Measurements of Alterations in Bone Mineral Density, and Body Composition in a Group of Type-2 Diabetic Women

Khalid Ghanim Majeed[1*], Muthanna Hashim Dawood[2], Ali Khairaldeen Mohialdeen[3]

Abstract

Aim: To assess the body composition of fat mass, lean mass, visceral fat mass, and total body water in DM patients and compares their findings with a healthy control group.
Material and Methods: A total of 86 people including 40 diabetes Mellitus type 2 matched for sex and age with 46 healthy control participated in the study. BMDs of the lumbar vertebrae and the hip regions like (total femur, femoral neck) were assessed using the DXA technique. The mean age of (DM) group was 59 ± 11.82 years, the height 1.55 ± 0.05 m., the weight 80.82 ± 13.25 kg, and BMI 33.81 ± 6.76 kg/m^2.
Results: The differences in measurements of the lumbar spine BMD (1.12 ± 0.13 g/cm^2), total femur BMD (1.10± 0.17 g/cm^2) neck of femur BMD (0.85± 0.35 g/cm^2), and total BMD of the body (0.90± 0.06 g/cm^2) were highly significant in healthy control group as compared to DM patients 0.84 ± 0.13 g/cm^2, 0.99±0.15 g/cm^2, 0.82± 0.24 g/cm^2 and 0.79 ± 0.09 g/cm^2 respectively.
Conclusion: The results shows a highly significant in the lumbar spine, total femur, and total BMC, and not significant in the neck of the femur. The total body lean compartment was not significantly different between DM patients and healthy control women groups. The total body water compartment in the DM women group was highly significant lower different comparing with a healthy control group. The mathematical equations to predict total bone density in DM type 2 and healthy control women were calculated.

Key Words: Diabetic, Bone Density, DXA, BIA, Fat Mass.
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Introduction

Most information in the characteristics of skeletal growth during childhood and adolescence has been obtained by non-invasive techniques that enable bone mass to be measured at various sites in the skeleton with great precision and accuracy (Varahra, 2018), (Xu, 2016). The bone mass of a particular part of the skeleton is directly dependent on both the volume or size of the part concerned and the density of the mineralized tissue contained within its periosteal envelope (Nana, 2011).
Dual-energy absorptiometry DXA is a technique that enables the direct determination of bone mass at these skeletal locations by simple mathematical equations using a pencil beam. The DXA technique uses two different energies of (35-70) KeV beams in the body through samarium and aluminum filter type STRATOS, DMS group, France (Nalda, 2011), (Majeed, 2019).
These two beams of the X-ray pass through the patient then are collimated by a brass detector collimator type of lanthanum chloride ($LaCl_3$) (Majeed, 2019).

Corresponding author: Khalid Ghanim Majeed
Address: [1*]Medical Physics, Department of Medical Physiology, College of Medicine, Ninevah University, Mosul, Iraq; [2]FICMS Orthopedic Surgeon, College of Medicine, Ninevah University, Mosul, Iraq; [3]FICMS Orthopedic Surgeon, College of Medicine, Ninevah University, Mosul, Iraq.
[1*]E-mail: khalid.majeed@uoninevah.edu.iq
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Calibration of the DXA machine by anthropometric phantom is using every 24 hours before measuring the participants (Nalda, 2011).

The DXA technique can not only measure the density and mass of the bones, but it can give us real results about the segmental and total fat mass, lean mass, and fat-free mass in 10-15 minutes (Kim, 2010).

Furthermore, magnetic resonance imaging, computed tomography, underwater weighing, analysis of neutron activation technique, and bioelectric impedance analysis (BIA) were also used in the assessment of body composition (Majeed, 2019).

BIA is widely be used for it is, non-invasive, safe, and very efficient (Majeed, 2019).

The BIA technique can estimate the whole body and limbs that may happen for one minute which can be applied using an alternating current of a sine-wave with single frequency 50 kHz and 550 mA. (Lee, 2014), (Kyle, 2004).

The standing BIA device consists of eight-electrode type BC-418 (Tanita Corp., Tokyo, Japan). This device is linked to stainless-steel plates for measuring segmental and total body impedance. Eight stainless-steel plates are using in this device (Lee, 2014).

