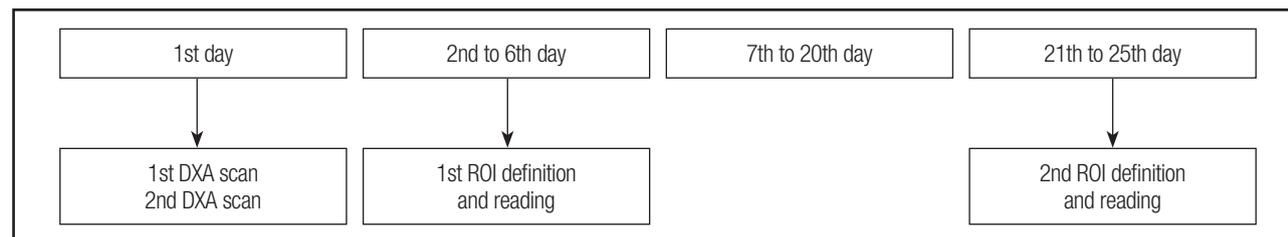| 1st day	2nd to 6th day	7th to 20th day	21th to 25th day
1st DXA scan 2nd DXA scan	1st ROI definition and reading		2nd ROI definition and reading

Figure 1.

Summary of the methodological design used in this study.

and lateral malleolus of tibiotalar joint. The medial and lateral boundaries of the ROI were made so that encompasses all soft tissue. The same points were considered for the right and left feet.

– *Leg:* it was measured starting from the line drawn on the medial and lateral malleolus of tibiotalar joint to the line drawn at the lower edge of the medial and lateral condyles of the knee joint. The medial and lateral boundaries of the ROI were made so that encompasses all soft tissue. The same points were considered for the right and left legs.

– *Thigh:* it was measured from the line drawn at the lower edge of the medial and lateral condyles of the knee joint to the lower edge of the ischium. The medial and lateral boundaries of the ROI were made so that encompasses all soft tissue. The same points were considered for the right and left thighs.

– *Pelvic area:* it was measured from the lower edge of the ischium to the posterior-superior border of the iliac crest. The medial boundary of the pelvic area was made by a line drawn from the midline of the pubic symphysis to the median line of the lumbar vertebra four (L4). The lateral boundary of the ROI was made so that encompasses all soft tissue. The same points were considered for the right half and the left half of the pelvic area.

– *Trunk:* it was measured from the posterior-superior edge of the iliac crest to the upper edge of the sternoclavicular joint. The lateral boundaries of the ROI (arm spacing) were made along the midline of the glenohumeral joint, right and left.

– *Hand:* it was measured starting from the lower edge of the distal phalanx of the middle finger to the line drawn on the lower edge of the medial and lateral styloid process of radiocarpal joint. The medial and lateral boundaries of the ROI were made so that encompasses all soft tissue. The same points were considered for the right and left hands.

– *Forearm:* it was measured from the line drawn on the lower edge of the medial and lateral styloid process of the radiocarpal joint to the line drawn on the medial and lateral epicondyles of the humerus. The medial and lateral boundaries of the ROI were made so that encompasses all soft tissue. The same points were considered for the right and left forearms.

– *Arm:* it was measured starting from the line drawn on the medial and lateral epicondyles of the humerus to the upper edge of the acromial extremity of the clavicle. The medial boundary of the ROI (separation of the trunk) was made in the midline of the glenohumeral joint and the lateral boundary was made so that all soft tissue was encompassed by the ROI. The same points were considered for the right and left arms.

– *Head:* it was measured from the upper edge of the sternoclavicular joint to the cranial vertex.

All ROI are illustrated in figure 2.

These ROI delineations were then used to compute the total mass of each body segment, for each subject. Using these outcome parameters, was computed the CV, the ICC and its CI95% to total mass of each body segment.
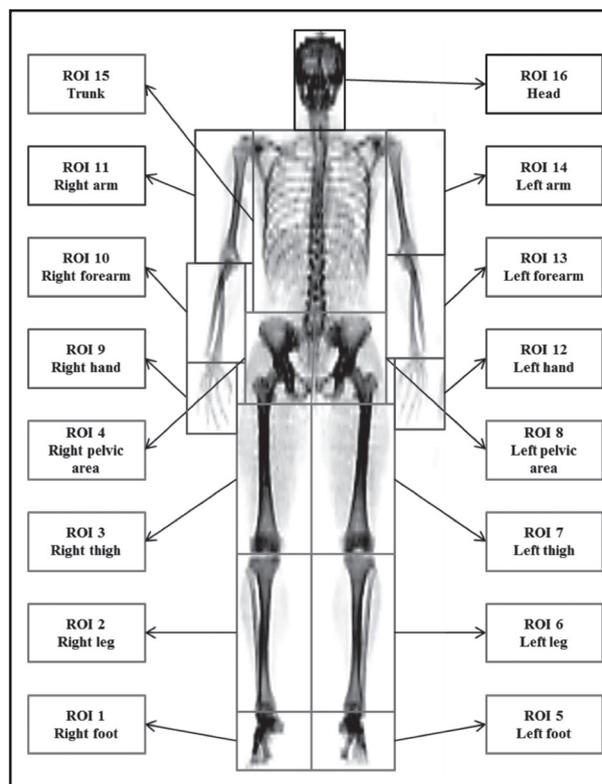

