Dual-Energy X-Ray Absorptiometry for Determination of Body Composition in a Porcine Model of Obesity Development

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Summary and Implications

To determine the efficacy of bioactive molecules for minimizing body fat accretion in mammals, an effective method for measuring changes in body fat must be used. In the current study, the precision and accuracy of the Dual Energy X-ray Absorptiometry (DEXA) estimates of the weight and tissue (fat, lean and bone mineral) content of two body depots (carcass and internal organs) were evaluated in heavy weight pigs (133-265 kg) serving as an obesity development model.

DEXA accurately estimated carcass weight, but underestimated the fat tissue contents and overestimated the lean tissue contents of both the carcass and organ depots relative to those estimated from chemical analysis of the fat and protein contents of the depots. However, DEXA precisely detected changes in carcass and organ depot weights (R^2= .99, .99 respectively) and less precisely detected changes in the depot's chemically determined fat (R^2 = .95, .73) and protein content (R^2= .88, .84). Specifically, for each 1 kg change in carcass and organ depot weights, DEXA predicted the changes with a 95 % confidence (2 SE of estimate) within ± .008 and .026 kg, respectively. For each 1 kg change in the two depot's chemically determined fat content, DEXA predicted the change within ± .092 and .338 kg, respectively. In conclusion, DEXA is a method that can precisely detect changes in body composition in large, heavy weight pigs being used in a model of obesity development.

Introduction

Dual-energy x-ray absorptiometry (DEXA) is becoming the standard measure in humans for body composition analysis due to its non-invasiveness, rapid results, low radiation dose, and reasonable costs. DEXA analysis consists of an x-ray scanning of a sample at two energy levels that discerns bone and soft tissue composition. Numerous studies have evaluated the use of this instrument for body composition measures in humans, pigs and pig half-carcasses. However, the precision of DEXA for estimating the body composition of carcass and organs depots in a porcine model of obesity development has not been determined.

With the growing epidemic of obesity in the world and research focusing on preventative and therapeutic methods to alleviate the problem, there is a need to identify suitable animal models for obesity development studies and to determine the precision and accuracy of a tool for measuring body composition in such models.

The purpose of this study was to evaluate the precision and accuracy of DEXA in predicting the fat and lean tissue content of large body weight (133-265 kg) animals serving as a model of obesity development. Specifically, the relationship of DEXA estimates of body fat, lean and bone mineral content relative to those estimated from the chemically analysis of the animal tissue depots was determined. The relationship of DEXA estimates of carcass fat and lean content relative to subcutaneous carcass fat depths also was assessed.

Materials and Methods

Thirty-two barrows at six months of age and weighing 150.5 ± 2.0 kg were individually penned and fed a dietary regimen that would result in obesity development (body fat accretion equivalent to 35 kg /animal and representing 48 % of BW gain) in a 144 day feeding period. Specifically, pigs were fed twice daily a ration providing a caloric intake equivalent to 1.8 times their individual caloric needs for body maintenance. Pigs representative of the range of weights existing in animals at the initiation (13 pigs, BW range 133 to 171 kg, pre-or low obesity state) and at the completion of the 144 day study (19 pigs, BW range of 185 to 266 kg, obesity development state) were evaluated.

Pigs were killed at the respective BW and two depots were isolated – the right carcass halve and major internal organs. The weight and composition of two body depots were determined by DEXA scanning. Each depot was then frozen, ground, and subsampled for chemical analysis. Dry matter, Kjeldahl N, ash, and total lipid were determined. Each component was corrected for water so that BMC, lean and fat tissue content could be estimated and thus compared to the DEXA estimates of composition. Specifically, the chemically determined carcass fat tissue content was estimated from the analyzed carcass fat content on the assumption that fat tissue consisted of 94 % chemical fat and 6 % water. The chemically determined carcass lean tissue content was estimated from the analyzed carcass protein (Kjeldahl N * 6.25) and water (minus the water assumed to be associated with fat tissue) contents. The chemically determined bone mineral content in the carcass was calculated by subtracting the estimated mineral content (.85 %) in boneless pork meat (Jebb et. al., 1995) from the chemically determined mineral content of the carcass. In addition, carcass subcutaneous fat depths at the first rib,

last rib, and last lumbar vertebrae along the midline of the carcass were determined.

Results and Discussion

The range of chemically determined fat content, expressed as a percentage of the tissue depot weight, was 29-47 % for the carcass and 41.6-42 % for the organ depot. The body fat was accrued principally in the carcass (92% of total body fat) with 8 % of the body fat present in the organ depots.

As expected, DEXA accurately predicted carcass weight relative to that determined gravimetrically (-1.4 kg or 2%, P= .57) and via chemical analysis (+ .66 kg or 1%, P= .79). Moisture loss during the transportation and scanning of the chilled carcass likely accounts for a portion of the lower DEXA estimated carcass weight. The unanalyzed carbohydrate content of the carcass tissue (~0.5 %) would largely account for the difference between the DEXA and chemically determined carcass weights.

DEXA underestimated carcass fat tissue content (-19.0 %, P< .01) relative to that determined by chemical analysis and overestimated lean tissue (+13 %, P< .01). Similar results have been reported in market weight pig studies. The significant underestimation of fat tissue by DEXA has been theorized to be due in part to tissue depth. Since DEXA assumes that the composition and amount of soft tissue behind bone is similar to that in front of bone, areas with large amounts of bone and non-uniform distribution of adipose such as the truncal region of pigs could be estimated erroneously by DEXA.

