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Comparison of the Lunar DPX-L and Prodigy dual-energy X-ray absorptiometers for assessing total and regional body composition

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Abstract

The purpose of this study was to assess the agreement of the Lunar DPX-L with the newer Prodigy dual-energy X-ray absorptiometer (DXA) for determining total-body and regional (arms, legs, trunk) bone mineral density (BMD), bone mineral content (BMC), fat mass (FM), lean tissue mass (LTM), total body mass (BM) and percent fat. A total of 106 apparently healthy males (n=34) and females (n=72) between the ages of 8–72 years were scanned consecutively on the DPX-L (software version 1.35) and Prodigy DXA (enCORE v. 3.6 software). Paired *t-tests* indicated significantly higher measures by Prodigy for BM (percent difference= 1.1%) and total-body BMD (2.2%), BMC (2.9%), FM (3.5%), and percent fat (2.8%; P<0.001), but not LTM (−0.2%). Regional estimates of FM and bone tended to be overestimated by Prodigy relative to DPX-L. The percent difference was most pronounced for FM in the arms (14.2%) and trunk (8.5%), BMD in the legs (4.9%), LTM in arms (5.6%), and BMC in the trunk (5.9%); but all total-body and regional measures were strongly and significantly correlated (P<0.001). The method of Bland and Altman indicated that the Prodigy overestimated DPX-L for BM (r=0.343; P<0.001), and total-body measures of BMD (r=0.460; P<0.001), and BMC (r=0.321; P<0.001) at higher values, as indicated by the significant, positive association between difference (Prodigy−DPX-L) versus mean ((Prodigy+DPX-L)/2). Regionally, Prodigy overestimated DPX-L for BMD in the legs, BMC in the legs and trunk, and FM in the arms at higher values (P<0.001). In contrast, FM in the legs was underestimated by Prodigy relative to DPX-L at higher values (P<0.001), and no regional bias was observed for LTM. In conclusion, we recommend that correction equations be used for comparing BM, total-body BMD and BMC, and regionally for BMD in the legs, BMC in the legs

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and trunk, and FM in the arms and legs. The use of correction equations for other estimates is not required for making direct comparisons.

Keywords

Lunar; DPX-L; Prodigy; DXA; validation; fat mass; lean mass; bone

Introduction

Dual-energy X-ray absorptiometry (DXA) has become a method of choice for assessing body composition in human and animal research. A major advantage of DXA over alternative methods is its ability to measure three compartments, including total and regional fat mass (FM), lean tissue mass (LTM), bone mineral content (BMC), and bone mineral density (BMD). DXA is relatively accurate; several validation studies have reported a close relationship to carcass analysis for bone, LTM, and FM in the pig [1, 2], rat [3], and mouse [4].

Since the introduction of DXA in the late 1980s, modifications have been made in newer instruments that have resulted in shorter scan times and better image quality. However, variations in DXA models, including the manufacturer [5–7], software version [7, 8], type of scanning beam [9, 10], and method of calibration, are all known to affect results [11]. Consequently, it is critical to evaluate instruments before comparisons among models can be made. Therefore, the purpose of this study was to assess the agreement of the GE-Lunar DPX-L, with the newer GE-Lunar Prodigy DXA for determining total and regional BMD, BMC, FM, LTM, total body mass (BM) and percentage fat.

Methods

Subjects

Characteristics of the study population are given in Table 1. A total of 106 apparently healthy individuals between the ages of 8 – 72 years were used in this study. The majority of participants were females (*n*=72), and they were comprised of various ethnicities, including Caucasian (*n*=52), African American, (*n*=9), and other (*n*=11), which included women of Asian, Indian, or Hispanic decent. Approximately one-third of the study participants were males (*n*=34), of which the majority were Caucasian (*n*=28), and the remainder were considered African American (*n*=3) or Other (*n*=3). This study was approved by the University of Alabama at Birmingham Institutional Review Board. All subjects or parents of minors gave written informed consent, and all women of child-bearing age were required to undergo a pregnancy test prior to participating.

