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Degree of thoracic kyphosis and peak torque of trunk flexors and extensors among healthy women☆,☆☆

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ABSTRACT

Objective: The aim of this study was to analyze the effects of aging on the degree of thoracic kyphosis and peak torque of the trunk flexor and extensor muscles among women without a densitometric diagnosis of osteoporosis.

Methods: Thirty women were selected to make up three groups: young women ($n = 10$; 24.60 ± 2.27 years of age); adults ($n = 10$; 43.50 ± 2.88); and elderly women ($n = 10$; 62.40 ± 2.67). Bone mineral density (BMD), degree of thoracic kyphosis and peak torque of the trunk flexors and extensors were evaluated. Differences between the groups were evaluated using the Kruskal–Wallis ANOVA and Mann–Whitney *U* tests. Pearson's correlation coefficient was used to assess correlations between the variables. The significance level was taken to be 5% ($p \leq 0.05$).

Results: The elderly group presented a greater degree of thoracic kyphosis ($p = 0.009$) and lower peak torque of the trunk flexors and extensors than the young group. The adult group presented lower peak torque of the trunk than the young group. A negative correlation was observed between age and peak torque of the trunk flexors and extensors ($p \leq 0.001$), and a positive correlation between age and the degree of thoracic kyphosis ($r = 0.58$; $p \leq 0.001$). The elderly group presented higher values for the eccentric/concentric ratio of the peak torque for flexors ($p = 0.03$) and extensors ($p = 0.02$).

Conclusion: This study suggests that physiological aging may be associated with a greater degree of thoracic kyphosis and lower muscle strength of the trunk flexors and extensors. Moreover, the elderly women showed a relative capacity for preservation of eccentric strength.

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Grau de cifose torácica e pico de torque de flexorese extensores de tronco entre mulheres saudáveis

Palavras-chave:
Cifose
Força muscular
Envelhecimento

RESUMO

Objetivo: analisar os efeitos do envelhecimento no grau de cifose torácica e no pico de torque dos músculos flexores e extensores de tronco entre mulheres sem diagnóstico densitométrico de osteoporose.

Métodos: foram selecionadas 30 mulheres para compor os três grupos: jovens (n = 10; 24,60 ± 2,27 anos); adultas (n = 10; 43,50 ± 2,88); e idosas (n = 10; 62,40 ± 2,67). Densidade mineral óssea (DMO), grau de cifose torácica e pico de torque de flexores e extensores de tronco foram avaliados. Diferenças entre os grupos foram avaliadas pelos testes Anova de Kruskal-Wallis e Mann-Whitney *U*. Correlações entre as variáveis foram avaliadas pelo coeficiente de correlação de Pearson. Foi considerado um nível de significância de 5% ($p \leq 0,05$).

Resultados: o Grupo Idosas apresentou um maior grau de cifose torácica (p = 0,009) e menor pico de torque extensor e flexor de tronco do que o Grupo Jovens. O Grupo Adultas apresentou menor pico de torque flexor de tronco do que o Grupo Jovens. Foram observadas correlação negativa entre idade e pico de torque flexor e extensor de tronco ($p \leq 0,001$) e correlação positiva entre idade e grau de cifose torácica (r = 0,58; $p \leq 0,001$). O Grupo Idosas apresentou valores mais altos para a relação excêntrico/concêntrico de pico de torque flexor (p = 0,03) e extensor (p = 0,02).

Conclusão: o envelhecimento fisiológico pode estar associado a um maior grau de cifose torácica e a menor força muscular de flexores e extensores de tronco. Ainda, as idosas mostram uma relativa capacidade de preservação da força excêntrica.

Introduction

Thoracic hyperkyphosis among women may occur as a result of aging and of certain health conditions, such as osteoporosis.[1–3] Kado et al.[3] found in a retrospective cohort study on 1196 women that progression of hyperkyphosis may result from multiple factors, including: age, vertebral fractures, low bone mineral density, degenerative intervertebral disk disease, family history of hyperkyphosis and loss of body mass.

