DOI: 10.5216/cab.v11i1.4393

INFLUENCE OF DIFFERENT TYPES OF ELECTRODES ON THE BIOELECTRICAL IMPEDANCE VALUES AND IN THE ESTIMATION OF LEAN BODY MASS (LBM) IN ADULT CATS

Thassila Caccia Feragi Cintra,[1] Júlio Carlos Canola,[2] Naida Cristina Borges,[3] Aulus Cavalieri Carciofi,[4] Ricardo Souza Vasconcelos[5] e Rosana Zanatta[6]

1 - Veterinary Doctor, intern at the Image Diagnosis Sector at the Veterinary Hospital of FCAV/UNESP - thassi_vet@hotmail.com;
2 - Professor PhD. (Doctor Assistant) of the Department of Veterinay Clinic and Surgery of FCAV/UNESP;
3 – Assistant Professor of the Department of Veterinay Medicine of UFG;
4 - Professor PhD. (Doctor Assistant) of the Department of Veterinay Clinic and Surgery of FCAV/UNESP;
5 – Doctorate Student in Veterinay Clinic and Surgery FCAV/UNESP;
6 – Doctorate Student in Image Diagnosis of the Department of Veterinay Clinic and Surgery of FCAV/UNESP.

ABSTRACT

The bioelectrical impedance is a method that applies impedance technology in the study of physical composition by evaluation of electrical conductivity difference on each organism tissue. The results of bioelectrical impedance (BIC) are expressed by the resistance (R) and reactance (Xc) primary measures. This study was carried out to verify the viability of the use of three different electrodes on the repeatability of R and Xc values in adult cats. The averages of R and Xc estimated by adhesive and acupuncture needles did not differ from each other ($p \geq 0.05$), and the smaller values of the variation coefficient acquired with these electrodes signaled for a better reproducibility of the results when compared with hypodermic needle. The different types of electrodes did not interfere on the LBM estimated by specific equation, but the acupuncture needle electrode was the most stable and easily applicable. The LBM values determined with the different types of electrode were higher ($p \leq 0.05$) than the LBM dual-energy X-ray absorptiometry (DEXA) values, probably due to the specific equation to LBM estimation used in this study.

KEY WORDS: Body composition, impedance, feline, lean body mass.

RESUMO

INFLUÊNCIA DE DIFERENTES TIPOS DE ELETRODOS SOBRE OS VALORES DA BIOIMPEDÂNCIA CORPORAL E NA ESTIMATIVA DE MASSA MAGRA (MM) EM GATOS ADULTOS

A bioimpedância (BIC) é um método que aplica a tecnologia da impedância no estudo da composição corporal pela avaliação da diferença da condutividade elétrica dos tecidos. Os resultados da BIC são expressos pelas medidas primárias de resistência (R) e reatância (Xc). Neste experimento o método foi conduzido para verificar a viabilidade do uso de três diferentes tipos de eletrodos sobre a reprodutibilidade dos valores de R e Xc em gatos adultos. As médias de R e Xc com adesivos e agulhas de acupuntura não diferiram entre si ($p \geq 0,05$), e os menores valores dos coeficientes de variação obtidos com estes eletrodos sinalizaram para uma melhor reprodutibilidade dos resultados quando comparados com os da agulha hipodérmica. Os diferentes tipos de eletrodos não interferiram nos valores da massa magra (MM) estimada por equação específica, porém a agulha de acupuntura mostrou ser o eletrodo mais estável e de melhor aplicabilidade. A MM determinada com os diferentes tipos de eletrodos foi superior ($p \leq 0,05$) à obtida com a absorciometria de raios-x de dupla energia (DEXA), provavelmente decorrente da equação utilizada na sua estimativa.

PALAVRAS-CHAVES: impedância, felinos, massa magra, composição corporal.

INTRODUCTION

Bioelectrical impedance (BIC) is a technique that records the water and fat quantity in the body by the passage of low intensity electric current. The greater the water and electrolytes amounts in the organism, the more easily the current will pass through it (BAUMGARTNER et al., 1990; CHUMLEA et al., 1993). The results are expressed by the primary measures of resistance (R) and reactance (Xc), being necessary the use of prediction equations to convert the values into lean body mass (LBM) estimations, according to GUO et al. (1989); GUO et al. (1996).

