J. Phys. Ther. Sci.
27: 2261–2270, 2015

Original Article

Physical activity and lifestyle effects on bone mineral density among young adults: sociodemographic and biochemical analysis

Ahmad H. Alghadir[1)], Sami A. Gabr[1, 2)*], Einas Al-Eisa[1)]

[1)] *Rehabilitation Research Chair, Department of Rehabilitation Sciences, College of Applied Medical Sciences, King Saud University: P.O. Box 10219 Riyadh 11433, Saudi Arabia*
[2)] *Department of Anatomy, Faculty of Medicine, Mansoura University, Egypt*

Abstract. [Purpose] The purpose of this study was to assess the possible role of physical activities, calcium consumption and lifestyle factors in both bone mineral density and bone metabolism indices in 350 young adult volunteers. [Subjects and Methods] All volunteers were recruited for the assessment of lifestyle behaviors and physical activity traits using validated questioners, and bone mineral density (BMD), serum osteocalcin (s-OC), bone-specific alkaline phosphatase (BAP), and calcium were estimated using dual-energy X-ray absorptiometry analysis, and immunoassay techniques. [Results] Male participants showed a significant increase in BMD along with an increase in bone metabolism markers compared with females in all groups. However, younger subjects showed a significant increase in BMD, OC, BAP, and calcium compared with older subjects. Osteoporosis was more common in older subjects linked with abnormal body mass index and waist circumference. Bone metabolism markers correlated positively with BMD, physically activity and negatively with osteoporosis in all stages. Also, moderate to higher calcium and milk intake correlated positively with higher BMD. However, low calcium and milk intake along with higher caffeine, and carbonated beverage consumption, and heavy cigarette smoking showed a negative effect on the status of bone mineral density. Stepwise regression analysis showed that life style factors including physical activity and demographic parameters explained around 58–69.8% of the bone mineral density variation in young adults especially females. [Conclusion] body mass index, physical activity, low calcium consumption, and abnormal lifestyle have role in bone mineral density and prognosis of osteoporosis in young adults.
Key words: Bone mineral density (BMD), Lifestyle, Physical activity

(This article was submitted Mar. 11, 2015, and was accepted Apr. 13, 2015)

INTRODUCTION

The strength of healthy bone can be assessed by continuous measurements of bone quality, bone mineral density (BMD), and bone structure[1, 2)]. Currently, these parameters are considered the ideal controlled measures of bone strength in normal and diseased bone cases[3–5)]. As explained from the physiology of bone, its formation is predominant during the first ten years of human growth. A previous study showed a homeostatic balance between the naturally occurring processes of bone formation and resorption among healthy humans with ages of 20–45 yrs; afterwards, in older ages a disorder in the balance state occurred via a slight increase in the resorption process, which in turn resulted in bone loss and a lower bone density[6)].

One of the most important bone diseases is osteoporosis, which is characterized by heavy bone loss and a decrease in its strength which increase the possibility of bone fractures[7, 8)].

In recent years, prevalence of osteoporosis has been increasing steadily worldwide. Osteoporosis occurs in both men and women with advancing age, especially in those over 50 years old[9, 10)]. It has been estimated that femoral neck fractures are increasing worldwide worldwide[11, 12)].

Aspects of human lifestyle such as diet, physical activity, and day time life have positive effects up on bone health especially bone loss or osteoporosis among older people[13)].

The change in bone contents and mass is controlled via many parameters. Genetic factors, peak bone mass (PBM), balanced nutrition, physical activity, and lifestyle risk factors (such as caffeine, tea, and carbonated beverage intakes, smoking, and alcohol consumption) represent most of the parameters that affect accumulation and maintenance of bone mass[8)]. Moreover, anthropometric data (body weight and body mass index [BMI]) are related factors that contribute to changes in total bone mass. Two studies have reported that high BMD is closely associated with elevated BMI in women[12)], and that obesity significantly decreases the risk for osteoporosis but does not decrease the risk for osteopenia[13)]. Also, it was reported that increases in central body fat

*Corresponding author. Sami A. Gabr (E-mail: nadalab2009@hotmail.com)

were negatively associated with BMD[14, 15].

Previously, it was reported that individuals with low physical activity were susceptible to bone disorders including bone loss or osteoporotic fracture[16]. Conversely, physically active people, even those who are older ages, resist the decrease in BMD, and this reduces their risk of fracture. Furthermore, increased physical activity results in an increase in BMD and a concomitant decrease in BMI[15, 17]. Many research works have reported that physical activity provides positive effects on BMD via mechanical loading mechanisms[18–24]. For example, this clearly observed among athletes who had higher BMDs more than age-matched sedentary controls[25, 26]. Thus, previously mentioned studies have reported that the importance of physical activity in reducing bone loss or osteoporosis depends on the design of exercise programs that have probable types and sources of mechanical loading mechanisms. Also, identification of the mechanisms that optimize BMD gain in young people may be the best response for osteoporosis prevention. Thus, we conducted this study to assess the possible effects of physical activity, calcium consumption and lifestyle factors on bone density and bone metabolism indices in young adult volunteers.

SUBJECTS AND METHODS

In the present cross-sectional survey study, data were collected by supervised experience data collectors during a six month period in 2012–2013. The present study examined 350 men and women who were 20–45 years old. Participants who were postmenopausal, were pregnant or had chronic diseases were excluded from this study. The subjects were grouped by age into two groups: group 1 (25–30 yrs; n = 186; 100 males and 86 females), and group 2 (31–45 years; n = 164; 60 males and 104 females). All participants signed an informed consent form before answering the questionnaire. Sociodemographic data were collected from all 350 participants. The present study received prior approval from the Ethics Committee of Rehabilitation Research Chair (RRC), King Saud University, Riyadh, KSA, under file number RRC-2012–005. All basic characteristics of the subjects are shown in Table 1.

Anthropometric data, body weight (kg) and height (m) were measured with a balance-beam scale and a stationary vertical height board. Body mass index (BMI; kg/m^2) was calculated as weight (kg) divided by height squared (m^2). Each participant was classified into one of five groups according to their BMI based on the WHO Asian BMI classifications, which are (1) < 18.5 kg/m^2, underweight; (2) 18.5 to < 23 kg/m^2, normal weight; (3) 23 to < 27.5 kg/m^2, pre-obese; and (4) ≥ 27.5 kg/m^2, obese[27]. Waist circumference (WC; cm) was measured at the minimum circumference between the iliac crest and the rib cage[28]

The questionnaire assessed five components of lifestyle behaviors: exercise, beverage consumption, dairy food intake, smoking, and genetic bone diseases. Each component was assessed with yes/no question; if a question was answered with yes, data was collected to examine the details, type, and frequency (regularity or irregularity by indicating times per week or per month). Data for exercise, beverage consumption, and dairy food intake were assessed during the six month collection periods. Beverage consumption was subdivided into subcategories of (1) tea or coffee (caffeine containing beverages), (2) alcoholic beverages (alcohol, beer or, wine), (3) carbonated sugary beverages (such as cola beverages) or other soft drinks, and (4) milk intake. In addition, data for other supplements (such as calcium rich foods or drugs) were also collected. Quantity of beverage intake was categorized according to average units of consumption, cups or packs, per week or per month. For milk intake, the subjects were assigned to one of two groups, low (less than average) or normal (equal or more than average). Subjects with coffee/tea or soft drink intake were divided into normal (less than average) and high groups (equal or more than average).

