Article

Analysis of Age-Based Bone Mineral Density in the Koran Adult population using Dual Energy X-ray Absorptiometry

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Abstract: Dual energy X-ray absorptiometry (DEXA) measuring tool is a reliable and accurate technology to measure bone density and bone mineral composition. This research examined the composition and bone density (bone mineral composition and bone mineral density) of the whole body and representative body parts using DEXA. The participants were 240 healthy adult men and women who were divided into three groups based on age. The total bone mineral density (BMD) of women amounted to an average of 1.14 g/㎠ in Group A, 1.14 g/㎠ in Group B, and 0.98 g/㎠ in Group C. For men, the average BMD was 1.25 g/㎠ in Group A, 1.20 g/㎠ in Group B, and 1.17 g/㎠ in Group C. As a result, the reduction of age-specific BMD was shown to have a correlation with aging and body mass index(BMI), and it is determined that exercising on a regular basis can prevent reduction in BMD by maintaining appropriate muscle mass.

Keywords: DEXA; BMD; BMC; Osteoporosis; BMI; Aging

1. Introduction

Dual energy X-ray absorptiometry (DEXA) is the most widely used method to measure bone mineral density (BMD), chiefly because it uses X-ray, which is non-invasive and low cost [1-3]. This measurement tool calculates the density of bone mass by measuring the rate differences of radiation transmittance in the analyzed bone mass, when the radiation from the tool penetrates the body [4,5]. By using a tube voltage of 80 Kv Cerium filter, DEXA utilizes photon energies of 40 keV and 80 keV [6]. Thus, it can be used to assess bone health conditions in any part of the body. It is widely used to measure and assess the parts of the body such as the regions of the lumbar and proximal femur [7].

Bones undergo mineralization and remodeling during their life cycle [8,9]. Generally, an imbalance in absorption and generation of osseous tissue occur in both men and women as they get older. This process causes the mineral synthetic imbalances of different body parts, which leads to reduced average BMD. The rate of mineral synthetic imbalance has been reported to be 26.59% for women and 14.56% for men [10].

The reduction in BMD causes diseases like osteoporosis, is responsible for pains in various body parts, and contributes to disabilities associated with the aged[11]. More specifically, the decrease in BMD due

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to aging exponentially amplifies the risks of bone fracture[12], which can lead to disabilities and death, and ultimately to higher amount of social costs[13]. Moreover, the decline in BMD increases the risk of additional secondary fracture[14]. Mortality from BMD reduction has been reported to be higher in men than women[15].

Although studies on the process of mineralization and reformation have been conducted, there is paucity of data on therapies such as hormone therapy, diet therapy and therapeutic exercise, which have been recommended as important therapies for decreased BMD. These interventions not only delay bone loss, but also helps in the maintenance and development of bones [16]. The importance of maintaining high BMD is highly emphasized in the medical community.

DEXA is necessary for accurately assessing and identifying bone conditions. According to the International Society for Clinical Densitometry (ISCD), DEXA is recommended as the most appropriate BMD measurement method that can then be applied to the diagnostic criteria of the World Health Organization (WHO) [17, 18]. DEXA measurement can predict and assess risks of bone fractures; according to research on osteoporosis and fractures, the BMD-estimated T-score <-2.5 (defined as osteoporosis) has a close correlation with development of bone fractures [19].

In light of these findings, this paper seeks to provide an important reference for the pathophysiology and treatment of bone diseases, including osteoporosis, by analyzing the BMDs of Koreans based on sex and age.

2. Materials and Methods

2.1 *Participants*

All 240 examinees (120 men, 120 women) were healthy adults living in Seoul, Korea and are composed of individuals aged between 20 to 73 years old. Prior to participating in the experiment, enrolled participants were informed of the objectives and procedures of the study and agreed to be active participants. Patients with diabetes, cardiovascular disorders and hypertension were excluded. Participants were divided into three groups based on their age. Group A included adults aged 20-39 years, Group B included ageing participants between 40-59 years, and Group C included elderly participants aged 60-73 years. The physical characteristics of the examinees were featured in Table 1 and 2.

