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CARDIOVASCULAR IMAGING

ORIGINAL ARTICLE

The relationship between bone mineral density and arterial stiffness in women

Murat Baykara, Cansu Öztürk, Filiz Elbüken

PURPOSE
The aim of this study was to investigate the correlation between bone mineral density (BMD) and arterial stiffness as a preclinical atherosclerosis criterion.

MATERIALS AND METHODS
Carotid and femoral artery Doppler ultrasonography and arterial stiffness measurements were performed on 113 female patients referred for BMD measurements.

RESULTS
The cross-sectional compliance and cross-sectional distensibility of the carotid artery were positively correlated with the BMD of the Ward's triangle, the femoral neck, and the lower femoral neck; and the Ward's triangle, respectively. A negative correlation was found between the intima-media thickness of the femoral artery and the femoral elastic modulus with the BMD of L1, L12, L13, and L23; and the BMD of L1, L3, L13, L24, L34, the femoral neck, the lower femoral neck, and Ward's triangle, respectively. The cross-sectional compliance and cross-sectional distensibility of the femoral artery were positively correlated with the BMD of the femoral neck, upper femoral neck, lower femoral neck, Ward's triangle; and the BMD of the total femur and Ward's triangle, respectively.

CONCLUSION
The arterial stiffness measurements in women are correlated with BMD, regardless of age and other demographic factors.

Key words: • *bone density* • *common carotid artery* • *femoral artery* • *elastic modulus* • *arterial stiffness*

Osteoporosis and atherosclerosis are the two most common diseases in older women. Usually, they are simultaneously present in the same individual and insidiously progress when a fracture or myocardial infarction occurs (1, 2).

Functional disorders of the arterial wall may develop much earlier than the appearance of the clinical signs of cardiovascular disease and structural changes of the arterial wall (3).

A strong relationship exists between coronary artery disease and intima-media thickness (IMT) of the main carotid artery, and between local atherosclerosis and IMT of the femoral artery (4, 5). Thus, the IMT measurement of the distant wall by high-resolution ultrasonography has been proven to be a beneficial clinical index in the early recognition of lower extremity and general atherosclerosis (1).

Arterial distensibility (AD) is a measurement of expansion and contraction abilities of the arteries caused by cardiac pulsation and relaxation (3). Both osteoporosis and atherosclerosis have been substantially attributed to the aging process (1). However, recent studies have shown that atherosclerosis, which shows a striking resemblance to bone turnover, and likely to be independent from age, is a systematic process (1, 6, 7).

Carotid flexibility was used as a new risk factor for cardiovascular disease in the design of population-based cohort or cross-sectional studies, including the Atherosclerosis Risk in Communities (ARIC), the Second Manifestations of Arterial Diseases (SMART), the Rotterdam study, the Baltimore Longitudinal Study of Aging (BLSA), and the Multi-Ethnic Study of Atherosclerosis (MESA) (3, 4, 8–10).

The discrepancies in the results of studies on the relationship between AD and atherosclerosis may be attributed to several factors, such as small sample sizes, dissimilar clinical characteristics of the study populations, AD analyses, being limited to different vascular beds, and the variability of the measurements (3).

Indices of arterial stiffness, including pulse wave velocity (PWV), have been found to be higher among those with angiographic coronary artery disease, as compared with individuals who do not have angiographic coronary artery disease, and some studies have demonstrated a positive correlation between arterial stiffness and the severity of coronary artery disease (11).

Previous studies have shown an association between osteoporosis and aortic and carotid atherosclerosis, cardiovascular mortality, stroke, and other causes of death among males and females (12–16).

The measurement of brachial-ankle PWV, which has a close association with carotid-femoral PWV, using advanced devices, allowed the prediction of carotid-femoral PWV to be made more easily. These PWV values were higher in subjects with coronary artery disease or with coronary risk factors, as compared with healthy subjects without risk factors.

From the Department of Radiology (M.B. ✉ *muratbaykara@hotmail.com*), Elazığ Training and Research Hospital, Elazığ, Turkey.

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A negative correlation was reported between PWV and bone mineral density (BMD) (17).

Although it is not known whether a relationship exists between osteoporosis and the incidence of cardiovascular disease, an increased arterial stiffness is observed in postmenopausal women with osteoporosis (15, 18).