The level of physical activity was estimated from the short form of the International Physical Activity Questionnaire (IPAQ). The data were collected as previously reported in the literature[29, 30].

Energy expenditure was estimated based on duration, intensity and frequency of physical activity (PA) performed in a typical week. The unit of measurement for energy expenditure was the Metabolic Equivalent (MET) derived from activity variables of the Global Physical Activity Questionnaire (GPAQ). The participants classified according to energy expenditure into, physically inactive (MET- minutes/ week of ≤ 500, n=25), moderate PA (MET minutes/week of 500–2,500, n= 25), and physically active (≥ 2,500 MET-minutes/ week; n= 25).

Test-retest reliability was assessed for two time points with an interval of 7 days between the two assessments (time 1 and 2). Internal consistency was calculated using Cronbach's alpha (α) for the five components of lifestyle behaviors in the questionnaire (exercise, beverage consumption, dairy food intake, smoking, and genetic bone diseases). The 7-day test-retest reliability was estimated using Pearson r and Spearman's rho statistics. It has been suggested that test-retest reliability coefficients of 0.80 or higher for these statistics are indicative of acceptable test re-test reliability[31]. All statistics were calculated for the entire sample, as well as separately by gender.

The data regarding daily diet, such as consumption of calcium-containing foods (milk, cheese, and yogurt) and of cola beverages were collected form participants food diaries, which were coded, checked for forms, and analyzed according to Canada's food guide to healthy eating[32] and procedures described elsewhere[33].

Lumbar spine, and total and femoral neck bone BMD were measured by a lumbar, dual- energy X-ray absorptiometry device (DXA; model DPX-IQ, software version 4.7e). The variation coefficient for the evaluations of all bone sites were between 0.7% and 2.4%[34].

All serum samples were taken at the same time of day for all participants to determine serum osteocalcin (ng/mL), which was determined using a MicroVue Osteocalcin enzyme immunoassay (QUIDEL Corporation, San Diego, CA), Serum bone-specific alkaline phosphatase (BAP) concentrations (U/L) were measured using a MicroVue BAP immunoenzymetric assay (Quidel Corporation, San Diego, CA, USA), and serum calcium was determined by colorimetric

Table 1. Demographic data, total body BMD, and bone metabolism indices of the 350 subjects

Anthropometric characteristics	Number of subjects (%), M±SD					
	Group 1 (25–30 yrs), n = 186			Group 2 (31–45 yrs), n = 164		
	Men, n=100	Women, n=86	Total, n=186	Men, n=60	Women, n=104	Total, n=164
Age	26.8 ± 4.5	28 ± 3.2	28.7 ± 4.8	39.2 ± 5.7	38.9 ± 6.2	38.6 ± 6.8
Body weight (kg)	56.8 ± 7.9	54.7 ± 9.2	58.7 ± 8.6	54.5 ± 10.4	56.3 ± 11.2	59.7 ± 10.8
Height (cm)	156.5 ± 4.7	162.3 ± 4.3	165.2 ± 3.6	167.4 ± 5.6	158.4 ± 6.2	164.5 ± 7.2
Total body BMD (g/cm^2)	1.3 ± 0.11**	1. 0 ± 0.13**	1.6 ± 0.14**	1.1 ± 0.10**	0.96 ± 0.12**	1.2 ± 0.15**
s.BAP	32.1 ± 5.2**	19.8 ± 4.9**	39.9 ± 5.2**	25.2 ± 6.3**	12.8 ± 3.7**	22.8 ± 2.7**
s. OC	25.5 ± 3.0**	11 ± 1.6**	28.5 ± 8.0**	16.5 ± 3.4**	9.5 ± 2.4**	18.9 ± 5.4**
sT.Ca	3.4 ± 3.1**	1.9 ± 0.6**	3.5 ± 3.6**	2.5 ± 2.6**	1.3 ± 0.5**	2.3 ± 2.6**
s-Ca++	1.9 ± 0.8**	1.2 ± 0.4**	2.8 ± 0.92**	1.5 ± 0.8**	0.9 ± 0.7**	1.85 ± 0.5**
BMI (kg/m^2)						
< 18.5 (underweight)	8 (8.0)	18 (20.93)	26 (13.97)	3 (5.0)	20 (19.2)	23 (14.2)
18.5 – < 23 (normal weight)	70 (70.0)	45 (52.32)	115 (61.8)	21 (35.0)	22 (21.15)	43 (26.2)
23 – < 27.5 (pre-obese)	18 (18.0)	18 (20.93)	36 (19.35)	27 (45.0)	50 (48.1)	77 (46.95)
≥ 27.5 (obese)	4 (4.0)	5 (5.8)	9 (4.8)	9 (15.0)	12 (11.54)	21 (12.8)
WC (cm)						
Normal:						
- WC ≤ 90 cm (males)	76 (76.0)		136 (73.1)	42 (70.0)		
- WC ≤ 80 cm (females)		60 (69.8)			65 (62.5)	125 (65.8)
Abnormal						
- WC > 90 cm (males)	24 (24.0)		50 (26.9)	18 (30.0)		65 (34.2)
- WC > 80 cm (females)		26 (30.23)			39 (37.5)	

BMI: body mass index; BMD: bone mineral density (g/cm^2); sBAP: serum bone-specific alkaline phosphatase (U/I); OC: serum osteocalcin (ng/ml); s-Ca++: serum free calcium (mmol/L); sT-Ca: serum total calcium (mmol/L); WC: waist circumference. *p < 0.05; **p < 0.01

methods with commercially available kits from Hoffmann-La Roche (Switzerland) on a Cobas Integra analyzer.

All statistical analyses were performed using the SPSS for Windows, version 16.0, statistical package (SPSS Software, Inc., Chicago, IL, USA). Firstly, the variables were analyzed in a descriptive way for means and standard deviations (mean ±SD). Repeated measures ANOVA followed by Bonferroni correction for multiple comparisons was applied for normally distributed parameters, and the Wilcoxon test and Student's t-test were applied for nonparametric parameters. An exploratory factor analysis for the components of lifestyle behavior scores were conducted to investigate which common components of the scale more effectively respond to physical activity traits. Estimation of daily calcium intake was positively biased and was corrected by its own square root (√x) before being used in the subsequent analyses. The Pearson (r) correlation coefficient was used for verification of correlations with physical traits, lifestyle, BMI, daily calcium intake, bone metabolism markers, and BMD. The null hypothesis was rejected at P < 0.05, which was the level of significance.

RESULTS

A total of 350 subjects were involved in this study. Based on age, the participants were classified into two groups, group 1 (25–31yrs), and group 2 (31–45 yrs).

Table 1, shows a significant increase (p < 0.01) in total BMD in younger participants (group 1) compared with older participants (group 2). This increase is attributed to the significant (p < 0.01) increase in bone metabolism markers, serum BAP, serum. Osteocalcin (OC), serum total calcium (sT-Ca++), and serum free- calcium(s-Ca++. However, age and gender showed a significant association with the profile of total BMD and bone metabolism markers, and there was significant change in BMD and bone metabolism markers in men compared with women in all participants groups (Table 1). Also, the data showed that the level of bone metabolism markers correlated (p < 0.01) positively with total BMD and negatively with stages of osteoporosis, as shown in Table 5.

