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Trends in bone mineral density among nutritional status categories of Vojvodina elderly population

Трендови минералне коштане густине у односу на нутритивни статус старије популације Војводине

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SUMMARY

Introduction/Objective Low bone mineral density (BMD) is commonly associated with alterations of nutritional status. The aims of the present study were to evaluate the prevalence of low BMD and its associated nutritional risk factors in Vojvodina population and to use linear regression equations to predict the BMD by using a simple marker of nutritional status, body mass index (BMI).

Methods: In this retrospective, cross-sectional study, the study population was subjects who were undergoing assessment of BMD between January to December 2017 and met the study inclusion criteria. A total of 1974 patients (1866 women and 108 men) were included in this analysis of nutritional status according to anthropometry and BMI index, and dual-energy X-ray absorptiometry (DEXA) measurements of BMD of the femoral neck and lumbar spine. The relationship between BMI and BMD was analysed by linear regression equation.

Results: Median age was 63 (56-70) years. Considering nutritional status category, there were 40% overweight, 31% obese and 29% normal weight subjects. In most of the sample, subject had low BMD, 37% had osteopenia and 25% had osteoporosis. In both bone areas we observed trends of lowering BMD as the subjects BMI decrease. Subjects with osteoporosis are more prone to BMI depended BMD changes, in regard to subjects with osteopenia and normal BMD. Also, normal weight subjects compared to overweight and obese, had highest prediction coefficients of BMI depended changes on BMD.

Conclusion: High prevalence of low BMD coexists with overweight and obesity in the elderly age category of females in Vojvodina. Prediction equations for the calculation of BMD can be used to evaluate the effect of BMI changes on BMD in clinical settings.

Keywords: Bone Mineral Density, Body Mass Index, Osteoporosis, Osteopenia, Linear regression

САЖЕТАК

Увод/циљ Смањена минерална коштана густина (БМД) се често повезује са поремећајима нутритивног статуса. Циљеви ове студије су били да се утврди преваленција смањене коштане густине и повезаност са нутритивним факторима ризика у узорку популације Војводине, и да се примене модели предикције БМД коришћењем једноставног маркера нутритивног статуса, индекса телесне масе (ИТМ).

Методе: У ретроспективној студији пресека, испитивану популацију су чинили пацијенти који су у периоду од јануара до децембра 2017. године урадили мерење БМД и испуњавали критеријуме за укључење у испитивање. У узорку од 1974 испитаника (1866 жена и 108 мушкараца), анализирани су нутритивни статус према антропометријским параметрима и ИТМ, као и двоенергетска рендгенска апсорпциона мерења БМД у регији врата бутне кости и лумбалне кичме. Повезаност између БМИ и БМД је испитивана линеарним регресионим једначинама.

Резултати: Медијана година живота испитаника је била 63 (56–70 година). Нутритивни статус је у 40% испитаника био прекомерна ухрањеност, у 31% гојазност и 29% нормална ухрањеност. Већина испитаника је имала смањену БМД, 37% је имало остеопенију, а 25% остеопорозу. У посматраним регијама кости уочили смо тренд снижавања БМД како се смањује ИТМ испитаника. Испитаници са остеопорозом склонији су промена БМД које су зависне од ИТМ, у односу на испитанике са остеопенијом и нормалном БМД. Нормално ухрањени, у компарацији са испитанцима других нутритивних категорија, имају најповољније коефицијенте раста БМД према регресионим једначинама.

Закључак: Висока преваленција смањене БМД је удружена са поремећајима нутритивог статуса, прекомерном ухрањености и гојазности, код старијих жена у Војводини. Једначине предвиђања за израчунавање БМД се могу користити за процену ефеката промене у ИТМ на БМД у клиничким условима.

Кључне речи: минерална коштана густина, индекс телесне масе, остеопороза, остеопенија, линеарна регресија

INTRODUCTION

The world population is about 7.6 billion people at this moment and it is expected to increase by one billion in the next ten years and to reach approximately 10 billion by 2050. Due to the simultaneous ageing trend of population at the global level, the number of elderly people over 60 years of age, which was 962 million in 2017, is expected to increase more

than double by 2050. [1]. In Serbia, almost one fifth of a female population and 15 % of males are older than 65 years. Also, current demographic trends of the population in Vojvodina indicate regressive type of age structure characterised by 40.2% of people over 50 years [2].