Study Design

Height and weight were measured for each subject, and recorded to the nearest 0.1 cm and 0.1 kg, respectively. Each subject was scanned consecutively on the DPX-L (GE-Lunar Corp., Madison, WI) and Prodigy DXA (GE-Lunar Corp., Madison, WI). DPX-L total-body scans were performed using software version 1.35 which determined an appropriate transverse speed of 16, 8 or 4 cm/sec based upon subject thickness. Scan times lasted approximately 15 minutes for children and 20–60 minutes for adults. Prodigy total-body scans were performed using enCORE v. 3.6 software. Unlike DPX-L, which uses a pencil-beam scanning geometry, Prodigy uses a narrow fan-beam; thus total-body scans are much faster, taking approximately 3 minutes for children, and 5–10 minutes for adults. All DPX-L and Prodigy scan analyses were performed by the same individual according to guidelines set forth by the manufacturer.

Regional analysis

In addition to total-body composition, regional estimates were made for the arms, legs, and trunk. This was accomplished by manually adjusting cut positions for each region of interest (ROI). For the left and right arm ROIs, one cut passed through the arm sockets and separated the hands and arms from the body. For the left and right leg ROIs, a cut passed through the femoral neck to separate each from the pelvis, a second cut was made laterally to separate the leg from the forearm and hand, and a third cut was made medially between the left and right leg. The trunk ROI was isolated by a cut located directly above the pelvis, another located directly below the chin, and cuts made on the left and right side of the body, which separated the trunk from the left and right arms, respectively.

Statistical analysis

Body composition parameters, including BM, FM, LTM, BMC, and BMD, were compared between instruments using paired *t-tests*. Linear regression was used to determine relationships between DPX-L and Prodigy, and the method of Bland and Altman [12] was used to assess agreement between the two instruments. Outcomes were considered statistically significant when $P < 0.05$. All analyses were performed using SAS (version 8.0, SAS Institute Inc., Cary, NC).

Results

Comparisons of total-body composition parameters measured by DPX-L and Prodigy are given in Table 2, and percent differences are given in Table 4. Paired *t-tests* indicated that Prodigy significantly overestimated BM (percent difference=1.1%), and total-body BMD (2.2%), BMC (2.9%), FM (3.5%), and percent fat (2.8%; $P < 0.001$), but not LTM (−0.2%; $P = 0.350$).

Regional measures by DPX-L and Prodigy are presented in Table 2 and percent differences in Table 4. For the arms, Prodigy significantly overestimated BMD (0.9%; $P < 0.05$), BMC (2.8%), FM (14.2%), LTM (5.6%), and percent fat (6.8%; $P< 0.001$). In the legs, Prodigy overestimated BMD (4.9%; $P < 0.001$) and BMC (0.9%; $P< 0.01$), underestimated FM (−1.6%; $P < 0.05$) and LTM (−1.2%; $P < 0.05$), but did not significantly differ from DPX-L for percent fat (0.1%; $P = 0.705$). In the trunk, Prodigy overestimated FM (8.5%), BMC (5.9%), and percent fat (6.9%; $P < 0.001$), and underestimated LTM (−1.6%; $P < 0.001$), but there was no difference in BMD (0.5%; $P = 0.096$).

Regression analysis indicated that slopes for BM and total-body BMD and BMC, were significantly different from the line of identity (slope ≠ 1; Table 3). For the arms, regression analysis indicated that slopes for BMD and BMC were significantly different from the line of identity ($P < 0.05$). In the legs, slopes for BMD, BMC, FM, and percent fat all differed from the line of identity ($P < 0.05$). In contrast, no parameters for the trunk were significantly different from the line of identity (slope = 1). Furthermore, all total-body and regional measures obtained with the two instruments were highly correlated ($P < 0.001$); correlation coefficients for total-body measures were 0.989 or higher, and 0.919 or higher for regional estimates.

Bland-Altman plots demonstrated a bias such that Prodigy overestimated DPX-L for BM (r = 0.343, $P < 0.001$), and total-body BMD (r = 0.460, $P < 0.001$) and BMC (r = 0.321, $P < 0.001$) at higher values (Fig. 1). In the arms, Prodigy demonstrated a propensity to overestimate DPX-L at larger values for FM (r = 0.286, $P < 0.01$) and percent fat (r = 0.212, *P* < 0.05; Table 4). In the legs, Prodigy overestimated BMD (r = 0.437, *P* < 0.001), and underestimated FM (r = −0.249, *P* < 0.05) at higher values, relative to DPX-L. In the trunk, Prodigy tended to overestimate BMC at higher values (r = 0.299, *P* < 0.01), and a trend was observed for FM (r = 0.176, *P* = 0.070).

