Validation of a Multi-Electrode Bioelectrical Impedance Analyzer with a Dual-Energy X-Ray Absorptiometer

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ABSTRACT

Sarcopenia, the loss of muscle mass, strength, and function due to ageing, is a major health concern for the growing older adult population. One challenge for prevention, diagnosis, and treatment of sarcopenia is the need for a dual-energy X-ray absorptiometry (DXA) analyzer to measure appendicular lean mass (ALM). DXA is the recommended measurement of muscle mass for sarcopenia, but is expensive and exposes subjects to radiation. Therefore, inexpensive, safe, and widely available alternative measurements, such as bioelectrical impedance analysis (BIA), need to be identified and validated to be practically utilized in clinical settings.

Purpose: The purpose of this study is to validate the multi-frequency BIA with 8 tactile electrodes (InBody 720) with the gold-standard DXA scan (Hologic Horizon W).

Methods: Participants were 277 older adults from 65 to 96 years old without history of cancer and severe medical or mental conditions. Individuals completed a 12-hour fast, refrained from activity that morning and wore scrubs. BIA and DXA analyses were taken immediately after each other.

Results: Correlation between the two methods for fat free mass (FFM), ALM, and percent body fat (PBF) were 0.93, 0.86 and 0.92, respectively, after adjusting for age and sex. Mean Percent Error (MPE) (DXA - InBody) and Mean Absolute Percent Error (MAPE), measures of prediction accuracy, were -13% and 13% for FFM, -12% and 13% for ALM, and 16% and 17% for PBF. Prediction equations were developed for improved estimation, in which age was coded in years and sex was coded as 1 for male and 0 for female:

DXA FFM= 0.83 (BIA FFM) + 0.025 (Age) + 2.0 (Sex) + 0.36 (R^2=0.96)

DXA ALM= 0.74 (BIA ALM) – 0.025 (Age) + 1.84 (Sex) + 4.15 (R^2=0.92)

DXA PBF= 0.71 (BIA PBF) – 0.089 (Age) – 3.3 (Sex) + 23.5 (R^2=0.91)

Conclusion: The BIA body composition variables are highly correlated with DXA variables. However, we found consistent overestimation of FFM and ALM and underestimation of PBF in BIA compared to DXA based on MPE and MAPE analyses, which were incorporated in the development of FFM, ALM, and PBF estimation equations.

INTRODUCTION

Until 8-electrode BIA cut-points are established, measurement of muscle mass by DXA may limit wide-spread screening of sarcopenia. The validation of BIA devices with DXA and development of prediction equations can improve the accuracy and may help to establish cut-points for appendicular lean mass.

METHODS

Study Sample

- 275 older adults without history of cancer, severe medical or mental conditions, uncontrolled diabetes or metabolic disease
- Participants completed a 12-hour fast and refrained from physical activity that morning
- Measures of body composition (InBody 720 & Horizon W model DXA) were one after the other
- Participants were recruited as part of an observational study and included if they had both BIA and DXA data available

InBody 720

- 8 electrodes utilizing multiple frequencies (1kHz, 5kHz, 50kHz, 250kHz, 500kHz and 1000kHz) and alternating current (100μA, 500μA) analyzed impedance in each arm, each leg and trunk (InBody USA, Cerritos, CA)
- Participants stood upright and barefoot on the device, grasped the handles of the analyzer and extended their arms out from the sides of their body
- Proprietary equations calculated whole body fat mass, fat-free mass and percentage body fat and segmental (individual arms, legs and trunk) lean soft tissue, which excluded fat and included skin, blood, muscle and bone
- ALM was calculated by summing the weight of lean soft tissue from the limbs

