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The effect of hip rotation on bone mineral density of the proximal femur measured by dual energy X-ray absorptiometry

Çift enerjili X-ışını soğurma cihazı ile yapılan kalça kemiği mineral yoğunluğu ölçümlerinde kalça rotasyonunun ölçüm sonuçlarına etkisi

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Objectives: The aim of this study was to compare the effect of lower extremity position changes on hip bone mineral density measured by dual energy X-ray absorptiometry.

Patients and methods: Sixty-nine healthy university students (30 men, 39 women; mean age 21.9±1.6; range 20 to 25 years) participated in this study. Participants were evaluated in two groups as male and female. A special positioning device was produced and used during bone mineral density measurements. Measurements were performed in positions of external 30°, external 15°, neutral 0°, internal 15°, and internal 30° of hip rotations. Measurements were evaluated at shaft, wards and trochanteric region of proximal femur. Differences between positions at shaft, wards, trochanter and total values were compared using repeated measures of analysis of variance.

Results: External rotation significantly increased bone mineral density values measured by dual energy X-ray absorptiometry in both male and female. The lowest bone mineral density value was measured at 30° internal rotation in both sexes. There were slight differences between neutral, 15° and 30° internal rotation positions, but these differences were not statistically significant.

Conclusion: Our findings suggest that position differences are important in adult healthy male and female during bone mineral density measurements of proximal femur using dual energy X-ray absorptiometry.

Key words: Densitometry; hip fractures; osteoporosis; risk factors.

Amaç: Bu çalışmada, alt ekstremite pozisyonundaki değişikliklerin, çift enerjili X-ışını soğurma cihazı ile yapılan, kalça kemiği mineral yoğunluğu ölçüm sonuçlarına etkisi karşılaştırıldı.

Hastalar ve yöntemler: Çalışmaya, sağlıklı 69 üniversite öğrencisi (30 erkek, 39 bayan; ort. yaş 21.9±1.6; dağılım 20-25 yıl) katıldı. Katılımcılar erkek ve bayan grubu olarak iki grupta incelendi. Kemik mineral yoğunluğu ölçümleri sırasında özel olarak üretilen bir pozisyon cihazı kullanıldı. Ölçümler, 30° dış, 15° dış, doğal 0°, 15° iç ve 30° iç dönme pozisyonlarında yapıldı. Ölçümler şaft, wards ve trokanter bölgeleri sonuçlarına göre değerlendirildi. Şaft, wards, trokanter pozisyonları ve toplam değerler arasındaki farklar tekrarlanan varyans analizi ölçüm yöntemiyle karşılaştırıldı.

Bulgular: Dışa rotasyonun, çift enerjili X-ışını soğurma cihazı ile ölçülen kemik yoğunluğunu her iki grupta da anlamlı olarak artırdığı görüldü. Her iki grupta da en düşük kemik mineral yoğunluğu değeri 30° içe dönük pozisyonda bulundu. Doğal pozisyon 0° ile 15° ve 30° içe dönük pozisyonları arasında küçük farklılıklar bulundu fakat bu farklılıklar istatistiksel olarak anlamlı bulunmadı.

Sonuç: Bulgularımız, sağlıklı yetişkin erkek ve bayanlarda çift enerjili X-ışını soğurma cihazı ile yapılan kemik yoğunluğu ölçümleri sırasındaki uyluk başı pozisyonunun ölçüm sonuçlarını etkilediğini gösterdi.

Anahtar sözcükler: Dansitometri; kalça kırığı; osteoporoz; risk faktörü.