DM type-2 is now considered a global health problem with economic burdens especially in the Middle East (Siddapur, 2015). DM may affect the rate of obesity by influencing the fat distributions when the body composition changes conflicting with the increasing risk of cardiovascular disease (Siddapur, 2015).

Having information about the body components of DM, it is necessary to know the type of treatments that patients must take, types of exercise and daily activities required, and knowing the foods that negatively affect the disease that works to increase their obesity (Owolabi, 2016).

Most of the previous studies focus on diabetes and reflecting the effect on total bone density. Therefore, in this research, we give on the effect of decreasing BMD in areas such as the lumbar vertebrae, the femur bone, neck of the femur, and total bone mineral density since these areas may be exposed to fracture, especially in women at menopause period with DM type-2 using both DXA and BIA techniques.

Therefore, the current study aims to assess the bone density, T-score, Z-score, body composition like fat mass, lean mass, visceral fat mass, and total body water of DM patients and compares their findings with a healthy control women group matching with the same age and sex using both DXA and BIA devices.

DXA Technique

The total attenuation of an x-ray passing through a specimen by the following equation:

$$I = I_0 \exp(-\mu x) \qquad [1]$$

Where: I_0 – initial x-ray intensity before passing a material

I – x-ray intensity after attenuation

x - the thickness (cm)

μ - total linear attenuation coefficient (cm^{-1})

When the beam passes through N different materials equation [1] can be written as:

$$I = I_0 \exp\left(-\sum_i^N (\mu/\rho)_i M_i\right) \qquad [2]$$

These equations are solved as below;

$$M_B = \frac{k \ln(I^H{}_0 / I^H) - \ln(I^L{}_0 / I^L)}{k\, \mu_B{}^H - \mu_B{}^L}$$

Where $k = \mu_S{}^L / \mu_S{}^H$

M_B is the areal density of the bone, μ_B - mass attenuation coefficient for bone, μ_S - mass attenuation coefficient for soft tissue.

L- low energy photon, H- high energy photon (Majeed, 2019).

Materials and Methods

A total of 86 people including 40 diabetic Mellitus type 2 matched with sex and age with 46 healthy control participated in the study.

The data were collected over 10 months at the DXA Laboratory, Physiology Department, College of Medicine, Ninevah University, Iraq-Mosul City.

The study was carried out under the Helsinki Declaration Principles.

All participants were asked to volunteer for the study. The study protocol conformed with the ethical guidelines and was approved by the ethics committee of the College of Medicine, Ninevah University, Iraq, Mosul.

The body composition like BMC, BMD, total FM, and total LM was measured. BMDs of the lumbar vertebrae (L1–L4) and the hip region (total femur, femoral neck) were assessed according to the protocols by using the DXA. The participants were asked to wear soft hospital gowns and remove all the metal or any accessories during the DXA scan (Qorbani, 2013).

Bioelectric Impedance Analysis (BIA), (Tanita BC-418, Tanita Corporation, Tokyo, Japan) is also used to measure fat-free mass FFM, visceral fat rating, and total body water for all participants (Lee, 2014).

There are eight stainless steel panels on the handgrip and also on the base of the foot weight sensor in BIA equipment. A low voltage current passes during the measurement with a single frequency of 50 kHz and 0.5A (Lee, 2014).

The exclusion criteria from the study protocol were: a history of hyperthyroidism and/or corticosteroid therapy for more than 6 months, and having chronic kidney and/or liver diseases.

All the data has been processed by the use of the statistical package SPSS version 19. Descriptive statistical methods were used to summarize and tabulate the data. Two independent samples (t-test) were used to assess the significance of differences in the mean between both DM type-2 and control groups.

A total of 86 people including forty diabetic Mellitus DM type 2 matched with sex and age with a forty-six healthy adult as control has participated in our study. The mean duration of DM type-2 patients was 3 years.

As stated in the study design, the two groups were matched for age, weight, height, and BMI, as shown in Table 1.

The anthropometric and body-composition variables of the two study groups are presented in Table 1 and Figures (1) through (2).

The mean age of (DM) group was 59 ± 11.82 years, the height 1.55 ± 0.05 m., the weight 80.82 ± 13.25 kg, and BMI 33.81 ± 6.76 kg/m². Whereas the mean age of the healthy volunteer was 56.67 ± 12.01 years, the height 1.54 ± 0.08 m., the weight 81.57 ± 15.86, and BMI 34.21± 5.77 kg/m². Descriptive statistics of the subjects according to their anthropometric measurements are shown in Table (1).