Hologic Horizon W model DXA

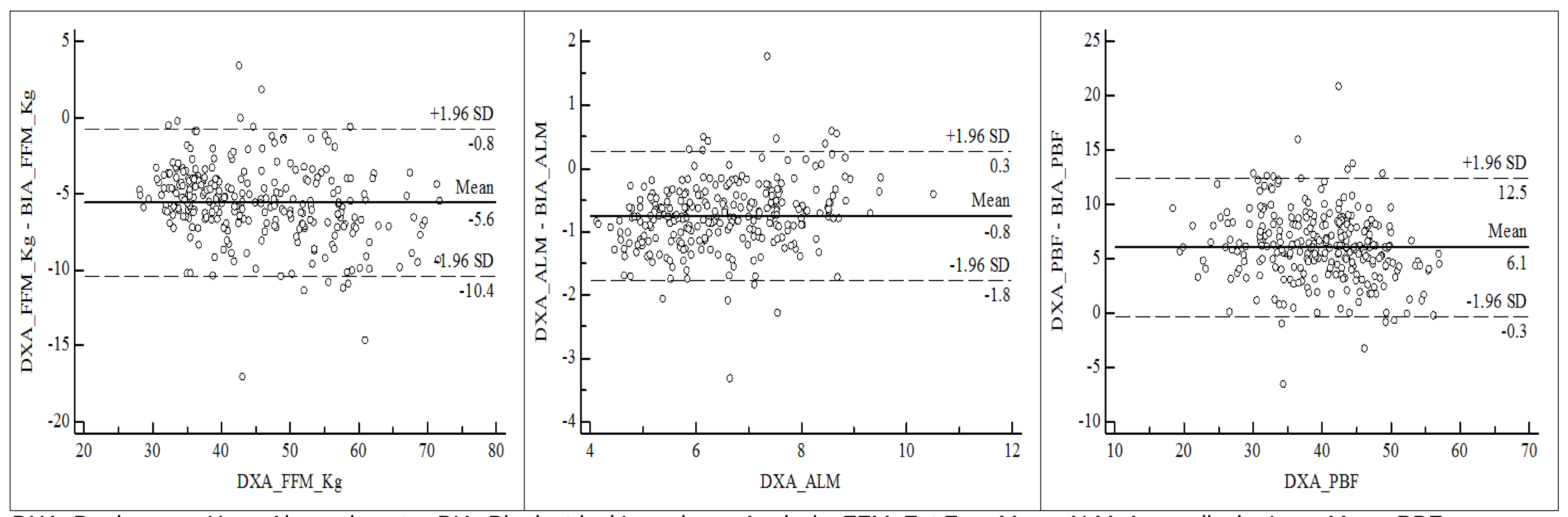
- A full body scan was performed on the device after daily calibration
- A trained technician performed the scan and analysis with the participant supine and wearing scrubs
- Whole and regional body composition were measured, including fat mass (FM), percentage body fat (%BF), fat-free mass (FFM), appendicular lean mass (ALM), bone mineral content and bone mineral density

Statistical Analysis

- Pearson correlation, mean percent error (MPE), mean absolute percent error (MAPE) were run to examine the association between InBody and DXA variables and assess error between the devices
- Bland-Altman plots were created to evaluate random and systematic error
- Multivariable linear regression was used to develop prediction equations for InBody variables

RESULTS

Figures 1 – 3. Bland-Altman Plots of FFM, ALM, and PBF.



DXA: Dual-energy X-ray Absorptiometry, BIA: Bioelectrical Impedance Analysis, FFM: Fat Free Mass, ALM: Appendicular Lean Mass, PBF: Percentage Body Fat

Prediction Equations to improve InBody720 estimates of FFM, ALM, and PBF.

DXA FFM= 0.83 (BIA FFM) + 0.025 (Age) + 2.0 (Sex) + 0.36 (R^2=0.96)

DXA ALM= 0.74 (BIA ALM) – 0.025 (Age) + 1.84 (Sex) + 4.15 (R^2=0.92)

DXA PBF= 0.71 (BIA PBF) – 0.089 (Age) – 3.3 (Sex) + 23.5 (R^2=0.91)

RESULTS

Table 1. Baseline Characteristics by Gender.