Study of the effects of BMI status revealed a significant increase in abnormal BMI in female participants compared with male in all groups. In the studied participants, the ratios of men with a normal BMI (70%; 35%) were higher than those of women (52.32%; 21.15%), respectively, as shown in Table 1. However, abnormal BMI profiles were reported in older men (obesity; 45.0%; 15.0%) and women (pre-obesity; 48.1%; obesity, 11.54%) in all groups compared with younger men (18.0%; 4.0%) and (20.93%; 5.8%), respectively. BMI was shown to be positively correlated with total BMD and negatively correlated with the stages of osteoporosis, as shown in Table 5. These data were supported by the waist circumference (WC) measurements, which revealed different variations in both aged groups. Although most of the subjects showed a normal WC, the proportions of men with a normal WC (more than 70%) were higher than those

Table 2. Assessment of BMD status measured by Lunar DPX-IQ bone densitometer (software version 4.7e) in the 350 subjects

BMD Status (T-score)	Number of subjects (%)					
	Group 1 (25–30 yrs)			Group 2 (31–45 yrs)		
	Men, n=100	Women, n=86	Total, n=186	Men, n=60	Women, n=104	Total, n=164
Normal (T-score ≥−1.0)	85 (85.0)	50 (58.14)	119 (72.6)	34 (66.7)	45 (43.3)	79 (48.2)
Osteopenia (−1.0 >T-score ≥−2.5)	12 (12.0)	30 (34.9)	42 (22.6)	17 (28.3)	40 (38.5)	49 (34.7)
Osteoporosis (T-score <−2.5)	3 (3.0)	6 (6.9)	9 (4.8)	9 (15.0)	19 (18.3)	28 (17.1)

Table 3. Test-re-tests reliability for the components of the lifestyle questionnaire for participants with an interval of 7 days between the two assessments (times 1 and 2)

Stress questionnaire Parameters	Full sample (N=350)		Men (N=160)		Women (N=190)	
	Pearson r	Spearman's rho	Pearson r	Spearman's rho	Pearson r	Spearman's rho
Smoking	0.88	0.89	0.89	0.81	0.82	0.86
Beverage consumption	0.9	0.80	0.88	0.93	0.81	0.81
Genetic bone diseases	0.86	0.91	0.92	0.85	0.87	0.90
Dairy food intake	0.89	0.85	0.91	0.89	0.90	0.88
Exercise (physical activity)	0.87	0.92	0.85	0.80	0.82	0.80
Overall	0.96	0.89	0.98	0.97	0.91	0.85

of women (62.5–69.8%) in both age groups. The numbers of men with a WC above normal were less than those of women (Table 1).

After measurement of BMD, the subjects were classified into 3 groups according to their BMD status: normal BMD (T-score ≥ −1.00) and low BMD, osteopenia (−1.00 > T-score ≥ −2.5) and osteoporosis (T-score < −2.5). The data in Table 2 show this variation in results for both genders. In younger subjects, more than 72.6% of both men and women had a normal BMD, and 22.6 and 4.8% of all subjects were found to have osteopenia and osteoporosis, respectively. However, the women aged 25–30 years showed the highest proportions of osteopenia and osteoporosis (34.9% and 6.9%). Compared with the younger groups, 48.2% of older men and women showed a normal BMD, and 34.7 and 17.1% of all subjects were found to have osteopenia and osteoporosis, respectively. However, the women aged 31–45 years showed the highest proportions of osteopenia and osteoporosis (38.5 and 18.3%).

Table 3, shows the test re-test reliability coefficients for the components of lifestyle questionnaire. The components of the lifestyle questionnaire showed strong reliability across the studied groups (Pearson r = 96; Spearman's rho=0.89). However, the test re-test reliability status of measured life style parameters was higher in men (Pearson r= 98; Spearman's rho=0.97) than in women (Pearson r = 99; Spearman's rho =0.85) at the two assessments (times 1 and 2). The data showed good reliability of the questionnaire with better results for investigating lifestyle among the studied participants.

The subjects of both the younger and older groups were asked to classify their milk consumption as "low", "moderate" or "high". The bone density values for the three groups were measured (Table 4). An analysis of variance indicated significant differences in bone density between the groups. In the 25 to 30 years old group, men and women with moderate milk consumption showed higher value of BMDs compared with those in the older group. However, the women of both groups showed a significant decrease (p=0.01) in BMD values compared with men in the same groups.

Current dietary calcium intake ranged from approximately 150 to 1,650 mg of calcium per day from foods classified as good sources of calcium (more than 75 mg of calcium per serving). The mean calcium intake for all subjects was approximately 800 mg of calcium per day. An analysis of variance indicated that there were significant differences (p=0.01) in bone density between subjects with low (less than 500 mg/d), moderate (500 to 900 mg/d) and high (more than 900 mg/d) dietary calcium intake (Table 4). In addition, there was significant difference in bone density between younger subjects, both men and women, and older subjects.

To investigate the possible relation between bone density and other lifestyle factors (cigarette smoking, coffee or tea consumption, and carbonated beverage intake), the results of men and women from both groups were compared. A significantly (p=0.01) higher bone density was reported for men and women who did not smoke and consumed less than of three cups of coffee, tea, or carbonated beverage per day. On the other hand, a lower mean bone density was reported for all subjects who smoked and consumed higher quantities of coffee, tea or carbonated beverages (Table 4).

The level of physical activity (PAL) appeared more important as a determinant of bone density. Subjects with moderate to high physical activity showed a significant increase (p=0.01) in bone density compared with those of with low physical activity, especially in younger men and women

Table 4. Various lifestyle independent variables and mean bone density in the 350 subjects