The aim of the present study was to investigate the usefulness of the correlation between BMD and arterial stiffness measurements as a preclinical atherosclerosis criterion.

Materials and methods

A total of 113 female patients who had been clinically referred for BMD analysis were included in the study. The mean age of the participants was 57.8 years (range, 31.9–77.9 years). They underwent Doppler ultrasonography examinations using an SSA-660A ultrasound system (Xario, Toshiba Medical Systems Corporation, Tochigi, Japan) and a PLT-704AT Probe (Toshiba Medical Systems Corporation). The probe was placed 2 cm proximal to bifurcation of the right carotid artery and 2 cm distal to the separation of the deep branch of the right femoral artery, and evaluation of the arterial stiffness measurements was performed by a pre-defined method (19).

All non-invasive measurements were made by the same investigator. IMTs and lumen diastolic (dD) and systolic (sD) diameters were measured at the common carotid and femoral artery.

The lumen cross-sectional area was calculated as $\pi dD^2/4$ and the wall cross-sectional area as $\pi(dD/2+IMT)^2-\pi(dD/2)^2$. Cross-sectional compliance and distensibility of the common carotid artery were calculated from diameter changes during systole and from simultaneously measured pulse pressure (ΔP) according to the following formula: Cross-sectional compliance=$\pi[(sD^2-dD^2)]/4\Delta P$; cross-sectional distensibility=$(sD^2-dD^2)/(dD^2.\Delta P)$. Diastolic wall stress was calculated as the mean arterial pressure multiplied by dD/2IMT. Whereas compliance provides information on elasticity of the artery as a hollow structure, incremental elastic modulus provides information on the properties of the wall material independently from arterial geometry. This variable was calculated as 3/(1+lumen cross-sectional area/wall cross-sectional area) divided by cross-sectional distensibility. Repeatability of measurements was assessed as previously described.

Arterial blood pressure measurements of the subjects were performed using an automatic sphygmomanometer (Vitagnost 2015 OC, MARS, Taiwan). Age, weight, height, and waist and hip circumference measurements, and other findings of the patients were recorded.

Relations were examined with Pearson's correlation coefficient using a computer software (Statistical Package for Social Sciences version 15.0, SPSS Inc., Chicago, Illinois, USA). A P value less than 0.05 was deemed to indicate statistical significance.

Results

A weak positive correlation was found between the cross-sectional compliance of the carotid artery and the BMD of Ward's triangle (r=0.197; $P = 0.068$). For cross-sectional distensibility of the carotid artery, a weak positive correlation was found with the BMD of the femoral neck (r=0.194; $P = 0.048$), lower femoral neck (r=0.213; $P = 0.042$), and Ward's triangle (r=0.251; $P = 0.007$). A weak negative correlation was found between carotid diastolic wall stress and the BMD of the femoral neck (r=-0.192; $P = 0.039$) and lower femoral neck (r=-0.209; $P = 0.026$). In terms of carotid elastic modulus, a weak negative correlation was found with the BMD of Lumbar spine (L) 1 (r=-0.219; $P = 0.020$), the lower femoral neck (r=-0.186; $P = 0.048$), and Ward's triangle (r=-0.252; $P = 0.002$).

A weak negative correlation was found between IMT of the femoral artery and the BMD of L1 (r=-0.188; $P = 0.046$), L12 (r=-0.197; $P = 0.067$), L13 (r=-0.196; $P = 0.036$), and L23 (r=-0.190; $P = 0.037$). For cross-sectional compliance of the femoral artery, a weak positive correlation was found with the BMD of the femoral neck (r=0.346; $P = 0.001$), upper femoral neck (r=0.215; $P = 0.027$), lower femoral neck (r=0.279; $P = 0.005$), Ward's triangle (r=0.386; $P = 0.001$), and with the BMD of the total femur (r=0.253; $P = 0.006$). A weak positive correlation was found between the femoral cross-sectional distensibility and the BMD of Ward's triangle (r=0.243; $P = 0.002$). For femoral elastic modulus, a weak negative correlation was found with the BMD of L1 (r=-0.189; $P = 0.045$), L3 (r=-0.210; $P = 0.018$), L13 (r=-0.185; $P = 0.049$), L24 (r=-0.192; $P = 0.045$), L34 (r=-0.194; $P = 0.040$), the femoral neck (r=-0.243; $P = 0.009$), the lower femoral neck (r=-0.230; $P = 0.025$), and Ward's triangle (r=-0.270; $P = 0.006$). The study results are shown in Tables 1 and 2.