Discussion

The results of this study demonstrate that a small, but significant overestimation by Prodigy relative to DPX-L exists for several measures of total-body composition; but it is important to point out that these differences were generally 3.5% or less, and are unlikely to be clinically relevant. However, for research purposes such consistent differences are substantial. Despite the relatively small differences and high degree of association between DPX-L and Prodigy, correction equations are recommended for estimates of BM, and total-body BMD and BMC, since Bland-Altman plots demonstrated a bias for Prodigy to overestimate these parameters, relative to DPX-L, at higher values. However, adjustment for LTM does not appear necessary, and correction equations for FM and percent fat may only be needed when small differences can impact the interpretation of an intervention or study outcome.

In regards to regional body composition, a pattern was observed in the arms such that Prodigy consistently overestimated all parameters to varying degrees. But findings were much less consistent in the legs and trunk, where Prodigy measures either overestimated, underestimated, or did not differ from DPX-L estimates. Furthermore, while all regional estimates were highly correlated, and tended to differ by less than 5%, some differences were much more substantial. For example, Prodigy overestimated FM in the arms and trunk by 0.3 kg and 0.9 kg respectively; this was an overestimation of 14.2% and 8.5%, respectively, and largely accounted for the 0.7 kg difference in BM between DPX-L and Prodigy.

In addition, the procedure of Bland and Altman uncovered a bias for Prodigy to overestimate or underestimate regional measures relative to DPX-L. Bias was detected in measures of fat and bone in the arms, legs, and trunk, but no regional bias was found for LTM. It is worth mentioning that after excluding individuals with a percent body fat >40%, which removed 18 individuals from the study (*n*=88), the large difference between instruments for arm FM decreased from 14.2% to 10.6%, but was still significant (*P* < 0.001). However, omission of the very obese individuals did eliminate the significant bias for Prodigy to overestimate arm FM at higher values (r = 0.156, *P* = 0.147). In summary, the results for regional estimates suggest that correction equations should be used when comparing BMD in the legs, BMC in the legs and trunk, and FM in the arms and legs. However, the use of correction equations for other regional estimates may only be necessary when accounting for very small differences.

Several studies have reported on differences in body composition between DXA models and manufacturers, including Hologic QDR systems (Hologic Inc. Watham, MA), Norland XR systems (Norland Medical Systems, Fort Atkinson, WI) and GE-Lunar instruments [11]. Variability between manufacturers and models can exist for several reasons, including differences in calibration methods, scanning speed, and scanning beam geometry [5, 6, 9–11].

Variations in body composition estimates have also been reported between the same model utilizing different software packages [7, 8]. Using the DPX-L, Van Loan *et al.* [8] observed differences for body composition measures in 20–40 year old women using software version 3.4 versus 3.6R. Therefore, it must be emphasized that the differences observed in the present study may reflect both the instruments themselves as well as the software packages used. For example, the software packages utilized in this study determined the appropriate scanning speed (out of three) for each individual based upon subject thickness, but the cut-off points used for determining the scanning speed differed between software. For example, the three DPX-L version 1.35 software scan speeds were *Fast* (subject thickness <22 cm), *Medium* (22–28 cm), and *Slow* (>28 cm). For the Prodigy encore v 3.6 software, the three scan modes were *Thin* (<13 cm), *Standard* (13–25 cm), and *Thick* (>25 cm). Therefore, inherent differences in scanning speed selection may have contributed to the observed variability between instruments for total-body and regional estimates. Furthermore, variability in regional estimates as a result of an inherent difference in ROI determination between software packages cannot be ruled out.

To our knowledge, this is the first investigation to compare the DPX-L and Prodigy DXA with the reported software packages for assessment of total and regional body composition. Because of the large sample size used, as well as the broad range in subject age and body size, correction equations from this cohort should be appropriate for a variety of study populations comprised of healthy individuals.

Conclusions

The results of this study demonstrated that a small, but significant difference exists between Prodigy and DPX-L for several total-body and regional estimates; but all measurements by the two instruments were highly correlated. These results, coupled with those from the Bland-Altman procedure, warrant the recommendation that correction equations be used when comparing BM, and total-body BMD and BMC, but may not be necessary for total-body FM and percent fat, unless small differences are important. In addition, correction equations should be used when comparing regional estimates of FM in the arms and legs, and BMC in the trunk, but may not be needed for other regional estimates unless small differences are critical to interpreting the outcome. The ability to compare values from DPX-L (software version 1.35) and Prodigy (enCORE v. 3.6 software) makes it possible for investigators to combine data from the two instruments. Furthermore, correction equations derived from this diverse cohort should be widely applicable to healthy populations.