Variable	BMD (M± SD), (g/cm^2)			
	Group 1 (25–30 yrs)		Group 2 (31–45 yrs)	
	Men, n=100	Women, n=86	Men, n=60	Women, n=104
Milk consumption				
Low (<3 packs/week)	1.86 ± 0.11 (n=25)	1.74 ± 0.15 (n=45)	1.68 ± 0.14 (n=15)	1.56 ± 0.18 (n=35)
Moderate (3–6 packs/week)**	1.98 ± 0.12 (n=65)	1.89 ± 0.16 (n=35)	1.83 ± 0.16 (n=25)	1.82 ± 0.15 (n=65)
High (≥6 packs/week)	1.76 ± 0.13 (n=10)	1.67 ± 0.14 (n=6)	1.67 ± 0.17 (n=20)	1.64 ± 0.12 (n=4)
Daily coffee / tea consumption, cups				
<3 cups**	1.98 ± 0.13 (n=72)	1.87 ± 0.11 (n=65)	1.91 ± 0.17 (n=45)	1.78 ± 0.11 (n=85)
3–4 cups	1.78 ± 0.15 (n=25)	1.69 ± 0.12 (n=15)	1.78 ± 0.13 (n=11)	1.66 ± 0.12 (n=13)
≥ 5 cups	1.65 ± 0.18 (n=23)	1.56 ± 0.13 (n=6)	1.67 ± 0.152 (n=4)	1.46 ± 0.09 (n=6)
Carbonated beverage intake				
Normal (<3 cups/week) **	2.0 ± 0.11 (n=85)	1.81 ± 0.12 (n=75)	1.96 ± 0.13 (n=55)	1.75 ± 0.10 (n=80)
High (≥3 cups/week)	1.75 ± 0.15 (n=15)	1.67 ± 0.16 (n=11)	1.76 ± 0.12 (n=5)	1.60 ± 0.11 (n=24)
Calcium intake **				
Low (<500 mg/day)	1.86 ± 0.14 (n=12)	1.85 ± 42.1 (n=7)	1.87 ± 0.15 (n=10)	1.78 ± 0.12 (n=35)
Moderate (500–900 mg/day)	1.98 ± 0.18 (n=80)	1.89 ± 0.15 (n=70)	1.88 ± 0.11 (n=42)	1.83 ± 0.08 (n=60)
High (> 900 mg/day)	1.93 ± 0.15 (n=8)	1.83 ±0.17 (n=9)	1.86 ± 0.14 (n=8)	1.81 ± 0.11 (n=9)
Smokes daily **				
No	2.1 ± 0.14 (n=90)	1.85 ± 0.13 (n=84)	1.95 ± 0.17 (n=55)	1.75 ± 0.17 (n=98)
Yes	1.79 ± 0.13 (n=10)	1.68 ± 0.15 (n=2)	1.82 ± 0.13 (n=5)	1.63 ± 0.14 (n=6)
Physical activity level				
Low (< 600 MET – min/week)	1.9 ± 0.15 (n=10)	1.76 ± 0.15 (n=6)	1.7 ± 0.11 (n=10)	1.5 ± 0.12 (n=12)
Moderate (≥ 600 MET– min/week) **	2.99 ± 0.17 (n=75)	1.89 ± 0.12 (n=75)	1.90 ± 0.15 (n=35)	1.86 ± 0.15 (n=73)
High (≥ 3,000 MET – min/week) **	3.2 ± 0.19 (n=15)	1.95 ± 0.13 (n=5)	1.97 ± 0.10 (n=15)	1.92 ± 0.12 (n=19)

BMD: bone mineral density (g/cm^2), *p < 0.05; **p < 0.01.

Table 5. Change in the level of bone metabolism markers and bone mineral density (BMD) in correlation to physical activity of the participants (n=350)

Bone metabolism markers (M ± SD)	Physical activity (IPAQ score; n=350)							
	Group 1 (25–30 yrs, n = 186)				Group 2 (31–45 yrs, n = 164)			
	In active (n =50)		Active (n = 136)		In active (n =100)		Active (n = 64)	
	Male	Female	Male	Female	Male	Female	Male	Female
Number	15	35	85	51	45	55	41	23
BMD	1.9±0.8	1.2±0.45	4.9±2.5 **	2.9±1.1 *	1.7±0.56	0.95±0.31	2.6±1.26 **	1.5±0.72 *
S.BAP	12.8±2.3	10.2±4.2	38.7±8.1 **	21.7±6.2 *	11.5±2.8	8.5±2.3	21.8±9.6 **	18.2±5.3 *
S. OC	18.9±6.2	14.9±3.7	32.8±9.3 **	23.1±4.8 *	14.9±3.4	11.9±3.9	24.7±7.9 **	20.1±6.9 *
sT.Ca	3.1±0.85	0.98±0.21	4.9±1.4 **	2.4±0.95*	1.0±0.25	0.78±0.42	2.9±0.92 **	1.5±0.70*
s-Ca ++	1.85±0.31	1.1±0.22	3.96±0.7 **	2.9±0.32 *	1.1±0.24	0.85±0.34	2.4±1.16 **	1.9±0.82*

BMD: bone mineral density (g/cm^2); sBAP: serum bone-specific alkaline phosphatase (U/I); OC: serum osteocalcin (ng/ml); s-Ca++: serum free calcium (mmol/L); sT-Ca: serum total calcium (mmol/L); *p < 0.01; **p < 0.001

(Table 4). However, a low BMD level was reported in older women compared to younger women. Physical activity was significantly correlated with BMD and bone metabolism markers according to gender and age in all participants, as shown in Table 5.

The correlation matrix between dependent and independent variables demonstrates that the BMDs of the studied subjects tended to increase according to body weight gain, calcium intake, BMI, age and coffee, tea or smoking habit. On the other hand, among the factors related to lifestyle, only calcium intake was negatively correlated with BMD, as reported in Table 6. Body weight, BMI, age, calcium intake, smoking or coffee intake, and PAL explained from 58 to 70% of the BMD variation of the studied subjects (Table 7).

DISCUSSION

Most studies have reported physical activity to be a promising nondrug modulator that enhances bone density and prevents the occurrence of bone loss and osteoporosis among children and adults[35]. Thus, they have reported that it decreases the risk of falling among older adults[36, 37].

Table 6. Correlation matrix between physical traits, lifestyle factors, and bone parameters of the 350 subjects

	Total body BMD	Osteopenia (−1.0 >T-score ≥−2.5)	Osteoporosis (T-score <−2.5)
Age (years)	0.52**	0.73**	0.46**
Gender	0.53**	0.57**	0.47**
Body weight (kg)	0.75**	0.65**	0.64**
BMI (kg/m^2) (under weight and overweight)	−0.67**	−0.48**	−0.58**
S.BAP	0.82**	−0.53**	−0.26**
S. OC	0.49**	−0.57**	−0.37**
sT.Ca	0.95**	−0.95**	−0.94**
s-Ca++	0.87**	−0.68**	−0.38**
Calcium consumption (mg/d)	−0.02**	−0.05**	−0.03**
Smokes daily	0.10*	0.09*	0.14*
Daily coffee / tea consumption	0.18**	0.28**	0.13**
Physical activity level	0.15**	0.11**	0.13**

BMD: bone mineral density (g/cm^2); sBAP: serum bone-specific alkaline phosphatase; OC: serum osteocalcin; s-Ca++: serum free calcium; sT-Ca: serum total calcium.*p < 0.05; **p < 0.01

Table 7. Beta coefficients and cumulative R^{2*} values derived from stepwise multiple regression models

	Full body BMD	Osteopenia	Osteoporosis
	R²*(β)	R²*(β)	R²*(β)
Body weight (kg)	58.3 (0.57)	45.7 (0.43)	43.5 (0.59)
Age (years)	9.8 (0.25)	17.5 (0.35)	5.7 (0.25)
BMI (kg/m^2)	3.7 (0.198)	4.1 (0.27)	3.96 (0.28)
Calcium consumption (mg/dl)	0.7 (0.08)	0.9 (0.09)	0.10 (0.065)
Daily coffee / tea consumption and smoking (cup/d; packs/w)	1.2 (–0.11)	0.7 (–0.08)	2.5 (–0.15)
Physical activity level (MET-minutes/week)	0.12 (0.011)	0.5 (0.073)	0.8 (0.017)
ΣR2 (%)	69.8	65.9	58

BMD: bone mineral density (g/cm^2) *p < 0.05; **p < 0.01

In this study, the BMD status of 350 healthy volunteers of both genders between the ages of 25 and 45. The subjects were classified by gender and age into two groups according to bone physiology (25–30 and 31–45 years). Data representing their anthropometric (BMI and WC) and lifestyle characteristics were collected to evaluate the correlation between them and BMD status.

Anthropometric measures such as BMI and WC are widely used as convenient indices of adiposity. Both BMI and WC were assessed to indicate the anthropometric factors of BMD. Our results showed that in the younger group (25–30 years), a normal BMI was reported in 61.8% of subjects compared with the older group (31–45 years), in which 26.2% of subjects showed a normal BMI. The older group had more individuals who were underweight (14.2 5% and 59.75%) compared with the younger group (13.47% and 24.15%), respectively.

