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COMPARISON OF MUSCLE STRENGTH AND BONE MINERAL DENSITY IN HEALTHY POSTMENOPAUSAL WOMEN

A Cross-sectional Population Study

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ABSTRACT. In this cross-sectional population study with 78 healthy 0.5–5 years postmenopausal, 49–55 year old females a significant simple linear correlation between lumbar spine LII-LIV bone mineral density and adjacent back extensor and flexor isometric muscle strength was found. With the stepwise multiple linear regression analyses the most significant predictors for lumbar spine LII-LIV and femoral neck bone mineral density were weight (partial R^2) ($R^2=0.197$, $p=0.0001$; $R^2=0.157$, $p=0.0009$) and age ($R^2=0.056$, $p=0.0205$; $R^2=0.036$, $p=0.0708$). Height and isometric muscle strength and endurance of muscles were not significant predictors. Weight and age were the most significant predictors also for isometric muscle strength. The mobility of spine, body fat content and anaerobic threshold had no correlation on bone mineral density.

Key words: muscle strength, bone mineral density, postmenopause, population.

Hormonal changes occurring during menopause are associated with alterations in skeleton and in muscles (18, 20, 22). Osteoporotic changes in bone and degeneration of muscle tissue could be at least partly regulated by the same factors and be parallel. Whole body potassium as an indicator of muscle mass and calcium as an indicator of bone mass correlate significantly with each other (38). There is also a significant correlation between the ash weight of L III vertebra and the weight of iliopsoas muscle (11) as well as between the X-ray density of L III vertebra and the width of the iliopsoas muscle at the same level (24). However, it is unclear to what extent the association between bone and muscle involution is causal and if these changes have the same etiology, for example menopausal hormonal changes. This is a fundamental question in planning either exercises and/or hormone replacement therapy against postmenopausal bone loss. Both mineral density of bone and muscle strength decrease by aging (18, 20). Bone loss is most rapid during postmenopause (18) and parallel rapid loss of muscle strength has been suggested (7, 20, 22). The purpose of this cross-sectional blinded study was to examine lumbar spine and femoral neck bone mineral density and adjacent muscular strength as well as their mutual relationship and possible factors effecting on them in a healthy postmenopausal female population.

MATERIAL AND METHODS

Study population

From a population of about 100 000 inhabitants the addresses of all 49–55 year old women were selected from public registration office and a questionnaire of menopause, previous diseases, usage of hormones and medications was sent randomly to every third of them (1 179). 833 of these (71 %) answered and 103 healthy, 0.5–5 years postmenopausal women who had not previously used hormones were chosen from these and invited to an interview and examination. Finally 78 (15 %/1 179) volunteers were included in the study after the women found not healthy in laboratory and gynecological examination were excluded. Exclusion criteria were selected on the basis of estrogen-progestin follow-up study. The main characteristics of the study group are presented in Table I. The criteria to exclude 15 women (out of the total of 103) were their reluctance to participate the trial (8 cases), overweight—BMI over 35—(3 cases), endometrial hyperplasia (2 cases), deafness (one case), and hip arthrosis (one case).

Bone mineral density

The bone mineral density of lumbar spine LII-IV and the femoral neck of these 78 volunteers was measured with X-ray dual photon absorptiometry (Lunar DPX®) in sagittal direction (12, 17). The measurement was performed in winter time from November to January (2).

Muscle strength

Muscle testing including endurance and maximal isometric strength measures for both back extensors and flexors was done between 2 p.m. – 7 p.m. in winter time from December to February (2). Before the actual testing each subject

Table I. *The main characteristics of the study group*

	Range	Mean	SD
Age (years)	49–55	52.6	1.5
Height (cm)	146.5–171.0	159.1	5.2
Weight (kg)	47.0–84.5	64.9	8.1
Body mass index (kg/cm^2)	18–34	25.6	3.5
Last menstruation (years)	0.5–5	2.37	1.12

warmed up for five minutes with bicycle ergometer without load. The endurance of trunk flexors was measured ten minutes later by using a sit-up test with maximal stress on abdominal straight and oblique and iliopsoas muscles. The subject was lying supine on plinth with knees flexed 90 degrees and hips flexed, ankles fixed with belt and then she started to lift the upper trunk in a half sitting position reaching with straight upper extremities wrists on knees as many times as possible without time limitation—the repetitions were counted. Ten minutes after the flexor muscle test the endurance of back extensor muscles was measured with extensor repeat test on prone with maximal stress on back extensor and partly gluteal hip extensor muscles. The subject was lying prone on plinth with belt fixation on ankles and hands on both sides and she lifted upper trunk from 45 degrees below horizontal plane up to horizontal plane as many times as possible without time limitation—the repetitions were counted. The maximal isometric extension and flexion strength of back were measured in a standing position with the Muskeli® apparatus (Digitest, Muurame, Finland). The calibration of the device was done after each fifth subject. The subject was fixed with belt in the device below anterior superior iliac spine and humeroscapular joint level after which she was asked to perform maximal flexion and extension torque of back against a bar for 5 sec; the best result was accepted from three successive attempts. One subject was excluded because of back pain and sciatica.