Figure 2.
Graphic representation of the 16 ROI analyzed.

STATISTICAL TREATMENT

All statistical analyzes were performed in SPSS for Windows, version 21 (IBM, Chicago, USA). Initially, the data were subjected to normality test of Shapiro-Wilk. After, the descriptive analysis of the data was done, through the mean and standard deviation (SD). The reliability of body composition measurements by DXA was determined by calculating the CV and the ICC. ICC was also used to verify the intraobserver reproducibility for the measurement of each one of the 16 ROI, with a CI95%. A level of statistical significance of $p < 0.05$ was established for all treatments.

RESULTS

The 15 volunteers tested had a mean age of 24.25 ± 5.52 years, with extremes ranging between 18.5 and 36 years; an mean height of 179.80 ± 7.23 cm, with extremes of 169 and 192 cm; an mean body mass of 78.15 ± 7.92 kg, with extreme values of 67 and 99 kg; and an mean BMI of 24.13 ± 1.34 kg/m², with extreme values ranging between 21.49 and 26.86 kg/m².

Regarding DXA reliability to measure the components of body composition, it may be seen in table I that for all components, a low CV and high internal consistency of measurement repeatability were found.

Table I. Results of DXA reliability to measure TBM, FM, LM and BMC

	Eval.	X	SD	CV	ICC (CI95%)	p-value
TMB	1st	76.79	7.95	2.3%	0.999 (0.998-1.000)	< 0.001
	2nd	76.57	7.69			
FM	1st	12.09	4.90	1.6%	0.998 (0.992-0.999)	< 0.001
	2nd	11.91	5.06			
LM	1st	60.71	6.21	0.3%	0.997 (0.992-0.999)	< 0.001
	2nd	60.79	6.03			
BMC	1st	3.66	0.58	0.1%	0.998 (0.993-0.999)	< 0.001
	2nd	3.66	0.60			

Eval.: evaluation; X: mean; SD: standard deviation; CV: coefficient of variation; ICC: intraclass correlation coefficient; IC95%: confidence interval of 95%; TBM: total body mass; FM: fat mass; LM: lean mass; BMC: bone mineral content.

The results of the intraobserver reproducibility for the measurement of the 16 ROI show a high consistency of the measures of the two assessments, with intraclass correlation values slightly lower in the feet, pelvic areas and trunk, as shown in the table II.

DISCUSSION

The reliability of results for DXA to measure the TBM, FM, LM and BMC, showed high levels of reproducibility for all components evaluated with lower CV (< 2.3%) and higher ICC (between 0.992 and 1.000).

Similar results were observed by Hind et al. (12), in a study that sought to assess DXA reliability *in vivo* (GE Lunar Prodigy) to measure body composition in 52 British adults. The authors found low CV for BMC (1.3%) and FM (2.5%). However, they did not describe the CV for LM and TBM. Similarly, Rothney et al. (14), in a study that aimed to characterize *in vivo* the reliability of total and regional body composition by DXA (GE Lunar iDXA) in a sample of obese American adults, found CV of 0.5% for BMC, 1% for FM and 0.5% for LM with the total body scanning.

In obese people, Carver et al. (11), who sought to evaluate DXA reliability (GE Lunar iDXA) to measure body composition and fat distribution, also observed low CV values for measures BMC (1.08%), FM (0.9%) and LM (0.94%). The authors also reported ICC values of 0.99 for the three components (BMC, FM and LM).

Based on the protocols, study objectives and characteristics such as quality control, reliability and valuation measures, the DXA may be considered as one of better methods to determining the values of FM, LM and BMC, and also one advanced and cost-effective technology that is useful for data acquisition of body composition in clinical trials of short to medium term, since its limitations are considered when planning the stages of an intervention (16,17).

Thus, regardless of the characteristics of the populations evaluated, DXA has shown good reliability, with high ICC and low CV (11,12,14), as observed in our study. These results allow us to consider the DXA as a method for assessing total body compo-

sition with precise and consistent results at different times of evaluation.