Population ageing results in the increased incidence of osteoporosis in elderly women [3]. Osteoporosis is a disease characterized with low bone mineral density (BMD) and compromised bone microarchitecture, both leading to the more expressed bone fragility and increased risk of fracture. According to the estimation done in 2010, 22 million women and 5.5 million men in Europe suffer from osteoporosis. About 40% of elderly women and from 15 to 30% of elderly men are likely to have osteoporotic fracture over the course of life [4, 5].

Low BMD and impaired bone quality are commonly associated with nutritional status. Altered nutritional status, mostly underweight category is associated with low BMD and compromised bone microarchitecture. Even though overweight and obesity are generally associated with higher BMD, recent studies imply that overweight and obesity patients also have serious negative impact on bone metabolism [6, 7, 8]. Obesity is heterogenous, multifactorial and complex disease which is positively associated to many chronic disorders. Its diagnosis is based on the evaluation of nutrition status [body mass index (BMI)], distribution of excessive fat deposits and determination of body composition [9]. Rates of nutritional abnormalities, overweight and obesity, are rising rapidly. The results of research from 2006 showed that more than a half of adult population of Serbia (55.7%) was overweight and obese. In Serbia, Vojvodina has the highest total prevalence of overweight and obesity, which is as high as 58.5% of the population [10].

Previous analysis focused on the subjects in Vojvodina shown high prevalence of osteopenia and significant positive correlation between T score and BMI in older women [11]. Additionally, nutritional status of the subjects was mostly disturbed, high prevalence of

overweight (43%) and obese subjects (20%) were reported. Considering the increasing trend of risk factors for low BMD in our population, ageing coexisted with nutritional status abnormalities, this study aimed to use linear regression equations to predict the BMD by using a simple marker of nutritional status, body mass index (BMI), on sample population subjects from the general population of Vojvodina.

METHODS

The study, a retrospective cross-sectional survey, was carried out at the Clinical Center of Vojvodina, Novi Sad. The study population was subjects who were undergoing assessment of BMD between January to December 2017 and met the study inclusion criteria. The study sample consisted of 1974 adults (1866 women and 108 men). The inclusion criteria of this study required all subjects to be aged 50 years and above, with complete medical documentation. Exclusion criteria was clinical evidence on existing secondary causes of BMD disorders (endocrine, gastrointestinal, hematologic, or rheumatic diseases, drug-induced osteoporosis) [12]. This study was approved by the Ethics Committee of the Clinical Center of Vojvodina.

Anthropometric measurements analyzed were body weight (medical weighing scale with precision of 0.1 kg, kg), body height (Martin anthropometer, cm) and BMI derived from Quetelet's equation. The subject's nutritional status was defined based on their BMI as normal weight (BMI 18.50 – 24.99 kg/m^2), overweight (BMI 25.00 – 29.99 kg/m^2), and obesity (BMI≥30.00 kg/m^2) [9].

BMD (g/cm^2) was measured with GE Lunar equipment by applying the method of dual-energy X-ray absorptiometry (DEXA) in the region of lumbar spine (calculated values were means of four measured values from L1 to L4) and femoral neck. According to the WHO

standards subjects were classified into subgroups: osteoporosis ($T \leq -2.5$), osteopenia ($-2.5 < T < -1.0$), normal finding ($T \geq -1.0$) [13].

Statistical Analysis

The obtained results were analysed in the computing environment MATLAB 8. Normality was examined with Shapiro-Wilk test, which showed that the analysed continuous parameters did not have a normal distribution and therefore they were represented in the form of median (Q1- Q3). Statistical significance was examined by applying Kruskal-Wallis test with post hoc testing on the defined subgroups (normal finding, osteopenia and osteoporosis), as well as on the subgroups according to the nutrition status of subjects (normal weight, overweight, and obesity). Finally, we have used linear regression to analyze trends of considered parameters in relation with BMI changes.

RESULTS

Table 1 shows general characteristics of the study group. The majority of study sample subjects were elderly women, within nutritional status category of overweight and with osteopenia in the region of femoral neck and lumbar spine.