The diminution of muscle strength and mass that accompanies aging has been correlated with an increased degree of thoracic kyphosis,[2] given that stabilization of the spine, which is promoted by the muscle mass, may be important in diminishing the incidence of postural deformities[2] and vertebral fractures.[4]

Granito et al.[5] found that the concentric and eccentric muscle torque of the trunk extensors presented a significant correlation with the degree of thoracic kyphosis among elderly people, and a significant difference between elderly women with and without osteoporosis. Furthermore, men and women might present loss of isometric, concentric and eccentric muscle torque with aging,[6] resulting from the loss of muscle mass and/or diminution of the capacity of the muscles to generate tension.[7] Sinaki et al.[8] found that men presented loss of 64% of the muscle torque of the trunk extensors between the fourth and ninth decades of life, and that women presented a loss of 50.4% between the fifth and ninth decades.

Thus, the objective of this study was to analyze the effects of aging on the degree of thoracic kyphosis and on the peak flexor and extensor torque of the trunk among healthy women without a densitometric diagnosis of osteoporosis. The hypothesis of the study was that there would be an increase in the degree of thoracic kyphosis and a diminution of flexor and extensor torque with advancing age.

Materials and methods

This was a cross-sectional study conducted among women without orthopedic, neurological or cardiovascular diseases, in different age groups. Thirty women were recruited and distributed into three different groups according to their ages.

Group of young women (*n* = 10): between 20 and 30 years of age.
Group of adult women (*n* = 10): between 40 and 50 years of age.
Group of elderly women (*n* = 10): over 65 years of age.

All the participants were given explanations about the procedures of the study. They voluntarily agreed to participate and signed a free and informed consent statement. The project was approved by the Ethics Committee for Research on Human Beings of the Federal University of São Carlos (88/2005) and was conducted in accordance with Resolution 196/96 of the National Health Council and with the Declaration of Helsinki.

Firstly, all the participants underwent a general evaluation with regard to the inclusion and exclusion criteria, conducted by a physiotherapist, in which their histories were taken in order to gather personal and health-related data, and a physical assessment was made, consisting of verifying body mass

(kg) and height (m). The body mass index (BMI) was calculated by dividing the body mass (kg) by the height squared (m^2).[9]

The women included were white nonsmokers with a sedentary lifestyle. The women were considered to be sedentary if they did less than 150 min of physical activity per week.[10] Women who presented any musculoskeletal or neurological disease that might compromise their sensory or motor function, cognitive deficits, use of drugs that affect the central nervous system or postural control (sedatives or anxiolytics), use of drugs that compromise muscle strength (corticosteroids), arthralgia in the lower limbs, a densitometric diagnosis of osteoporosis ($t < -2.5$) or other disorders of the lumbar spine were excluded.

Densitometry evaluations were done by means of a computerized densitometer, using the dual-emission X-ray absorption method with the Lunar DPX-L equipment (Lunar, Madison, WI, USA), at the Romeu Santini Institute. Radiographic examinations of the thoracic spine to determine the thoracic kyphosis measurements were done at the Integrated Imaging Diagnostics Center (CIDI).

Subsequently, the volunteers underwent an evaluation of peak concentric torque (PCT) and peak eccentric torque (PET) of the trunk flexors and extensors, by means of the Biodex Multi-Joint System 3 isokinetic dynamometer (Biodex Inc., Chattanooga, USA). Firstly, the participants performed 5 min of warm-up on an ergometric bicycle at a velocity of 25 km/h. Following this, they were positioned as seated on the dynamometer chair at 90° of hip flexion. Their position was stabilized by means of a device for fixing the knees flexed at 90°, along with use of belts in the hip region, middle third of the thigh and chest region. The axis of the dynamometer was positioned at the L5-S1 intervertebral space, in order to assess trunk flexion and extension.[11]

Three concentric contractions and three eccentric contractions for trunk flexion and extension movements were performed in order to determine the peak torque. The evaluations were performed for a range of motion of 20° (between 10° of trunk flexion and 10° of trunk extension). The test/retest correlation coefficient was greater among the women.[11] The evaluations were performed for the velocities of 20°/s and 45°/s, which correspond to significant functional movement times for the trunk. The velocity of 10°/s suggested by Dvir and Keating[11] was not well tolerated by the participants in a pilot study and was not used in the present study. A resting period of 30 s was maintained between the tests.

All the tests were performed by the same examiner and the participants were encouraged to flex and extend the trunk with the greatest force possible. Two free repetitions were allowed before the effective test, so as to become familiarized with the equipment. The peak torque normalized according to body weight was used for the analyses.