Results

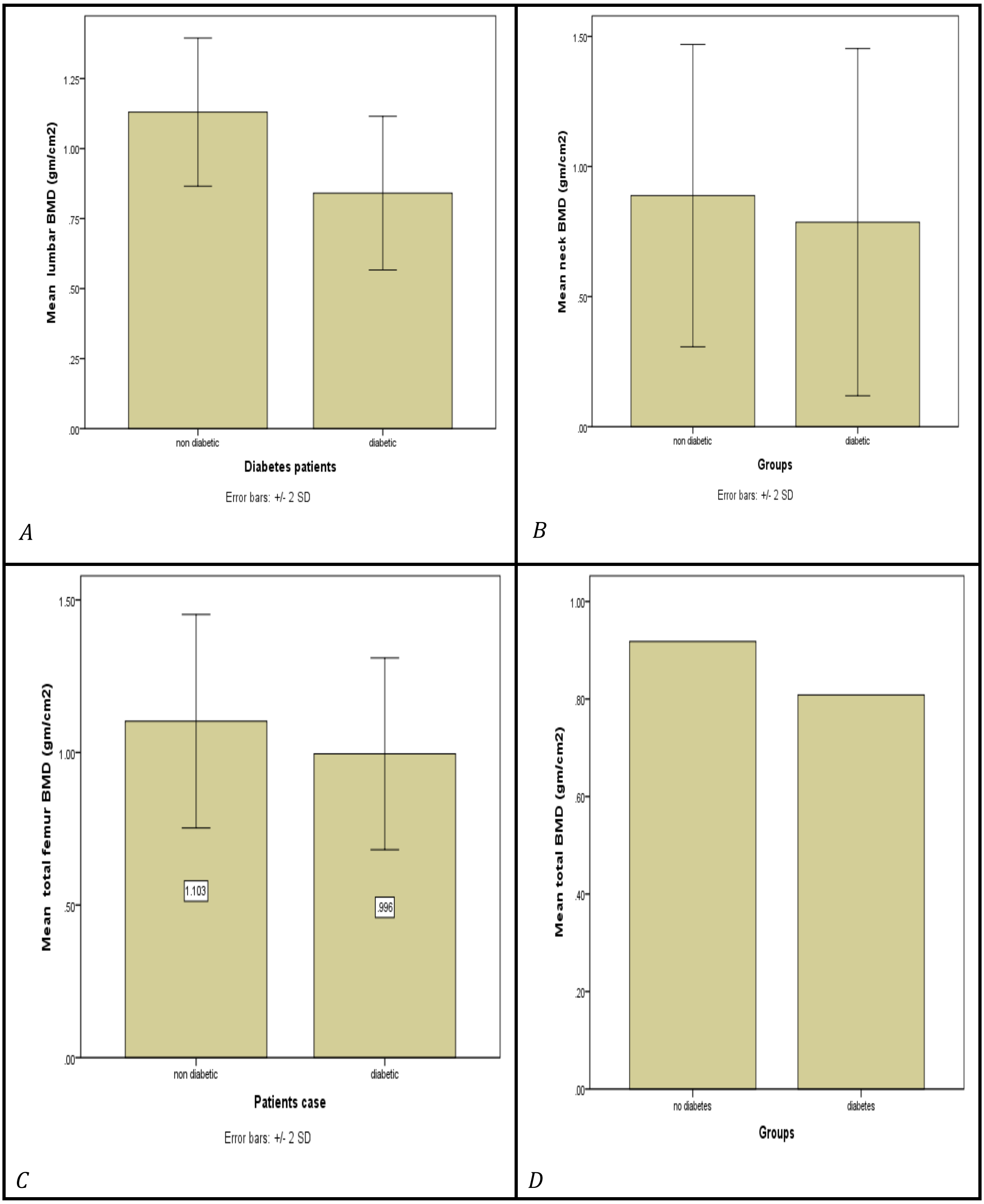
Table 1. Descriptive characteristics among participants of the measurements (N=86)

	Diabetes			None diabetes		
Variables	**Mean ± SD**	**Minimum**	**Maximum**	**Mean ± SD**	**Minimum**	**Maximum**
Age (years)	59.12 ± 11.82	31	86	56.67 ± 12.01	21	84
Height (m.)	1.55 ± 0.05	1.42	1.74	1.54 ± 0.08	1.35	1.75
Weight (kg)	80.82 ± 13.25	50	106	81.57 ± 15.86	48	121
Body mass index (kg/m²)	33.81 ± 6.76	19.05	54.48	34.21 ± 5.77	20.78	44.74

The results show that the BMC of the lumbar spine, neck of femur, total femur and, total body were higher in healthy adults comparing to diabetic patients. The results were highly significant; p<0.0001 in the lumbar spine, total femur, and total BMC, and not significant in the neck of the femur as shown in Table 2.