Discussion

Cardiovascular disease and osteoporosis are the main causes of morbidity and mortality among postmenopausal women (15, 18). Aging is well-known to be associated with both osteoporosis and atherosclerosis (18, 20, 21).

Although various methods have been developed to evaluate endothelial function, high-resolution B-mode ultrasonography is generally used. Arterial IMT is a sensitive marker for early atherosclerotic vascular wall changes, particularly in the main carotid arteries (4).

Arterial stiffness, which has been determined to reflect the functional characteristics of the arteries, is another parameter used in estimating cardiovascular risk. Carotid IMT measurement using ultrasonography shows a good correlation with pathologic measurements, and this method can be repeated (4, 19).

Increased carotid IMT is significantly related with known cardiovascular risk factors and may progress to a carotid plaque, which is a more severe atherosclerotic lesion (19, 22). Human arteries are dynamic vessels that respond to different stimuli by re-modeling their own structure and size (22).

Some studies have shown that although the relationship between BMD and vascular calcification disappears after age adjustments, in other studies it has been found to be independent of age (12, 23).

In many studies, an independent relationship was found between the BMD, which represents the low BMD values in the cortical areas, and vascular calcification (14, 24). However, the studies that primarily measure trabecular (spine) BMD are unsuccessful in demonstrating this relationship (13, 14, 23, 24).

Previously, this situation was attributed to the methodological traps related to the measurement of BMD by dual X-ray absorptiometry (1). In fact, dual X-ray absorptiometry measurements deviate due to the presence of calcified plaques in the neighboring vessels and to the osteophytes (24).

By contrast, previous studies have shown a negative correlation between

Table 1. Clinical characteristics of study patients

	Minimum	Maximum	Mean	SD
Age (years)	31.90	77.90	57.82	9.57
Height (cm)	140.00	166.00	153.81	5.58
Weight (kg)	44.00	114.00	71.28	13.71
Body mass index (kg/m^2)	19.53	47.96	30.08	5.27
Waist circumference (cm)	61.00	112.00	87.63	10.84
Hip circumference (cm)	78.00	135.00	107.31	10.46
Waist/hip ratio	0.54	0.94	0.82	0.06
Carotid IMT (mm)	0.30	0.90	0.48	0.13
Cross-sectional compliance of carotid artery	0.08	0.39	0.18	0.07
Cross-sectional distensibility of carotid artery	0.00	0.02	0.01	0.00
Diastolic wall stress of carotid artery	63.16	409.50	185.22	67.53
Carotid elastic modulus	40.62	307.06	127.34	57.75
Femoral IMT (mm)	0.20	1.00	0.40	0.16
Cross-sectional compliance of femoral artery	0.04	0.83	0.19	0.11
Cross-sectional distensibility of femoral artery	0.00	0.03	0.01	0.00
Diastolic wall stress of femoral artery	65.14	675.00	235.82	121.74
Femoral elastic modulus	25.06	434.80	116.65	74.52
Bone mineral density (g/cm^3)				
L1	0.60	1.32	0.88	0.14
L2	0.57	1.34	0.90	0.15
L3	0.59	1.37	0.93	0.16
L4	0.62	1.42	0.93	0.16
L12	0.60	1.29	0.89	0.14
L13	0.65	1.28	0.90	0.14
L14	0.65	1.31	0.91	0.14
L23	0.65	1.36	0.92	0.15
L24	0.65	1.37	0.92	0.15
L34	0.67	1.39	0.93	0.15
Femur neck	0.63	1.37	0.89	0.15
Upper femoral neck	0.51	1.82	0.76	0.20
Lower femoral neck	0.68	1.52	1.01	0.16
Wards triangle	0.42	1.49	0.73	0.18
Femur trochanter	0.55	1.69	0.79	0.15
Femur shaft	0.73	1.64	1.13	0.17
Femur total	0.65	1.40	0.95	0.14

SD, standard deviation; IMT, intima-media thickness; L, lumbar spine.

