ORIGINAL PAPER

Nagoya J. Med. Sci. **77**. 647 ~ 652, 2015

Cross-calibration of pencil-beam (DPX-NT) and fan-beam (QDR-4500C) dual-energy X-ray absorptiometry for sarcopenia

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ABSTRACT

Sarcopenia, defined as the loss of muscle mass accompanied by weakness, is an important factor leading to frailty and is a growing concern in the aging Japanese society. Muscle mass can be calculated by dual-energy X-ray absorptiometry (DXA), but results differ between devices produced by different manufactures. Thus, cross-calibration is needed to compare body composition results in multicenter trials or when scanners are replaced. The purpose of this study was to perform an *in vivo* calibration of total body scans between pencil-beam (DPX-NT, GE Healthcare) and fan-beam (QDR-4500C, Hologic Inc.) DXA units. A total 30 subjects (15 women, 15 men, mean age = 35 years, range 22–49 years) were recruited. The lumbar bone mineral density (BMD), femoral neck BMD, appendicular fat and lean body mass, and the appendicular skeletal muscle mass index (ASMI) were highly correlated ($r = 0.979–0.993$, $r^2 = 0.889–0.977$). The conversion formulas were as follows: lumbar BMD, $Y = –0.08 + 1.16X$ (X = QDR-4500C, Y = DPX-NT), femoral neck BMD, $Y = –0.015 + 1.11X$, and ASMI $Y = 0.92 + 0.90X$. There is excellent comparability between the DPX-NT and the QDR-4500C DXA units. However, cross-calibration equations are required to assess muscle volume, fat, and ASMI in multicenter studies investigating sarcopenia.

Key Words: sarcopenia, dual-energy X-ray absorptiometry, calibration, pencil-beam, fan-beam

INTRODUCTION

The loss of skeletal muscle mass that occurs with advancing age is called sarcopenia.[1)] Elderly patients with sarcopenia have an increased risk of age-related disease due to muscle dysfunction.[2)] Sarcopenia also causes frailty, falls, fracture, and is a growing concern in the aging Japanese society.[3,4)]

Recently, the European Working Group on Sarcopenia in Older People (EWGSOP) published clinical guidelines but the widely accepted definition of sarcopenia remains controversial.[5)] EWGSOP recommended basing the diagnosis on the presence of both decreased muscle function and low muscle mass, which was defined as muscle mass ± 2 SD below the mean in young

Received: May 18, 2015; accepted: October 6, 2015

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healthy participants in the Rosetta Study.[6] There are several techniques available to measure skeletal muscle mass. Dual-energy X-ray absorptiometry (DXA) is an attractive method for both research and clinical use.[7] In Japan, GE Healthcare and Hologic Inc. comprise 84.8% of the DXA market (Japan Osteoporosis Foundation 2008). However, the differences between these two DXA instruments are unknown, and there are no studies performing cross-calibration of muscle mass, which is required to examine and compare sarcopenia in multicenter studies or when a scanner is replaced. The purpose of this study was to perform an *in vivo* calibration of a total body scan between a pencil-beam (DPX-NT, GE Health care) and fan-beam (QDR-4500C, Hologic Inc.) DXA unit, with a focus on skeletal muscle mass.

MATERIALS AND METHODS

Subjects

A total 30 volunteer subjects equally distributed between genders (15 females, 15 males) and age groups (20–29, 30–39, and 40–49 years; [n = 5] per age group in both gender groups) with a mean age = 35 years (range 22–49 years) were recruited. The study protocol was approved by the National Center for Geriatrics and Gerontology ethics committee. All subjects provided informed written consent to participate.

DXA measurements

The height and weight were measured in each subject, and a total body DXA was performed using pencil-beam (DPX-NT, GE Healthcare) initially, immediately followed by fan-beam (QDR-4500C, Hologic Inc.). The DPX-NT scan lasted approximately 15 min and the QDR-4500C approximately 3 min. The appendicular skeletal muscle mass (ASM) was calculated from the sum of the lean soft-tissue mass of the arms and legs. Sarcopenia was determined using a measure of relative muscle mass, the appendicular skeletal muscle mass index (ASMI), because muscle mass is strongly correlated with height. ASMI was calculated as follows: ASM (kg)/height^2 (m^2).[8] Bone mineral density (BMD) was also measured.

Statistical analysis

The data were analyzed using the paired t-test, linear regression analysis, and Bland–Altman plots to establish the relationship between the measurements in the two systems. Statistical significance was designated at $P < 0.05$.

RESULTS

Comparison of the total body imaging results between the pencil-beam and fan-beam showed no significant difference between the two units, except in the lumbar BMD and femur BMD. The BMD, lean mass, and ASMI were slightly higher in the pencil-beam than in the fan-beam instrument. However, fat was slightly higher in the fan-beam unit (Table 1).