Table 1. Physical characteristics of adults according to age

Sex_ \ Item / age		Height (cm)	Weight (kg)	BMI (kg/m²)
male	20-39 (n=40)	174.0±5.70	75.72±13.70	25.77±3.70
	40-59 (n=40)	167.4±4.40	69.87±8.10	24.50±3.07
	60-73 (n=40)	166.4±5.60	68.93±9.40	24.86±3.36
	Total (n=120)	169.77±6.32	71.98±11.40	25.04±3.40
female	20-39 (n=40)	158.6±4.80	59.08±10.0	23.48±3.84
	40-59 (n=40)	155.1±5.10	58.76±7.50	24.29±2.77

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60-73 (n=40)	152.6±4.50	57.06±6.60	24.29±3.18
Total (n=120)	155.5±8.18	58.37±5.37	24.02±3.29

Value are mean±standard deviation; BMI : Body mass index, calculated by weight/height^2;
(n) : research object number

2.2 Experimental procedure

The experimental procedure of this experiment is as shown in Fig. 1.

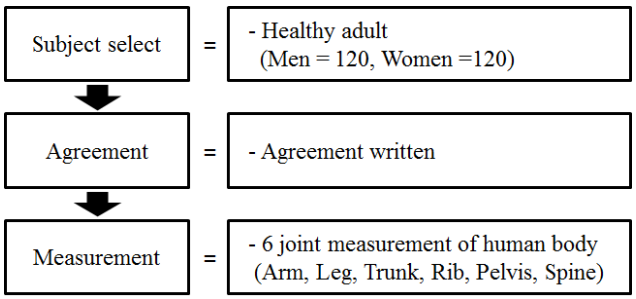

Fig 1. Experimental procedure

2.3 DEXA measurement

The DEXA measurement was taken in the morning on an empty stomach of the participants. DEXA was used to measure BMD and BMC (bone mineral content) for the whole body. During the measurement, participants were lightly-dressed and were lying straight on the scanning table. The presets for the applied DEXA (Lunna Radiation corp., Madison, Wisconsin, U.S.A) were photon energy of 66 KeV and 40 KeV by conducting collimation on 1.68 mm intervals. For Scan type, DPX-L(GE-Lunar Corp., Madison, WI) was used and the software version for acquiring data was 3.1. The left and right arms, legs and torso, and the BMC and BMD for the whole body was measured.

2.4 Data Analysis

The SAS ver. 9.2 statistical program was utilized for analysis. Mean and standard deviation for sex, ages, height, weight, BMD, and BMC were calculated, and two-way analysis of variance (ANOVA) used to determine whether there were differences among the different age groups, and between men and women. Tukey's post-hoc adjustment was carried out for variables found to be statistically significant. The significance level (α) for testing hypotheses in this study was set at 0.05.

3. Result

3.1 Basic statistics of BMD and BMC factor based on sex and ages

The basic statistics of BMD and BMC factor based on sex and ages are shown below; Table 2 for men

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and Table 3 for women.

Table 2. The mean values weight, height, BMD and BMC in various body segments of men. (Mean±SD)

Item \ Age	Group A	Group B	Group C
wt	75.72±13.7	69.87±8.1	68.93±9.4
ht	174.0±5.7	167.4±4.4	166.4±5.6
BMD(arms)	0.99±0.09	0.97±0.11	0.93±0.11
BMD(legs)	1.36±0.10	1.29±0.13	1.24±0.12
BMD(trunk)	1.01±0.08	0.95±0.09	0.94±0.12
BMD(ribs)	0.77±0.06	0.72±0.06	0.72±0.09
BMD(pelvis)	1.26±0.12	1.18±0.15	1.11±0.17
BMD(spine)	1.20±0.13	1.15±0.14	1.14±0.18
BMD(total)	1.25±0.00	1.20±0.09	1.17±0.11
BMC(arms)	396.5±70.90	371.5±62.33	353.3±58.01
BMC(legs)	1192±200.1	1038±154.8	1004±143.5
BMC(trunk)	990.2±141.8	850.4±149.7	819.6±174.0
BMC(total)	3172±421.2	2842±389.2	2715±372.8

Group A: 20-39yrs; Group B: 40-59yrs; Group C: 60-79yrs; ht: height(cm); wt: weight(kg); BMD(g/cm^2): bone mineral density; BMC(g): bone mineral content

Table 3. The mean values weight, height, BMD and BMC in various body segments of women. (Mean±SD)

Item \ Age	Group A	Group B	Group C
wt	59.08±10.0	58.76±7.5	57.06±6.6
ht	158.6±4.8	155.1±5.1	152.±64.5
BMD(arms)	0.81±0.08	0.80±0.15	0.69±0.07
BMD(legs)	1.14±0.10	1.14±0.11	0.97±0.10
BMD(trunk)	0.91±0.09	0.90±0.10	0.78±0.08
BMD(ribs)	0.68±0.06	0.68±0.07	0.60±0.05
BMD(pelvis)	1.11±0.13	1.09±0.13	0.92±0.10
BMD(spine)	1.13±0.15	1.12±0.16	0.92±0.13
BMD(total)	1.14±0.08	1.14±0.09	0.98±0.08
BMC(arms)	222.6±57.53	228.5±52.11	190.1±34.79
BMC(legs)	785.3±158.6	772.5±146.8	649.7±96.81
BMC(trunk)	694.5±176.0	694.3±160.4	525.6±114.7