Clinical characteristics of the subjects by BMD categories are given in Table 2. Observed subjects differ significantly according to their age, osteoporotic subjects were significantly older compared to osteopenic and those with normal bone mass [65 (59 - 76) vs. 62 (58 - 71) vs. 60 (54 - 66), $p<0.001$]. The subjects with osteoporosis had significantly lower BMI values compared to subjects with osteopenia and subjects with normal BMD in the both observed bone region [25.5 (21.7 - 27.3) vs. 27.3 (23.9 - 30.0) vs. 28.9 (25.9 - 32.4) kg/m^2, $p<0.001$]

Table 3 show regional BMD measurements (BMD, T-score and Z-score) in the region of femoral neck and lumbar spine by the nutritional status of the patients ($p<0.001$). The obese patients had significantly higher values of BMD, T-score and Z-score compared to overweight and normal weight subjects ($p<0.001$). The overweight subjects had significantly higher values of BMD, T-score and Z-score compared to normal weight subjects ($p<0.001$).

The method of linear regression was applied on the entire dataset to determine the associations between BMI and regional BMD measurements (BMD, T-score and Z-score) in the region of femoral neck and lumbar spine, and the obtained results are given in Table 4. Trend analyses based on regression approaches indicate the tendency of BMD increase with increasing BMI, as shown in Figure 1.

The association between BMI and regional BMD measurements (BMD, T-score and Z-score) in the region of femoral neck and lumbar spine was determined in the groups of osteoporosis, osteopenia and normal finding and the results obtained by linear regression are given in Table 5a, 5b and 5c. In regression equation, the prediction coefficients between BMI and the osteodensitometry measurements were the highest in the group with osteoporosis as compared with the other two groups, which means that the observed parameters change most rapidly with the change of BMI in that group.

The graphs are given in Figure 2. The estimations can be done by means of the obtained formulae and graphs. For example, if a person is in the group with osteoporosis and has BMI= 22kg/m^2, the observed parameter values are expected to be:

Femoral neck BMD measurements

BMD = 0.01*22 + 0.509 = 0.729

T-score = 0.081*22 - 4.128 = -2.346

Z-score = 0.047*22 - 2.171 = -1.137

Lumbar spine BMD measurements

BMD = 0.004*22 + 0.7 = 0.788

T-score = 0.031*22 - 4.007 = -3.325

Z-score = -0.014*22 - 1.159 = -1.467

The association between BMI and both bone site measurements was determined in a similar way in the groups of normal weight, overweight and obesity, and the results obtained by linear regression are given in Table 6a, 6b and 6c. Prediction coefficients of change in BMD dependent on BMI were the highest in the group of subjects with normal weight in regard to the other two groups, which means that the observed parameters change most rapidly with the change of BMI in that group. The graphs are given in Figure 3. The estimations can be done by means of the obtained formulae and graphs. For example, if a subject in the group with normal weight has BMI= 22kg/m^2, the observed parameter values are expected to be:

Femoral neck BMD measurements

BMD = 0.021*22 + 0.349= 0.811

T-score = 0.175*22 - 5.521= -1.671

Z-score = 0.161*22 - 4.299=-0.757

Lumbar spine BMD measurements

BMD = 0.012*22 + 0.671 = 0.935

T-score = 0.103*22 - 4.253= -1.987

Z-score = 0.099*22 - 2.698 = -0.52

DISCUSSION

Osteoporosis is the most common type of metabolic bone disease in developed countries. The progressive course of disease could lead to severe complications and represents an important social and economic problem [5]. Results from our study have shown

that the majority of studied elderly subjects in Vojvodina have relatively high prevalence of bone structural deterioration due to loss of bone mass, as well as nutritional status abnormalities.