	All (n=277)	Range	Male (n=115)	Range	Female (n=162)	Range
Age	72.8(5.8)	65-96	72.9(5.9)	65-96	72.8(5.7)	65-90
Height (cm)	168.3(9.7)	148.2-198.0	176.7(7.5)	154.4-198.0	162.4(6.1)	148.2-176.0
Weight (g)	76.9(16.8)	42.0-130.3	86.0(14.8)	49.8-125.4	70.4(15.1)	42.0-130.3
BMI	27.0(4.9)	16.0-45.9	27.5(4.1)	18.7-40.4	26.7(5.4)	16.0-45.9
FFM (g)						
DXA	45.1(10.3)	28.1-71.8	54.9(7.2)	38.0-71.8	38.2(5.3)	28.1-56.4
InBody	50.7(11.2)	32.8-80.9	61.1(8.4)	39.2-80.9	43.4(6.0)	32.8-62.9
ALM (kg/ht2)						
DXA	6.52(1.2)	4.1-10.5	7.5(0.9)	5.5-10.5	5.8(0.9)	4.1-8.6
InBody	7.3(1.2)	5.0-10.9	8.3(0.8)	6.4-10.9	6.6(0.8)	5.0-10.0
ALM (kg)						
DXA	18.8(5.0)	10.4-32.4	23.5(3.5)	15.1-32.4	15.3(2.6)	10.4-24.2
InBody	21.0(5.5)	12.4-38.5)	26.0(4.1)	16.8-38.5	17.4(3.0)	12.4-26.5
%BF						
DXA	39.7(7.8)	18.5-57.0	34.0(5.9)	18.5-46.9	43.8(6.2)	26.0-57.0
InBody	33.6(9.0)	8.8-56.4	28.2(7.3)	8.8-45.1	37.4(8.1)	17.0-56.4

BMI: Body Mass Index, FFM: Fat Free Mass, DXA: Dual-energy X-ray Absorptiometry, BIA: Bioelectrical Impedance Analysis,, ALM: Appendicular Lean Mass, %BF: Percentage Body Fat

Table 2. Correlation adjusted for Age and Sex.

Correlations	All	Males	Females
FFM (g)	**DXA**		
InBody	0.93	0.94	0.91
ALM (kg/ht2)	**DXA**		
InBody	0.86	0.88	0.84
%BF	**DXA**		
InBody	0.92	0.92	0.93

FFM: Fat Free Mass, ALM: Appendicular Lean Mass, %BF: Percentage Body Fat, DXA: Dual-energy X-ray Absorptiometry

Table 3. MPE and MAPE by Gender.

MPE	All (mean(SD))	All (min-max)	Male (mean(SD))	Male (min-max)	Female (mean(SD))	Female (min-max)
FFM	-0.13(0.05)	-0.40-0.08	-0.11(0.05)	-0.24-0.80	-0.14(0.06)	-0.40-0.04
ALM	-0.12(0.09)	-0.50-0.24	-0.10(0.08)	-0.32-0.07	-0.14(0.09)	-0.50-0.24
%BF	0.16(0.10)	-0.19-0.52	0.18(0.11)	-0.19-0.52	0.15(0.09)	-0.07-0.49
MAPE	All (mean(SD))	All (min-max)	Male (mean(SD))	Male (min-max)	Female (mean(SD))	Female (min-max)
FFM	0.13(0.05)	0.00-0.40	0.11(0.05)	0.01-0.24	0.14(0.06)	0.00-0.40
ALM	0.13(0.08)	0.00-0.50	0.11(0.07)	0.00-0.32	0.14(0.08)	0.01-0.50
%BF	0.17(0.10)	0.00-0.52	0.18(0.10)	0.00-0.52	0.15(0.09)	0.00-0.50

MPE: Mean Percentage Error ($\frac{100\%}{n}\sum_{t=1}^{n}\frac{(DXA-InBody)}{DXA}$), MAPE: Mean Absolute Percentage Error ($\frac{100\%}{n}\sum_{t=1}^{n}\frac{Abs|(DXA-InBody)|}{DXA}$), FFM: Fat Free Mass, ALM: Appendicular Lean Mass, %BF: Percentage Body Fat

CONCLUSION

The Bioelectrical Impedance Analyzer (InBody720) has many advantages over the gold-standard DXA, like cost, size and short scan time, but overestimates Fat-Free Mass, Appendicular Lean Mass and underestimates Percentage Body Fat. Prediction equations may improve accuracy and allow more wide-spread use of BIA in lieu of DXA.

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