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Bone mineral density (BMD) measurement of the proximal femur using dual energy X-ray absorptiometry (DEXA) is a well-established and widely used method of hip fracture risk assessment and a major determinant of bone strength in today's clinical practice of osteoporosis.[1] Bone mineral density of the proximal femur can be defined as the rate of radiation beam attenuated by the three dimensional bone structure that is evaluated through a two-dimensional projected image, so called "regional bone density".[2] It is well stated that the attenuation of radiation beam is dependent on physical density, bone size and position at measurement.[2-4]

The position of the shaft and angle of rotation along the longitudinal axis of the femur during DEXA measurement is assumed to affect BMD.[5,6] Clinical studies[6,7] focused mainly on postmenopausal women with an age range of 21 to 86 years. Cadaver studies,[5,8,9] on the other hand, had limited samples. Some studies indicated an increase[6] while others revealed a decrease[8] in BMD with internal rotation. There was, however, no consensus on the best position to predict proximal femoral BMD by DEXA. It is assumed that *(i)* position of proximal femur will affect BMD measured by DEXA, *(ii)* there will be differences in BMD between different regions of hips at certain positions, and *(iii)* there will be differences between men and women in adult healthy individuals.

The aims of this study were to evaluate *(i)* the effects of leg rotation on proximal femur BMD measurements by DEXA, *(ii)* the differences of regions at certain positions, and *(iii)* the differences between men and women in adult healthy university students.

PATIENTS AND METHODS

Participants

Participants of this study were 69 (30 men, 39 women; mean age 21.9±1.6; range 20 to 25 years), volunteer university students. Availability of subjects for DEXA measurement was the major inclusion criteria. All subjects' dominant side was their right sides. Information on the study and possible side effects were described to the participants and a written consent was obtained. The experimental protocol was approved by the local ethical committee.

Methods

A comparative research design was utilized primarily on the BMD values of the right and left proximal femur at different positions. In order to ensure a high degree of internal validity, all measurements were made by the same technician and researcher.

TABLE I

Physical characteristics of participants

	Number	Age (years)	Height (cm)	Weight (kg)	BMI (kg/m^2)
Male	30	22.3±1.6	178.8±6.4	75.9±10.0	23.7±2.9
Female	39	21.6±1.5	163.8±4.4	55.6±6.7	20.7±2.1
Total	69	21.9±1.6	170.4±9.2	64.4±13.1	22.0±2.9

BMI: Body mass index.

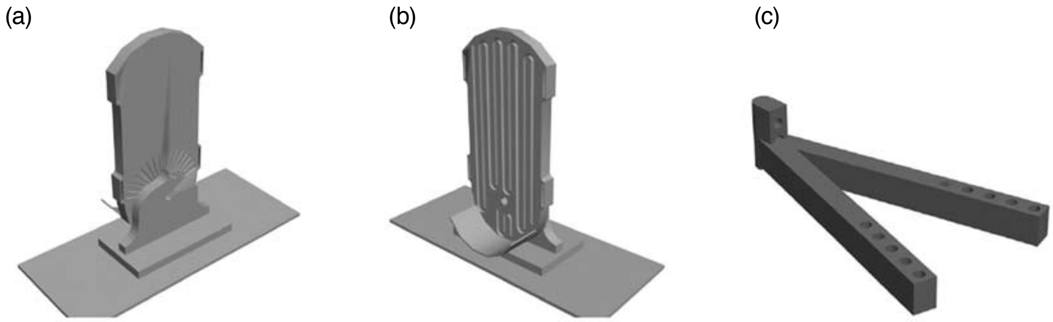

Figure 1. Specially designed positioning device; **(a)** back view of the foot stabilizer, **(b)** front view of the foot stabilizer. Both feet were concomitantly positioned in the stabilizers and their positions were secured using two Velcro bands, and **(c)** the abduction positioner of the device.

Figure 2. Subject positioned on the specially designed rotation jig.

Body height and weight were measured with the Seca anthropometer and beam-balance scale (Seca, Vogel & Haike, Hamburg, Germany). Body mass index (BMI) was calculated as weight (in kilograms) divided by the square of height (in meters). Physical characteristics of participants are tabulated in Table I.