In this study, subjects were mostly women (95%), mean age 63 (56-70) years. Considering bone abnormalities, majority of the subjects had low bone mass, 37% had osteopenia and 25% had osteoporosis. The study results are like those of other surveys in the Europe with 21 % of women aged ≥ 50 years estimated to have osteoporosis [4]. Our observed results are in line with physiological process of age-related bone remodelling, considering that the peak of bone mass is reached in the middle of third decade in the life, and afterwards, the gradual physiological involution of bone mass follows with ageing. Also, known effects of estrogen deficiency on cortical bone mineralization and loss of bone strength are present in elderly population [14]. During the ageing continuum, the imbalance between bone formation and bone resorption with consequent bone mass loss could be exacerbated by several pathophysiological factors. Extrinsic pathophysiological factors, alternations in nutrition and physical inactivity, could promote the decline in bone mass and osteoporosis [15].

Regarding nutritional status in our studied subjects aged ≥ 50 years, there were 40% overweight, 31% obese and 29% normal weight subjects. Obese subjects from our sample had considerably higher values of BMD in the region of femoral neck and lumbar spine compared to overweight and normal weight subjects. In both bone areas, we observed trends of lowering BMD as the subjects BMI decrease.

Age-related changes of body composition and physical inactivity could also have complex effect on bone health. Despite the generally positive effects of weight on bone health in elderly, alterations of nutritional status associated with greater fat mass may be potentially harmful [16, 17]. Some studies have suggested that being overweight and obese

results in a detrimental effect on bone health. Obesity is primarily associated with a certain type of osteoporotic fractures in aging individuals, regardless of greater BMD. The data obtained by the Global Longitudinal Osteoporosis in Women study show that the general prevalence and incidence of fractures did not significantly differ between obese and normal weight subjects, but obese subjects were more prone to the ankle and upper leg fractures [18]. Leslie et al. performed a large prospective study of 40,050 women and 3,600 men age ≥50 years of age, to assess the relationship between skeletal health and estimated total body lean and fat mass. Study showed that increased lean mass is protective to skeletal health and positively associated with BMD, while excessive fat mass had no effect on BMD. Also, higher fat mass was not independent risk factor of fractures over the study period [19]. Further, some studies reported that complications of osteoporosis usually occur in obese subjects with coexisting comorbid conditions requiring corticosteroid therapy, asthma and emphysema [20].

Our results shown that subjects with osteoporosis were mostly within overweight nutritional category. In inactive elderly individuals, overweight is usually associated with abdominal obesity [21]. The common approach that the excessive body mass has a protective role in osteoporosis prevention has been doubted due to results of studies on the negative effect exerted by the abdominal - visceral adipose tissue (AT) on the BMD. In addition to the AT effects to bone by mechanical burden and conversion of gonadal steroids, increased bone marrow adipogenesis, secretion of proinflammatory cytokines and adipokines could exert negative effects of adipocytes in the bone tissue [22].

Furthermore, regression equations and prediction coefficients in our study showed that subjects with osteoporosis are more prone to BMI depended BMD changes, regarding subjects with osteopenia and normal BMD. Also, normal weight subjects compared to overweight and obese, had highest prediction coefficients of changes in BMD. These

observations are in accordance with results obtained from studies by other researchers [23,24]. In this study the higher BMI had a more significant correlation with the femoral neck BMD than with BMD of lumbar spine. The femoral neck has a higher percentage of cortical bones as compared with the vertebrae, which can have a stronger effect on a cortical than on trabecular bone [25]. Elderly population, and obesity is associated with an inadequate status of micronutrients or hidden hunger, thus indirectly affecting bone status [26,27].

Limitations of this study include its cross-sectional design and setting, thus preventing causal relationships and generalization. Further details on specific aspects of body composition, data considering physical activity and predictors of bone status such as diet, nutrients are also needed.

CONCLUSION

High prevalence of low bone mass coexists with overweight and obesity in the elderly age category of females in Vojvodina. Prediction equations for the calculation of BMD can be used to evaluate the effect of BMI changes on BMD in clinical settings.