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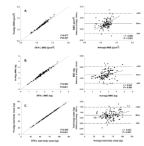

Figure 1.
Regression and Bland-Altman Plots for A) total-body bone mineral density (BMD), B) total-body bone mineral content (BMC), and C) total body mass (BM).

Table 1

Subject characteristics.

(*n*=106)	Mean ± SD	Range
Age (years)	35.9 ± 14.4	8.4 – 72.0
Weight (kg)	70.8 ± 18.2	26.2 – 119.8
Height (cm)	166.4 ± 13.1	123.0 – 190.5
Body mass index (kg/m^2)*	25.9 ± 5.1	15.7 – 44.5

*BMI calculation excludes individuals <19 yrs of age; *n*=96.

Table 2

Comparison of body composition parameters measured by DPX-L and Prodigy DXA (mean±SD).

Region	Parameter	DPX-L	Prodigy	P^a
Total body[b]	BMD (g/cm^2)	1.167 ± 0.128	1.191 ± 0.139	<0.001
	BMC (kg)	2.61 ± 0.67	2.68 ± 0.70	<0.001
	Fat mass (kg)	21.2 ± 10.4	22.0 ± 10.3	<0.001
	Lean tissue mass (kg)	45.7 ± 12.4	45.6 ± 12.5	0.350
	Total body mass (kg)	69.5 ± 18.0	70.2 ± 18.1	<0.001
	Percent fat (%)	29.8 ± 9.9	30.6 ± 9.8	<0.001
Arms	BMD (g/cm^2)	0.908 ± 0.158	0.916 ± 0.155	<0.05
	BMC (kg)	0.35 ± 0.12	0.36 ± 0.12	<0.001
	Fat mass (kg)	1.7 ± 1.0	2.0 ± 1.1	<0.001
	Lean tissue mass (kg)	5.1 ± 2.2	5.4 ± 2.2	<0.001
	Percent fat (%)	24.3 ± 10.1	26.0 ± 10.7	<0.001
Legs	BMD (g/cm^2)	1.238 ± 0.174	1.299 ± 0.187	<0.001
	BMC (kg)	1.02 ± 0.29	1.03 ± 0.28	<0.01
	Fat mass (kg)	8.4 ± 4.2	8.2 ± 4.0	<0.05
	Lean tissue mass (kg)	15.7 ± 4.5	15.6 ± 4.5	<0.05
	Percent fat (%)	32.7 ± 11.3	32.8 ± 11.2	0.705
Trunk	BMD (g/cm^2)	0.928 ± 0.123	0.933 ± 0.126	0.096
	BMC (kg)	0.77 ± 0.23	0.81 ± 0.26	<0.001
	Fat mass (kg)	10.2 ± 5.5	11.1 ± 5.7	<0.001
	Lean tissue mass (kg)	21.7 ± 5.6	21.4 ± 5.7	<0.001
	Percent fat (%)	29.7 ± 10.2	31.8 ± 10.2	<0.001

[a]Comparisons made by paired *t-tests*

[b]Total body parameters include the head in the estimate

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Table 3

Linear regression analysis for total and regional body composition parameters measured by DPX-L and Prodigy DXA.