This difference between the two instruments was also apparent in the Bland–Altman analysis (Table 2). The lumbar BMD was 0.16 g/cm^2 higher, the femur BMD 0.082 g/cm^2 higher, the lean mass in the arm 27.85 g higher, fat in the leg 396.15 g lower, and the ASMI was 0.23 kg/m^2 higher in DPX-NT than in QDR-4500C; all these differences and average were correlated. The lean mass of the leg was 287.95 g higher, and fat in the arm was 192.21 g lower in DPX-NT than in QDR-4500C, but these differences and average were not correlated. Figure 1 shows the

differences between the mean values in the pencil-beam and fan-beam DXA instruments.

To translate the values between the two DXA instruments, several equations were used, which are detailed in Table 3. The correlation coefficients were approximately 1.0, indicating that the individual values for the pencil-beam and fan-beam measurements were highly correlated. The conversion formulas were as follows: lumbar BMD, Y = –0.08 + 1.16X (X = QDR-4500C, Y = DPX-NT); femoral neck BMD, Y = –0.015 + 1.11X; and ASMI, Y = 0.92 + 0.90X.

Table 1 Comparison of total body composition results between pencil-beam and fan-beam

Scan mode	Lumbar	Femur	Lean mass (unilateral)		Fat (unilateral)		ASMI (kg/m^2)
	BMD (g/cm^2)	BMD (g/cm^2)	Arm (g)	Leg (g)	Arm (g)	Leg (g)	
Pencil-beam							
mean	1.17	0.97	2480	7639	791.8	2960	7.24
SD	0.16	0.16	758	1979	479.5	1401	1.28
min.	0.96	0.74	1460	5227	156	954	5.40
max.	1.47	1.358	3989	12375	2154	7351	10.53
Fan-beam							
mean	1.01**	0.89*	2452	7351	983.9	3356	7.01
SD	0.13	0.15	810	2035	452.6	1285	1.40
min.	0.82	0.69	1371	4704	278.1	1428	4.92
max.	1.32	1.26	4114	12145	2312	7768	10.48

n = 30 (15 males, 15 females).
Pencil-beam = DPX-NT, GE Health care. Fan-beam = QDR-4500C, Hologic Inc.

Table 2 Result of Bland-Altman Analysis for DPX-NT versus QDR-4500C

region		Mean Difference	Upper limit of agreement	Lower limit of agreement	Correlation coefficient†
Lumbar	BMD (g/cm^2)	0.16	0.23	0.089	0.70**
Femur	BMD (g/cm^2)	0.082	0.15	0.015	0.55**
Lean mass (unilateral)	Arm (g)	27.85	247.49	–192.12	–0.47**
	Leg (g)	287.94	889.51	–313.61	–0.19
Fat (unilateral)	Arm (g)	–192.21	8.16	–392.58	0.27
	Leg (g)	–396.15	153.85	–946.16	0.42*
ASMI (kg/m^2)		0.23	0.71	–0.24	–0.51**

BMD (Bone Mineral Density) †Correlation of mean difference and average of DPX-NT value and QDR-4500C value
Difference = DPX-NT value – QDR-4500C value
*Significant $p < 0.05$, **Significant $p < 0.01$

Table 3 Cross-Calibration Equations to Convert QDR-4500C to DPX-NT

region		a	b	Correlation coefficient
Lumbar	BMD (g/cm^2)	–0.08	1.16	0.99
Femur	BMD (g/cm^2)	–0.015	1.11	0.98
Lean mass (unilateral)	Arm (g)	202.5	0.93	0.99
	Leg (g)	–566.2	0.96	0.99
Fat (unilateral)	Arm (g)	–228.2	1.04	0.98
	Leg (g)	–633.9	1.07	0.98
ASMI (kg/m^2)		0.92	0.90	0.99

BMD (Bone Mineral Density)

Y = a + b X (Y = DPX-NT, X = QDR-4500C)