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Table 1. General characteristics of the study sample subjects

Characteristics (n = 1974)	
Female (n/N, %)	1866/1974 (95%)
Age in years	63 (56 - 70)
BMI (kg/m^2)	27.4 (24.5 - 30.9)
FN - BMD(g/cm^2)	0.9 (0.7 - 1.0)
FN - T Score	-1.1 (/-1.9/ - 0.3)
FN - Z Score	-0.3 (/-1/ - 0.4)
LS - BMD – (g/cm^2)	1.0 (0.9 - 1.1)
LS - T score	-1.5 (/-2.5/ - 0.4)
LS - Z score	-0.3 (/-1/ - 0.7)

BMI (kg/m^2) – body mass index; BMD - bone mineral density; FN – femoral neck, LS - lumbar spine

Table 2. Clinical characteristics and osteodensitometry measurements of the study sample subjects by categories

Parameters	Osteoporosis (n=494)	Osteopenia (n = 745)	Normal finding (n = 735)	Kruskal-Wallis test	Post hoc testing
Age (years)	65 (59 - 76)	62 (58 - 71)	60 (54 - 66)	p<0.001	p<0.001*
BMI (kg/m^2)	25.5 (21.7 - 27.3)	27.3 (23.9 - 30.0)	28.9 (25.9 - 32.4)	p<0.001	p<0.001*
Femoral neck BMD measurements					
BMD (g/cm2)	0.8 (0.6 - 0.7)	0.9 (0.76 - 0.84)	1.0 (0.9 - 1.0)	p<0.001	p<0.001*
T Score	-2 (/-3.3/ – /-2.6/)	-1.1 (/-2.0/ – /-1.4/)	-0.4 (/-0.7/ - 0.3)	p<0.001	p<0.001*
Z Score	-0.9 (/-2.2/ – /-1.2/)	-0.4 (/-1.2/ – /-0.4/)	0.1 (/-0.1/ – /-0.9/)	p<0.001	p<0.001*
Lumbar spine BMD measurements					
BMD (g/cm^2)	0.8 (0.7 - 0.9)	0.9 (0.8 - 1.0)	1.1 (1.0 - 1.2)	p<0.001	p<0.001*
T Score	-3 (/-3.7/ – /-2.2/)	-1.8 (/-2.8/ – /-1.3/)	0.0 (/-1.6/ – 0.3)	p<0.001	p<0.001*
Z score	-1.4 (/-2.0/ – /- 0.5/)	-0.4 (/-1.2/ – /- 0.1/)	1 (/-0.5/ - 1.3)	p<0.001	p<0.001*

BMI (kg/m^2) – body mass index, BMD (g/cm^2) - bone mineral density, * post hoc testing between groups osteoporosis vs. osteopenia, osteoporosis vs. normal finding, osteopenia vs. normal finding

Table 3. Comparisons of regional bone mineral density measurements in the region of femoral neck and lumbar spine by the nutritional status of the patients

Parameters	Normal weight (N=579) 23.1 (21.6 – 24.03) kg/m^2	Overweight (N=790) 27.3 (26.3 – 28.6) kg/m^2	Obesity (N=605) 32.8 (31.2-35.3) kg/m^2	Kruskal-Wallis test	post hoc testing
Femoral neck bone mineral density measurements					
BMD (g/cm^2)	0.8 (0.7 - 0.9)	0.9 (0.8 - 1.0)	0.9 (0.8 - 1.0)	p<0.001	p<0.001*
T Score	-1.6 (/-2.3/ – /-0.9/)	-1.1 (/-1.9/ – /- 0.3/)	-0.6 (/-1.4/ – /- 0.2/)	p<0.001	p<0.001*
Z Score	-0.7 (/-1.3/ - 0.0)	-0.3 (/-1.1/ - 0.4)	0.0 (/-0.7/ - 0.6)	p<0.001	p<0.001*
Lumbar spine bone mineral density measurements					
BMD (g/cm^2)	1.0 (0.8 - 1.1)	1.0 (0.9 - 1.1)	1.1 (1.0 - 1.0)	p<0.001	p<0.001*
T Score	-1.9 (/-2.9/ – /-1.0/)	-1.6 (/-2.5/ – /-0.5/)	-1 (/-2.5/ – /-0.5/)	p<0.001	p<0.001*
Z Score	-0.5 (/-1.3/ - 0.3)	-0.2 (/-1.0/ – 0.7)	-0.1 (/-0.9/ – 1.1)	p<0.001	p<0.001*

BMD – Bone mineral density

Table 4. Regression equations of BMD of femoral neck and lumbar spine in relation to BMI in all subjects