Bone mineral density of the right and left proximal femur was obtained using a Lunar-DPX® IQ (Madison, Wisconsin, USA) DEXA device. Dual femur analysis software provided by the manufacturer was used to determine proximal femoral BMD values at the levels of femoral neck, trochanter, wards and total femur. Bone mineral density of participants was evaluated as g/cm^2. During scans, the lower extremities of participants were positioned in a specially designed custom-made (Fame-med, METU Technopol, Ankara, Turkey) positioning device (Figure 1, 2). All participants were told to turn the leg from hip and they practiced before the scan. It was also told that the machine could help fixing this turning by stabilizing the legs.

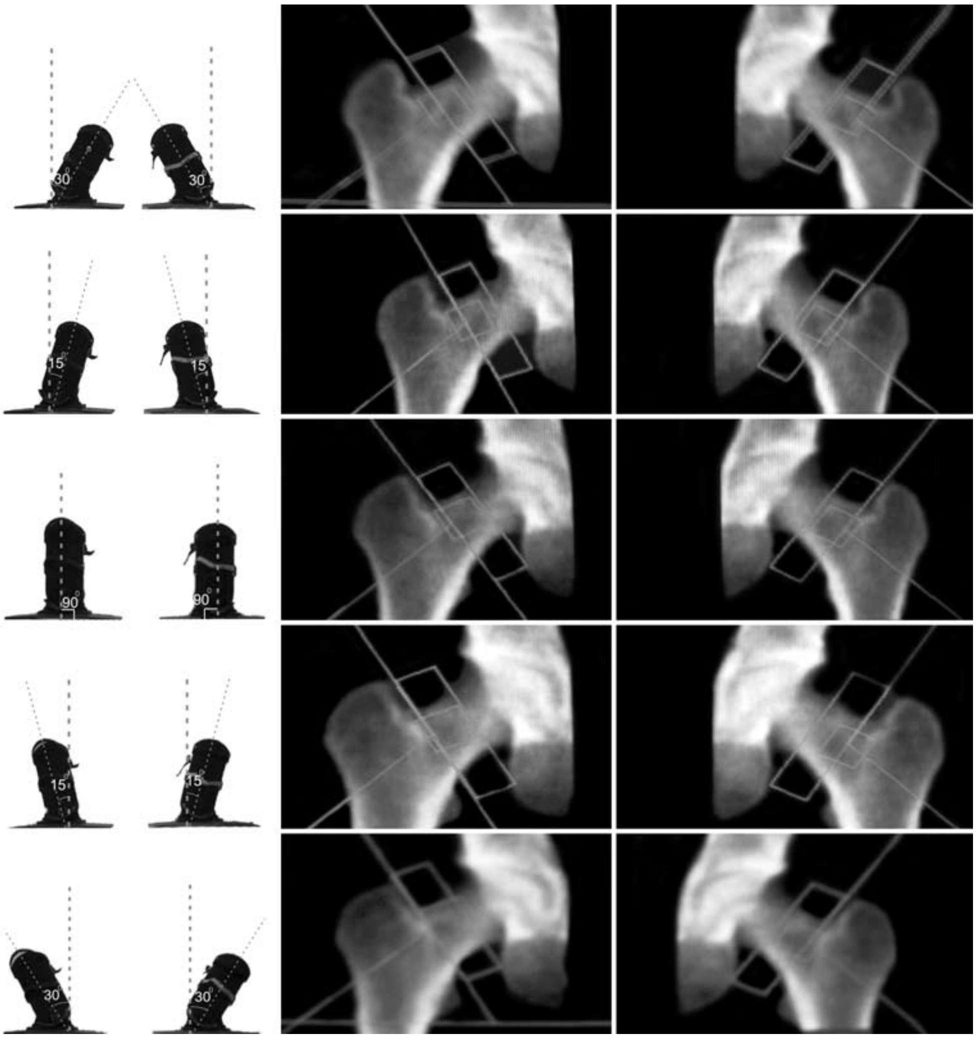

Figure 3. The positioning device and scan images at different rotations.