Table 2. The comparison of body composition between DM patients and control groups

Regions	Mean±SD (diabetes)	Mean±SD (none diabetes)	P-value	95% CI of the difference
Lumbar spine BMC, (gm)	42.65 ± 18.88	63.38 ± 8.01	0.0001	13.23 – 28.22
Total femur BMC, (gm)	33.24 ± 7.20	35.62 ± 6.33	0.007	0.85 – 5.62
Neck of femur BMC, (gm)	3.65 ± 1.35	3.81 ± 1.35	0.6	0.47 – 0.79
Total body, BMC, (kg)	1.53 ± 0.26	1.77 ±0.29	0.0001	0.11 – 0.35



Figures 1-A, B, C, and D. The comparisons of body composition between both DM type-2 and control groups

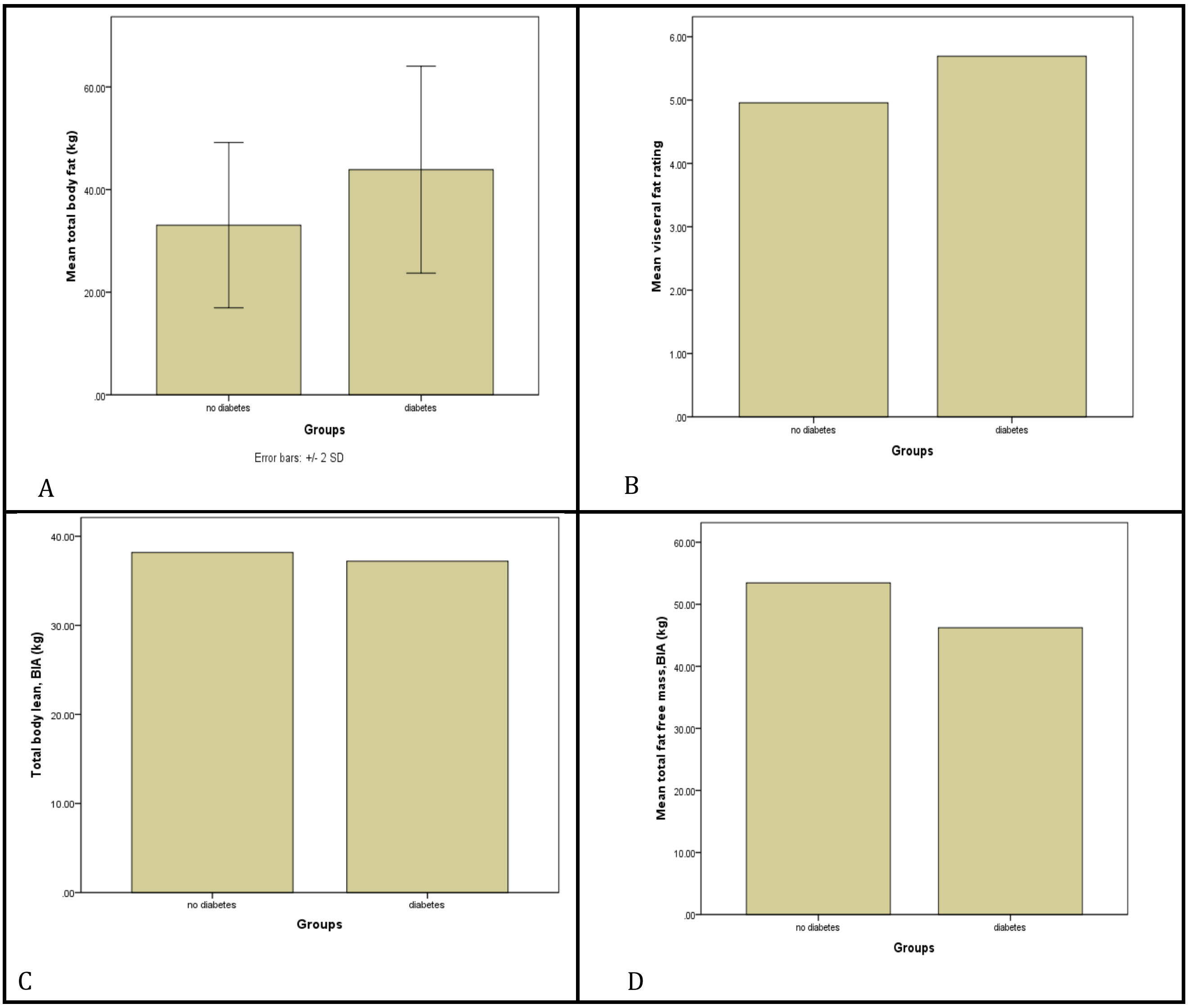


Figure 2-A, B, C and D. The comparison of body composition between both DM and control groups

The advanced calculations show that the measurements of the lumbar spine BMD, total femur BMD, neck of femur BMD and total BMD of the body were highly significant in healthy control group and equal to (1.12 ± 0.13 g/cm^2), (1.10± 0.17 g/cm^2), (0.85± 0.35 g/cm^2) and (0.90± 0.06 g/cm^2) comparing to the DM patients 0.84 ± 0.13 g/cm^2, 0.99±0.15 g/cm^2, 0.82± 0.24 g/cm^2 and 0.79 ± 0.09 g/cm^2 respectively; p= 0.0001 as shown in figure 1- (A, B, C, D).

Most importantly, the results of the total T-Score as shown in Table 3, which is an index for bone health status calculated on basis of a younger healthy population. For the lumbar spine, the DM women group was highly significantly lower than that for the healthy women group (i.e., -1.47 ± 0.98 vs. 0.74 ±1.18, respectively; P < 0.0001). At the same time, the total femur DM women were significantly lower than that for the healthy women group (i.e., -0.36± 1.04 vs. 0.34± 1.17 respectively; P < 0.001). For the neck of the femur DM women group also significantly lower than that for the healthy group (i.e., -0.35± 1.07 vs. 0.23± 1.27, respectively; 0.01). Lastly, the T-score of the total BMD of the body was highly significantly lower for the DM patient group comparing to the healthy group (-1.94 ± 0.81 vs. -0.96 ± 0.59, respectively; p <0.0001).