Formulas	Trend
Femoral neck BMD measurements	
BMD = 0.011 × BMI + 0.581	↑
T Score = 0.091 × BMI - 3.621	↑
Z Score = 0.057 × BMI - 1.906	↑
Lumbar spine BMD measurements	
BMD = 0.011 × BMI + 0.698	↑
TScore = 0.094 × BMI - 4.012	↑
ZScore = 0.052 × BMI - 1.589	↑

BMI (kg/m^2) – body mass index; BMD (g/cm^2) – bone mineral density

Table 5a. Regression equations of BMD of femoral neck and lumbar spine in relation to BMI in subjects with osteoporosis

Formulas	Trend
Femoral neck BMD measurements	
BMD = 0.01 × BMI + 0.509	↑
T Score = 0.081 × BMI - 4.128	↑
Z Score = 0.047 × BMI - 2.171	↑
Lumbar spine BMD measurements	
BMD = 0.004 × BMI + 0.7	↑
TScore = 0.031 × BMI - 4.007	↑
ZScore = /-0.014/ × BMI - 1.159	↓

BMI (kg/m^2) – body mass index; BMD (g/cm2) – bone mineral density

Table 5b. Regression equations of BMD of femoral neck and lumbar spine in relation to BMI in subjects with osteopenia

Formulas	Trend
Femoral neck BMD measurements	
BMD = 0.006 × BMI + 0.691	↑
T Score = 0.061 × BMI - 2.884	↑
Z Score = 0.036 × BMI - 1.399	↑
Lumbar spine BMD measurements	
BMD = 0.002 × BMI + 0.92	↑
TScore = 0.013 × BMI - 2.144	↑
ZScore = /-0.016/ × BMI - 0.013	↓

BMI (kg/m^2) – body mass index; BMD (g/cm2) – bone mineral density

Table 5c. Regression equations of BMD of femoral neck and lumbar spine in relation to BMI in subjects with normal BMD measurements

Formulas	Trend
Femoral neck BMD measurements	
BMD = 0.006 × BMI + 0.79	↑
T Score = 0.053 × BMI - 1.912	↑
Z Score = 0.032 × BMI - 0.075	↑
Lumbar spine BMD measurements	
BMD = 0.004 × BMI + 1.075	↑
TScore = 0.035 × BMI - 0.811	↑
Zscore = /-0.015/ × BMI - 0.701	↓

BMI (kg/m^2) – body mass index; BMD (g/cm^2) – bone mineral density

Table 6a. Regression equations of BMD of femoral neck and lumbar spine in relation to BMI in normal weight subjects

Formulas	Trend
Femoral neck BMD measurements	
BMD = 0.021 × BMI + 0.349	↑
T Score = 0.175 × BMI - 5.521	↑
Z Score = 0.161 × BMI - 4.299	↑
Lumbar spine BMD measurements	
BMD = 0.012 × BMI + 0.671	↑
TScore = 0.103 × BMI - 4.253	↑
ZScore = 0.099 × BMI - 2.698	↑

BMI (kg/m^2) – body mass index; BMD (g/cm2) – bone mineral density

Table 6b. Regression equations of BMD of femoral neck and lumbar spine in relation to BMI in overweight subjects

Formulas	Trend
Femoral neck BMD measurements	
BMD = 0.012 × BMI + 0.555	↑
T Score = 0.097 × BMI - 3.737	↑
Z Score = 0.057 × BMI - 1.848	↑
Lumbar spine BMD measurements	
BMD = 0.015 × BMI + 0.597	↑
TScore = 0.118 × BMI - 4.643	↑
ZScore = 0.067 × BMI - 1.909	↑

BMI (kg/m^2) – body mass index; BMD (g/cm2) – bone mineral density

Table 6c. Regression equations of BMD of femoral neck and lumbar spine in relation to BMI in obese subjects

Formulas	Trend
Femoral neck BMD measurements	
BMD = 0.008 × BMI + 0.661	↑
T Score = 0.075 × BMI - 3.094	↑
Z Score = 0.023 × BMI - 0.789	↑
Lumbar spine BMD measurements	
BMD = 0.011 × BMI + 0.719	↑
TScore = 0.089 × BMI - 3.876	↑
ZScore = 0.027 × BMI - 0.756	↑

