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EFFECT OF THE LUMBAR SCOLIOSIS ON THE RESULTS OF DUAL-ENERGY X-RAY ABSORPTIOMETRY OF THE AXIAL SKELETON

ABSTRACT

(AUTHOR'S EXTENDED SUMMARY)

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The dissertation consists of 103 pages and contains 8 figures and 10 tables. The bibliography includes 105 scientific sources, of which 2 in Cyrillic and 103 in Latin.

The author is a PhD student in the Department of Orthopedics and Traumatology at the Medical University-Pleven.

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Defense materials are available at the Department of Science and are posted on the web site of Medical University Pleven.

CONTENT:

ABBREVIATIONS USED

BMD	bone mineral density
WHO	World health organisation
OP	Osteoporosis
NSAR	non-steroidal anti-inflammatory drug
BMI	body mass index
IAS	idiopathic adolescent scoliosis
DS	degenerative scoliosis
CS	corticosteroids
RA	Rheumatoid arthritis
DEXA	Dual energy X-ray absorptiometry
SD	standard deviation
keV	kiloelectron volt
OST	Osteoporosis Self-Assessment
ORAI	osteoporosis risk assessment instrument
SCORE	simple calculated osteoporosis risk estimation
OSIRIS	Osteoporosis Index of Risk
FRAX®	fracture risk assessment tool
ASD	adult spinal deformity
ASD	degenerative de novo
FRAX MO	FRAX Major Osteoporotic
FRAX Hf	FRAX hip fracture
DICOM	Digital Imaging and Communications in Medicine
ANOVA	Analysis of variance

1. Introduction

Double-energy X-ray absorptiometry (DEXA) is the gold standard for assessing bone mineral density (BMD) and is recommended for women ≥65 years of age, regardless of risk factors, all postmenopausal women under 65 years of age with at least one risk factor and women in perimenopause with significant risk factors. Low BMD has been found to be a potential risk factor for the formation of degenerative lumbar scoliosis. Spinal curvature in the lumbar region is one of the most common problems caused by degenerative changes in old age. Its incidence in older women varies from 7.5% to 13.3%. On the one hand, lumbar scoliosis and osteoporosis are common problems in the elderly and usually occur simultaneously, and on the other hand, this type of scoliosis can lead to difficulties in interpreting DEXA tests. According to the recommendations of the International Society for Clinical Densitometry, the BMD of all vertebrae (L1-L4) should be included in the analysis of the mean BMD values and the total T-score of the lumbar spine. In addition, it is suggested that in the event of a mismatch between the T-scores of adjacent vertebrae> 1.0 standard deviation (SD), there may be a vertebral fracture and such a vertebra with a very large difference in the T-score that cannot be estimated due to structural changes should be excluded from the overall analysis.

1.1. Double-energy X-ray absorptiometry (DEXA) – principles

The DEXA test is an X-ray three-component method (3-C), which provides information on 3 types of tissues - adipose, bone and "lean". It is based on photon absorptiometry and the so-called attenuation phenomenon. Due to the different molecular structure of the tissues, they deflect and absorb different amounts of photons, as a result of which different levels of photons reach the

receiver. The dual energy source in DEXA allows the recognition of bone mineral density (BMD), adipose tissue and "lean" tissue by determining the ratio (R) of the attenuation coefficients of the two energy rays. The two photon beams differ in intensity - 38 and 70 kiloelectronvolts (keV) as the beam with lower energy is stopped mainly by the bones, and the beam with higher energy passes through the soft tissues and bones.

1.2. Rules for proper lumbar spine scanning with DEXA

Position optimization in the DEXA study is essential. First of all, the axis of the patient's body must be well centered. Improper positioning is one of the main reasons for errors in the assessment of the IMC. When examining the lumbar spine, the patient should lie on the table with his legs placed on a special block and armpits placed on a pillow. The goal is to reduce lumbar lordosis and bring the spine closer to the table. All external artifacts must be removed. Proper scanning requires the spine to be in the center of the image, to be as upright as possible to prevent scoliosis above 15 °, the image to start from the middle of the fifth lumbar vertebra, to see the gripping parts of the ribs for the 12th thoracic vertebra and in the two lower corners to show the wings of the iliac bones.

1.3. Interpretation of DEXA results

DEXA results are reported as numerical values for BMD, T-score and Z-score. The T-score compares the BMD of the subject with a young healthy population and the Z-score compares the BMD of the subject with his peers. In 1994, the WHO set thresholds for diagnosing osteopenia and osteoporosis with DEXA. As a result, DEXA measurements are currently the benchmark for the clinical diagnosis of osteoporosis. In particular, the WHO classifies BMD based

on T-score as normal BMD (≥-1.0 SD), osteopenia (<-1.0 SD and > -2.5 SD), osteoporosis (≤-2.5) and severe osteoporosis (≤ -2.5). with a fracture).