Numerically, DEXA overestimated organ weights determined gravimetrically (+ .7 kg, 3.3%; P<. 01) and those estimated from chemically determined contents (+1.6 kg, 8.3%; P< .01). This overestimation is likely accounted for due to the unanalyzed carbohydrate content in the organ tissues as well as the carbohydrate (i.e., fiber) fraction in the undigested digesta. As observed for carcass tissues, DEXA underestimated organ fat tissue content (-1.9 kg, -26 %, P< .01) relative to that determined by chemical analysis and overestimated lean tissue (3.9 kg, +27 %, P< .01).

DEXA had a high precision in detecting changes in chemically determined weights of carcass (R^2= .99) as well as fat (R^2= .95) and protein (R^2= .88) contents. The standard error of the estimates (SEE) for DEXA predicting a unit change in chemically determined carcass weight, fat and protein content were .004, .046, .013 kg, respectively. Based on these data, for each one kg change in carcass weight, DEXA predicted the change with a 95% confidence interval (±2 SEE) within ± .008kg. Similarly for each one kg change in chemically determined carcass fat and protein content, DEXA predicted the change within ± .092 kg and .026 kg, respectively. DEXA was substantially less precise (R^2= .50) in predicting changes in carcass bone mineral content (SEE= ± .216 kg).

DEXA also had a high precision in detecting changes in chemically determined organ weight (R^2= .99) but was less precise in detecting changes in fat (R^2= .73) and protein (R^2= .84) content. The SE of the estimates for DEXA predicting a unit change in chemically determined organ weight, fat and protein content were .013, .169, .016 kg, respectively. Based on these data, for each one kg change in organ weight, DEXA predicted the change with a 95% confidence interval (±2 SEE) within ± .026 kg. Similarly for each one kg change in chemically determined organ fat and protein content, DEXA predicted the change within ± .338 and .032 kg, respectively.

DEXA estimates of body fat and lean tissue contents (expressed as percent of body weight) related to subcutaneous carcass fat depths and longissimus muscle cross sectional area. DEXA estimates of body fat accounted for a majority of the variation in subcutaneous fat depth at the tenth rib and midline last lumbar, last rib and first rib with R^2 values of .76, .78, .63 and .61, respectively, and SE of the estimates of .158, .159, .166, and .206 mm, respectively. DEXA estimates of lean tissue content were not associated with tenth rib longissimus muscle area (R^2= .003).

In conclusion, DEXA precisely predicted changes in body depot weight and fat and lean tissue contents in large, heavy weight pigs being used in a model of obesity development. The precision was less in the internal organ depots than carcass depots.

Table 1. Mean Body Weights and Tissue Contents Estimated by Chemical, DEXA and Gravimetric Analyses. [a]

Body Depot	Component	Method of Analysis, kg Chemical	DEXA	Gravimetric	P
Carcass [b]					
	Weight [d]	75.69±3.33	76.35±3.26	77.75±3.30	.78
	Fat	30.70±1.59	24.87±1.62		<.01
	Lean	43.67±1.94	50.26±1.87		<.01
	BMC	1.32±0.08	1.32±0.06		.99
Organ [c]					
	Weight [e]	18.13±0.65	19.76±0.58	19.11±0.56	<.01
	Fat	7.34±0.29	5.45±0.20		<.01
	Lean	10.44±0.36	14.31±0.51		<.01
	BMC	0.35±0.01	ND		

[a]Values are means±SEM
[b]N=32 for carcass analyses
[c]N=19 for organ analyses
[d]No difference between DEXA and gravimetrical carcass weight (P= .57)
[e]Significant difference between DEXA and gravimetrical organ weight (P< .01)

Table 2. Regression of Chemically Determined Body Depot Weight and Fat and Lean Tissue Content on DEXA Determined Weights and Tissue Contents. [a,e]

Body Depot	Tissue Component	Intercept (a) Mean	SEE	Probability	Slope (b_1) Mean	SEE	Probability	R^2
Carcass[b]	Fat	1.59	1.27	.22	1.101	0.048	<.01	.95
	Lean	0.86	0.64	.19	0.188	0.013	<.01	.88
	BMC[c]	0.39	0.295	.20	1.186	0.216	<.01	.50
	Total	0.57	0.31	.08	1.011	0.004	<.01	.99
Organ[d]	Fat	0.69	0.94	.47	1.143	0.1695	<.01	.73
	Lean	0.23	0.24	.34	0.156	0.016	<.01	.84
	Total	0.90	0.25	<.01	0.926	0.013	<.01	.99

[a]Chemically determined tissue component, kg = a + b_1(DEXA determined tissue weight, kg)
[b]Right carcass half
[c]Chemical determined depot weights and fat and lean tissue contents were calculated from the chemically analyzed fat, protein, water and mineral content of the tissues. Bone mineral content (BMC) of the carcass was calculated by subtracting the ash content (.85%) of pork meat from the analyzed ash content of the carcass.
[d]Lungs-heart and associated thoracic fat and liver; gastrointestinal tract with contents and associated mesenteric and omental fat and spleen
[e]N=32 for carcass depot and N= 19 for organ depot

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