BMI (kg/m^2) – body mass index; BMD (g/cm2) – bone mineral density

Figure 1. Trend lines of bone mineral density of femoral neck and lumbar spine in relation to body mass index in all subjects

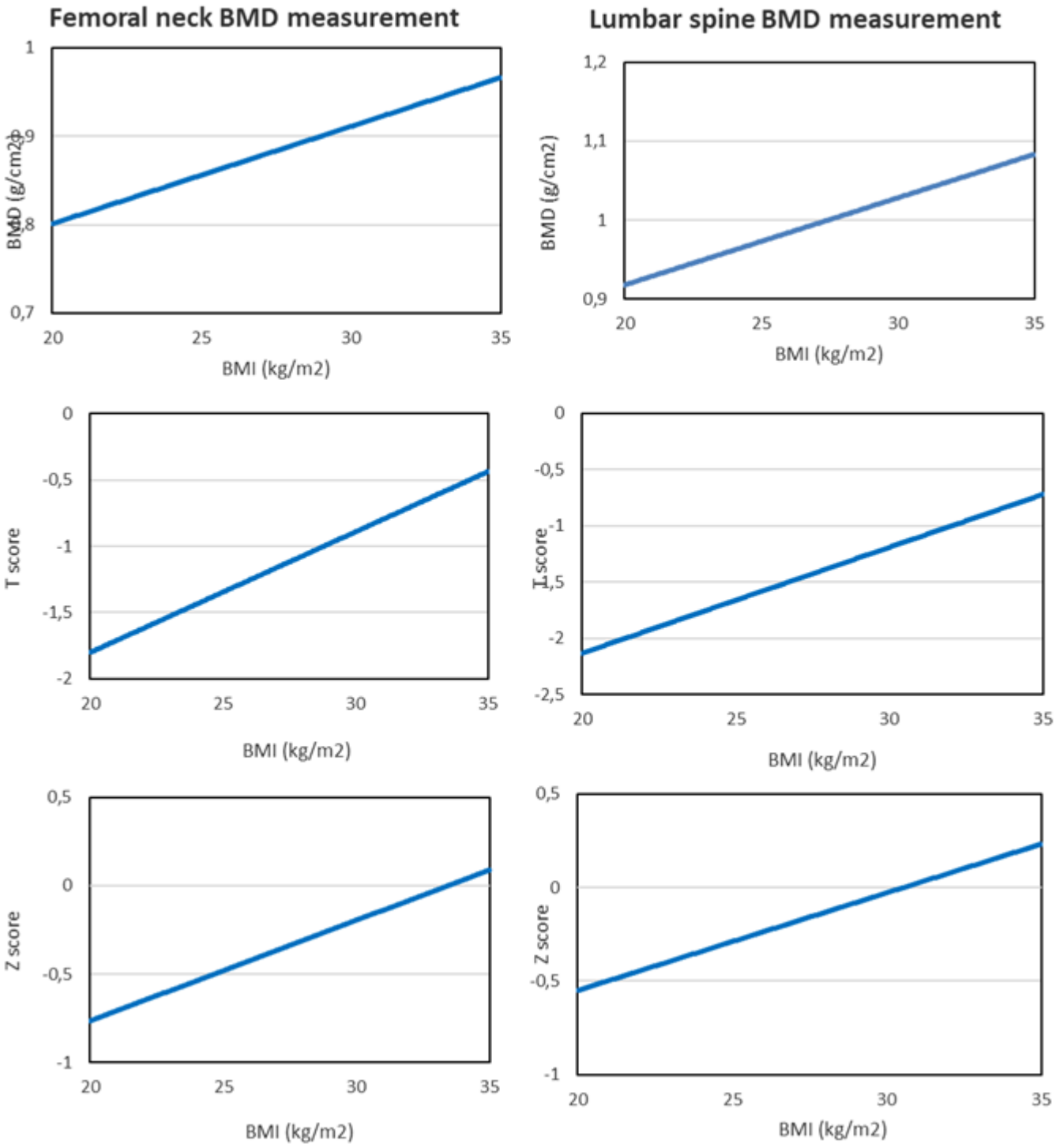

Figure 2. Trend lines of bone mineral density of femoral neck and lumbar spine for groups Osteoporosis, Osteopenia and Normal finding in relation to body mass index in all subjects