Region	Parameter	Regression equation	Line of Identity		Regression		
			Slope (*P*)[a]	Intercept (*P*)[a]	r^2	*P*	SEE
Total body	BMD (g/cm^2)	PROD = 1.069DPX − 0.055	<0.001	<0.001	0.977	<0.001	0.02
	BMC (kg)	PROD = 1.037DPX − 0.021	<0.01	0.576	0.983	<0.001	0.09
	FM (kg)	PROD = 0.994DPX + 0.886	0.328	<0.001	0.996	<0.001	0.68
	LTM (kg)	PROD = 1.009DPX − 0.465	0.164	0.113	0.996	<0.001	0.78
	BM (kg)	PROD = 1.007DPX + 0.265	<0.001	<0.05	0.998	<0.001	0.36
	Fat %	PROD = 0.982DPX + 1.366	0.080	<0.001	0.989	<0.001	1.01
Arms	BMD (g/cm^2)	PROD = 0.954DPX + 0.049	<0.05	<0.05	0.946	<0.001	0.04
	BMC (kg)	PROD = 0.961DPX + 0.023	<0.05	<0.001	0.969	<0.001	0.02
	FM (kg)	PROD = 1.034DPX + 0.189	0.439	<0.001	0.845	<0.001	0.43
	LTM (kg)	PROD = 0.999DPX + 0.289	0.969	<0.01	0.968	<0.001	0.39
	Fat %	PROD = 1.022DPX + 1.122	0.431	<0.001	0.931	<0.001	2.82
Legs	BMD (g/cm^2)	PROD = 1.063DPX − 0.017	<0.001	0.393	0.978	<0.001	0.03
	BMC (kg)	PROD = 0.970DPX + 0.039	<0.05	<0.001	0.985	<0.001	0.03
	FM (kg)	PROD = 0.942DPX + 0.354	<0.001	<0.01	0.977	<0.001	0.60
	LTM (kg)	PROD = 0.969DPX + 0.309	0.093	0.309	0.964	<0.001	0.86
	Fat %	PROD = 0.980DPX + 0.684	<0.05	<0.05	0.992	<0.001	1.03
Trunk	BMD (g/cm^2)	PROD = 1.004DPX + 0.001	0.875	0.951	0.949	<0.001	0.03
	BMC (kg)	PROD = 1.046DPX + 0.010	0.211	0.741	0.887	<0.001	0.09
	FM (kg)	PROD = 1.016DPX + 0.705	0.315	<0.001	0.976	<0.001	0.88
	LTM (kg)	PROD = 0.997DPX − 0.294	0.873	0.462	0.968	<0.001	1.02
	Fat %	PROD = 0.985DPX + 2.519	0.409	<0.001	0.964	<0.001	1.94

[a] *P* for slope = 1, and intercept = 0.

Table 4

Limits of agreement for total and regional body composition parameters measured by DPX-L and Prodigy DXA.

Region	Parameter	Difference (Prodigy − DPX-L)	Percent Difference (%)	Limits of agreement (Difference ± 2SD)	r[a]	p[a]
Total body	BMD (g/cm^2)	0.025	2.2	−0.020 — 0.071	0.460	<0.001
	BMC (kg)	0.075	2.9	−0.115 — 0.265	0.321	0.001
	FM (kg)	0.751	3.5	−0.615 — 2.118	−0.063	0.520
	LTM (kg)	−0.071	−0.2	−1.636 — 1.493	0.167	0.087
	BM (kg)	0.755	1.1	0.011 – 1.499	0.343	<0.001
	Fat %	0.838	2.8	−1.216 — 2.891	0.120	0.221
Arms	BMD (g/cm^2)	0.008	0.9	−0.065 — 0.081	−0.083	0.400
	BMC (kg)	0.010	2.8	−0.034 — 0.053	0.134	0.171
	FM (kg)	0.247	14.2	−0.600 — 1.095	0.286	<0.01
	LTM (kg)	0.285	5.6	−0.493 — 1.064	0.086	0.381
	Fat %	1.646	6.8	−3.989 — 7.281	0.212	<0.05
Legs	BMD (g/cm^2)	0.061	4.9	0.001 – 0.120	0.437	<0.001
	BMC (kg)	0.009	0.9	−0.062 — 0.080	0.185	0.058
	FM (kg)	−0.133	−1.6	−1.421 — 1.155	−0.249	<0.05
	LTM (kg)	−0.184	−1.2	−1.921 — 1.554	−0.069	0.481
	Fat %	0.039	0.1	−2.060 — 2.137	0.168	0.085
Trunk	BMD (g/cm^2)	0.005	0.5	−0.053 — 0.062	0.131	0.179
	BMC (kg)	0.045	5.9	−0.131 — 0.221	0.299	<0.01
	FM (kg)	0.865	8.5	−0.896 — 2.626	0.176	0.070
	LTM (kg)	−0.356	−1.6	−2.394 — 1.682	0.075	0.447
	Fat %	2.059	6.9	−1.817 — 5.936	0.015	0.882

[a]Correlation coefficient and level of significance for Bland-Altman plot. A simple correlation was performed between the Difference (Prodigy−DPX-L) and the corresponding average ((Prodigy+DPX-L)/2) for each estimate; a significant association is indicative of a bias between instruments.