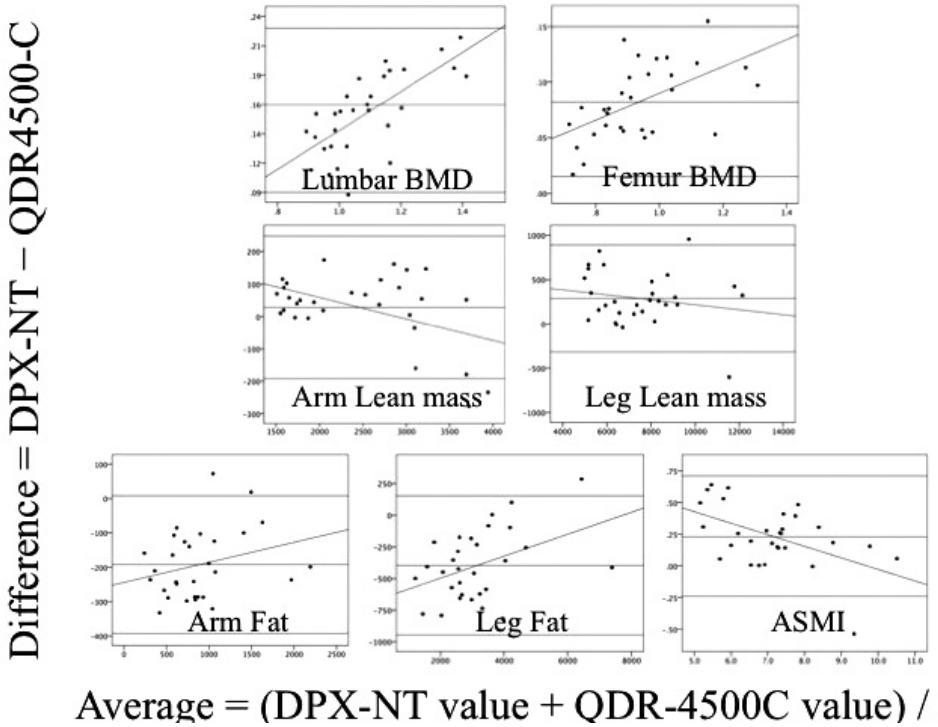

Fig. 1 Bland–Altman plot of the difference between pencil-beam (DPX-NT, GE Healthcare) and fan-beam (QDR-4500C, Hologic Inc.) DXA devices according to the mean values. The regression line is shown.

DISCUSSION

Sarcopenia is the loss of muscle mass leading to weakness and is an important factor in the loss of mobility and increased falls, which are both concerns in the aging Japanese society. There are several instruments available to assess muscle volume. Measurement of the thigh muscle cross-sectional area by magnetic resonance or computed tomography is the gold standard

in research, but this technique is limited due to radiation exposure, high cost, and poor accessibility.[5] Alternatively, muscle mass can be calculated by the less invasive DXA.[9,10] Recently, several studies have recommend cut-off values for the ASMI.[7,11] The Asian Working Group for Sarcopenia (AWGS) defined sarcopenia in Asians as an ASMI less than 7.0 kg/m^2 in men and less than 5.4 kg/m^2 in women.[12] In this manner, ASMI calculated by DXA has gained importance, but DXA findings differ between devices produced by different manufactures. Moreover, studies have only performed ASMI cross-calibration of bioelectrical impedance analysis (BIA) to BIA or DXA to BIA.[13,14] Thus, ASMI cross-calibration between two DXA units is needed to enable comparison of imaging findings in multicenter trials or when scanners are replaced. Furthermore, cross-calibration using *in vitro* phantoms may be misleading; therefore, we utilized human subjects (*in vivo*).[15]

As expected, there are notable differences between the DPX-NT and QDR-4500C, shown in Table 2. The lean mass and ASMI were higher in the pencil-beam (DPX-NT) unit than in the fan-beam (QDR-4500C) unit, while fat was higher in the QDR-4500C (Table 1). These results demonstrate that there is an unavoidable difference between the pencil-beam and fan-beam techniques. Several studies have compared pencil-beam DXA and fan-beam DXA except DPX-NT and QDR-4500C, and reported similar findings.[16-18] The reason for these differences is unknown. Several explanations may be that the reference values or cut off points for the attenuation coefficients used to define the relative lean and fat fractions of total soft tissue mass differ between pencil-beam and fan-beam, also the whole-body scan take about 15 minutes in pencil-beam and take about 3minutes in fan-beam.[19]

In our analysis, the paired t-test revealed significant differences only in the lumbar BMD and femur BMD, whereas ASMI showed a 0.23 kg/m^2 difference between the units that was not significant. The Bland–Altman analysis (Figure 1, Table 3) showed the relationships between the differences and mean values of the DPX-NT and QDR-4500C. The differences in the ASMI and arm lean mass were significantly dependent on the mean values, whereas the leg lean mass and fat were independent. These results indicate that the difference in ASMI was smaller and more constant between the two instruments than other parameters, such as the leg lean mass, fat, and BMD. Therefore, ASMI is a suitable parameter for multicenter trials of sarcopenia, and cross-calibration ensures accuracy. An excellent linearity with a 0.94–0.99 correlation coefficient was observed in the cross-calibration equations converting the QDR-4500C values to the DPX-NT values (Table 3). Thus, this study also provides useful translation equations to assess sarcopenia in multicenter trials.

The findings of the present study are limited by the small sample size, which resulted in a smaller range of DXA values. These results may not be applicable to other pairs of instruments or ethnicities.

CONCLUSION

This study documented excellent comparability between the DPX-NT and the QDR-4500C DXA units. However, cross-calibration equations are required to assess muscle volume, fat, and ASMI in multicenter studies investigating sarcopenia.

CONFLICTS OF INTEREST

This study was funded in 2010 by a Comprehensive Research on Aging and Health research

grant from the Ministry of Health, Labour and Welfare of Japan, and Chukyo longevity medical and promotion foundation.

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