TABLE II

Mean differences between pairs of male at neck, wards, trochanteric regions and total scores

Male	Neck		Wards		Trochanter		*Total*	
	Mean Diff.	Std. Err.	Mean Diff.	Std. Err.	Mean Diff.	Std. Err.	Mean Diff.	Std. Err.
1 Int 30-Int 15	-0.009	0.008	0.002	0.011	-0.016	0.006	-0.008	0.007
2 Int 30-Neut 0	-0.018	0.006	-0.030	0.019	-0.038	0.010	-0.029	0.008
3 Int 30-Ext 15	-0.040*	0.009	-0.085	0.022	-0.045*	0.009	-0.057*	0.010
4 Int 30-Ext 30	-0.063*	0.013	-0.139*	0.025	-0.054*	0.008	-0.085*	0.014
5 Int 15-Neut 0	-0.009	0.007	-0.031	0.012	-0.023	0.011	-0.021	0.007
6 Int 15-Ext 15	-0.031	0.009	-0.087*	0.016	-0.029	0.010	-0.049*	0.009
7 Int 15-Ext 30	-0.054*	0.010	-0.140*	0.021	-0.038*	0.008	-0.078*	0.012
8 Neut 0-Ext 15	-0.022*	0.006	-0.055*	0.008	-0.006	0.013	-0.028*	0.007
9 Neut 0-Ext 30	-0.045*	0.009	-0.109*	0.022	-0.016	0.011	-0.057*	0.012
10 Ext 15-Ext 30	-0.022	0.007	-0.054	0.021	-0.009	0.007	-0.028	0.010

*: The mean difference is significant at the 0.005 level; Int: Internal; Ext: External; Neut: Neutral.

The positioning device was able to fix the lower extremities at any position between 90º internal and external foot rotation. Scans were implemented at neutral (0°), 15° and 30° internal and external rotations (Figure 3). Abduction between the legs was 15°.

Statistical analysis

Descriptive statistics included the means and standard deviations of BMI and BMD scores at all positions. Bone mineral density differences between positions at shaft, wards, trochanter and total values were compared using repeated measures of analysis of variance (repeated-ANOVA). Main effect was compared with the method of multiple comparisons by Bonferroni confidence interval adjustment. Statistical computation was performed using the SPSS for Windows, version 13 (SPSS Inc, IL, USA).

In order to decrease the probability of commiting type 1 error, Bonferroni technique was used and alpha level was determined as 0.005 by dividing the alpha level (0.05) to the number of pairs (10 pairs).

RESULTS

In present study, we compared male and female groups separately. For each group, proximal femur was evaluated in neck, wards, trochanter and average. In this study, multivariate tests indicate a significant position effect on BMD results in proximal neck of femur in both male and female groups. Therefore, pair-wise comparisons were conducted

TABLE III

Mean differences between pairs of female at neck, wards, trochanteric regions and total scores

Female	Neck		Wards		Trochanter		*Total*	
	Mean Diff.	Std. Err.	Mean Diff.	Std. Err.	Mean Diff.	Std. Err.	Mean Diff.	Std. Err.
1 Int 30-Int 15	0.005	0.004	0.003	0.004	-0.010	0.003	-0.001	0.002
2 Int 30-Neut 0	-0.002	0.005	-0.006	0.006	-0.022*	0.004	-0.010	0.004
3 Int 30-Ext 15	-0.021	0.006	-0.043*	0.011	-0.035*	0.004	-0.033*	0.006
4 Int 30-Ext 30	-0.059*	0.008	-0.112*	0.014	-0.049*	0.007	-0.073*	0.008
5 Int 15-Neut 0	-0.007	0.003	-0.009	0.005	-0.012*	0.002	-0.009	0.003
6 Int 15-Ext 15	-0.025*	0.004	-0.046*	0.009	-0.025*	0.003	-0.032*	0.004
7 Int 15-Ext 30	-0.063*	0.006	-0.115*	0.012	-0.039*	0.006	-0.072*	0.006
8 Neut 0-Ext 15	-0.018*	0.003	-0.038*	0.006	-0.013*	0.002	-0.023*	0.003
9 Neut 0-Ext 30	-0.057*	0.005	-0.106*	0.009	-0.027*	0.005	-0.063*	0.006
10 Ext 15-Ext 30	-0.038*	0.004	-0.069*	0.007	-0.014	0.004	-0.040*	0.004