The results of the studied subjects showed a variation in the total BMD according to both gender and age. The mean bone density was significantly higher for subjects with a mean age of 28.7± 4.8 years and especially in men with a mean age of 38.6±6.8 years compared with the other subjects. These data were supported by a significant increase in bone metabolism markers, such as sBAP, OC, sT-Ca, and s-Ca++, in males who had normal demographics and physically active compared with females of the same age group. However, age and gender showed a significant association with the profile of total BMD and bone metabolism markers. There was significant change in BMD and bone metabolism markers in men compared with women in all participants, whereas, the level of bone metabolism markers were correlated ($p < 0.01$) positively with total BMD and negatively with the stages of osteoporosis present in the participants with low physical activity and an abnormal BMI. OC and sBAP have been shown to be sensitive to alterations in bone metabolism due to physical exercise. The data in the present study were in line with those of others who reported significant increases in OC and sBAP following 16 wk of resistance training[38–40]. The data were matched with others who reported significant correlation between serum calcium and bone density in physically active persons. On the other hand, physical activity stimulates the endocrine glands which increases serum calcium and have positive effects on BMD[41]

This prediction is supported by a previous report that concluded that body mass was a factor affecting bone accretion, and that considered body weight a strong predictor of BMD[42]. Although it is widely known that a high body weight or high BMI is related to a high bone mass, this is not the case in our data, there are prior reports indicating that a high percentage body fat and WC were related to a low BMD and vertebral fracture[43], and that obesity significantly decreased the risk of osteoporosis but did not decrease the risk for osteopenia[13]. Moreover, a recent study reported that fat mass was not beneficial to bone in adolescents and young adults[44]. In addition, the supportive results of Guney et al.[45], showed that a lower BMI was associated with a low BMD and fractures. Other studies also found associations between body weight and BMD, both in girls and young women[46, 47]. Bone mineralization and resistance, both in adults and children, result in stress that compresses the skeleton, and since body weight places the most constant mechanical stress on bones, the correlation between BMD and body weight is understandable[48, 49]. Similarly, a previous study reported an association between age and BMD in all bone sites in adolescents[50].

In the present study, higher proportions of normal (73.1%) and lower (26.9%) WC data were reported in younger subjects compared with those obtained for older subjects (65.8%; 34.2%), respectively. However, more abnormal WC data were reported in women than men in both groups. This result parallels that of with Flegal et al.[51] who reported that both BMI and WC were considered more convenient and interrelated parameters that can serve as body fatness indicators more accurately than percentage of body fat. These anthropometric parameters suggested that abnormal BMI in men results from the increase in fat and lean mass but not the central fat. A previous report showed that bone density is closely related to fat mass in premenopausal women, but less so in men[52].

The BMD status of all subjects was assessed by Lunar DPX-IQ bone densitometer. The variation coefficients found in the evaluations for all bone sites were between 0.7% and 2.4%. In this study, bone status was classified into 3 groups; normal BMD (T-score ≥ -1), osteopenia ($-1 >$ Tscore ≥ -2.5) and osteoporosis (T-score < -2.5).

The data obtained showed that 34.7% and 17.1% of older subjects had a low BMD (osteopenia and osteoporosis) compared to younger subjects (22.6% and 4.8%) respectively. According to gender, women of both groups showed a higher proportion of osteopenia and osteoporosis compared with men. On the other hand, older women showed a low BMD (osteopenia, 38.5%; osteoporosis, 18.3%) compared with younger female subjects (34.9%; 6.9%), respectively. Previous studies, reported that after a transient period of stability, an incessant age-related loss of bone begins. The involution of bone with the progress of age is observed in both genders, but the rate of loss is much greater in women[53].

Normally, adolescents and young adult's exhibit rapid growth and their bone mass should reach a maximum, however, variation in BMD values may be related to lifestyle, and recent evidence has revealed that these age groups have increased sweetened beverage consumption and decreased milk consumption, which are associated with low bone density in young adults[54].

Also, most articles reported that promotion of bone loss or osteoporosis emerges from the compatibility action between the remodeling and modeling processes for accrual and bone formation in childhood and adolescence. However, in adulthood, normal bone mass was conserved via a remodeling mechanism[55].

Our data about lifestyle behaviors of young adults indicate determinants of low bone mass; certain lifestyle behaviors are a concern, but remedying them may prevent osteoporosis in later life. However, when considering the BMD status of all subjects, we found that 26.0% and 0.11% had osteopenia and osteoporosis, respectively. The data obtained of all studied groups suggested that BMD status could be correlated with promoting risk factors of bone mass later with aging.

In addition to the anthropometric factors, lifestyle factors such as caffeine or tea intake, carbonated beverages intakes, smoking, dairy food intake, and exercise were also assessed in this study. The range of dietary calcium intake among our subjects paralleled that reported for Western populations[56].

Our results indicate that subjects with moderate to high dietary calcium and milk intake showed a significant increase in total BMD among both age groups. It was reported that low calcium intake among children and adolescents increased their exposure rates to bone loss and osteoporosis in adulthood[57, 58].

Milk is considered one of the most complete foods enriched with needed amounts of minerals such as calcium and essential vitamins for formation of healthy bone. It was reported in previous studies that calcium has a positive effect on bone mass formation among all ages of the population, children, adolescents, adults, and the elderly[59]. This is due to the high levels of calcium in milk, as reported previously[60]. Milk has been recommended for premenopausal women to provide a positive improvement in bone density[61].

Regarding the clinical significance of influences such as cigarette smoking on BMD, it is uncertain whether smoking causes loss of bone or fracture[62]. However, smoking may promote postmenopausal bone loss[63].

The data of our study showed a negative effect of cigarette smoking on the status of BMD among older subjects especially women compared with men. The data showed a significant correlation ($p=0.01$) with total BMD and osteoporosis. Women who smoke cigarettes experience menopause earlier[64], and have a lower body weights and lower serum estrogen concentrations than women who do not smoke[65]. In past years, there has not been enough data available concerning the effects of smoking on bone density; however, the influence may be indirectly mediated through factors such as estrogen[62].

Recently, research work has shown that smoking negatively affects on BMD among males, as shown by a reduction in bone density at the hip and distal and ultra distal forearm. It has also been concluded that the harmful effect of smoking is dependent on the time period rather than the dose among elderly men[63, 64].

The drastic effect of smoking habit on bone, especially the trabecular bone, and its variable effect according to gender may be related to significant changes in hormonal levels in both genders[65]. Smoking produces significant anti-

estrogenic effects among female smokers[66], and increased levels of free testosterone in male smokers[67–70]. So, in our study, the difference in the data between females and males may be related to changes in gonadal hormones caused by smoking.

In the present study, consumption of caffeine and carbonated beverages and low milk intake were considered a significant variables and potential determinants of BMD (p-value = 0.01). The data showed heavy caffeine and carbonated beverages intakes was often associated with a low BMD in subjects, and depending on the level of milk intake, this could result in bone fractures, especially in women of both age groups. This analysis is in agreement with a previous study reporting that coffee or caffeine intake was a risk factor for bone fracture depending on the level of milk intake, but only in individuals with low calcium intakes[71].