Other measurements. Maximal flexion and extension mobility of lumbar spine was measured with flexicurve (4). Lateral bending was measured with the movement of middle finger on femoral side (21). Physical fitness was determined in a bicycle ergometer test—anaerobic threshold—(1) in another visit. Body fat content was determined with skinfolds (13).

The anaerobic threshold is found with bicycle ergometer test by increasing load step by step after the aerobic threshold has been reached and blood lactate increases linearly with respect to work. The point, where lactate elimination is maximal and equal to production, is called anaerobic threshold. The expired gases are collected and analysed with Medikro 202E Ergospirometry®. The oxygen of gas sample of expired air is measured with paramagnetic method, carboxydioxide with infrared method and the volume of expired air with pneumotakograf. The oxygen consumption and ventilation during last minute of each step is calculated and a curve of the relationship of lactate and ventilation to cycling power is drawn. The first change in linearity is aerobic threshold and the second greater change is anaerobic threshold where the elimination of lactate is maximal. The blood (B-lactate) samples are taken from finger tip capillary blood. The bicycle test was performed under control of a physician and the blood pressure was controlled on each step and EKG monitored continuously.

The testers and subjects did not know the results of bone mineral density and other measurements.

Bone mineral density measurement with X-ray dual photon absorptiometry (Lunar DPX®) in sagittal direction has proved to be very reproducible (precision error $<1\%$) (12). The reproducibility of other tests were tested with 15 healthy females on two following days. Intratester reproducibility of the method of testing isometric muscular strength of back extensors and flexors with Muskeli® apparatus and Digitest® device was high ($r=0.98$, $r=0.97$). The precision error of Digitest device is less than 1.0 kg. Flexicurve intertester and intratester reproducibility was high ($r=0.85$, $r=0.93$) (4) technical drawing error less than one degree. Lateral bending measurement intertester and intratester reproducibility was also high ($r=0.86$, $r=0.96$) (21). The accuracy of body fat content measurement with skinfolds is satisfactory with low values but not so good with high values (13).

Statistics

The associations between variables were assessed with simple linear regression. Adjusted regression coefficients were then found by using stepwise multiple linear regression (to study the predictability of one factor using several variables). p values for entry into the model (partial R^2) at the levels of 0.05 or less were considered evidence of a statistically significant finding. The reproducibility of tests were calculated with simple linear regression.

RESULTS

Bone mineral density

The measurement values are presented in Table II. Bone mineral density of lumbar spine and femoral neck were very significantly correlated ($R^2=0.510$, $p=0.0001$). Weight had a very significant correlation to lumbar and femoral bone mineral density ($R^2=0.197$, $p=0.0001$; $R^2=0.157$, $p=0.0003$). Lumbar and femoral bone mineral density had significant negative correlation to age ($R^2=0.061$; $p=0.026$). Femoral neck bone mineral density had significant correlation to postmenopause time ($R^2=0.081$, $p=0.012$). No correlation was found between postmenopause time, anaerobic threshold, body fat content or height and lumbar bone mineral density ($R^2<0.015$, $p>0.05$). The mobility of lumbar spine had no significant correlation to bone mineral density of the lumbar spine.

Muscle strength

The isometric extensor and the flexor strength of back had significant negative correlation to age ($R^2=$

0.086, $p=0.009$; $R^2=0.058$, $p=0.034$) and also to postmenopause time ($R^2=0.055$, $p=0.038$; $R^2=0.06$, $p=0.031$). Body weight had significant positive correlation to the isometric extensor muscle and the flexor muscle strength of back ($R^2=0.062$, $p=0.03$; $R^2=0.097$, $p=0.055$). The back flexor muscle repeat test and the extension repeat test were significantly correlated to weight ($R^2=0.104$, $p=0.004$; $R^2=0.080$, $p=0.012$) and to anaerobic threshold ($R^2=0.058$, $p=0.034$; $R^2=0.143$, $p=0.0007$). The extension repeat test had a significant correlation to isometric extensor muscle strength ($R^2=0.237$, $p=0.036$) but the flexion repeat test none on isometric flexor muscle strength.

Bone mineral density and muscle strength

There was a significant correlation between the isometric flexor muscle strength of back and the bone mineral density of lumbar spine ($R^2=0.1003$, $p=0.0047$) and the isometric muscle strength of back extensors and lumbar spine bone mineral density ($R^2=0.1067$, $p=0.0035$). Repeat tests did not correlate on bone mineral density.