*: The mean difference is significant at the 0.005 level; Int: Internal; Ext: External; Neut: Neutral.

in order to assess which means differ from each other. Pair wise comparisons are shown at Table II and III.

Dual energy X-ray absorptiometry scans show that in both male and female groups, BMD values tend to increase from internal 30° to external 30°. In most of the regions of proximal femur, the differences between internal and external measurement results were statistically significant. Differences between positions are demonstrated in box-plots for male and female groups in Figure 4 and 5, respectively.

DISCUSSION

Bone mineral density of the proximal femur is an important predictor of fracture risk. Even small decreases in BMD of the proximal femur increase the risk of fracture several times. It was assumed that the BMD of the proximal femur should be affected by the position of the lower extremity. Variability of the lower extremity position during DEXA measurement limits the reliability of fracture risk assessments. Therefore, the purposes of this study were to evaluate *(i)* the effects of leg rotation on proximal femur BMD measurements by DEXA, *(ii)* the differences of regions at certain positions, and *(iii)* the differences between male and female in adult healthy university students.

The strongest part of the study, on the other hand, was that both hips were evaluated in healthy male and female, and a novel positioning device was produced and used. Comparison between

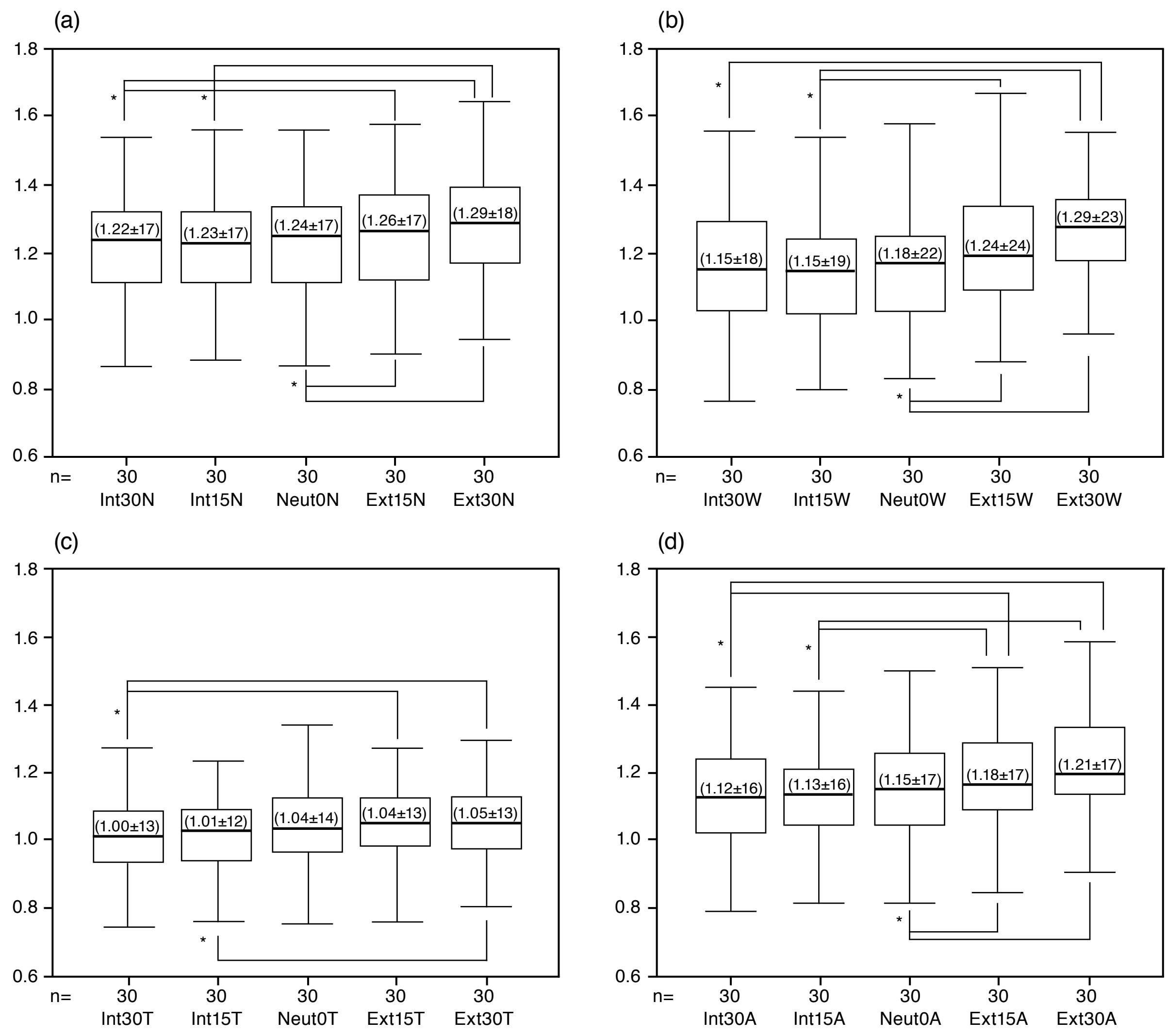

Figure 4. Bone mineral density for different regions in male participants, **(a)** neck, **(b)** wards, **(c)** trochanter, **(d)** total. *: Significantly different (p<0.005); Int: İnternal; Ext: External; Neut: Neutral.

positions presented significant effects of lower extremity rotation on BMD results of the proximal femur during DEXA measurements for both male and female.

In this study, proximal femurs were evaluated for three different regions and total BMD values at five different rotational angles. The difference between the results of BMD measurements at different lower extremity rotations for both male and female was significant. In both groups, the lowest BMD value by DEXA was measured at 30° internal rotation in all regions. Bone mineral density at external rotation was higher than that of the neutral and the internal rotation positions. These findings were in accordance with previous studies[5,6,9,10] that presented a decrease with internal but an increase with external rotation. Some studies[7,8] however, presented BMD increase in both internal and external rotation. Rosenthall[7] indicated an increase of BMD in internal rotation in 35% of his patients while the remaining 65% presented higher BMD values in neutral position. Goh et al.[8] revealed a BMD increase in 15° internal rotation. They also presented an increase of BMD from neutral to 30° external rotation. The results of the present study, where an increase of BMD from neutral to external rotation was observed, were consistent with the external rotation part of Goh et al's[8] study. Nevertheless, unlike Goh et al's[8] study, an increase in BMD was not observed with internal rotation.

Martini et al.[11] presented a decrease in BMD in external rotation in patients with prosthetic

