Using Dual-Energy X-Ray Absorptiometry to Measure Limb and Digestive Organ Composition in Laboratory Rats

DEXA (dual-energy x-ray absorptiometry) can measure minute differences in bone density, composition of fat tissues, lean tissues, and percentage of fats. It may be possible to use this technology to measure the effects of exercise, diseases, controlled substances and treatments on tissues and tissue systems. We tested the precision of this technique in measurements of the hind limb, the forelimb, the stomach and the intestines of laboratory rats. We dissected nine laboratory rats of same sex, strain, treatment, and lifestyle for comparison. We weighed the relevant body components and then analyzed them using a PIXImus DEXA apparatus. We found consistent patterns for the composition of each structure. This technique could be used to measure changes in bone density, muscle mass, and fat composition that occur in limbs and the digestive system after participation in an exercise program.

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Introduction

DEXA (dual-energy x-ray absorptiometry) was used to determine the effects of exercise and diet on laboratory rats. Exercise and dieting are known to control bone density, fat tissue and lean tissue. Aerobic and anaerobic exercises have different effects on the muscle and fat mass. Aerobic exercise, which is also known as weight-bearing exercise, increases the efficiency of muscles to do their job and does not cause hypertrophy of skeletal muscles, but of the heart instead. It also increases bone density, as repeated mechanical stress can cause mineral deposition in the bones where stress is applied. Anaerobic exercise increases skeletal muscle mass by increasing connective tissue and increasing glycogen storage, which is the energy supply for muscles. Anaerobic exercise causes muscle hypertrophy. Diet affects bone density through the intake of calcium ions and vitamin D. The level of calcium circulating in the blood affects bone deposition and reabsorption; vitamin D also plays a key role in absorption and use of calcium. Intake of carbohydrates and proteins dictates muscle energy and fat deposition.

DEXA finds differences by sending high energy x-rays to detect bones and low energy x-rays to detect lean tissues. The two images created are combined to form a single photo. DEXA guarantees quality and accuracy of measurements. The DEXA apparatus tests itself to see if it can accurately define the set amounts of bone and lean tissue in the phantom, within user-defined error margins. If it does not measure the phantom accurately within these margins, it will not test a rat subject until it measures the phantom accurately. In this research, we tested the plausibility of using this technology for identifying minuscule differences in lean and bone tissues within the limbs, the intestines, and the stomach. This would lead to further study of how exercise and dieting can affect the density of bones, muscles and fats.

Methods

We used a DEXA apparatus, PIXImus, designed for laboratory rats. The PIXImus measured the bone mineral composition, the lean tissue mass, the fat tissue mass and the total mass for each organ. For the experiment, nine male rats were used. All rats were of the same strain, and same species, *Rattus norvegicus*. All nine rats had a life span of 6 months, born on January 1, 2004 and died on June 18, 2004. The rats, other than being slightly overweight, were normal for their age and strain. After weighing the total body mass, all rats were dissected with scalpels, dissecting scissors, forceps and dissecting pins. Once the organs were removed, they were put on the PIXImus specimen trays and weighed on an electric balance. Once the mass was recorded, the specimen tray with the organ was put on the PIXImus x-ray machine, and it recorded the BMD, BMC, total mass, lean tissue mass, fat tissue mass, and percentage of fat.

Results

The limbs and organs studied had consistent patterns of composition but had different levels of variation. The limbs had the lowest levels of variation.

In the hind limb, the bone mineral composition had the least variation, showing DEXA's accuracy and precision in measuring bones. The lean tissue, fat tissue and total tissues varied more, a result of differing dissecting techniques. The right forelimb had similar results, with low bone mineral composition measurements, and slightly higher lean tissue, fat tissue and total tissue measurements. The intestines had low measurements for lean tissue, fat tissue and total tissue; however, the bone mineral composition had extremely varied results. The intestines had better defined guidelines for removal, keeping variation low. Because the intestines contain no bone, even a small difference in mineral detection would cause a variation from the mean. The results for the stomach varied even more than in the intestines. While still being high, the total and fat tissues had the lowest variation for the stomach. The variation in the lean tissue suggested that the organ itself is too variable with its sizes and shapes to measure quantitatively significant changes. The bone mineral composition varied so much because there was an insignificant amount of minerals. Even a slight change caused a major change in composition. (Table 1)

Table 1. Mean composition of the limbs and digestive organs of nine laboratory rats

	BMC	Lean Tissue	Fat Tissue	Total Tissue
Intestines	0.005 ± 0.002 (45)	6.2 ± 0.8 (11)	1.5 ± 0.1 (12)	7.7 ± .7 (9)
Stomach	0.004 ± 0.004 (99)	11.2 ± 2.04 (32)	6 ± 1 (18)	17.4 ± 2.1 (28)
Right hind limb	0.5 ± 0.003 (13)	4.5 ± 1.5 (13)	3.2 ± .7 (12)	7.5 ± 8 (11)
Right forelimb	0.1 ± 0.04 (9)	24.3 ± 4.9 (19)	11.5 ± 1.9 (16)	35.8 ± 5.4 (15)

CONCLUSION

Because the PIXImus DEXA measurements were accurate, we can conclude that it is a plausible tool to assess bone and tissue mass. The standard deviations were low enough for the bones in the limbs that we can conclude that DEXA's capability to measure bone composition is accurate.

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