Table 2. The relationship between BMD and the measures of arterial stiffness

BMD	Carotid CSC	Carotid CSD	Carotid DWS	Carotid EM	Femoral IMT	Femoral CSC	Femoral CSD	Femoral EM
L1	*P* = 0.187	*P* = 0.108	*P* = 0.476	r=-0.219 *P* = 0.020	r=-0.188 *P* = 0.046	*P* = 0.420	*P* = 0.454	r=-0.189 *P* = 0.045
L3	*P* = 0.294	*P* = 0.228	*P* = 0.776	*P* = 0.114	*P* = 0.067	*P* = 0.108	*P* = 0.775	r=-0.210 *P* = 0.018
L12	*P* = 0.422	*P* = 0.210	*P* = 0.585	*P* = 0.094	r=-0.197 *P* = 0.036	*P* = 0.518	*P* = 0.331	*P* = 0.089
L13	*P* = 0.380	*P* = 0.222	*P* = 0.613	*P* = 0.097	r=-0.196 *P* = 0.037	*P* = 0.468	*P* = 0.517	r=-0.194 *P* = 0.049
L23	*P* = 0.449	*P* = 0.249	*P* = 0.700	*P* = 0.140	r=-0.190 *P* = 0.044	*P* = 0.488	*P* = 0.185	*P* = 0.645
L24	*P* = 0.380	*P* = 0.158	*P* = 0.961	*P* = 0.136	*P* = 0.051	*P* = 0.158	*P* = 0.463	r=-0.192 *P* = 0.045
L34	*P* = 0.330	*P* = 0.231	*P* = 0.897	*P* = 0.145	*P* = 0.094	*P* = 0.396	*P* = 0.171	r=-0.194 *P* = 0.040
Femur neck	*P* = 0.222	r=0.194 *P* = 0.048	r=–0.192 *P* = 0.039	*P* = 0.097	*P* = 0.639	r=0.346 *P* = 0.001	*P* = 0.088	r=-0.243 P = 0.009
Upper femoral neck	*P* = 0.212	*P* = 0.350	*P* = 0.687	*P* = 0.119	*P* = 0.705	r=0.215 *P* = 0.027	*P* = 0.247	*P* = 0.237
Lower femoral neck	*P* = 0.288	r=0.213 *P* = 0.042	r=-0.209 *P* = 0.026	r=-0.186 *P* = 0.048	*P* = 0.460	r=0.279 *P* = 0.005	*P* = 0.222	r=-0.230 *P* = 0.025
Wards triangle	r=0.197 *P* = 0.068	r=0.251 *P* = 0.007	*P* = 0.687	r=-0.252 *P* = 0.002	*P* = 0.692	r=0.386 *P* = 0.001	r=0.243 *P* = 0.002	r=-0.270 *P* = 0.006
Femur total	*P* = 0.219	*P* = 0.253	*P* = 0.779	*P* = 0.164	*P* = 0.468	r=0.253 *P* = 0.006	*P* = 0.457	*P* = 0.329

BMD, bone mineral density; CSC, cross-sectional compliance; CSD, cross-sectional distensibility; DWS, diastolic wall stress; EM, elastic modulus; IMT, intima-media thickness; L, lumbar spine.

lumbar BMD and IMT; however, the absence of such a correlation has been defined in patients. The distribution of atherosclerosis may differ greatly among vascular beds, and this may explain some findings that seemed contradictory in the literature (24).

In a study in which various possibilities were reviewed, inflammation was suggested to be one of the processes affecting bone loss (25). Many inflammatory mediators in the circulation, which are known to be the markers of cardiovascular risk, initiate the atherogenesis in the arterial wall (1).

Many researchers have suggested a role for hyperlipidemia and lipid oxidation, and inflammation (25). In vitro studies have shown that oxidized lipids stimulate osteoblastic differentiation of vascular cells but inhibit the similar differentiation of the bone cells (1).

The other likely mechanism may be imitation of the chronic infection via oxidized lipid deposition in the tissue, thus initiating an immune response that supports the hardening of soft tissue, which keeps the infectious agents closed within the walls, and softening of the hard tissue by the release of a substrate for the growth of infectious agents (1).

Although a number of explanations have been proposed, the underlying mechanism of the relationship between BMD and arterial stiffness has not yet been completely understood (18). Epidemiological data have suggested that estrogen deficiency is a risk factor for both cardiovascular diseases and osteoporosis (1).