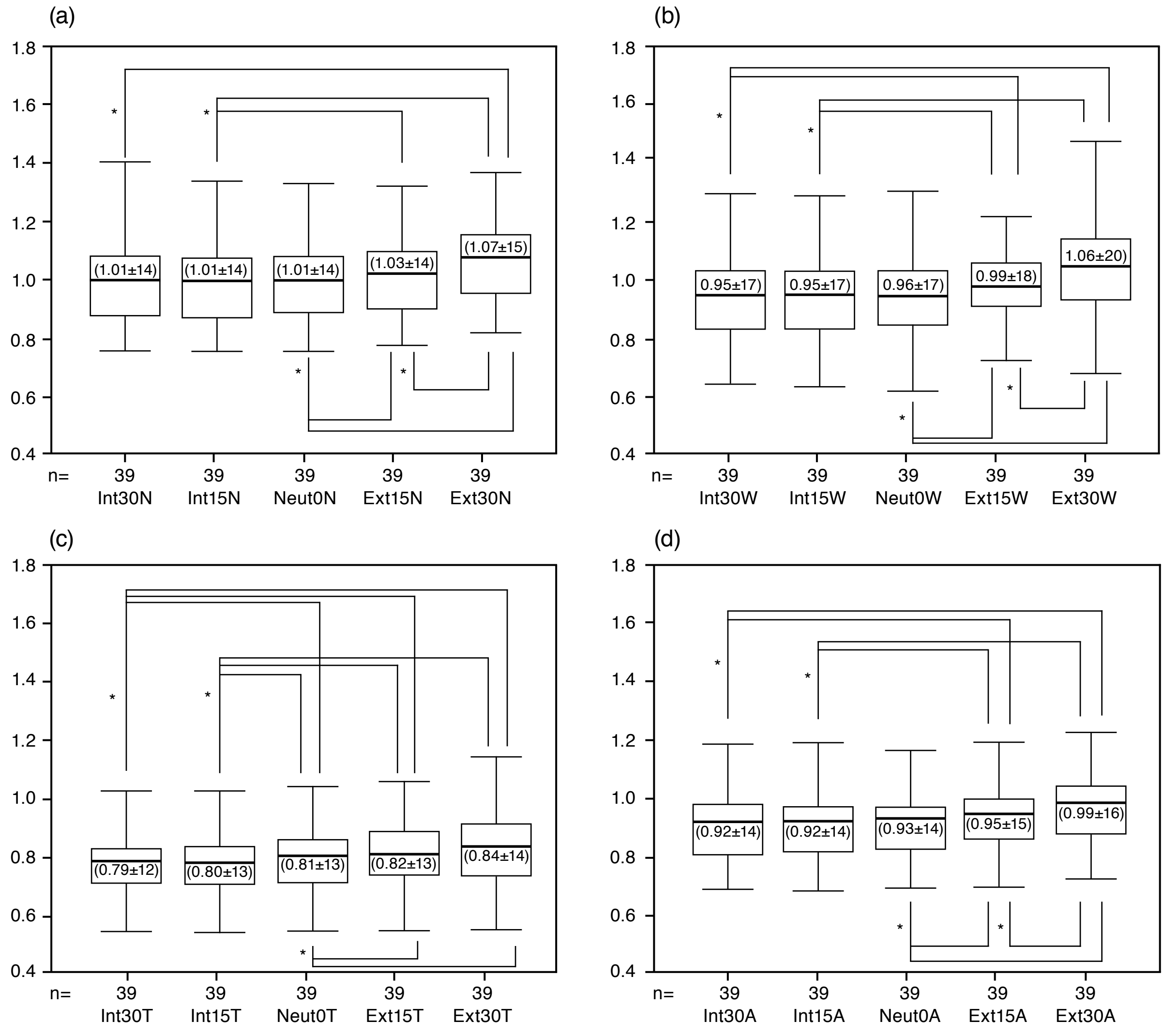

Figure 5. Bone mineral density for different regions in female participants, **(a)** neck, **(b)** wards, **(c)** trochanter, **(d)** total. *: Significantly different ($p<0.005$); Int: İnternal; Ext: External; Neut: Neutral.

implants and explants. In that study, the importance of positioning for determining periprosthetic BMD is clearly underlined for longitudinal follow-up studies.

In conclusion, external rotation at the lower extremity significantly increases BMD values measured by DEXA in both sides in women but not in men. A position device that can keep the proximal femur at neutral and/or internal rotation will identify the lowest BMD in healthy adults, which is significantly important in women.

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