According to the National Osteoporosis Foundation (NOF)[72], people who have large amounts of caffeine intakes per day may have an increased risk of broken bones and that larger coffee intake may interfere with the calcium absorption in the intestine and in turn promotes bone loss with time. Although, Heaney[73] reported a negative effect of caffeine on calcium absorption that considered too small, and could be compensated with more milk and calcium uptake according to the standard values previously recommended by NOF[72].

Furthermore, Conlisk and Galuska[74] revealed that excess caffeine consumption contributed to a significant decrease in BMD in both the lumbar spine and femoral neck of healthy white women aged 19−26 years. These findings should be taken into account to protect low bone mass resulting from excess caffeine intake.

Besides caffeinated beverages, it has been widely reported that consumption of carbonated beverages has a negative effect on bone mineral accrual with poor calcium intakes. Low calcium intake among children and adolescents increases their risk of osteoporosis in later life[75, 76]. Although, most of our subjects had lower intakes of caffeine and carbonated beverages (soft drinks), both factors should be a concern for young adults to maintain and promote bone health during old age. The tendency to consume these beverages increased with advancing age. A recent study by Kalkwarf et al.[75] suggested that the protective bone mass collection behavior is important in premenopausal women if they did not obtain sufficient calcium in their diet during the period in which they had their maximal peak bone mass. The young subjects in our study in particular should increase their consumption of milk or calcium-rich foods to promote bone health and prevent osteoporosis during aging.

Physical activity with various mechanical loadings plays an integral part in stimulating bone formation and thus aids in regulating bone size, shape, and strength[77].

The most important lifestyle factor recorded in this study is the type and frequency of exercise. The PAL appeared to be more important as a determinant of bone density. Subjects with moderate to high physical activity showed a significant increase (p=0.01) in bone density compared with those with low physical activity, especially in younger men and women. Most studies reported significant positive correlation between BMD and physical activity[19, 21].

Generally, most human studies have reported that mechanical loading of physical exercise produces a significant increase in BMD among athletes and tennis players compared with sedentary controls of the same age [22, 78–80]. Also, supporting research data obtained from pre- and peripubertal children confirmed that physical exercise of various intensities produces a remarkable increase in BMD, as previously reported in the literature. However, the effect of physical activity has a differential effect according to age whereas in older adults, with the effect of physical activity on BMD in older adults being smaller and less consistent[81–83]. Also, previous studies showed significant continuing increase in bone mass in exercising premenopausal young women compared to non-exercising controls[84, 85]. Similarly, adolescent athletes of both genders involved in weight-bearing or high-impact activities showed higher bone densities and larger bone sizes than sedentary controls who were less active[86, 87].

Thus most studies confirmed that exercise has more positive effects on bone improvement in early periods of age that extend into adulthood to conserve bone or resist bone loss or disorder in into adulthood[88]. Thus, exercise at younger ages appears to have a significant role in preventing bone loss or osteoporosis in the elderly. Our study confirmed these observations by clearly showing that physical activity was positively correlated with high BMD.

In summary, our study showed that BMI, physical activity, calcium and milk intake, age, and anthropometric data are factors that correlate with BMD status in young adults.

In conclusion, our data suggested that BMI and physical activity, along with other risk factors such as low milk and calcium consumption, high caffeine and carbonated beverage intake, and smoking, are also associated with BMD.

ACKNOWLEDGEMENT

This project was financially supported by King Saud University, Vice Deanship of Research Chairs, Rehabilitation Research Chair.

REFERENCES

1) NIH Consensus Development Panel on Osteoporosis Prevention, Diagnosis, and Therapy: Osteoporosis prevention, diagnosis, and therapy. JAMA, 2001, 285: 785–795. [Medline] [CrossRef]
2) Cho JH, Kim MT, Lee HK, et al.: Factor analysis of biochemical markers associated with bone mineral density in adults. J Phys Ther Sci, 2014, 26: 1225–1229. [Medline] [CrossRef]
3) Tanaka R, Junya Ozawa J, Umehara T: Does exercise intervention improve muscle strength and balance of Japanese subjects with osteoporosis?: a systematic review and meta-analysis of randomized controlled trials. J Phys Ther Sci, 2013, 25: 397–401. [CrossRef]
4) Ammann P, Rizzoli R: Bone strength and its determinants. Osteoporos Int, 2003, 14: S13–S18. [Medline]
5) Kanis JA, Borgstrom F, De Laet C, et al.: Assessment of fracture risk. Osteoporos Int, 2005, 16: 581–589. [Medline] [CrossRef]
6) Johnell O, Kanis JA, Oden A, et al.: Predictive value of BMD for hip and other fractures. J Bone Miner Res, 2005, 20: 1185–1194. [Medline] [CrossRef]
7) Ralston SH: Bone Mass through the Lifespan. In: Women's Health Medicine. Elsevier, 2006, pp 145–148.
8) Korkmaz N, Tutoğlu A, Korkmaz I, et al.: The relationships among vitamin D level, balance, muscle strength, and quality of life in postmenopausal patients with osteoporosis. J Phys Ther Sci, 2014, 26: 1521–1526. [Medline] [CrossRef]
9) Melton LJ 3rd: Epidemiology worldwide. Endocrinol Metab Clin North