The radiographic examinations of the thoracic spine were performed in lateral view. The radiographic films were used to measure the degree of kyphosis, which was determined using the Cobb angle.[12] The radiographs were produced in the mornings, by the same person, who had seven years of experience of this type of evaluation. Precise attention was paid in producing the radiographs, so as to avoid posture variations that might affect the degree of kyphosis.

Table 1 – Characterization of the sample.

	Group of young women	Group of adult women	Group of elderly women
Age (years)	24.60 ± 2.27	43.50 ± 2.88	62.40 ± 2.67
Body mass (kg)	56.90 ± 4.04	59.40 ± 11.37	64.69 ± 5.48
Height (m)	1.65 ± 0.04	1.61 ± 0.08	1.57 ± 0.06
BMI (kg/m^2)	20.90 ± 1.45	22.79 ± 2.71	26.20 ± 2.32

Statistical analysis

The data were expressed as the mean ± standard deviation. All the analyses were performed by means of the Statistica 7.0 software (Copyright Statsoft Inc., 1984–2004) and the significance level was taken to be 5% ($p \leq 0.05$). Initially, the data was assessed using the Shapiro–Wilks test to determine whether the distribution was normal. Since the distribution was found to be not normal, difference between the groups relating to the degree of thoracic kyphosis and the peak trunk flexion and extension torque were determined by means of the nonparametric Kruskal–Wallis ANOVA test. When the principal effect was significant, comparisons in pairs were made using Bonferroni adjustments for multiple comparisons. Correlations between the variables were determined using Pearson's correlation coefficient, such that $r = 0.10$ to 0.30 was classified as weak, $r = 0.40$ to 0.60 as moderate and $r = 0.70$ to 1.0 as strong.[13]

Results

Table 1 presents the results of characterizing the groups, i.e. age, body mass, height and body mass index (BMI).

Table 2 presents the values for the degree of thoracic kyphosis, peak isokinetic torque, peak concentric torque (PCT) and peak eccentric torque (PET) for the trunk flexor and extensor muscles at the velocities of 20°/s and 45°/s. It was observed that the degree of thoracic kyphosis was significantly greater and that the peak concentric and eccentric torque of the trunk extensors at the velocities of 20°/s and 45°/s was significantly lower in the group of elderly women, in relation to the group of young women. Moreover, the peak concentric and eccentric torque of the trunk flexors at the velocities of 20°/s and 45°/s was significantly lower in the groups of elderly women and adult women, in relation to the group of young women.

Table 3 presents the percentage relationships between the trunk extensor and flexor torques in the different groups of volunteers, during concentric and eccentric muscle actions at the two velocities of the isokinetic test. There was no significant difference in the peak extensor/flexor torque relationships between the groups.

Table 4 presents the percentage relationships between the torques obtained during eccentric and concentric contractions in the different groups of volunteers, in evaluating the trunk extensor and flexor muscles and the two velocities of the isokinetic test. There was no significant difference in the peak eccentric/concentric torque relationships between the groups at the velocity of 45°/s. The relationship between the eccentric and concentric contractions at the velocity of 20°/s was greater in the group of elderly women than in the group of

Table 2 – Degree of thoracic kyphosis and peak isokinetic, concentric and eccentric torque of the trunk flexors and extensors at the velocities of 20°/s and 45°/s.

	Group of young women	Group of adult women	Group of elderly women	*p* Value
Trunk extensors				
Degree of thoracic kyphosis	29.99 ± 5.12	36.11 ± 3.71[a]	37.14 ± 2.67[a]	0.009
PCT 20°/s (N/m)	329.31 ± 89.97	260.05 ± 49.59	212.98 ± 52.73[a]	0.007
PCT 45°/s (N/m)	326.62 ± 61.29	278.20 ± 45.06	212.70 ± 53.72[a]	0.002
PET 20°/s (N/m)	326.62 ± 61.29	267.68 ± 45.89	236.11 ± 51.96[a]	0.005
PET 45°/s (N/m)	393.34 ± 73.35	337.87 ± 52.46	273.93 ± 51.77[a]	0.002
Trunk flexors				
PCT 20°/s (N/m)	178.04 ± 32.73	112.25 ± 19.27[a]	93.71 ± 23.63[a]	<0.001
PCT 45°/s (N/m)	172.50 ± 30.53	131.28 ± 21.34	105.54 ± 19.85[a]	<0.001
PET 20°/s (N/m)	195.61 ± 19.30	134.07 ± 19.79[a]	118.12 ± 25.50[a]	<0.001
PET 45°/s (N/m)	234.14 ± 22.79	181.58 ± 33.96[a]	144.45 ± 28.31[a]	<0.001

PCT, peak concentric torque; PET, peak eccentric torque.
[a] Significant in relation to the group of young women.

