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ORIGINAL ARTICLE

The impact of nonstandard hip rotation on densitometric results of hip regions and potential misclassification of diagnosis

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Abstract

Summary The present study is intended to investigate the degree to which insufficient internal rotation could impact the densitometric results and change the diagnosis. A significant difference was found between the results in nonstandard compared with standard rotation and an increase in the BMD and *T*- and *Z*-scores from nonstandard to standard rotation. Likewise, a change in diagnosis was observed in a significant proportion of patients.

Purpose To investigate the impact of nonstandard rotation of hip on the densitometric results of femoral neck and total femur region as well as the amount of change in diagnosis (i.e., misclassification of diagnosis) based on hip region.

Methods Ninety-seven patients (88 females and 9 males) were included in the study. After receiving informed consent, each subject underwent a densitometric scanning in two modes, one with standard rotation of the leg and the other with nonstandard rotation (i.e., the leg in relaxed position without applying the positioner to strap the foot to) of the same leg. All data were analyzed using the auto-analysis option of the HOLOGIC® software. Bone densitometric results, *T*- and *Z*-scores, rate of change in diagnosis, and also the agreement between the diagnoses in the two modes are calculated and compared by using a paired-sample *t* test and cross-tabulation.

Results The mean age of 97 patients was 56.91 ± 11.70 years. A significant difference was found in the BMDs, *T*-scores, and *Z*-scores of the neck and total femur regions of interest in standard and nonstandard rotations. We found an increase in the BMD of the femoral neck and total femur of 0.020 and 0.010 g/cm^2, respectively, from standard to nonstandard leg rotation and that this, in turn, led to a 0.4 and a 0.13 increases in *T*-scores of the neck and total femur, respectively, from standard to nonstandard rotation. In the diagnosis based on femoral neck only, the diagnosis changed in 17 (17.5%) patients, i.e., 12 (12.4%) from osteopenia to normal, 3 (3.1%) from osteoporosis to osteopenia, and 2 (2.0%) from below the expected range for age to within the expected range for age. There was only a change of one level in diagnosis.

Discussion and conclusions According to the results, the changes in the BMD and *T*- and *Z*-scores can be interpreted as underdiagnosis or, in simple terms, not finding the disease or underestimating the level of disease. Therefore, proper rotation of the leg is an important factor during densitometry. Any deviation from standard rotation changes the BMD of those regions, and thereby the *T*- and *Z*-scores accordingly, and thus the diagnosis.

Keywords Leg rotation · Nonstandard · Densitometry · Misclassification of diagnosis

Introduction

Osteoporosis is currently a costly disease with potentially significant morbidity and mortality in patients and has a considerable economic burden on public health services. Timely and correct diagnosis and treatment are of particular interest among health professionals [1–3]. The accuracy of the diagnosis is subject to a variety of errors caused by a number of technical factors. Utilization of established and validated procedural protocols and diagnostic criteria for correct diagnosis is essential. Dual x-ray absorptiometry (DXA) of the lumbar vertebrae and hip and the World Health Organization (WHO) diagnostic criteria are now accepted as the standard methods for densitometric measurements and interpretation [4–6]. Based on International Society for Clinical Densitometry (ISCD) protocols, for standard densitometry of

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the hip, nondominant leg must be positioned in a way that a sufficient degree of internal rotation (i.e., to 15° with 23-cm distance between heels by using a positioner supplied by the manufacturer) is achieved. In this way, the long axis of the femoral neck will be parallel to the detector surface and thus minimizes the depth of bone tissue and maximizes the surface area facing to the incident photons to overcome the physiological anteversion [7]. Any deviation from the standard rotation can result in errors in measurement. In addition to this, consistent hip positioning and leg rotation in serial studies for treatment monitoring are also of critical importance. In some other circumstances (e.g., previous fractures, and degenerative disorders of hip joint), patients may be unable to position their legs with standard internal rotation. Although positioners supplied by manufacturers are used, there are variations in positioning and amount of internal rotation among technologists with different levels of training and experience [8–13]. The extent to which this issue may affect the results is important to the treating physician. Although there are publications addressing the effect this issue has on bone mineral density (BMD) results, to our knowledge, from practical point of view, the degree of changes in *T*- and *Z*-scores as direct indices for making diagnosis and the rate of misclassified diagnosis have been scarcely investigated. The present study focuses on the impact of nonstandard rotation of the leg on densitometric results of the femoral neck and total femur region as well as the percentage of patients with a change in or misclassification of diagnosis.