In the same way, Z-Score, which is a bone health measure calculated on basis of an age-matched healthy population. For the lumbar spine, the DM women group was significantly lower than that for the healthy women group (i.e., -0.80 ± 1.14 vs. 1.60± 1.19, respectively; p <0.0001). For the total femur DM women was lower than that for the healthy women group (i.e., 0.59± 0.99 vs. 0.98± 0.95, respectively). For the neck of the femur DM women group also lower than that for the healthy group (i.e., 0.81± 1.13 vs. 1.04± 1.23, respectively).

Lastly, the Z-score of the total BMD of the body was lower for the DM patient group comparing to the healthy group (-0.48 ± 0.97 vs. -0.19 ± 0.65, respectively; p< 0.0001) as shown in Table 3.
This implies a direct effect of menopause on bone health status, which can be clinically evaluated by the significant changes in both T- and Z-Scores for diagnosing osteopenia and osteoporosis.

Table 3. The comparisons of body composition between both DM type 2 and control groups

Regions	Mean±SD (diabetes)	Mean±SD (non diabetes)	P-value	95% CI of the difference
Lumbar spine BMD, g/cm^2	0.84 ± 0.13	1.12 ± 0.13	0.0001	0.22- 0.35
Total femur BMD, g/cm^2	0.99±0.15	1.10± 0.17	0.0001	0.030 – 0.18
Neck of femur BMD, g/cm^2	0.82± 0.24	0.85± 0.35	0.0001	-0.10 – 0.16
Total body BMD, g/cm^2	0.79 ± 0.09	0.90± 0.06	0.0001	0.082 – 0.15
T-score of the lumbar spine	-1.47 ± 0.98	0.74 ±1.18	0.0001	1.69 – 2.72
Z-score of the lumbar spine	-0.80 ± 1.14	1.60± 1.19	0.0001	1.11 – 2.24
T-score of the femur	-0.36± 1.04	0.34± 1.17	0.001	0.18 – 1.21
Z-score of the femur	0.59± 0.99	0.98± 0.95	0.09	-0.075 – 0.84
T-score of the neck of femur	-0.35± 1.07	0.23± 1.27	0.01	0.044 – 1.12
Z-score of the neck of femur	0.81± 1.13	1.04± 1.23	0.1	-0.31 – 0.78
T-score of the total BMD	-1.94 ± 0.81	-0.96 ± 0.59	0.0001	0.67 – 1.29
Z-score of the total BMD	-0.48 ± 0.97	-0.19 ± 0.65	0.10	-0.067 – 0.65