Predictability of bone mineral density with several variables

Weight was the main predictor for bone mineral density of lumbar spine calculated using the stepwise multiple linear regression analyses ($R^2=0.197$, $p=0.0001$). The second important predictor tested was age ($R^2=0.056$, $p=0.0205$) and the third height, ($R^2=0.029$, $p=0.100$) which was not significant. The isometric extensor strength was on the fourth place and the isometric flexor strength on the fifth—statistically they were not significant. Weight was also the main predictor for femoral neck bone mineral density ($R^2=0.157$, $p=0.0009$), the isometric extensor strength the second ($R^2=0.054$, $p=0.027$), which can be significant occasionally and age the third ($R^2=0.036$, $p=0.071$) which is almost significant.

Predictability of muscle strength with several variables

The main predictor for isometric back extensor muscle strength calculated with stepwise multiple linear regression analyses was age ($R^2=0.087$, $p=0.009$) and the second one height ($R^2=0.060$, $p=0.025$), the third being weight ($R^2=0.048$, $p=0.041$). The main predictor for isometric back flexor muscle strength was weight ($R^2=0.096$, $p=0.006$) and the second one was age ($R^2=0.053$, $p=0.035$).

Table II. *The measurement results*

Measurement	Range	Mean	SD
Bone mineral density			
of lumbar spine	0.743–1.376	1.031	0.136
of femoral neck	0.639–0.908	0.887	0.127
(g/cm^3)			
Maximal isometric back			
extensor m. strength	27–68	46.6	8.0
flexor m. strength	15–48	29.5	6.9
(kg)			
Back repeat test			
extensors	17–120	52.7	20.7
flexors	0–57	26.5	13.2
(repeats)			
Lumbar spine maximal			
extension mobility	4–36	20.7	6.8
flexion mobility	40–77	55.5	8.2
(degrees)			
Lumbar spine maximal			
lateral bending dx	100–240	166.3	28.5
lateral bending sin	75–240	166.2	33.5
(mm)			
Anaerobic threshold			
(ml/kg/min)	12.2–33.6	20.7	4.3
Body fat content (%)	16.5–64.4	32.1	8.7

DISCUSSION

Our results show clear correlation between bone mineral density of lumbar spine and isometric muscle strength of back flexors and extensors. However, it also demonstrates that both of these variables are more dependent on weight and age than on each other. The correlation between isometric muscle strength of back extensors and bone mineral density of LII-IV supports earlier results (30). Our current finding about the correlation between bone mineral density of lumbar spine and flexor muscles is also in accordance with the observations that individuals with higher bone density have larger muscle mass (8, 24, 38). The influence of hormonal metabolism and heredity to both is possible. Androstendione is metabolized to estriol in fat tissue (19) but body fat content did not explain the correlation—although body fat content measurement has relatively low accuracy on high values (13). We could not confirm the previously found positive correlation between maximal oxygen uptake or anaerobic threshold and bone mineral density (6) in this study. Anaerobic threshold which we used in determining physical fitness is more influenced by training than maximal oxygen uptake

(10). Neither of the muscle repeat tests had any association to lumbar spine bone mineral density. Height did not correlate to lumbar spine or femoral neck bone mineral density as previously had been described (14).

Immobilization is known to decrease bone mineral density (34). Active muscle exercises have been found to effect on postmenopausal radius bone mineral density in some studies (31, 32, 33) but not in all (35). The bone mineral density of postmenopausal radius has been found to increase during a 6-week training period (gripping 30 sec with tennis ball each day) (3). The same result has also been achieved with other kinds of compressive and diverse exercises loading the radius (32). Back strengthening exercises on prone have been found to improve muscular strength but not to improve bone mineral density of lumbar spine or delay bone loss (31). The influence of gravity was assumed to be very important on bone mineral density, which has also been noticed during space flights (25) and swimming and in-water exercises (23, 27). Comparing calcium excretion after cycling in supine or sitting position as well as standing or sitting after immobilization, it has been assumed that gravity is more important than muscle activities (15). Jogging and other weight bearing exercises have increased postmenopausal bone mineral density in lumbar spine but not in radius (5, 7, 9, 16). These are in accordance with our results. In preventing postmenopausal lumbar and femoral osteoporosis weight bearing exercises seem to be the most useful ones. The sufficient dose of weight-bearing exercises is unclear, but about one hours walking or jogging four times a week has been suggested (29). Motoric skills can be developed by muscle exercises, which is also very important in preventing osteoporotic fractures.

CONCLUSIONS

The causal association between postmenopausal lumbar spine bone mineral density and back muscle strength cannot be assumed in this cross-sectional study because of the possibility that there are the same etiological factor—weight and age, possibly heredity and hormonal metabolism—inducing the correlation. The most important predictors for postmenopausal bone mineral density of lumbar spine and femoral neck seem to be weight and age.

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