Am, 2003, 32: 1–13, v. [Medline] [CrossRef]
10) Bonura F: Prevention, screening, and management of osteoporosis: an overview of the current strategies. Postgrad Med, 2009, 121: 5–17. [Medline] [CrossRef]
11) Demir M, Ulas T, Tutoglu A, et al.: Evaluation of oxidative stress parameters and urinary deoxypyridinoline levels in geriatric patients with osteoporosis. J Phys Ther Sci, 2014, 26: 1405–1409. [Medline] [CrossRef]
12) Handa R, Ali Kalla A, Maalouf G: Osteoporosis in developing countries. Best Pract Res Clin Rheumatol, 2008, 22: 693–708. [Medline] [CrossRef]
13) WHO: Scientific Group on the Prevention and Management of Osteoporosis. Prevention and management of osteoporosis: report of a WHO Scientific Group, Geneva, PA. Geneva: World Health Organization, 2000, pp 1–3.
14) Cassidy A: Diet and menopausal health. Nurs Stand, 2005, 19: 44–52, quiz 54–55. [Medline] [CrossRef]
15) Han JT, Lee SY: A comparison of vital capacity between normal weight and underweight women in their 20s in South Korea. J Phys Ther Sci, 2012, 24: 379–381. [CrossRef]
16) Morin S, Leslie WD, Manitoba Bone Density Program: High bone mineral density is associated with high body mass index. Osteoporos Int, 2009, 20: 1267–1271. [Medline] [CrossRef]
17) Andreoli A, Bazzocchi A, Celi M, et al.: Relationship between body composition, body mass index and bone mineral density in a large population of normal, osteopenic and osteoporotic women. Radiol Med (Torino), 2011, 116: 1115–1123. [Medline] [CrossRef]
18) Fu X, Ma X, Lu H, et al.: Associations of fat mass and fat distribution with bone mineral density in pre- and postmenopausal Chinese women. Osteoporos Int, 2011, 22: 113–119. [Medline] [CrossRef]
19) Moayyeri A: The association between physical activity and osteoporotic fractures: a review of the evidence and implications for future research. Ann Epidemiol, 2008, 18: 827–835. [Medline] [CrossRef]
20) Langsetmo L, Hitchcock CL, Kingwell EJ, et al. Canadian Multicentre Osteoporosis Study Research Group: Physical activity, body mass index and bone mineral density-associations in a prospective population-based cohort of women and men: the Canadian Multicentre Osteoporosis Study (CaMos). Bone, 2012, 50: 401–408. [Medline] [CrossRef]
21) Shipp KM: Exercise for people with osteoporosis: translating the science into clinical practice. Curr Osteoporos Rep, 2006, 4: 129–133. [Medline] [CrossRef]
22) Zernicke R, MacKay C, Lorincz C: Mechanisms of bone remodeling during weight-bearing exercise. Appl Physiol Nutr Metab, 2006, 31: 655–660. [Medline] [CrossRef]
23) Barry DW, Kohrt WM: Exercise and the preservation of bone health. J Cardiopulm Rehabil Prev, 2008, 28: 153–162. [Medline] [CrossRef]
24) Beck BR, Snow CM: Bone health across the lifespan—exercising our options. Exerc Sport Sci Rev, 2003, 31: 117–122. [Medline] [CrossRef]
25) Kohrt WM, Bloomfield SA, Little KD, et al. American College of Sports Medicine: American College of Sports Medicine Position Stand: physical activity and bone health. Med Sci Sports Exerc, 2004, 36: 1985–1996. [Medline] [CrossRef]
26) Nikander R, Sievänen H, Heinonen A, et al.: Femoral neck structure in adult female athletes subjected to different loading modalities. J Bone Miner Res, 2005, 20: 520–528. [Medline] [CrossRef]
27) Wee HL, Cheung YB, Loke WC, et al.: The association of body mass index with health-related quality of life: an exploratory study in a multiethnic Asian population. Value Health, 2008, 11: S105–S114. [Medline] [CrossRef]
28) Aekplakorn W, Kosulwat V, Suriyawongpaisal P: Obesity indices and cardiovascular risk factors in Thai adults. Int J Obes, 2006, 30: 1782–1790. [CrossRef]
29) Bull FC, Maslin TS, Armstrong T: Global physical activity questionnaire (GPAQ): nine country reliability and validity study. J Phys Act Health, 2009, 6: 790–804. [Medline]
30) Trinh OT, Nguyen ND, van der Ploeg HP, et al.: Test-retest repeatability and relative validity of the Global Physical Activity Questionnaire in a developing country context. J Phys Act Health, 2009, 6: S46–S53. [Medline]
31) Kline P: Handbook of Psychological Testing, 2nd ed. New York: Routledge.2000.
32) Canada's food guide to healthy eating (2003). Ottawa, Canada (Health Canada), 1992. http:/www.hc-sc.gc.ca/nutrition.
33) Whiting SJ, Colleaux C, Bacchetto T: Dietary intakes of children age 8 to 15 years living in Saskatoon. J Can Diet Assoc, 1995, 56: 119–125.
34) Fonseca RM, de França NM, Van Praagh E: Relationship between indicators of fitness and bone density in adolescent Brazilian children. Pediatr Exerc Sci, 2008, 20: 40–49. [Medline]
35) Nordström A, Karlsson C, Nyquist F, et al.: Bone loss and fracture risk after reduced physical activity. J Bone Miner Res, 2005, 20: 202–207. [Medline] [CrossRef]
36) Winters-Stone KM, Snow CM: Site-specific response of bone to exercise in premenopausal women. Bone, 2006, 39: 1203–1209. [Medline] [CrossRef]
37) Tanaka R, Ozawa J, Umehara T: Exercise intervention to improve the bone mineral density and bone metabolic markers as risk factors for fracture in Japanese subjects with osteoporosis: a systematic review and meta-analysis of randomized controlled trials. J Phys Ther Sci. 2012, 24: 1349–1353. [CrossRef]
38) González-Agüero A, Vicente-Rodríguez G, Gómez-Cabello A, et al.: A 21-week bone deposition promoting exercise programme increases bone mass in young people with Down syndrome. Dev Med Child Neurol, 2012, 54: 552–556. [Medline] [CrossRef]
39) Maïmoun L, Mariano-Goulart D, Couret I, et al.: Effects of physical activities that induce moderate external loading on bone metabolism in male athletes. J Sports Sci, 2004, 22: 875–883. [Medline] [CrossRef]
40) Aydın T, Taspınar O, Akbal Y, et al.: Serum bone markers levels and bone mineral density in familial mediterranean Fever. J Phys Ther Sci, 2014, 26: 1459–1463. [Medline] [CrossRef]
41) Pourvaghar MJ: The effect of 2 month-regular aerobic training on students' rest time serum calcium, phosphorus and magnesium variations. Gazz Med Ital, 2008, 167: 105–108.
42) Elgán C, Fridlund B: Bone mineral density in relation to body mass index among young women: a prospective cohort study. Int J Nurs Stud, 2006, 43: 663–672. [Medline] [CrossRef]
43) Kim KC, Shin DH, Lee SY, et al.: Relation between obesity and bone mineral density and vertebral fractures in Korean postmenopausal women. Yonsei Med J, 2010, 51: 857–863. [Medline] [CrossRef]
44) Janicka A, Wren TA, Sanchez MM, et al.: Fat mass is not beneficial to bone in adolescents and young adults. J Clin Endocrinol Metab, 2007, 92: 143–147. [Medline] [CrossRef]
45) Guney E, Kisakol G, Ozgen G, et al.: Effect of weight loss on bone metabolism: comparison of vertical banded gastroplasty and medical intervention. Obes Surg, 2003, 13: 383–388. [Medline] [CrossRef]
46) El Hage R, Jacob C, Moussa E, et al.: Influence of the weight status on bone mineral content and bone mineral density in a group of Lebanese adolescent girls. Joint Bone Spine, 2009, 76: 680–684. [Medline] [CrossRef]
47) Wang MC, Bachrach LK, Van Loan M, et al.: The relative contributions of lean tissue mass and fat mass to bone density in young women. Bone, 2005, 37: 474–481. [Medline] [CrossRef]
48) Hall SJ: Biomecanica Basica, 4th ed. Rio de Janeiro: Guanabara Koogan, 2000.
49) Koca I, Boyaci A, Tutoglu A, et al.: The relationship between quadriceps thickness, radiological staging, and clinical parameters in knee osteoarthritis. J Phys Ther Sci, 2014, 26: 931–936. [Medline] [CrossRef]
50) Arabi A, Nabulsi M, Maalouf J, et al.: Bone mineral density by age, gender, pubertal stages, and socioeconomic status in healthy Lebanese children and adolescents. Bone, 2004, 35: 1169–1179. [Medline] [CrossRef]
51) Flegal KM, Shepherd JA, Looker AC, et al.: Comparisons of percentage body fat, body mass index, waist circumference, and waist-stature ratio in adults. Am J Clin Nutr, 2009, 89: 500–508. [Medline] [CrossRef]
52) Reid IR, Plank LD, Evans MC: Fat mass is an important determinant of whole body bone density in premenopausal women but not in men. J Clin Endocrinol Metab, 1992, 75: 779–782. [Medline]
53) Nilas L, Christiansen C: Bone mass and its relationship to age and the menopause. J Clin Endocrinol Metab, 1987, 65: 697–702. [Medline] [CrossRef]
54) Nielsen SJ, Popkin BM: Changes in beverage intake between 1977 and 2001. Am J Prev Med, 2004, 27: 205–210. [Medline] [CrossRef]
55) Rizer MK: Osteoporosis. Prim Care Clin Off Pract, 2006, 33: 943–951. [CrossRef]
56) Walker AR: The human requirement of calcium: should low intakes be supplemented? Am J Clin Nutr, 1972, 25: 518–530. [Medline]
57) French SA, Lin BH, Guthrie JF: National trends in soft drink consumption among children and adolescents age 6 to 17 years: prevalence, amounts, and sources, 1977/1978 to 1994/1998. J Am Diet Assoc, 2003, 103: 1326–1331. [Medline] [CrossRef]
58) Whiting SJ, Healey A, Psiuk S, et al.: Relationship between carbonated and other low nutrient dense beverages and bone mineral content of adolescents. Nutr Res, 2001, 21: 1107–1115. [CrossRef]
59) Cashman KD: Review: Milk minerals (including trace elements) and bone health. Int Dairy J, 2006, 16: 1389–1398. [CrossRef]
60) Institute of Medicine: Dietary Reference Intakes: Calcium, Magnesium, Phosphorus Vitamin D, and Fluoride. National Academy Press, USA, 1997.