Human and animal organisms have the volume constituted by intra and extracellular fluids that behave as heterogeneous electrical conductors, cell membranes that work as electrical capacitors, amd body fat which, acting as an isolator, offers resistance to the electrical current passage. This way, the organism can be considered a circuit constituted by elements of resistance and capacitance, which offer oposition to the conduction of alternating electrical current, known as impedance, and which dependes on the frequence (BAUMGARTNER et al., 1990; CHUMLEA et al., 1993; CHUMLEA & GUO, 1994).

The resistance (R) is attributed to the opposition to the electrical flow when it passes through the intra and estracellular means. Lean tissues (muscles and viscera) are great conductors because they contain great amounts of water and electrolytes, and they represent low electrical resistance. Fat tissues and bones are not considered good quality conductors because they show low quantities of electrolytic fluids and high resistance (BAUMGARTNER et al., 1990; CHUMLEA & GUO, 1994).

The reactance (Xc) is the opposition to the electrical flow caused by the capacitance. It is related to the dynamic performance of cell membranes, of tissue interfaces, and of non-ionic tissues. In many cases it varies regardless of the resistance. Cell membranes function as capacitors due to the two proteic layers, both with intense biological activity and hydrophilic properties, limiting a weakly conductor structure. In human beings this structure represents the indicator of lean body mass quantity and intracellular body mass, being related to the hydric and intracellular ballance (BAUMGARTNER et al., 1990; CHUMLEA & GUO, 1994).

The phase angle (φ) is a linear method for the measurement of the relation between R and Xc in series or parallel circuits, and it can vary from zero (resistive circuit, i.e., with no cell membrane) to 90 degrees (capacitive circuit, i.e., there is only the cell membrane, and no fuids). The 45 degrees angle represents a circuit with equivalent capacity of resistance and reactance. The φ is calculated by the arctangent relation of the reactance and the resistance ($\varphi = \arctan Xc/R$). The result obtained, expressed in radius, is multiplied by $180°/\pi$, or by the approximate value of 57.296 to operate the degrees conversion (BAUMGARTNER et al., 1988, 1990; CHUMLEA et al., 1993).

In medicine, biometry uses mesurements of skinfolds, circumferences and bone diameter in vatious body segments. Although it is not precise, it is undoubtely the most used non-invasive procedure to characterize groups and populations (PETROSKI, 1995). Many biometric mesurements are used in veterinary medicine, except the skinfold measurement, because the presence of fur, and the easily detachable skin, specially in dogs, render the measurement difficult and reduce the accuracy of the technique (MUNDAY, 1994; STANTON et al., 1992).

The dua-energy x-rays absorciometry method (DEXA) is the three-compartiment model, which divides the body inyo total mineral mass (TMM), lean body mass (LBM), and fat body mass (FBM). The technique precision was estimated in 2.7% (MADSEN et al., 1997) and 8.8% (MAZESS et al., 1990) for fat percentage in human beings, and 5.8 % in cats (MUNDAY, 1994). LAFLAMME & HANNAH (2005) confirmed the DEXA exam as the best choice to assess body composition, when they evaluated 18 cats in a weight loss program with two levels of protein in the diet.

According to LUKASKI et al. (1986), DEURENBERG et al. (1991) and PICHARD et al. (2000), the BIC aplicability is well stablished in human beings for the reference values for the primary measurements of resistance (R), reactance (Xc) and phase angle (PA), as well as for the prediction equations formulated to convert the measured values into estimates of fat body mass (FBM) and lean body mass (LBM). Nevertheless, these studies are still rare in animals. STANTON et al. (1992) prepared prediction equations to assess the LBM in cats, without specifyinf the values of R and Xc.

Factors such as body temperature, hydration level, body positioning, and serum concentration of electrolytes influence the values measured by BIC (KUSHNER et al., 1990). The type of electrode used also interferes in the values. JENIN et. al. (1975), in a work with human beings, warned that the discomfort caused by the needle, the difficulty of insertion in uniform depth, and the trauma caused in the tissues can influence the measured values. However, few authors considered the necessity of stablishing or defining the type of electrode according to the animal specicies being studied. For this reason, this experiment was carried out with the objective of evaluating the precision of three different types of electrodes (hypodermic needle, acupuncture needle, and self-adhesive covered with conductor gel), in the assessment of R, Xc and PA primary values, as well as its use in the assessment of LBM in adult cats. To validate LBM estimate obtained by BIC for each type of electrode researched, the estimate was correlated to LBM values determined by the dual-energy x-rays absorciometry (DEXA), considered the ideal method to estimate FBM and LBM.