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BMC(total)	2261±433.5	2266±402.8	1830±271.5

Group A: 20-39yrs; Group B: 40-59yrs; Group C: 60-79yrs; ht: height(cm); wt: weight(kg); BMD(g/cm^2): bone mineral density; BMC(g): bone mineral content

3.2 Differences in BMD factor based on sex and ages

The results of two-way ANOVA for BMD of sex according to ages were shown in Table 4. In addition, the results of the post-hoc test were featured in Table 5 and 6.

Table 4. The results of two-way ANOVA for BMD of men & women according to age

Source	DF	SS	MS	F Value	Pr > F
Model	5	1.61163354	0.32232671	40.09	0.0001
Error	234	1.88121320	0.00803937		
Gender	1	0.83994322	0.83994322	104.48	0.0001
Age	2	0.57732961	0.28866481	35.91	0.0001
Gender * Age	2	0.15328471	0.07664236	9.53	0.0001
Corrected Total	239	3.49284673			

According to two-way ANOVA based on gender and ages, it showed a difference of $F(1, 234)=104.48$ ($p<0.01$), depending on gender. The age-based results also showed a difference of $F(2,234)=35.91$ ($p<0.01$), and the reciprocal action between gender and ages showed a $F(2, 234)=9.53$($p<0.01$) difference. In the Tukey post-hoc, there was a valid difference between men and women, and certain distinctions were found in Group A, B and C.

Table 5. Tukey post-hoc in men according to age

Source	DF	SS	MS	F	Pr > F	post-hoc
Model	2	0.11420968	0.05710484	6.57	0.0020	
Error	111	0.96530018	0.00869640			
Age	2	0.11420968	0.05710484	6.57	0.0020	a b c
Corrected Total	113	1.07950986				

a = group A(20-39 yrs) ; b = Group B(40-59 yrs) ; c = Group C (60-73 yrs)

By analyzing Table 5, a one-way ANOVA based on ages showed a valid $F(2, 111)=6.57$ ($p<0.01$) difference in age changes of the male group. Moreover, there appeared a valid difference between Group A and C in the Tukey post-hoc.

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Table 6. Tukey post-hoc in women according to age

Source	DF	SS	MS	F	Pr > F	post-hoc
Model	2	0.66760870	0.33380435	44.83	0.0001	
Error	123	0.91591302	0.00744645			
Age	2	0.66760870	0.33380435	44.83	0.0001	a b c
Corrected Total	125	1.58352171				

a = group A(20-39 yrs) ; b = Group B(40-59 yrs) ; c = Group C (60-73 yrs)

By analyzing Table 6, a one-way ANOVA based on ages showed a valid $F(2, 123)=44.38$ ($p<0.001$) difference in age changes of the women group. In addition, Tukey post-hoc was a statistically significant difference between Group A and B compared to Group C.
These results can be deduced that the decline in the body BMD in accordance to the aging has a close relationship with a loss of muscle mass and a decrease in BMC

3.3 Differences in BMC factor based on sex and ages

The results of two-way ANOVA for BMC of sex according to ages were shown in Table 7. In addition, the results of the posteriori test were featured in Table 8 and 9.

Table 7. The results of two-way ANOVA for BMC of sex according to age

Source	DF	SS	MS	F Value	Pr > F
Model	5	47913917.88	9582783.58	63.20	0.0001
Error	234	35479495.92	151621.78		
Gender	1	36614251.09	36614251.09	241.48	0.0001
Age	2	7409161.57	3704580.78	24.43	0.0001
Gender*Age	2	1479315.02	739657.51	4.88	0.0084
Corrected Total	239	83393413.80			

According to Table 7 presenting the results of two-way ANOVA based on gender and ages, it showed a difference of $F(1, 234)=241.48$ ($p<0.01$), depending on gender. The age-based results also showed a difference of $F(2,234)=24.43$ ($p<0.01$), and the reciprocal action between gender and ages showed a $F(2, 234)=4.88$($p<0.01$) difference.

