Original Research Article

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Comparative analysis of T-score and Z-score in controlled and uncontrolled glycemic postmenopausal women

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Abstract

Introduction: Osteoporosis is a major health concern in postmenopausal women, characterized by reduced bone mineral density (BMD) and increased fracture risk. The decline in estrogen after menopause accelerates bone loss, which may be further aggravated by chronic conditions such as diabetes mellitus. This study aims to compare T-scores and Z-scores between diabetic and non-diabetic postmenopausal women.

Methods: This cross-sectional study was conducted in the Medicine Department of Sir Salimullah Medical College Mitford Hospital, from July 2023 to June 2024. A total of 120 cases were included in this study according to the selection criteria. Data were processed and analyzed by the Statistical Package for the Social Sciences 22.0. A $P < 0.05$ was considered statistically significant.

Result: Among 120 postmenopausal women, diabetics had lower T-scores and Z-scores than non-diabetics, with lumbar spine T-score significantly lower in the 11–20 years post-menopause group (−3.34 ± 1.65 vs. −2.24 ± 1.42, $P = 0.010$). In diabetics, uncontrolled glycemia (HbA1c >7) markedly reduced femoral neck T-score (−3.24 ± 1.00 vs. −2.04 ± 0.77, $P < 0.001$) and lumbar spine T-score (−4.27 ± 1.06 vs. −2.08 ± 1.03, $P < 0.001$), with similar trends in Z-scores. Duration since menopause showed a significant negative correlation with T-scores at both femoral neck (r = −0.440, $P < 0.001$) and lumbar spine (r = −0.337, $P = 0.008$).

Conclusion: Postmenopausal women with diabetes, especially with uncontrolled glycemia, showed significantly lower T- and Z-scores at both femoral neck and lumbar spine, indicating higher osteoporosis risk. The negative correlation of T-scores with menopausal duration underscores the combined adverse effects of aging and poor glycemic control on bone health.

Keywords: Postmenopausal women, T-score, uncontrolled DM, Z-score

Introduction

Postmenopausal women face a sharp rise in osteoporotic fracture risk due to estrogen deficiency, age-related bone loss, and accumulation of comorbidities. Dual-energy X-ray absorptiometry (DXA) remains the clinical standard for assessing bone mineral density (BMD), with results reported as T-scores (comparison with a young-adult reference) and Z-scores (comparison with age- and sex-matched norms).[1] International Society for Clinical Densitometry guidance recommends T-scores

for diagnostic classification in postmenopausal women, while Z-scores aid interpretation of whether BMD is appropriate for age and in identifying secondary contributors to skeletal fragility.[1] In a population with diabetes mellitus, however, the relationship between DXA-derived BMD and fracture risk is atypical, challenging the sufficiency of a single metric and motivating comparative use of both T- and Z-scores. Type 2 diabetes mellitus (T2DM) confers a higher risk of hip and non-vertebral fractures despite normal or even higher areal BMD on DXA, implicating deficits in bone quality, microarchitecture, and material properties that are not captured by BMD alone.[2-5] Large cohorts and meta-analyses show that compared with non-diabetic peers, older adults with T2DM have elevated fracture rates at a given T-score, and that conventional fracture risk tools calibrated to T-scores (e.g., Fracture risk assessment tool (FRAX) with femoral neck BMD) tend to underestimate risk in diabetes.[2,6,7] Proposed "workarounds" (e.g., entering rheumatoid arthritis as a surrogate risk factor, reducing femoral neck T-score by ~0.5 SD, or adjusting age) improve calibration but are imperfect and not universally adopted.[6,7] These observations underscore that BMD position relative to young-adult norms (T-score) can paint an overly reassuring picture in diabetes, whereas the age-standardized perspective (Z-score) may better reveal whether BMD is unusually low (or high) for age when glycemic dysregulation is present. Glycemic control itself appears to modify skeletal phenotypes in postmenopausal women. Hyperglycemia, advanced glycation end-products, microvascular disease, sarcopenia, and altered bone turnover have all been implicated in diabetic bone fragility.[4,5] Contemporary studies focusing specifically on postmenopausal women report nuanced associations between long-term glycemic indices and bone density or volumetric density: For example, investigations linking higher or prolonged HbA1c exposure with differences in lumbar trabecular volumetric BMD, while not consistently translating into categorical osteoporosis by T-score thresholds.[8] A recent population study of elderly men and postmenopausal women found complex, site-specific relationships between T2DM and BMD, reinforcing that diabetes's skeletal effects are not uniform and may depend on glycemic control and body composition.[9] Moreover, work in older women shows that diabetes-related fracture risk persists even when BMD appears preserved, likely reflecting degraded bone quality and impaired physical function – again suggesting that reliance on T-scores alone may miss clinically meaningful risk.[2,10] From a measurement standpoint, several factors further complicate T-score interpretation in diabetes and in older women: Higher body mass index (BMI) with greater soft tissue and fat distribution, spinal osteophytes and aortic calcification (which can artifactually elevate lumbar BMD), and degenerative changes – all of which may inflate T-scores without improving bone strength.[1,4,5] Z-scores, by referencing peers of the same age and sex, can contextualize whether a patient's BMD is unexpectedly low in that milieu; conversely, a "normal" or elevated Z-score alongside poor glycemic control might still coexist with elevated fracture risk due to qualities of bone not captured by DXA.[3-5,7]