Table 3 – Relationships between extensor/flexor torques during concentric and eccentric muscle contractions, at the velocities of 20°/s and 45°/s.

	Group of young women (%)	Group of adult women (%)	Group of elderly women (%)	*p* value
PCT (N/m) 20°/s	189	232	230	0.06
PCT (N/m) 45°/s	196	214	202	0.64
PET (N/m) 20°/s	182	201	202	0.27
PET (N/m) 45°/s	168	191	192	0.23

PCT, peak concentric torque; PET, peak eccentric torque.

Table 4 – Relationships between peak eccentric/concentric torques obtained in evaluations on trunk extensor and flexor muscles.

	Group of young women (%)	Group of adult women (%)	Group of elderly women (%)	*p* value
Extensors 20°/s	107	103	112[a]	0.02
Extensors 45°/s	121	122	132	0.24
Flexors 20°/s	112	120	127[b]	0.03
Flexors 45°/s	139	138	137	0.96

[a] Significant in relation to the group of adult women.
[b] Significant in relation to the group of young women.

adult women (extensors) and in the group of young women (flexors), which indicates that there was lower proportional loss of eccentric force with aging.

Table 5 presents the results from the correlation analyses between age and the degree of thoracic kyphosis and the peak torque. Age presented a significant positive correlation with the degree of thoracic kyphosis and a negative correlation with the peak concentric and eccentric torque of the trunk flexors and extensors at the two velocities. The correlation between age and the peak trunk flexor torque could be considered to be strong for the two velocities.

Table 5 – Correlations between age and the degree of thoracic kyphosis and peak concentric and eccentric torque of the trunk flexors and extensors.

	Age (years)	
	r	*p*
Thoracic kyphosis (degrees)	0.58	<0.001
PCT flexors 20°/s	−0.77	<0.001
PCT flexors 45°/s	−0.75	<0.001
PET flexors 20°/s	−0.81	<0.001
PET flexors 45°/s	−0.82	<0.001
PCT extensors 20°/s	−0.62	<0.001
PCT extensors 45°/s	−0.68	<0.001
PET extensors 20°/s	−0.58	<0.001
PET extensors 45°/s	−0.66	<0.001

PCT, peak concentric torque; PET, peak eccentric torque.

Discussion

In the present study, the degree of thoracic kyphosis in the groups of adult and elderly women was observed to be greater

than among the young women. There was also a moderate positive correlation between the degree of thoracic kyphosis and age, which indicates that aging may lead to an increase in the degree of thoracic kyphosis. In the study by Granito et al.,[5] the degree of thoracic kyphosis presented a negative correlation with bone mineral density, which indicates that bone mass may contribute toward increasing the degree of thoracic kyphosis. Furthermore, Cortet et al.[14] conducted a study with a view to comparing the spinal curvatures of women with and without osteoporosis. Ninety-eight postmenopausal women were evaluated, among whom 51 had a densitometric diagnosis of osteoporosis and at least one vertebral fracture, while the other 47 were included in the control group. The authors found that there was a significantly greater degree of thoracic kyphosis among the women with osteoporosis ($63^\circ \pm 13^\circ$), in relation to those without osteoporosis ($52^\circ \pm 11^\circ$).[14] However, the data from the present study demonstrated that it was not only the bone mass and, consequently, the compression fractures among women with osteopenia/osteoporosis that were responsible for increasing the degree of thoracic kyphosis among elderly women, given that only women without a densitometric diagnosis of osteoporosis were included in this study. Fon et al.[15] examined the degree of thoracic kyphosis in 316 individuals who were considered to be normal, with ages between two and 77 years. From analysis on chest radiographs using the modified Cobb method, they concluded that aging gives rise to an increasing degree of thoracic kyphosis. Milne and Williamson[16] and Bartynski et al.[1] also demonstrated that thoracic kyphosis was progressive with advancing age, among individuals of both sexes, which corroborates our results.