MATERIAL AND METHODS

Twenty gonadectomized cats of undefined breed (UDB), 10 males and 10 females, of ages within five and seven years, were used. The animals came from the experimental animal shelter of the research laboratory of nutrition and nutriotional deseases of cats and dogs – UNESP- Jaboticabal-SP.

The BIC and DEXA tests, the biometrical measurements, and the assessment of body weight (BW) with a digital scale (Marte, model LC 50) were carried out with the animals under a 12-hour fasting and intramuscular anesthesia with an association of levomepromazine chloridrate (Neozine 5mg/mL – Aventis Pharme LTDA), tiletamine chloridrate and zolazepam chloridrate (Zoletil 50mg/mL – Virbac do Brasil Indústria e Comércio LTDA), in the respective doses of 0.5, 2.5 and 2.5 mg/kg of body weight.

To perform the BIC exam a monofrequency bioelectrical impedance analyzer was used (Model RJLQuantum II Bioimpedance Analyser), generator of 50kHz and 800 μA alternate current. The animals were positioned in prone recumbency on a rubber plate, placed over a wooden table. The thoracic and pelvic limbs were directed cranium-laterally and caudally, respectively. The electrodes were positioned, according to Stanton et al. (1992), in the following anatomical sites: frontal region between the eyes; middle line on the sacrococcygeal articulation, middle line on the occipital protuberance; and lumbosacral junction.

The anatomical sites were trichotomyzed and submitted to asepsis with iodine-alcohol, and after that, the three types of electrodes, a 0.40mm x 13mm stainless steel hypodermic needle (Becton Dickinson, Rutherford, NJ), a 0.40mm x 15 mm stainless steel spiral handle acupuncture needle (Yang Nacional), and 25 x 22mm disposable adhesives ECG (Marquette Electronics Jupiter, FL) were tested. The electrodes were connected to the connexion clamps attached to the BIC device by black and red wires, configuring inductor and detector electrodes, respectively. Inductor electrodes were attached to the fronal region, between the eyes, and to the middle line on the sacrococcygeal articulation; the detectors electrodes were positioned on the middle line on the occipital protuberance, and on the lumbosacral junction. The readings of R and Xc were obtained in third copies for each type of electrode. The PA was calculated by the the arctangent relation of the electrical Xc and R, and the results were expressed in radius and multiplied by 180 /π ou 57.296 in order to operate the degree conversion, as cited by BAUMGARTNER; CHUMLEA & ROCHE (1990) e CHUMLEA et al. (1993).

The DEXA exam (Hologic, Delphi W model, version 11. 2:5), used to assess the lean body mass (LBM) reference value, was constituted of three consecutive sweepings of the total body, without repositioning the animals on the examination table. The animals were positioned in dorsal recumbency with thoracic and pelvic limbs extended to the caudal position. Thoracic limbs remained parallel to the thorax and to the spinal cord. The animal position on the table was mantained by the use of impermeable scotch tape fixed transversally to the head, thorax, pelvis and pelvic limbs (LAUTEN et al., 2000; LAUTEN et al., 2001).

Biometric measures with the animal in left lateral recumbency were carried out with a tape measure graduated in centimeters. The animal´s lenght (AL), the pelvic circumference (PC), and right thoracic limb lenght (RTL) were measured according to the specifications by HAWTHORNE & BUTTERWICK (2000) and STATON et al. (1992). These measures associated to the R measures determined by BIC were used to estimate the LBM by the equation proposed by STATON et al. (1992).

The measures of R, Xc and PA, for each type of electrode, were compared by the Tukey Test ($p \leq 0.05$). The LBM means estimated by STANTON´s et al. equations (1992), for each type of electrode were compared to the LBM determined by the DEXA exam, by the use of Tukey Test ($p \leq 0.05$) for paired samples. Pearson correlation was used to stablish the relation between the values obtained by STANTON´s et al. equations (1992) and the ones obtained by the DEXA.

RESULTS AND DISCUSSION

Despite factors as the body position and the patient discomfort during the electrodes application, the BIC is considered a simple and safe technique for epidemioligical and clinical studies for the evaluation of FBM, LBM, and body fluids in humans (JENIN et al., 1975; KUSHNER et al., 1990; LUKASKI et al., 1985). These factors become more evident in animals due to the positioning and immobilization difficulties during the exam (MUNDAY, 1994).

R and Xc means were ($p \leq 0.05$) superior for the hypodermic needles (HN), and they did not show significant variation ($p \geq 0.05$) between the adhesive electrodes (AE) and the acupuncture needles (AN). PA mean was higher ($p \leq 0.05$) for the adhesive electrode related to the acupuncture needle, differing significantly for the acupuncture needle ($p \leq 0.05$), but not for the hypodermic needle ($p \geq 0.05$) (Table1).