Methods

Ninety-seven patients without any significant disorder affecting the hip joints and proximal femurs who were referred to our department for a densitometry scanning in 2017 were selected consecutively from about 310 after receiving an informed consent. All scans were performed using a HOLOGIC® densitometry scanner (QDR® series Explorer by HOLOGIC®, Inc.) with a manufacturer-designed positioner for adequate internal rotation (HOLOGIC® HIP POSITIONING FIXTURE). After performing DXA scan with standard protocol, the scan was repeated on the same leg in nonstandard rotation (i.e., the leg in neutral position) without applying the positioner to strap the foot to (Fig. 1). This indicates a substantial deviation from the standard rotation. The scans were analyzed automatically by the standard software (HOLOGIC® APEX® Software, version 3.3) with least operator interaction on femoral neck and total femur and spine (L1–L4) regions, which are the currently accepted regions for making the diagnosis [4]. However, in circumstances with obviously erroneous placement of the regions of interest (ROI), borders are adjusted manually according to the protocols provided by the manufacturer. BMDs and *T*- and Z-scores of the femoral neck and total femur ROIs were compared statistically in standard and nonstandard rotation by applying paired-sample *t* test in SPSS software. The statistical significance was considered at the level of 0.05. The definition for diagnosis was based on the WHO and ISCD criteria (using *T*-scores of below −2.5, between −2.5 and −1, and −1 and above, as osteoporosis, osteopenia, and normal in men older than 50 and postmenopausal women of any age and *Z*-scores of −2 or below and above −2 as below or within the expected range for age in men under 50 and premenopausal women) in both scans [4, 5]. The diagnoses were made once using the neck region only and again using the neck, total femur, and spine regions as accepted by the ISCD in both scans. For the assessment of misclassification of diagnosis, the percentage of patients with a change or reclassification in diagnosis from the standard protocol (i.e., with adequate internal rotation) was calculated. Finally, the agreement between each set of diagnosis (standard rotation versus nonstandard rotation) was analyzed by cross-tabulation and calculation of the coefficient of kappa. Prior to the start of the study, ethical clearance was obtained from the university ethics committee.

Results

The subjects recruited in the present study were aged from 28 to 85. Of 97 patients included in the study, 88 (90.7%) were female and 9 (9.3%) were male. Of 88 female participants, 68 were postmenopausal and 20 premenopausal and of 9 male patients, 6 were over 50 and 3 below 50. The data regarding age, weight, height, body mass index (BMI), and densitometric results of the spine region are summarized in Table 1. Of 97 participants, the results obtained from densitometric analysis of the neck and total femur in both standard and nonstandard rotation are presented in Table 2. Using a paired-sample *t* test, a significant difference was found between the BMDs, *T*-scores, and *Z*-scores of the neck and total hip ROIs in the standard and nonstandard rotation. The mean differences between the two rotations and the 95% confidence intervals (95% CI) are provided in Table 3.

The data regarding the diagnosis of all 97 patients based on the femoral neck only and also based on the femoral neck, total femur, and spine in the standard and nonstandard rotation are summarized in Table 4. In the diagnosis based on femoral neck only, the diagnosis changed in 17 (17.5%) patients, i.e., 12 (12.4%) from osteopenia to normal, 3 (3.1%) from osteoporosis to osteopenia, and 2 (2.0%) from below the expected range for age to within the expected range for age. There was only a change of one level in the diagnosis. By cross-tabulation for the measurement of agreement between the diagnosis in standard and nonstandard rotation, the coefficient of kappa was 0.75 (p value < 0.0001). In the diagnosis based on femoral neck, total femur, and spine, the diagnosis