Little has been done to evaluate the intraobserver reproducibility of measurements of the ROI in DXA, especially since most studies assessing the reproducibility of this method were based in automatic measurements performed by the device. Thus, this study presents an unprecedented contribution to the scientific literature by evaluating the reproducibility of measurements intra analyzed for the 16 ROI, in which higher ICC values were obtained (between 0.952 and 0.999), indicating an excellent measurement reliability of this method for all body regions.

Similarly, the study by Buckinx et al. (10), which aimed to evaluate the correlation between the bioelectric impedance and DXA (Hologic QDR Discovery) for assessment of body composition in 138 Belgian adults, found an intraobserver reproducibility also high [ICC = 0.89 (0.86 to 0.92) for the total sample], although presented lower values than the ones of this study. However, Buckinx et al. (10) did not determine the reproducibility of measures for body segments; neither established which procedure used to define the ROI in the members.

The ICC is a statistical calculation that can be used to indicate reliability or reproducibility between two measurements for the same evaluator. The more ICC approaches 1, the higher the precision or reproducibility, thereby resulting in equal values of 0.90 or superior can be regarded as very high, values between 0.70 and 0.89, can be regarded as high and values between 0.50 and 0.69, as moderate (18). In this sense, the values found in this study indicate an intraobserver agreement very high for the definitions and readings of the measures, regardless of the region scanned and region size.

Thus, it is possible to consider that in measurements TBM, FM, LM and BMC, the DXA has very high reliability. In this study, for the 16 ROI analyzed, was also obtained a high intraobserver reproducibility, which indicates a high reliability for both measures, for the instrument and the observer.

This study presents a possible limitation for evaluating only a sample of men, once sex can influence body composition (19,20) and that the amount of fat may involve greater variations in mea-

Table II. Intraobserver reproducibility results for measuring of the 16 ROI of analyzed body segments

Body segments	Eval.	X	SD	ICC (CI95%)	p value
Right foot	1st	1.02	0.08	0.955 (0.866-0.985)	< 0.001
	2nd	1.03	0.08		
Left foot	1st	1.03	0.09	0.952 (0.857-0.984)	< 0.001
	2nd	1.05	0.10		
Right leg	1st	3.45	0.51	0.998 (0.995-0.999)	< 0.001
	2nd	3.43	0.50		
Left leg	1st	3.41	0.49	0.998 (0.994-0.999)	< 0.001
	2nd	3.40	0.48		
Right thigh	1st	9.00	1.06	0.994 (0.982-0.998)	< 0.001
	2nd	9.12	1.15		
Left thigh	1st	8.73	0.99	0.996 (0.987-0.998)	< 0.001
	2nd	8.82	1.07		
Right pelvic area	1st	7.09	0.86	0.986 (0.959-0.995)	< 0.001
	2nd	6.94	0.82		
Left pelvic area	1st	7.07	0.95	0.989 (0.968-0.996)	< 0.001
	2nd	6.93	0.84		
Trunk	1st	24.21	2.39	0.983 (0.950-0.994)	< 0.001
	2nd	24.18	2.29		
Right hand	1st	0.34	0.08	0.994 (0.982-0.998)	< 0.001
	2nd	0.34	0.08		
Left hand	1st	0.32	0.10	0.996 (0.987-0.999)	< 0.001
	2nd	0.32	0.10		
Right forearm	1st	1.27	0.22	0.999 (0.998-1.000)	< 0.001
	2nd	1.26	0.22		
Left forearm	1st	1.21	0.20	0.995 (0.986-0.998)	< 0.001
	2nd	1.21	0.20		
Right arm	1st	2.81	0.47	0.992 (0.975-0.997)	< 0.001
	2nd	2.78	0.48		
Left arm	1st	2.79	0.42	0.993 (0.979-0.998)	< 0.001
	2nd	2.76	0.45		
Head	1st	5.78	0.41	0.995 (0.984-0.998)	< 0.001
	2nd	5.81	0.41		

Eval.: evaluation; X: mean; SD: standard deviation; ICC: intraclass correlation coefficient; CI95%: confidence interval of 95%.

surements of DXA (Valentine et al., 2008). However, we opted for this strategy in order to minimize a possible influence of factors related to the female gender, as the menstrual cycle, in the body composition. Future researches should establish the possible differences in segmental body composition between genders.

Based on the results of this study, we can conclude that the calculations performed with DXA in young people show a high reproducibility for both, TBM and FM, LM and BMC. In addition, the definition of specific body segments, the ROI, performed by a single observer, presents high reproducibility in both large and small segments.

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