The lowest variation coefficients (VC) were found with the application of the adhesive electrodes for the measures of R, Xc and PA (0.62%, 0.69%, 5.93%, respectively), followed by the acupuncture needle (R=0.66%, Xc=1.69%, PA=9.99%), and the hypodermic needle (R=7.34%, Xc=19.83, PA=29.22). These results show that bioelectrical impedance estimated by adhesive electrodes and by acupuncture needles present greater stability and better reproducibility than the ones obtained by the hypodermic needle.

Table 1. Averages and standard deviation (±), variation coefficients (%) and minimum and maximum values (Min - Max) of the resistance, reactance, and phase angle measures for the adhesive electrode (AE), the acupuncture needle (AN) and the hypodermic needle (HN), tested in adult cats in the BIC exam. UNESP – Jaboticabal/ 2005.

BIC	Type of electrode	Averages	Standard deviation	Variation coefficient (%)	Min-Max
Resistance (Ω)	Adhesive	173,97[a]	±1,05	0,62	147,00-208,67
	Acupuncture needle	173,53[a]	±1,13	0,66	137,33-202,33
	Hypodermic needle	242,85[b]	±18,62	7,34	172,67-316,33
Reactance (Ω)	Adhesive	33,10[a]	±0,23	0,69	29,00-39,67
	Acupuncture needle	28,25[a]	±0,48	1,69	22,00-32,67
	Hypodermic needle	41,93[a]	±8,90	19,83	23,33-67,00
Phase angle (°)	Adhesive	10,94[a]	±0,65	5,93	9,60-12,24
	Acupuncture needle	9,37[b]	±0,94	9,99	7,23-10,85
	Hypodermic needle	9,85[ab]	±2,88	29,22	4,19-14,04

Averages followed by the same letter did not differ by Student t test for paired samples ($p<0.05$).

Studieds carried out with animals of other species indicate that there are variations in BIC primary values due to the use of different types of electrodes; the same was certified in this work.

HALL et al. (1988) verified in rats that the values of R and Xc measured by aluminium metal tape varied during the whole examination (VC=8.5%), while the measures obtained by silver needle (gauge 28) and hypodermic needle (20-gauge) showed greater stability and better reproducibility (VC=2%). The results obtained in this work indicate that the BIC value obtained by the acupuncture needle presentes better reproducibility than the ones obtained by the hypodrmic needle.

The hypodermic needle produces instability in the bioelectrical impedance values assessment and consequently in the LBM estimation due to non-propperly fixing in the subcutaneous tissue and to frequent loosing. HOFFER et al. (1969) pointed out for the problems related to the use of hypodermic needles as electrodes in human beings. According to these authors, pain and discomfort, difficulty at determining a uniform depth, and traumas in the subcutaneous tissue interfere in the results. These observations were not considered by STANTON et. al. (1992), who utilized this type of electrode in the assessment of the BIC primary values in cats for the later formulation of LBM and FBM prediction equations.

The self-adhesive produced measure assessments with great stability. However, in order to the electrodes achieve adequate adherence, the adhesive appilcation requires the previously skin preparation with trichotomy, the use of blades to shave the fur, besides ether application to reduce the fat layer that recovers the skin. These procedures restric its use in the veterinay clinic routine, as well as the almost mandatory necessity of the animal chemical contention, and the restriction to the trichotomy imposed by the owners.

Table 2 ilustrates the results related to the precision at estimating LBM for the three types of electrodes. The values of LBM estimated for each type os electrode by the use of the prediction equation suggested by STANTON et al. (1992) were compared to the values of LBM determined by the DEXA exam. Difference ($p \geq 0.05$) between the LBM average values estimated by the STANTON´s et al. equation (1992), using the R value obtained with different electrodes, was not found. Nevertheless, the LBM average determined by the DEXA was significantly lower ($p \leq 0.05$) than the average values estimated by the equation.

Table 2. Averages and standard deviation (±) of the lean mass variable (Kg), estimated by the absorciometry of dua-energy x-rays method (DEXA) and estimated by Stanton´s et. al equation (1992) for the electrodes AD, NA, HN, and correlation coefficients (CC) determined by the relation between the amount of LBM estimated by Stanton´s et. al equation (1992) and determines by DEXA for each tested electrode, regardless of the animal´s sex (M e F) , and considreing the animal sex, males (M) and females (F). UNESP-Jaboticabal/2005.