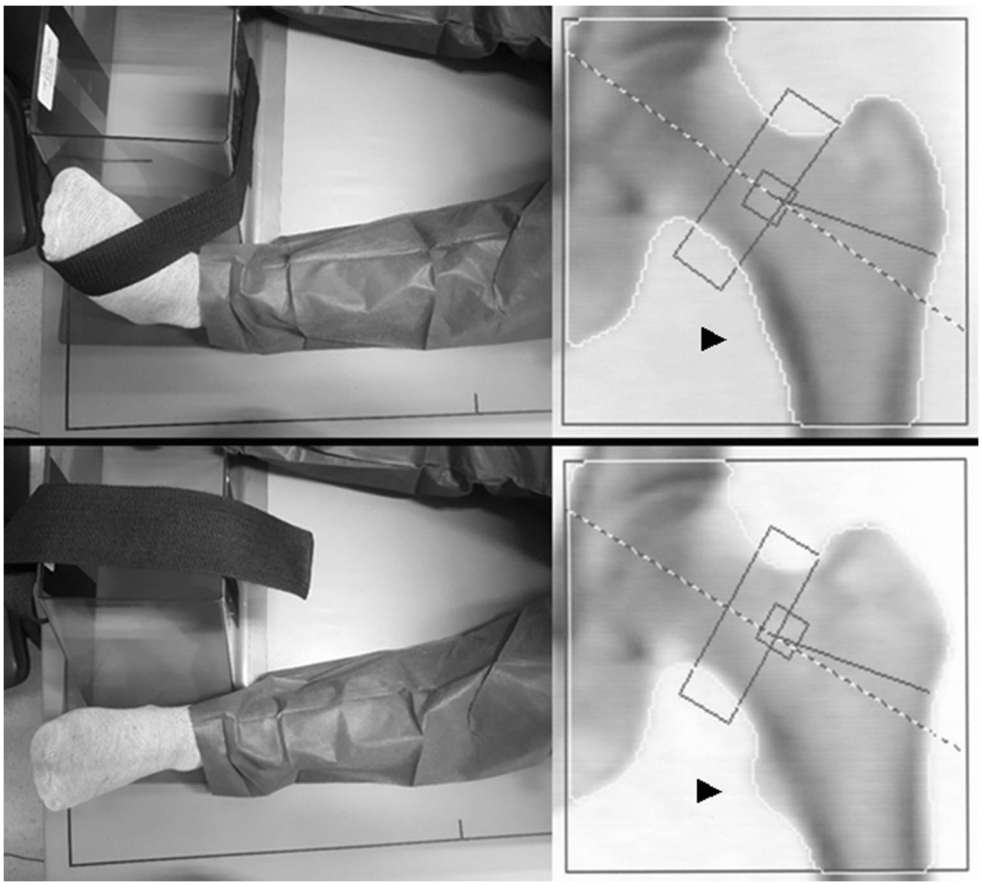

Fig. 1 Bone densitometry scan of the hip region with internal rotation using a manufacturer-designed positioner to strap the foot to (upper panel) and nonstandard rotation, i.e., neutral position, without strapping the foot to the positioner (lower panel). The lesser trochanter (marked by an arrowhead on both scans) is less noticeable in adequate and sufficient internal rotation compared with that in the nonstandard rotation and is generally used as a visual marker for a rough estimation of adequacy of internal rotation

reclassified in 3 (3.1%) patients, which all changed from osteopenia to normal. The measurement of agreement provided a kappa of 0.96 (p value < 0.0001).

Discussion

Internal rotation of the leg by strapping of the foot to standard positioners during densitometry is an essential part of the standard procedural guidelines to improve the consistency of the scan results in various patients as well as in the same patient in serial studies, in other words, to achieve a higher precision. Unfortunately, this goal is not attained in many circumstances because of varying degrees of individual's anteversion of femoral neck and patients' abilities to lay their legs in sufficient degree of internal rotation which may be compromised in some disorders of the hip [4–7]. The inter- and intra-operator variabilities for sufficiency and adequacy of internal rotation by technologists also pose more uncertainty in the technical accuracy of the scan. Therefore, the degree to which these changes may occur and affect the results is of great importance. In this paper, we examined the effect of nonstandard leg rotation on the densitometric results of the hip region. The authors' attention was focused not only on the changes in the bone mineral density of the femoral neck and total femur regions but also on the changes in the *T*- and *Z*-scores and on the misclassification of the diagnosis. There is little information, to our knowledge, regarding the different aspects of the consequences of this technical issue as well as its confusing or inconclusive results in the literature.

The findings of the present study were, to some extent, in agreement with most of the prior studies which had shown an increase in BMD of the femoral neck and a lesser degree of increase in BMD of the total femur region from standard

Table 1 Basic data of the patients recruited in the study

Description	Mean (± SD)
Age	
Female	57.05 (± 11.36)
Male	55.56 (± 15.32)
Total	56.91 (± 11.70)
Weight	69.35 (± 11.14)
Height	160.08 (± 8.00)
BMI	27.17 (± 4.58)
Spine BMD	0.90 (± 0.13)
Spine *T*-score	− 1.37 (± 1.19)
Spine *Z*-score	− 0.16 (± 1.20)

BMD, body mass index; *BMD*, bone mineral density

Table 2 Densitometric data of neck and total hip regions of interest in standard and nonstandard rotation