Bone and arteries are the target tissues for estrogen. Estrogen receptors identified on the osteoblasts, osteoclasts, and vascular endothelial and smooth muscle cells support the idea that estrogen has a direct effect on vascular and bone cells (18).

Hormone replacement therapy increases the BMD and decreases the carotid-femoral PWV in postmenopausal women (18, 26, 27).

Other likely mechanisms can also explain the existing findings. Secondary hyperparathyroidism, which can be induced by vitamin D deficiency in the elderly, is associated with bone loss as well as deposition of calcium in soft tissues (18).

The postmenopausal increase in plasma homocysteine is a cardiovascular risk factor, and osteoporosis is a common characteristic of the patients with homocystinuria. Moreover, impaired endothelial function, which is probably responsible for the increase in the serum angiotensin converting enzyme activity and the decrease in the serum concentrations of nitrite/nitrate, has been reported in the forearm resistant arteries in postmenopausal women (1, 18, 28).

These factors may play an important role in the pathogenesis of both osteoporosis and arterial stiffness (18). Unfortunately, no information could be obtained from the participants of the present study.

The differences in the methods used for the measurement of AD are responsible for the different, sometimes contradictory, relationship between vascular risk factors or vascular outcomes and AD (3).

An important finding of the present study was the absence of a significant relationship between carotid artery IMT and any of the BMDs, contrary to the study that reported a significant relationship with the BMD of the trochanter, the femoral neck, Ward's triangle, and total femur (1).

Unlike the study reporting just the opposite of our results, our study showed a significant relationship between femoral IMT and BMD, as was previously reported (1, 14, 15). The relationship with only lumbar BMD was particularly significant.

Similar to the previous studies, we recommend that bone status should be evaluated in patients with vascular disease to assess the required preventive and therapeutic interventions (1).

Some potential limitations exist in the present cross-sectional study. First, the cases have been selected among patients referred for BMD measurement, instead of a large population. This selection bias may explain the high prevalence of osteoporosis among the participants. Additionally, arterial stiffness might have resulted from another condition, for example a non-atherosclerotic arteriopathy. Furthermore, adiposity or body fat distribution has not been evaluated.

Osteoporotic postmenopausal women show increased arterial stiffness, indicating that they are likely to have a high risk for cardiovascular disease. AD can reliably be measured by ultrasonography. However, even a small variance in these measurements may lead to an important deviation in AD measurements.

Although the present study has demonstrated a relationship between BMD and AD, studies with a large series, comparing the age, ethnicity, body mass index, and biochemical values of the individuals, are still needed, and our results should be evaluated in this respect. The results of our study showed that the incidence of vascular stiffness appears high in postmenopausal women with decreased BMD. The diagnosis and treatment of atherosclerosis in the preclinical period will decrease the risk of cerebrovascular and cardiac diseases.

Conflict of interest disclosure

The authors declared no conflicts of interest.