Table 8. Tukey post-hoc in men according to age

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Source	DF	SS	MS	F	Pr > F	post-hoc
Model	2	4445694.39	2222847.20	14.00	<.0001	
Error	111	17621312.60	158750.56			
Age	2	4445694.393	2222847.19	14.00	<.0001	a b c
Corrected Total	113	22067006.99				

a = group A(20-39 yrs) ; b = Group B(40-59 yrs) ; c = Group C (60-73 yrs)

In the Tukey post-hoc results, there was a valid difference between men and women, and certain distinctions were found in each group. By analyzing Table 9, a one-way ANOVA based on ages showed a valid $F(2, 111)=14.00$ ($p<0.01$) difference in age changes of the male group. Moreover, there was a statistically significant difference between Group B and C compared to Group A in the Tukey post-hoc.

Table 9. Tukey post-hoc in women according to age

Source	DF	SS	MS	F	Pr > F	post-hoc
Model	2	4836043.54	2418021.77	16.65	0.0001	
Error	123	17858183.32	145188.48			
Age	2	4836043.54	2418021.77	16.65	0.0001	a b c
Corrected Total	125	22694226.86				

a = group A(20-39 yrs) ; b = Group B(40-59 yrs) ; c = Group C (60-73 yrs)

By analyzing Table 9, a one-way ANOVA based on ages showed a valid $F(2, 123)=16.65$ ($p<0.01$) difference in age changes of the women group. In addition, Tukey post-hoc was a statistically significant difference between Group A and B compared to Group C.

From the results above, the most influential factor for BMD in both men and women was revealed to aging and gender factor. In particular, as aging progresses, it is thought that it affects the decrease of BMD and BMC along with the decrease of height and weight. In addition, in women, postmenopausal groups showed a significant decrease in BMC and BMD in the group over 60 years old.

Therefore, it can be considered that changes in body composition with aging drastically reduce BMD and BMC.

4. Discussion

The bones function to mechanically support the body and protect deep organs. They become the center of exercise and serve as a reservoir of various minerals. Bones are continuously developing throughout the growth period until the age of 30 to 40 years when structural growth of the bone is completed.

 doi:10.20944/preprints202008.0485.v1

Therefore, bone mineral density continues to increase, resulting in peak bone mass and solidification. Osteoporosis is a serious metabolic disease that is accompanied by qualitative changes in bone microstructure and it can lead to fractures of the spine, femur, and radius.

The most common metabolic bone disease, osteoporosis, is a condition of reduced BMD. Patients suffering from osteoporosis are at risk of bone fractures even from less forceful impact to the bones [20]. Although osteoporosis is more common in women, previous studies have reported that osteoporotic fractures are also frequent in men [21, 22].

Based on this rationale, this study analyzed the relationship between bone mineral content and adults who are over 20 years old (male=120, female=120) to examine changes in bone density according to gender and age. The purpose of this research is to examine changes in the distribution of bone density in relation to menopause and to use our findings for various medical purposes and practices related to osteoporosis in the future.

In particular, DEXA is the most commonly used clinical tool for the diagnosis of osteoporosis. It is safe because it has relatively less radiation exposure with a short inspection time. In addition, it can directly measure the total bone mass and has high diagnostic accuracy, sensitivity, and reproducibility.

The indicators of bone health are bone mass, BMC and BMD, and BMD alone are used as a standard for diagnosing osteoporosis [23, 24]. Therefore, osteoporosis should be recognized as a major disease that affects both women and men. This current research measured BMC and BMD of 240 adult men and women by using DEXA. The mean BMD in men and women was inversely correlated with age. These findings were similar to the results of Ohmura's study [25], which effectively demonstrated that BMD of Japanese women in their 20s and 70s was inversely proportional to their age. Moreover, the BMC and BMD distinctions in different ages showed that the total mineral contents of men in group A rated the highest, and that of women in group A and B were similar to these results. Also the BMC showed a significant difference according to the age of both male and female, and it showed a negative correlation with decreasing form as aging progressed.

Park et al.[26] reported that age has the highest inverse correlation with BMD. Other factors associated with BMD included race, family history of osteoporosis, estrogen hormone, calcium intake, weight and physique. In addition, age was stated as a major predictor for BMD and osteoporosis[27]. In terms of the difference between total bone mineral content and bone density between the groups, men from group A (20-39 years old) had the highest total bone mineral content. Men from group B also had relatively high bone mineral content compared to men from group C. In the case of women, groups A (20-39 years old) and B (40-59 years old) showed a similar pattern of relatively high bone mineral content compared to group C.

These results are similar to those of a previous study [25, 27], which showed a correlation between age and weight as a factor influencing bone density. Our results are consistent with the findings of Ohmura et al. [25], which showed that Japanese women have low BMDs and the difference is several times greater for women after menopause..