Methods

This cross-sectional study was conducted in the Department of Medicine at Sir Salimullah Medical College Mitford Hospital over 12 months from July 2023 to June 2024. A total of 120 postmenopausal women were enrolled, including 60 women with T2DM (case group) and 60 age-matched non-diabetic women (control group). Postmenopause was defined as the absence of menstruation for at least 12 consecutive months. Diagnosis of T2DM followed the American Diabetes Association criteria, and diabetic participants had been receiving oral antidiabetic drugs alone or in combination with insulin for a minimum of 1 year. Exclusion criteria included women with secondary causes of osteoporosis (such as endocrine disorders or chronic kidney disease), those taking medications that affect bone metabolism (e.g., corticosteroids, bisphosphonates, hormone replacement therapy), women with surgical or premature menopause (<40 years), chronic inflammatory diseases, or malignancies.

Data were collected using a structured pro forma, documenting sociodemographic characteristics, age at menarche, age at menopause, duration since menopause, and, for diabetic participants, duration of diabetes, glycemic control assessed by HbA1c, and treatment details. Anthropometric measurements were taken to calculate BMI. BMD at the femoral neck and lumbar spine was assessed for all participants using DXA, and T-scores and Z-scores were recorded. Statistical analysis was performed using standard software, with continuous variables presented as mean ± standard deviation and categorical variables as frequencies and percentages. Comparisons between groups were conducted using unpaired *t*-tests and Chi-square tests, and a $P < 0.05$ was considered statistically significant.

Results

Table 1 shows the distribution of the study subjects according to age in diabetic and non-diabetic postmenopause patients. Most of the patients were in the age group 60–69 years in both groups. The mean age of the patients was 65.83 ± 8.75 years and 62.17 ± 7.67 years in diabetic and non-diabetic post-menopausal patients.

Table 2 shows T-score and Z-score in the femoral neck and lumbar spine in Diabetic and Non-diabetic postmenopause patients. T-score and Z-score both in the femoral neck and lumbar spine were significantly lower in diabetic patients than those of non-diabetic patients.

Table 3 shows T-score and Z-score in the femoral neck and lumbar spine in controlled and uncontrolled diabetic postmenopause patients. T-score and Z-score both in the femoral neck and lumbar spine were significantly lower in diabetic patients with HbA1c >7.

Table 4 shows the correlation of duration of menopause with BMD in postmenopausal women with and without diabetes mellitus. There was a significant negative correlation of duration of menopause with T-score of both femoral neck and lumbar spine in postmenopausal women with and without diabetes mellitus.

Table 1: Distribution of the study subjects according to age in Diabetic and Non-diabetic (*n*=120)

Age (years)	Diabetic (*n*=60) *n* (%)	Non-diabetic (*n*=60) *n* (%)	*P*-value
50–59	8 (13.3)	19 (31.7)	0.013
60–69	32 (53.3)	32 (53.3)	
≥70	20 (33.3)	9 (15.0)	
Mean±Standard deviation	65.83±8.75	62.17±7.67	0.016

Table 2: T-score and Z-score in case and control according to duration since menopause (*n*=120)

Variables	Diabetic (*n*=60) (Mean±SD)	Non-diabetic (*n*=60) (Mean±SD)	*P*-value
T-score (Femoral neck)			
Duration since menopause			
1–10	−1.91±0.47	−1.60±0.92	0.399
11–20	−2.57±1.18	−2.11±1.01	0.126
21–30	−2.98±0.81	−2.50±1.21	0.200
>30	−3.52±1.21	−3.40±0.00	0.932
T-score (Lumbar spine)			
Duration since menopause			
1–10	−1.94±0.98	−1.77±0.50	0.537
11–20	−3.34±1.65	−2.24±1.42	0.010
21–30	−3.67±1.22	−3.07±1.23	0.204
>30	−3.72±1.54	−3.00±0.00	0.684
Z-Score (Femoral neck)			
Duration since menopause			
1–10	−0.71±0.55	−0.65±0.85	0.854
11–20	−1.27±1.16	−0.72±0.96	0.061
21–30	−1.09±0.92	−0.98±0.68	0.738
>30	−1.40±0.94	−0.80±0.00	0.580
Z-Score (Lumbar spine)			
Duration since menopause			
1–10	−0.80±0.97	−0.74±0.58	0.845
11–20	−1.86±1.26	−0.68±1.42	0.002
21–30	−1.75±1.17	−0.97±1.25	0.100
>30	−0.98±1.46	−0.10±0.00	0.602