References

1. Hmamouchi I, Allali F, Khazzani H, et al. Low bone mineral density is related to atherosclerosis in postmenopausal Moroccan women. BMC Public Health 2009; 9:388.
2. NIH Consensus Development Panel on Osteoporosis Prevention, Diagnosis, and Therapy. Osteoporosis prevention, diagnosis, and therapy. JAMA 2001; 285:785–795.
3. Godia EC, Madhok R, Pittman J, et al. Carotid artery distensibility: a reliability study. J Ultrasound Med 2007; 26:1157–1165.
4. Simons PCG, Algra A, Bots ML, Grobbee DE, van der Graaf Y. Common carotid intima-media thickness and arterial stiffness: indicators of cardiovascular risk in high-risk patients: the SMART Study. Circulation 1999; 100:951–957.
5. Taniwaki H, Shoji T, Emoto M, et al. Femoral artery wall thickness and stiffness in evaluation of peripheral vascular disease in type 2 diabetes mellitus. Atherosclerosis 2001; 158:207–214.
6. Doherty TM, Asotra K, Fitzpatrick LA, et al. Calcification in atherosclerosis: bone biology and chronic inflammation at the arterial crossroads. Proc Natl Acad Sci USA 2003; 100:11201–11206.
7. Tintut Y, Demer LL. Recent advances in multifactorial regulation of vascular calcification. Curr Opin Lipidol 2001; 12:555–560.
8. van Popele NM, Grobbee DE, Bots ML, et al. Association between arterial stiffness and atherosclerosis: the Rotterdam Study. Stroke 2001; 32:454–460.
9. Riley WA, Evans GW, Sharrett AR, Burke GL, Barnes RW. Variation of common carotid artery elasticity with intimal-medial thickness: the ARIC study. Ultrasound Med Biol 1997; 23:157–164.
10. Bild DE, Bluemke DA, Burke GL, et al. Multi-ethnic study of atherosclerosis: objectives and design. Am J Epidemiol 2002; 156:871–881.
11. Barenbrock M, Spieker C, Kerber S, et al. Different effects of hypertension, atherosclerosis and hyperlipidemia on arterial distensibility. J Hypertens 1995; 13:1712–1717.
12. Kiel DP, Kauppila LI, Cupples LA, Hannan MT, O'Donnell CJ, Wilson PW. Bone loss and the progression of abdominal aortic calcification over a 25 year period: the Framingham Heart Study. Calcif Tissue Int 2001; 68:271–276.
13. Tanko LB, Bagger YZ, Christiansen C. Low bone mineral density in the hip as a marker of advanced atherosclerosis in elderly women. Calcif Tissue Int 2003; 73:15–20.
14. Sumino H, Ichikawa S, Kasama S, et al. Relationship between carotid atherosclerosis and lumbar spine bone mineral density in postmenopausal women. Hypertens Res 2008; 31:1191–1197.
15. von der Recke P, Hansen MA, Hassager C. The association between low bone mass at the menopause and cardiovascular mortality. Am J Med 1999; 106:273–278.
16. Bliuc D, Nguyen ND, Milch VE, Nguyen TV, Eisman JA, Center JR. Mortality risk associated with low-trauma osteoporotic fracture and subsequent fracture in men and women. JAMA 2009; 301:513–521.
17. Hirose K, Tomiyama H, Okazaki R, et al. Increased pulse wave velocity associated with reduced calcaneal quantitative osteosono index: possible relationship between atherosclerosis and osteopenia. J Clin Endocrinol Metab 2003; 88:2573–2578.
18. Sumino H, Ichikawa S, Kasama S, et al. Elevated arterial stiffness in postmenopausal women with osteoporosis. Maturitas 2006; 55:212–218.
19. Atabek ME, Kurtoglu S, Pirgon O, Baykara M. Arterial wall thickening and stiffening in children and adolescents with type 1 diabetes. Diabetes Res Clin Pract 2006; 74:33–40.
20. Seeman E. Pathogenesis of bone fragility in women and men. Lancet 2002; 359:1841–1850.
21. Millonig G, Malcom GT, Wick G. Early inflammatory immunological lesions in juvenile atherosclerosis from the pathobiological determinants of atherosclerosis in youth (PDAY) Study. Atherosclerosis 2002; 160:441–448.
22. Cobble M, Bale B. Carotid intima-media thickness: knowledge and application to everyday practice. Postgrad Med 2010; 122:10–18.
23. Vogt MT, San Valentin R, Forrest KY, Nevitt MC, Cauley JA. Bone mineral density and aortic calcification: the Study of Osteoporotic Fractures. J Am Geriatr Soc 1997; 45:140–145.
24. van der Klift M, Pols HA, Hak AE, Witteman JC, Hofman A, de Laet CE. Bone mineral density and the risk of peripheral arterial disease: the Rotterdam Study. Calcif Tissue Int 2002; 70:443–449.
25. Hamerman D. Osteoporosis and atherosclerosis: biological linkages and the emergence of dual-purpose therapies. QJM 2005; 98:467–484.
26. The Writing Group for the PEPI. Effects of hormone therapy on bone mineral density: results from the postmenopausal estrogen/progestin interventions (PEPI) trial. JAMA 1996; 276:1389–1396.
27. Kawecka-Jaszcz K, Czarnecka D, Olszanecka A, Rajzer M, Jankowski P. The effect of hormone replacement therapy on arterial blood pressure and vascular compliance in postmenopausal women with arterial hypertension. J Hum Hypertens 2002; 16:509–516.
28. Sanada M, Taguchi A, Higashi Y, et al. Forearm endothelial function and bone mineral loss in postmenopausal women. Atherosclerosis 2004; 176:387–392.