These results are thought to be due to a decrease in bone mineral density and bone mineral contents with increasing age, i.e., a decrease in lean mass, due to increased bone resorption of osteoclasts caused by the lack of estrogen secretion from the ovaries, after menopause. In addition, as noted by Tremollieres & Ribot [27], race, osteoporosis family history, calcium intake, weight and physique may be affected.

Our study was inconsistent with previous studies [28, 29], which showed that the mineral content

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showed a slight increase after the 30s and very rapidly decreased after the 50s, before and after menopause.

Ohmura et. al [25] also mentioned that in pre-menopausal women, Japanese women had 5% lower BMD than Caucasian women in America or Europe, and the difference multiplied after menopause. Unlike women, osteoporosis in men can be classified into primary (with uncertain pathogenic determinants) and secondary (with clear underlying cause). Men more commonly suffer from secondary osteoporosis which can be caused due to low body mass index, smoking, excessive alcohol consumption and lack of exercise.

On the one hand, in bone growth and maintenance, calcium is known as an essential nutrient that is necessary to lower bone replacement rate and to reduce bone resorption [31]. The major causes of reduction in BMD and bone mineral in both men and women as they age are secretion of calcium and phosphorus regulation hormones, changes in bone metabolism, reduction in activities due to aging and lack of proper diet. Thus, for aged women after menopause, the reason behind the reduction in BMD and bone mineral in this study is considered to be reduced estrogen which increases osteoclastic bone resorption. In addition, groups A and B showed a significant difference from C group in BMD and BMC. We confirmed that there was no difference according to age before menopause, and that it was a change corresponding to a time when estrogen deficiency became apparent when the menopause was over 60 years old. On the other hand, low body mass index, smoking, excess alcohol intake, and a lack of exercise are thought to cause BMD reduction in tandem with the influences of hormones in the men. However, there is a significant difference between group A and group C for BMD and BMC factors in men, and there is no significant difference between group B. It is thought that hormone changes are relatively small in the same age group as women. Therefore, it seems that some factors affecting BMD and BMC for women and men are different.

Calcium, which lowers the rate of bone turnover and reduces bone resorption, is known as an essential nutrient [31], which facilitates bone growth and bone preservation. Reduced calcium absorption rates in the bone can lead to reduced bone density and bone mineral quantity in both men and woman as they age. In addition to reduced secretion of phosphorous and calcium regulating hormones, changes in bone metabolism, decreased physical activity and inadequate diet can also reduce BMD and BCD.'

This study indicates that the BMD of adult Korean women is remarkably lower than that of Caucasian women, and BMD reduction accelerates after menopause. This phenomenon is considered to have a close relationship with reduction in muscle mass, especially that of legs. Therefore, we suggest that exercising on a regular basis is critical to maintain muscle mass and BMD before menopause.

Specific exercise-related education and nutrition guides are required according to gender and age.

Finally, we hope that the findings of this study will be helpful to predict the risk of osteoporosis in the future by evaluating the bone density of Koreans according to age group. We also hope that this study helps medical practitioners to make appropriate decisions to help patients cope with the reduction of exercising abilities caused by aging and BMD reduction due to changes in diet habits. We hope this study also encourages the creation of detailed health education guides.

This study should be interpreted considering the following limitations: The results may not be extrapolated to people living in different a environment.

5. Conclusions

In order to prevent osteoporosis in middle aged people, it is necessary to have routine BMD and bone mineral measurement using accurate equipment like DEXA. In addition, sufficient protein, calcium, and Vitamin D intake, and resistive exercises can prevent underweight, and reduction in BMD and BMC. Moreover, for the women near or approaching menopause, proper dietary controls and continuous exercises can protect against drastic decline in body fat, muscle mass and BMD. Furthermore, This study has identified age- and sex-specific differences in BMD & BMC in city-dwelling Koreans. Further studies are however required to be able to extrapolate these findings to a larger population: Comparative studies for adults with different living conditions, such as residents in large cities and rural areas and studies that compare and analyze the correlation between factors related to BMD & BMC are suggested.

Author Contributions: Conceptualization, JC.L. and JY.P.; methodology, HJ.L. and JY.P.; software, JC.L.; formal analysis, JY.P. and HJ.L.; investigation, JC.L. and JY.P.; resources, JC.L.; data curation, JC.L.;Writing—Original draft preparation, JY.P.; Writing—Review and editing, JC.L. HJ.L. and JY.P.; visualization, HJ.L. and JY.P.; supervision, JC.L. and JY.P.; project administration, HJ.L. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Conflicts of Interest: The authors declare no conflict of interest.

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