Description	Mean (± SD)	95% CI
Femoral neck area (cm^2)		
Standard	4.76 (± 0.37)	4.69–4.84
Nonstandard	4.78 (± 0.43)	4.70–4.87
Total femur area (cm^2)		
Standard	31.88 (± 4.25)	31.02–32.73
Nonstandard	33.41 (± 4.82)	32.43–34.38
Femoral neck BMD (g/cm^2)		
Standard	0.71 (± 0.10)	0.69–0.74
Nonstandard	0.76 (± 0.11)	0.74–0.78
Total femur BMD (g/cm^2)		
Standard	− 0.83 (± 0.12)	0.81–0.86
Nonstandard	− 0.85 (± 0.13)	0.82–0.88
Femoral neck *T*-score		
Standard	− 1.23 (± 0.94)	− 1.42 to − 1.04
Nonstandard	− 0.84 (± 0.99)	− 1.04 to − 0.64
Total femur *T*-score		
Standard	− 0.91 (± 0.98)	− 1.11 to − 0.72
Nonstandard	− 0.79 (± 1.03)	− 0.99 to − 0.58
Femoral neck *Z*-score		
Standard	− 0.12 (± 0.95)	− 0.31–0.07
Nonstandard	0.29 (± 0.97)	0.09–0.48
Total femur *Z*-score		
Standard	− 0.08 (± 1.01)	− 0.28–0.12
Nonstandard	0.04 (± 1.06)	− 0.17–0.26

internal rotation to nonstandard leg rotation. Our results (0.04 g/cm^2 and 0.01 g/cm^2 increase in BMD of neck and total femur, respectively) were consistent with other results; for example, those in the research by Rosenthall [9] showed 65% increase in the BMD of the subjects (0.025 g/cm^2 and 0.016 g/cm^2 increase in BMD of neck and total hip, respectively). However, studies by Goh et al. [10] and Wilson et al. [8], as two of the earliest ones of this kind, showed similar findings which were expressed as a percentage of change to the standard position. Other studies [11, 12] in the hip region also demonstrated an increase in the BMD accordingly. Results from Celik et al. [13] demonstrated a trend of BMD increase from internal rotation to external rotation. A slight difference was obtained between internal rotation and neutral position. Additionally, we found an increase in the BMD of the femoral neck and total femur of 0.020 and 0.010 g/cm^2, respectively, from standard to nonstandard leg rotation and that this, in turn, led to a 0.4 and a 0.13 increases in the *T*-scores of the neck and total femur, respectively, from standard to nonstandard rotation, which was paid less attention by previous studies. These increases are meant by a one-level change in the diagnosis in a significant proportion (i.e., 17.5%) of patients, when using only femoral neck for diagnosis. In 3%, osteoporosis downgraded to osteopenia and in about 12% of patients, and osteopenia changed to normal. This result can be interpreted as underdiagnosis or, in simple terms, not finding the disease or underestimating the level of the disease. It is noteworthy that the change in BMD and thus in *T*-score seems to be not high enough to a two-level reclassification in the diagnosis. However, when using three regions (i.e., the femoral neck, total femur, and spine) for diagnosis, depending on the densitometric results of the spine, the consequence is much less concerning (i.e., in 3% of patients) and is less sensitive to errors created by malpositioning and improper rotation compared with the diagnosis based on femoral neck only. This significant misclassification of diagnosis, in the absence of adequate and sufficient leg rotation, can have a major impact on clinical practice, whether in initial diagnosis or serial scans. More importantly, the above findings are produced when a major deviation of leg position is present compared with the standard internal rotation, and therefore, deviation at limited angles would bear less significant impact.

Limitations The area of the ROIs in bone densitometry could impact the BMD result [4]. In the present study, we analyzed the scans using the automatic option of the software, namely auto-analysis. Where appropriate, the ROIs were adjusted manually with the intent of the highest matches between the

Table 3 Mean difference and 95% CI of the neck and total hip regions of interest in standard and nonstandard rotation