Moreover, advanced body-composition analysis for weight components, using the DXA and BIA technique, which is shown in Table 4 and Figures (1) and (2) showed that the total FM compartment in the DM women group was highly significantly different comparing with healthy groups (i.e., 46.82 ± 7.98 vs. 32.23 ± 7.54 kg, respectively; p <0.0001). In the same way, the total body lean compartment was not significantly different between DM patients and healthy control women groups (i.e., 37.24 ± 5.92 vs. 38.15 ± 5.37 kg, respectively). The visceral fat rating and total fat-free mass compartments using the BIA technique were not also different between both groups (i.e., 5.69 ± 3.83 vs. 4.95 ± 4.10) respectively) and (i.e., 46.21 ± 8.80 vs. 53.46 ± 9.41 kg, respectively). Thus, neither body weight nor its tissue components (i.e., total body lean, FFM, and visceral fat rating) were affected by the DM patients group, since their values were numerically comparable with the control women group. The total body water compartment in the DM women group was highly significant lower different comparing with a healthy control group (i.e., 31.54 ± 2.50 kg vs. 38.08 ± 7.88 kg), respectively; p <0.0001.

Table 4. The body compartments between DM type 2 and control groups

Regions	Mean±SD (diabetes)	Mean±SD (none diabetes)	P- value	95% CI of the difference
Total body fat, (kg)	46.82 ± 7.98	32.23 ± 7.54	0.0001	-17.98 – (-11.19)
Total body lean, (g)	37.24 ± 5.92	38.15 ± 5.37	0.50	-2.06 – 3.65
Visceral fat rating, BIA	5.69 ± 3.83	4.95 ± 4.10	0.50	-3.28 – 1.81
Total fat free mass, BIA (kg)	46.21 ± 8.80	53.46 ± 9.41	0.07	-0.76 – 15.25
Total body water, BIA (kg)	31.54 ± 2.50	38.08 ± 7.88	0.0001	3.65 – 9.43

In this study, we used results of segmental BMD for the sites more susceptible to fracture risks (i.e., spine BMD and pelvis BMD) in addition to total BMD measurements to develop mathematical equations to predict bone density in DM type 2 and healthy control women. To this end, an initial multiple regression model was used to determine the effect of simultaneously adding the covariates:

lumbar spine, neck of femur, and total femur on total BMD, respectively, as the dependent variables, separately for each group.

The equations below show the prediction equations for every predictor using the below formula (Aggarwal,2016):

Dependent variable = constant + (B_1)*(independent variable "segment part")+ (B_2)*(independent variable "segment part") + (B_3)*(independent variable "segment part")

However, it is equal to:

$$Y = B_o + B_1 . X_1 + B_2 . X_2 + B_1 . X_3 \quad (3)$$

Where Y represents the value of the variable being predicted.

B_o is represented y - Interception.

B_1 represents the slope of the straight line.

$X_{1,2,3}$ represents the value of the independent variables of the segmental parts which already known.

The following equations can be used to correct the mathematical equations to predict total bone density in DM type 2 and healthy control women respectively are below;

Total BMD for DM-2 type group= 0.59- 0.065* (total femur) - 0.05* (neck of femur) + 0.35* (lumbar spine) (4)

Where the amounts of correlation coefficient R=0.96, coefficient of determination R^2=0.92; p=0.0001.

The total femur, neck of femur, and lumbar spine explained at least 92% of the variability in each BMD site predicted values.

Total BMD for healthy control group= 0.48+ 0.004* (total femur) - 0.002* (neck of femur) + 0.37* (lumbar spine) (5)

Where R= 0.98, R^2= 0.96; p=0.0001.