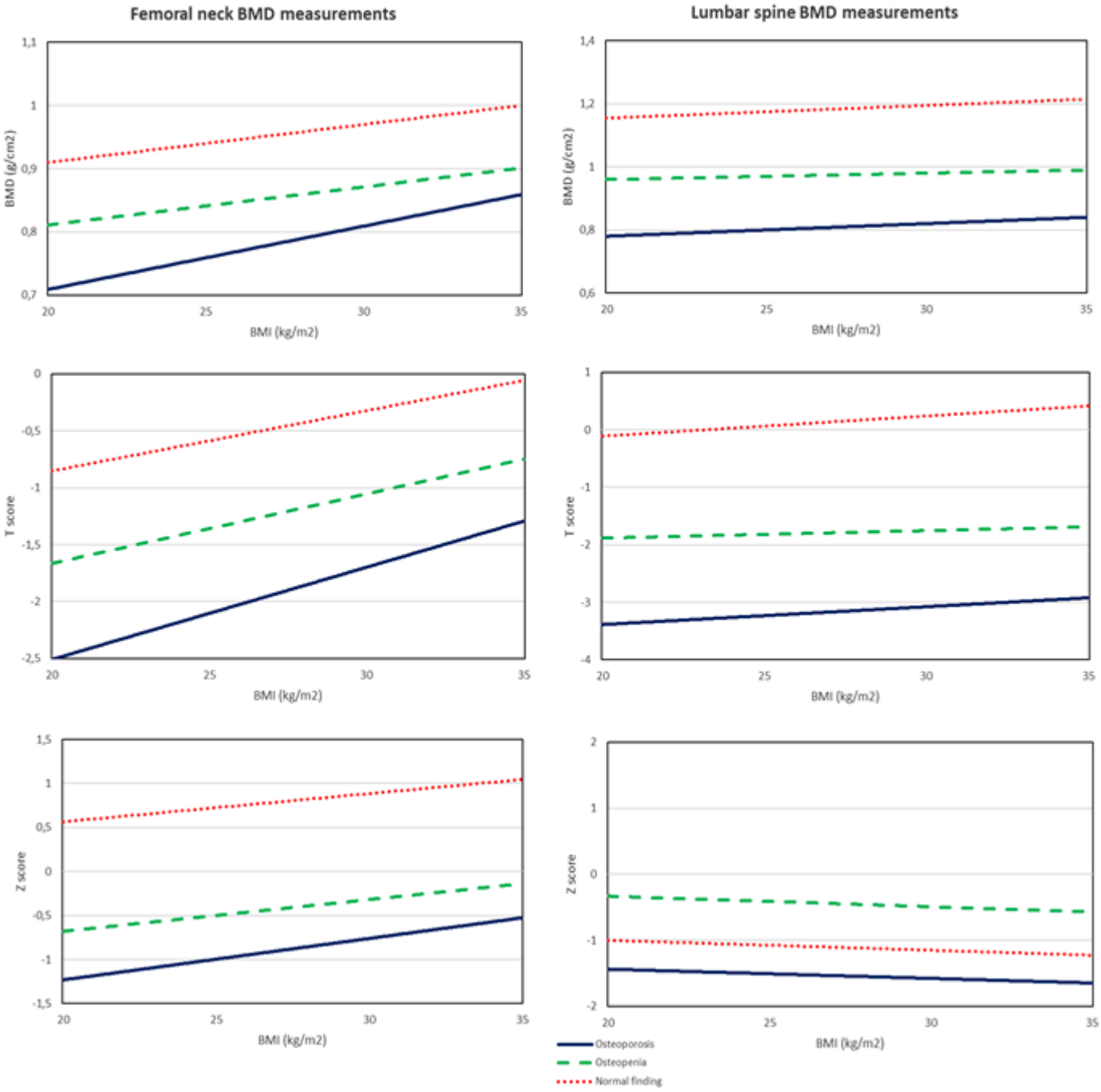

Figure 3. Trend lines of bone mineral density of femoral neck and lumbar spine for groups Normal weight, Overweight and Obesity in relation to body mass index in all subjects