In the present study, we observed that the concentric and eccentric muscle torque of the trunk extensors was significantly lower among the elderly women, in relation to the young women. However, for the trunk flexors, we observed that this was significantly lower among both the elderly and the adult women, in relation to the young women. Moreover, age showed a strong negative correlation with trunk flexors and a moderate negative correlation with trunk extensors.

The reduction in extensor torque with advancing age that was observed in the present study has also been observed in other studies. Sinaki et al.[8] identified a loss of peak trunk extensor torque of 50.4% between the fifth and ninth decades of life. Singh et al.[17] observed a loss of peak torque of 46% between the third and sixth decades of life. Limburg et al.[18] found that there was a progressive reduction in trunk extensor torque in successive decades of life.

On the other hand, the data of our study presented a strong correlation between trunk flexor torque and age, which indicates that there was a notable loss of trunk flexor strength among the women, with increasing age. Moreover, the adult women presented a significant difference in relation to the young women regarding peak trunk flexor torque, which was not observed in relation to the trunk extensor muscles.

Among women, pregnancy may compromise the integrity of the trunk flexor muscles, which constitutes a further factor possibly contributing toward diminution of muscle torque with aging, which is evident between the ages of 40 and 50 years. According to Liaw et al.,[19] structural and functional deficits of the abdominal muscles persist for six months after childbirth. Incomplete recovery of the integrity (distance) of the linea alba may give rise to a mechanical deficit and results in a reduction in the capacity of the abdominal musculature to produce force.[19]

Despite the diminished muscle torque with aging, regarding both trunk extensors and trunk flexors, the same relationship between extensor and flexor torque was maintained in the different age groups. Therefore, aging did not give rise to imbalance between the muscle groups. On the other hand, there was a smaller proportional loss of eccentric strength with aging, especially for the trunk extensors and flexors at 20°/s.

In the study by Lindle et al.,[6] the women presented loss of isometric, concentric and eccentric strength at peak knee extension torque. However, the variation in peak eccentric torque was lower. The women presented better preservation of muscle contraction quality for peak eccentric torque.

The mechanisms for preservation of eccentric strength among elderly people seem to have mechanical and cellular origins and include active and passive elements for regulating muscle resistance to deformation. During eccentric contraction, it is possible to develop the same torque for isometric and concentric contractions, but with a smaller number of motor fibers activated, for different muscle groups. Accumulation of non-contractile tissue in the muscle-tendon unit may provide a mechanical advantage during eccentric contractions.[20]

The positive aspects of the present study can be considered to include the sample power, which was 71%, calculated from the volunteers' bone mineral density data. This ensures that the results have the strength for generalizations to be made from the data to the general population. Furthermore, the bone mineral density measurements were made by means of bone densitometry (DXA), which is considered to be the gold standard for noninvasive densitometric diagnosis of osteoporosis and has been used to evaluate the risk of fractures in the spine, hip and other peripheral regions of the skeleton, among postmenopausal women.[21,22]

Conclusion

The main limitation of our study was that the physiotherapist responsible for the assessments was not blinded, i.e. it was not possible to disregard the allocation of the subjects between the groups. Future studies, which could also include men, are necessary in order to exclude sex-related factors in determining the effects of aging on the degree of thoracic kyphosis and the trunk muscle torque.

Thus, the data of the present study suggest that physiological aging among women may be responsible for increasing the degree of thoracic kyphosis and decreasing the trunk extensor and flexor torque, with proportionally lower loss of eccentric strength.

REFERENCES

1. Bartynski WS, Heller MT, Grahovac SZ, Rothfus WE, Kurs-Lasky M. Severe thoracic kyphosis in the older patient in the absence of vertebral fracture: association of extreme curve with age. AJNR Am J Neuroradiol. 2005;26(8):2077–85.