61) Welten DC, Kemper HC, Post GB, et al.: A meta-analysis of the effect of calcium intake on bone mass in young and middle aged females and males. J Nutr, 1995, 125: 2802–2813. [Medline]
62) Rodysill KJ: Postmenopausal osteoporosis—intervention and prophylaxis. A review. J Chronic Dis, 1987, 40: 743–760. [Medline] [CrossRef]
63) Daniell HW: Osteoporosis of the slender smoker. Vertebral compression fractures and loss of metacarpal cortex in relation to postmenopausal cigarette smoking and lack of obesity. Arch Intern Med, 1976, 136: 298–304. [Medline] [CrossRef]
64) Andersen FS, Transbøl I, Christiansen C: Is cigarette smoking a promotor of the menopause? Acta Med Scand, 1982, 212: 137–139. [Medline] [CrossRef]
65) Jensen J, Christiansen C, Rødbro P: Cigarette smoking, serum estrogens, and bone loss during hormone-replacement therapy early after menopause. N Engl J Med, 1985, 313: 973–975. [Medline] [CrossRef]
66) Sneve M, Emaus N, Joakimsen RM, et al.: The association between serum parathyroid hormone and bone mineral density, and the impact of smoking: the Tromso Study. Eur J Endocrinol, 2008, 158: 401–409. [Medline] [CrossRef]
67) Ward KD, Klesges RC: A meta-analysis of the effects of cigarette smoking on bone mineral density. Calcif Tissue Int, 2001, 68: 259–270. [Medline] [CrossRef]
68) Hannan MT, Felson DT, Dawson-Hughes B, et al.: Risk factors for longitudinal bone loss in elderly men and women: the Framingham Osteoporosis Study. J Bone Miner Res, 2000, 15: 710–720. [Medline] [CrossRef]
69) Kapoor D, Jones TH: Smoking and hormones in health and endocrine disorders. Eur J Endocrinol, 2005, 152: 491–499. [Medline] [CrossRef]
70) Lorentzon M, Mellström D, Haug E, et al.: Smoking is associated with lower bone mineral density and reduced cortical thickness in young men. J Clin Endocrinol Metab, 2007, 92: 497–503. [Medline] [CrossRef]
71) Barrett-Connor E, Chang JC, Edelstein SL: Coffee-associated osteoporosis offset by daily milk consumption. The Rancho Bernardo Study. JAMA, 1994, 271: 280–283. [Medline] [CrossRef]
72) National Osteoporosis Foundation (NOF): Can soft drinks cause a problem for my bones? 2011, http://www.nof.org (Accessed May 2012)
73) Heaney RP: Effects of caffeine on bone and the calcium economy. Food Chem Toxicol, 2002, 40: 1263–1270. [Medline] [CrossRef]
74) Conlisk AJ, Galuska DA: Is caffeine associated with bone mineral density in young adult women? Prev Med, 2000, 31: 562–568. [Medline] [CrossRef]
75) Kalkwarf HJ, Khoury JC, Lanphear BP: Milk intake during childhood and adolescence, adult bone density, and osteoporotic fractures in US women. Am J Clin Nutr, 2003, 77: 257–265. [Medline]
76) Hsieh YF, Turner CH: Effects of loading frequency on mechanically induced bone formation. J Bone Miner Res, 2001, 16: 918–924. [Medline] [CrossRef]
77) Karlsson MK, Hasserius R, Obrant KJ: Bone mineral density in athletes during and after career: a comparison between loaded and unloaded skeletal regions. Calcif Tissue Int, 1996, 59: 245–248. [Medline] [CrossRef]
78) Bass SL, Saxon L, Daly RM, et al.: The effect of mechanical loading on the size and shape of bone in pre-, peri-, and postpubertal girls: a study in tennis players. J Bone Miner Res, 2002, 17: 2274–2280. [Medline] [CrossRef]
79) Nurmi-Lawton JA, Baxter-Jones AD, Mirwald RL, et al.: Evidence of sustained skeletal benefits from impact-loading exercise in young females: a 3-year longitudinal study. J Bone Miner Res, 2004, 19: 314–322. [Medline] [CrossRef]
80) Lee DJ, Ko WS, Cho BJ: The effects of exercise participation on bone mineral density and bone mineral content in swimmers. J Phys Ther Sci, 2012, 24: 1137–1139. [CrossRef]
81) Gunter K, Baxter-Jones AD, Mirwald RL, et al.: Jump starting skeletal health: a 4-year longitudinal study assessing the effects of jumping on skeletal development in pre and circum pubertal children. Bone, 2008, 42: 710–718. [Medline] [CrossRef]
82) Wallace BA, Cumming RG: Systematic review of randomized trials of the effect of exercise on bone mass in pre- and postmenopausal women. Calcif Tissue Int, 2000, 67: 10–18. [Medline] [CrossRef]
83) Kim IG, So WY: The relationship between household income and physical activity in Korea. J Phys Ther Sci, 2014, 26: 1887–1889. [Medline] [CrossRef]
84) Ginty F, Rennie KL, Mills L, et al.: Positive, site-specific associations between bone mineral status, fitness, and time spent at high-impact activities in 16- to 18-year-old boys. Bone, 2005, 36: 101–110. [Medline] [CrossRef]
85) Kamide N, Shiba Y, Koide K: The timed up and go test is related to quantitative ultrasound parameters of bone strength in Japanese community-dwelling elderly women. J Phys Ther Sci, 2009, 21: 373–378. [CrossRef]
86) Nordström A, Högström M, Nordström P: Effects of different types of weight-bearing loading on bone mass and size in young males: a longitudinal study. Bone, 2008, 42: 565–571. [Medline] [CrossRef]
87) Forwood MR, Baxter-Jones AD, Beck TJ, et al.: Physical activity and strength of the femoral neck during the adolescent growth spurt: a longitudinal analysis. Bone, 2006, 38: 576–583. [Medline] [CrossRef]
88) Bass S, Pearce G, Bradney M, et al.: Exercise before puberty may confer residual benefits in bone density in adulthood: studies in active prepubertal and retired female gymnasts. J Bone Miner Res, 1998, 13: 500–507. [Medline] [CrossRef]