Data were expressed as frequency and mean (±standard deviation). An unpaired *t*-test was done to measure the level of significance.
SD: Standard deviation

Table 3: T-score and Z-score in case group according to glycemic status (*n*=60)

Variables	HbA1c≤7 (*n*=25) (Mean±SD)	HbA1c>7 (*n*=35) (Mean±SD)	*P*-value
T-score			
Femoral neck	−2.04±0.77	−3.24±1.00	<0.001
Lumbar spine	−2.08±1.03	−4.27±1.06	<0.001
Z-Score			
Femoral neck	−0.57±0.86	−1.61±0.88	<0.001
Lumbar spine	−0.68±0.97	−2.33±0.94	<0.001

Data were expressed as frequency and mean (±standard deviation). An unpaired *t*-test was done to measure the level of significance. SD: Standard deviation

Table 4: Correlation of duration of menopause with bone mineral density in both case and control (*n*=120)

Parameter	With DM		Without DM	
	r-value	*P*-value	r-value	*P*-value
T-score				
Femoral neck	−0.440	<0.001	−0.329	0.010
Lumbar spine	−0.337	0.008	−0.319	0.013
Z-Score				
Femoral neck	−0.177	0.175	−0.039	0.765
Lumbar spine	−0.038	0.774	0.060	0.648

Pearson's correlation coefficient test was used to measure the level of significance

Discussion

The present study evaluated the comparative patterns of T-scores and Z-scores in postmenopausal women with and without diabetes mellitus, with particular focus on the influence of glycemic status and duration since menopause. Our findings demonstrate that both T-scores and Z-scores at the femoral neck and lumbar spine were consistently lower in diabetic women compared to non-diabetic counterparts. In this study mean age of the patients was 65.83 ± 8.75 years and 62.17 ± 7.67 years in diabetic and non-diabetic post-menopausal patients, respectively. In the study of Anaforoglu *et al*.[11] mean age was 61.9 ± 8.6 years and 60.1 ± 9.3 years in diabetic and non-diabetic postmenopause women, respectively. As we can see, the mean age of the cases in our study is more than the average of other similar studies. In this study, the Femoral neck T-score was −2.72 ± 1.08 versus −2.03 ± 1.06 in diabetic women and non-diabetic women (P = 0.001), respectively. Lumbar spine T-score was −3.32 ± 1.51 versus −2.25 ± 1.21 in diabetic women and in non-diabetic women (P < 0.001), respectively. Karimifar *et al*.[12] investigated BMD in postmenopausal women with Type 2 diabetes and compared it with postmenopausal non-diabetic women. They found that Lumber T scores were −2.16 ± 1.27 versus −2.10 ± 1.08 (P = 0.60), femoral neck T-score was −1.09 ± 0.96 versus −0.72 ± 1.00 (P = 0.00) in diabetic and non-diabetic groups, respectively, which is similar to our study. There was a significant difference in femoral neck T score between the diabetic and non-diabetic group ($P \leq 0.001$). Femoral neck T-score was significantly lower in diabetic women than in non-diabetic women in the study of Moghimi *et al*.[13] conducted in Iran. In our study, in controlled glycemic postmenopausal women femoral neck T-score was −2.04 ± 0.77, and the lumbar spine T-score was −2.08 ± 1.03. But in uncontrolled glycemic women femoral neck T-score was −3.24 ± 1.00 (P < 0.001), and the lumbar T-score was −4.27 ± 1.06 (P < 0.001). Just like in our study, there was a significant difference in the prevalence of femoral neck osteoporosis between the two groups in the study of Leidig-Bruckner *et al*.,[14] and the incidence of osteoporosis in the diabetic group was significantly higher than in the other group. There are controversial results surrounding the correlation of Type 2 diabetes and osteoporosis in the study of Incalzi *et al*.[15] Although it has been shown in some studies that Type 2 diabetes has a protective effect on post-menopausal osteoporosis. In the study of Schwartz *et al*.[2] could not find any significant difference in the femoral neck's bone mass between healthy and diabetic patients.

Limitations of the study

The study was conducted in a single hospital with a small sample size. So, the results may not represent the whole community.

Conclusion

Postmenopausal women with diabetes, especially with uncontrolled glycemia, showed significantly lower T- and Z-scores at both femoral neck and lumbar spine, indicating higher osteoporosis risk. The negative correlation of T-scores with menopausal duration underscores the combined adverse effects of aging and poor glycemic control on bone health.

Recommendation

Regular BMD assessment using both T- and Z-scores should be incorporated into the routine care of postmenopausal women with diabetes, particularly those with poor glycemic control, to enable early detection of osteoporosis and timely preventive interventions.

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Conflicts of interest

None declared.

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