Animals	DEXA	BIC					
		Adhesive	CC for AE	Acupuncture needle	CC for AN	Hypodermic needle	CC for AN
M e F (n=20)	2,84 ± 0,52[a]	AE	0,89**	3,78 ± 0,87[b]	0,89**	3,71 ±0,86[b]	0,90**
M (n=10)	3,12 ± 0,53[a]	4,10 ± 0,88[b]	0,94**	4,10 ± 0,87[b]	0,94**	4,02 ± 0,89[b]	0,94**
F (n=10)	2,57 ± 0,36[a]	3,46 ± 0,78[b]	0,81*	3,46 ± 0,77[b]	0,81*	3,40 ± 0,75[b]	0,82*

Averages followed by the same letter did not differ by Student t test for paired samples ($p<0.05$).
Significant correlation coefficients $p<0.05$* $p<0.01$**

These results confirm the observations by STANTON et al. (1992) that the predictions equations that utilize values from the BIC exam can overestimate the LBM. They also agree with the works carried out with human beings, as the ones by VAZQUEZ & JANOZKY (1991) that tested eight BIC equations for the prediction of the LBM and seven among them overestimated the LBM determination. FRANCKOWIAK et al. (2003) confirmed that the LBM prediction equations using the R measures overestimate the LBM in human beings.

The LBM values estimated by the equation of STANTON et. al. (1992), for the three types of electrodes, presented high correlation with the values obtained by the DEXA (Table 2), showing that the BIC is an efficient method for the assessment of the LBM in cats.

In the BIC, the type of electrode is the only variable that can interfere in the assessment of the primary values of R and Xc or in the overestimation of the LBM. Other factors such as the ones cited by KUSHNER et al. (1990) can interfere in a more relevant way in the results, and they must be eveluated in animals.

CONCLUSION

Although acupuncture needles, hypodermic needles, and electrode adhesives did not significantly interfere in the BIC evaluation and consequently in the LBM assessment in adult cats, it can be concluded that electrodes made with acupuncture needles present better reproducibility, being the most stable method and with the greatest practical applicability in the assessment of the primary values of R and Xc, within the conditions and methodology used in this experimental model.

ACKNOWLEDGEMENTS

The authors acknowledge the financial resources from the Research Support Fund fo São Paulo (Fundo de Apoio a Pesquisa do Estado de São Paulo – FAPESP) and from the Fundation for the developement of UNESP (Fundação para o Desenvolvimento da UNESP – FUNDUNESP).

REFERENCES

BAUMGARTNER, R. N.; CHUMLEA, W. C.; ROCHE, A. F. Bioelectric impedance for body composition. **Exercise and Sport Sciences Reviews**, v. 18, p. 193-224, 1990.

CHUMLEA, W. C.; GUO, S. S. Bioelectrical impedance and body composition: present status and future directions. **Nutrition Reviews**, v. 54, n. 4, p.123-131, 1994.

CHUMLEA, W. C.; GUO, S. S.; KUCZMARSKI, R. J.; VELLAS, B. Bioelectric and anthropometric assessments and reference data in the elderly. **The Journal of Nutrition**, v. 123, p. 449-453, 1993.

DEURENBERG, P.; VAN DER KOOY, K.; LEENEN, R.; WESTSTRATE, J. A.; SEIDEI, J. C. Sex and age specific prediction formulas for estimating body composition from bioelectrical impedance: a cross-validation study. **International Journal of Obesity**, v. 15, p. 17-25, 1991.

FRANCKOWIACK, S. C.; FONTAINE, K.; ANDERSEN, A. E. Comparison of proximal and distal placements of electrodes to assess body composition by bioelectrical impedance in obese adults. **Journal of Strenght and Conditioning Research**, Colorado Springs, v. 17, n. 3, p. 522-526, 2003.

GUO, S. S.; CHUMLEA, W. C.; COCKRAM, D. B. Use of statistical methods to estimate body composition. **The American Journal of Clinical Nutrition**, v. 64, n. 3, p.428S-35S, 1996.

GUO, S. S.; ROCHE, A. F.; HOUTKOOPER, L. Fat-free mass in children and uoung adults predicted from bioelectric impedance and anthropometric variables. **The American Journal of Clinical Nutrition**, v. 50, n. 3, p. 435-443, 1989.