2. Mika A, Unnithan VB, Mika P. Differences in thoracic kyphosis and in back muscle strength in women with bone loss due to osteoporosis. Spine (Phila, PA, 1976). 2005;30(2):241–6.
3. Kado DM, Huang MH, Karlamangla AS, Cawthon P, Katzman W, Hillier TA, et al. Factors associated with kyphosis progression in older women: 15 years' experience in the study of osteoporotic fractures. J Bone Miner Res. 2013;28(1):179–87.
4. Sinaki M, Itoi E, Wahner HW, Wollan P, Gelzcer R, Mullan BP, et al. Stronger back muscles reduce the incidence of vertebral fractures: a prospective 10 year follow-up of postmenopausal women. Bone. 2002;30(6):836–41.
5. Granito RN, Aveiro MC, Renno ACM, Oishi J, Driusso P. Comparison of thoracic kyphosis degree, trunk muscle strength and joint position sense among healthy and osteoporotic women: a cross sectional preliminary study. Arch Geriatr Gerontol. 2012;54:e199–202.
6. Lindle RS, Metter EJ, Lynch NA, Fleg JL, Fozard JL, Tobin J, et al. Age and gender comparisons of muscle strength in 654 women and men aged 20–93 yr. J Appl Physiol (1985). 1997;83(5):1581–7.
7. Frontera WR, Hughes VA, Lutz KJ, Evans WJ. A cross-sectional study of muscle strength and mass in 45- to 78-yr-old men and women. J Appl Physiol (1985). 1991;71(2):644–50.
8. Sinaki M, Nwaogwugwu NC, Phillips BE, Mokri MP. Effect of gender, age, and anthropometry on axial and appendicular muscle strength. Am J Phys Med Rehabil. 2001;80(5):330–8.
9. De Castro SH, de Mato HJ, Gomes MB. Anthropometric parameters and metabolic syndrome in type 2 diabetes. Arq Bras Endocrinol Metabol. 2006;50(3):450–5.
10. Hallal PC, Dumith SC, Bastos JP, Reichert FF, Siqueira FV, Azevedo MR. Evolution of the epidemiological research on physical activity in Brazil: a systematic review. Rev Saude Publica. 2007;41(3):453–60.
11. Dvir Z, Keating J. Reproducibility and validity of a new test protocol for measuring isokinetic trunk extension strength. Clin Biomech (Bristol, Avon). 2001;16(7):627–30.
12. Lombardi Jr I, Oliveira LM, Mayer AF, Jardim JR, Natour J. Evaluation of pulmonary function and quality of life in women with osteoporosis. Osteoporos Int. 2005;16(10):1247–53.
13. Dancey CP, Reidy J. Estatística sem matemática para psicologia: usando SPSS para Windows. 3rd ed. Porto Alegre: Artmed; 2006.
14. Cortet B, Houvenagel E, Puisieux F, Roches E, Garnier P, Delcambre B. Spinal curvatures and quality of life in women with vertebral fractures secondary to osteoporosis. Spine (Phila, PA, 1976). 1999;24(18):1921–5.
15. Fon GT, Pitt MJ, Thies Jr AC. Thoracic kyphosis: range in normal subjects. AJR Am J Roentgenol. 1980;134(5):979–83.
16. Milne JS, Williamson J. A longitudinal study of kyphosis in older people. Age Ageing. 1983;12(3):225–33.
17. Ajit Singh DK, Bailey M, Lee R. Strength and fatigue of lumbar extensor muscles in older adults. Muscle Nerve. 2011;44(1):74–9.
18. Limburg PJ, Sinaki M, Rogers JW, Caskey PE, Pierskalla BK. A useful technique for measurement of back strength in osteoporotic and elderly patients. Mayo Clin Proc. 1991;66(1):39–44.
19. Liaw LJ, Hsu MJ, Liao CF, Liu MF, Hsu AT. The relationships between inter-recti distance measured by ultrasound imaging and abdominal muscle function in postpartum women: a 6-month follow-up study. J Orthop Sports Phys Ther. 2011;41(6):435–43.
20. Roig M, Macintyre DL, Eng JJ, Narici MV, Maganaris CN, Reid WD. Preservation of eccentric strength in older adults: evidence, mechanisms and implications for training and rehabilitation. Exp Gerontol. 2010;45(6):400–9.
21. Lewiecki EM, Watts NB, McClung MR, Petak SM, Bachrach LK, Shepherd JA, et al. International Society for Clinical Densitometry. Official positions of the international society for clinical densitometry. J Clin Endocrinol Metab. 2004;89(8):3651–5.
22. Brandão CM, Camargos BM, Zerbini CA, Plapler PG, Mendonça LM, Albergaria BH, et al. 2008 official positions of the Brazilian Society for Clinical Densitometry – SBDens. Arq Bras Endocrinol Metabol. 2009;53(1):107–12.