Description (difference)	Mean (± SD)	95% CI	*p* value
Femoral neck			
Standard Area - nonstandard area	− 0.02 (± 0.27)	− 0.72–0.03	0.522
Standard BMD - nonstandard BMD	− 0.04 (± 0.05)	− 0.05 to − 0.03	0.000
Standard *T*-score - nonstandard *T*-score	− 0.39 (± 0.44)	− 0.48 to − 0.31	0.000
Standard *Z*-score - nonstandard *Z*-score	− 0.40 (± 0.44)	− 0.49 to − 0.32	0.000
Total femur			
Standard Area - nonstandard area	− 1.52 (± 1.88)	− 1.90 to − 1.15	0.000
Standard BMD - nonstandard BMD	− 0.01 (± 0.02)	− 0.02 to − 0.01	0.000
Standard *T*-score - nonstandard *T*-score	− 0.13 (± 0.22)	− 0.17 to − 0.08	0.000
Standard *Z*-score - nonstandard *Z*-score	− 0.12 (± 0.21)	− 0.17 to − 0.08	0.000

Table 4 Number and percentage of patients with a change in the diagnosis

Diagnosis	Standard rotation	Nonstandard rotation
Femoral neck only		
Normal	25 (25.8%)	37 (38.1%)
Osteopenia	42 (43.3%)	33 (34.0%)
Osteoporosis	7 (7.2%)	4 (4.1%)
Within the expected range for age	21 (21.6%)	23 (23.7%)
Below the expected range for age	2 (2.1%)	0 (0.0%)
Femoral neck, total femur, and spine		
Normal	14 (14.4%)	17 (17.5%)
Osteopenia	42 (43.3%)	39 (40.2%)
Osteoporosis	18 (18.6%)	18 (18.6%)
Within the expected range for age	21 (21.6%)	21 (21.6%)
Below the expected range for age	2 (2.1%)	2 (2.1%)

two scans in each patient. In the femoral neck region, the difference was not significant, but in the total femur region, despite the statistical significance, the difference was clinically negligible. Another important issue that may render the results, in some way and to some extent, biased, is the effect of the sampling process, here, 97 from about 310 patients referred for densitometric scanning whose data in terms of gender, age, and BMI are not collected and therefore analyzed.

Conclusion

Being aware of various potential technical sources of changes in BMD and *T*- and *Z*-scores of the hip region and their impact on clinical diagnosis is critical for both physicians and technologist and deserve more attention.

Compliance with ethical standards

Conflicts of interest None.

Ethical approval The study was approved by the Ethics committee of the School of Medicine, Shahid Beheshti University of Medical Sciences.

References

1. Black DM, Rosen CJ (2016) Clinical practice. postmenopausal osteoporosis. N Engl J Med 374:254–262
2. Jackson RD, Donepudi S, Mysiw WJ (2008) Epidemiology of fracture risk in the Women's Health Initiative. Curr Osteoporos Rep 6: 155–161
3. Wu CH, Kao IJ, Hung WC, Lin SC, Liu HC, Hsieh MH, Bagga S, Achra M, Cheng TT, Yang RS (2018) Economic impact and cost-effectiveness of fracture liaison services: a systematic review of the literature. Osteoporos Int 29:1227–1242
4. International Atomic Energy Agency (2011) Dual energy X ray absorptiometry for bone mineral density and body composition assessment. International Atomic Energy Agency, Vienna
5. Blake GM, Fogelman I (2010) An update on dual-energy x-ray absorptiometry. Semin Nucl Med 40:62–73
6. Watts NB (2004) Fundamentals and pitfalls of bone densitometry using dual-energy X-ray absorptiometry (DXA). Osteoporos Int 15: 847–854
7. Cheng XG, Nicholson PH, Boonen S, Brys P, Lowet G, Nijs J, Dequeker J (1997) Effects of anteversion on femoral bone mineral density and geometry measured by dual energy X-ray absorptiometry: a cadaver study. Bone 21:113–117
8. Wilson CR, Fogelman I, Blake GM, Rodin A (1991) The effect of positioning on dual energy X-ray bone densitometry of the proximal femur. Bone Miner 13:69–76
9. Rosenthall L (2004) Range of change of measured BMD in the femoral neck and total hip with rotation in women. J Bone Miner Metab 22:496–499
10. Goh JC, Low SL, Bose K (1995) Effect of femoral rotation on bone mineral density measurements with dual energy X-ray absorptiometry. Calcif Tissue Int 57:340–343
11. Lekamwasam S, Lenora RS (2003) Effect of leg rotation on hip bone mineral density measurements. J Clin Densitom 6:331–336
12. McKiernan F, Washington W (2005) Effect of subtle positioning flaws on measured bone mineral density of the hip. J Clin Densitom 8:330–334
13. Celik O, Salci Y, Manisali M, Korkusuz F (2009) The effect of hip rotation on bone mineral density of the proximal femur measured by dual energy X-ray absorptiometry. Eklem Hastalik Cerrahisi 20: 71–77