HALL, C. B.; LUKASKI, H. C.; MARCHELLO, M. J. Estimation of rat body composition using tetrapolar bioelectrical impedance analysis. **Nutrition Reports International**, v. 39, n. 3, p. 627-633, 1988.

HAWTHORNE, A. J.; BUTTERWICK, R. F. Indice de masa corporal felina: una medida simple del contenido de grasa corporal en los gatos. **Waltham Focus**, v. 10, n. 1, p. 32-33, 2000.

HOFFER, E. C.; MEADOR, C. K.; SIMPSON, D. C. Correlation of whole-body impedance with total body water. **Journal of Applied Physiology**, v. 27, n. 4, p. 531-534, 1969.

JENIN, P.; LENOIR, J.; ROULLET, C.; THOMASSET, A.; DUCROT, H. Determination of body fluid compartments by electrical measurements. **Aviation Space and Environmental**

Medicine, v. 46, p. 152-155, 1975.

KUSHNER, R. F.; KUNIGK, A.; ALSPAUGH, M.; ANDRONIS, P. T.; LEITCH, C. A.; SCHOLLER, D. A. Validation of bioelectrical impedance analysis as a measurement of change in body composition in obesity. **The American Journal of Clinical Nutrition**, v. 52, p. 219-223,1990.

LAFLAMME, D.; HANNAH, S. S. Increased dietary protein promotes fat loss and reduces loss of lean body mass during weight loss in cats. **International Journal of Applied Research in Veterinary Medicine**, v. 3, n. 2, p. 62-68, 2005.

LAUTEN, S. D.; COX, N. R.; BAKER, G. H.; PAINTER, D. J.; MORRISON, N. E.; BAKER, H. J. Body composition of growing and adult cats as measured by use of dual energy x-ray absorptiometry. **Comparative Medicine**, v. 50, n. 2, p. 175-183, 2000.

LAUTEN, S. D.; COX, N. R.; BRAWNER JR., W. R.; BAKER, H. J. Use of dual energy x-ray absorptiometry for noninvasive body composition measurement in clinically normal dogs. **American Journal of Veterinary Research**, v. 62, n. 8, p. 1295-1301, 2001.

LUKASKI H. C.; JOHNSON P. E.; BOLONCHUCK W. W.; LYKKEN G. L. Assessment of fat free mass using bio-electrical impedance measurements of the human bidy. **The American Journal of Clinical Nutrition**, v. 41, n. 7, p. 810, 1985.

LUKASKI, H. C.; BOLONCHUK, W. W.; HALL, C. B.; SIDERS, W. A. Validation of tetrapolar bioelectrical impedance method to assess human body composition. **Journal of Applied Physiology**, v. 60, p. 1327-1332, 1986.

MADSEN, O. R.; JENSEN, J. E. B.; SORENSEN, O. H. Validation of a dual energy x-ray absorptiometer: measurement of bone mass and soft tissue composition. **European Journal of Applied Physiology and Occupational Physiology**, v. 75, p. 554-558, 1997.

MAZESS, R. B.; BARDEN, H. S.; BISEK, J. P.; HANSON, J. Dual- energy x-ray absorptiometry for total-body and regional bone-mineral and soft-tissue composition. **The American Journal of Clinical Nutrition**, v. 51, p. 1106-1112, 1990.

MUNDAY, H. S. Assessment of body composition in cats and dogs. **International Journal of Obesity**, v.18, Suppl. 1, p. S14-21, 1994.

PETROSKI, E. L. Desenvolvimento e validação de equações para a estimativa da densidade corporal em adultos. **Revista Brasileira de Atividade Física e Saúde**, v. 1, n. 2, p. 89-91, 1995.

PICHARD, C.; KYLE, U. G.; BRACCO, D.; SLOSMAN, D. O.; MORABIA, A.; ACHUTZ, Y. Reference values of fat-free and fat masses by bioelectrical impedance analysis in 3393 healthy subjects. **Nutrition**, v. 16, p. 245-254, 2000.

STANTON, C. A.; HAMAR, D. W.; JOHNSON, D. E.; FETTMAN, M. J. Bioelectrical impedance and zoometry for body composition analysis in domestic cats. **American Journal of Veterinary Research**, v. 53, n. 2, p. 251-257, 1992.

VAZQUEZ, J. A.; JANOSKY, J. E. Validity of bioelectrical-impedance analysis in measuring changes in lean body mass during weight reduction. **The American Journal of Clinical Nutrition**, v. 54, p. 970-975, 1991.

Submitted on: 22 July 2008. Accepted on: 20 May 2009.