The total femur, neck of femur, and lumbar spine explained at least 96% of the variability in each BMD site predicted values.

These new models are considered as a new assessment at the Iraqi level to compare bone density for diabetic patients and compare it with healthy people through the use of DXA and electrical impedance techniques.

Discussion

In the present study, the changes in total BMC, total BMD, total fat mass, lean mass, and total body water compartments were assessed for ethnically uniform groups of DM patients and healthy controls which were matched for sex, age, weight, height, and BMI.

Miyatani M et al reported that using leg-to-leg BIA could be used for making a routine assessment with DM type 2 and measuring body composition analysis (Miyatani, 2012).

Other researches revealed that a user of a BIA device was useful, applicable, and a good technique for the evaluation of body composition in obese, and cardiometabolic disorders (Ugras, 2020).

The measurement of BMD of the lumbar spine, total femur, and neck of femur was significantly lower for DM patients, as compared to healthy control, which is in the line with findings reported by Asokan et al (Asokan, 2017).

Reduced total BMD puts DM patients at increased risk of osteoporosis and fractures (Asokan, 2017). Fractures in DM patients usually occur at sites of heavy stress. These may occur in the vertebrae, femoral necks, with femoral necks being the most common site (Asokan, 2017), (Vestergaard, 2007).

Oei L et al reported that a higher BMD level in subjects with diabetes was more than non-diabetics independent of age, gender, BMI, and medication use (Oei, 2013).

Chen H et al (Chen,2018) reported that both BMD and bone alkaline phosphatase (BAP) was associated with the factor of age in both diabetes and non-diabetes patients so that as age was increased the total BMD will be decreased significantly and BAP will increase.

Brewster et al pointed out that the men with DM were going to store excess fat in the area of the abdomen to make the risk of dyslipidemia, with impaired glucose regulation (Brewster, 2008).

Some of the researchers reported that the body composition and BMD were similar with and without DM patients using the DXA mechanism (Ingberg, 2004).

Ingberg et al (Ingberg, 2004) observed that a lower ratio between both abdomen fat mass and total fat mass dealing with male DM compared with the control group of the participants.

Heshka et al observed that a higher lean mass and less fat mass with those having DM type 2 compared with healthy control (Heshka, 2008).

Owolabi et al show that a higher physique rate, visceral fat, and body fat, when compared with sex and age, matched healthy control using bioelectric impedance analysis BIA technique (Owolabi, 2016).

The lack of daily diet information for diabetic patients and its effect on the increase or decrease of visceral fats rate and total body fats remains unclear and vague (Owolabi, 2016).

Siddapur et al show that higher T-scores are associated with DM type-2 postmenopausal women with osteoporosis comparing with non-diabetics persons (Siddapur, 2015).

Our study revealed that the measurement of total body water and total lean mass were lower for DM patients, as compared to healthy control, which is in the line with the figure reported by Owolabi et (Owolabi, 2016).

Oei L et al studied the influence of glucose control on skeletal complications with type-2 diabetes about BMD, bone geometry parameters, and fracture risk. They divided their groups into adequately controlled diabetes and inadequately controlled diabetes. They found that (inadequately controlled diabetes) ICD groups have an increased fracture risk compared with those having (adequately controlled diabetes) ACD and individuals without diabetes (Oei, 2013).

Conclusion

The measurement of BMD of the lumbar spine, total femur, and neck of femur was significantly lower for DM patients, as compared to healthy control. The total body lean compartment was not significantly different between DM patients and healthy control women groups**.** The total body water compartment in the DM women group was highly significant lower different comparing with a healthy control group**.** In this study, we developed mathematical prediction equations for the total BMD based on the variables neck of femur, total femur, and lumbar spine. We used these equations to predict total BMD in DM type 2 and healthy control Iraqi women.

To the best of our knowledge, this is the first report of an association between anthropometric variables and BMD by DXA scans from various sites. To validate these prediction equations, studies that include the largest study groups, including a large study of age groups from young males and females in middle school to ages of over seventy, for both sexes will be necessary.

Researchers suggest that citizens should be educated about the symptoms of the DM and thus take the necessary measures and conduct laboratory tests permanently.

Providing testing devices for bone density and stiffness of the bone, as well as BIA for measuring the degree of obesity in health centers.

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