The axial skeleton (spine and hip) is the most suitable place to measure BMD, as it is the place that suffers from the most severe fractures. In particular, the lumbar spine (L1 to L4) and the proximal femur (total hip, femoral neck, trochanter, and WARD area) were measured with axial DEXA devices.

It has been proven that the most reliable prognosis for future fractures is achieved by measuring the location of the future fracture. Thus, the risk of fracture of the femur is best assessed by the proximal BMD of the femur while vertebral fractures are best determined by measuring the BMD of the lumbar spine. Because DEXA is a two-dimensional technique, it has some inherent limitations and cannot help distinguish cortical and trabecular bone, as well as differentiate changes due to bone geometry (eg variations in the third dimension). In addition, microstructural characteristics (eg trabecular shape, size, number, orientation, etc.) cannot be assessed.

There are factors that can lead to clinically significant diagnostic errors: the presence of osteomalacia leads to underestimation of bone mass; osteoarthritis of the spine or hip can increase the measured bone density without improving the actual skeletal strength. Soft tissue calcifications, previous fractures, severe scoliosis, or vertebral deformities can be sources of error in diagnosing osteoporosis with DEXA measurement.

The use of the DEXA test requires well-trained staff: incorrect positioning of the patient, scan analysis or errors in interpretation can lead to errors in diagnosis and subsequent therapy. In addition, it should be remembered that the DEXA measurement always exposes the patient to a certain dose of radiation. Although the radiation dose in modern DEXA devices is small, it still hinders the feasibility of the technique for large-scale population studies.

1.4. Examination of BMD with DEXA

Bone mineral density (BMD) is defined as the bone mineral content divided by the projected area of the scanned image and is represented by the following formula:

BMD = BMC / area (g / cm2), where BMC is the bone mineral content

The BMD can also be represented as a T-score and a Z-score, which represent the number of standard deviations (SDs) relative to the reference mean. The T-score describes the difference between the BMD of the study patient and the mean BMD of the standard young population (20-30 years of age, when the BMD usually reaches a peak value). The Z-score shows the difference between the patient's BMD and the mean BMI of the controls corresponding to the patient's age and sex.

The BMD measured by DEXA also serves to assess fracture risk and monitor the effect of treatment.

The recommended skeletal areas for measuring BMD for diagnostic purposes are:

1. lumbar spine (anterior-posterior projection) in all patients
2. proximal femur in all patients
3. forearm, only if the vertebral bodies in anterior-posterior projection or proximal femur cannot be measured or correctly interpreted (advanced arthritic changes, previous vertebral fractures, vertebro- or kyphoplasty, coxarthrosis, arthroplasty), presence of hyperparathyroidism or above the limit of the device), inability of the patient to take the correct position for the measurement.

The diagnosis of osteoporosis is based on the area with the lowest measured value of BMD (lumbar spine, femoral neck, total hip, radius).

Repeated measurements of BMD with DEXA are recommended:

1. In treated patients to monitor the effect of treatment. Retention or elevation of BMD, which is associated with reduced fracture risk, is acceptable. The loss of BMD requires additional assessment (lack of adherence to therapy, lack of response to treatment).

2. In untreated patients to determine the amount of bone loss. Rapid bone loss is an indication to start treatment and is associated with an increased fracture risk.

Repeated measurements are performed with the same apparatus, in the same area as the initial ones. A comparison of the BMD measured on different instruments is allowed only if cross-calibration has been performed.

1.5. Fracture risk assessment

Factors for assessing fracture risk include a history of parental hip fracture, smoking, excessive alcohol consumption, low body weight and others. If there is at least one risk factor, a reasonable approach to determining the need for an osteodensitometer test is to use a clinical risk assessment tool. The methods offered are many and varied.

1.6. Osteopenia

Osteopenia is a clinical term, a condition of decreased BMD below normal reference values or a T-score in the range of -2.5 and -1. The reduction of BMD is a reflection of the worsening of microarchitectonics in the bones. Osteopenia occurs when the balance between osteoclasts and osteoblasts is disturbed and bone mass is reduced quantitatively. Histologically, there is a thinning of the trabeculae, a decrease in the size of the osteon and an increase in the haversian

canals. The factors for the development of osteopenia are many and can be correctable and uncorrectable. Uncorrectable factors are age, race, gender and family predisposition. Peak bone mass accumulates until the age of 30 and then begins gradual bone resorption. The European race has a higher risk than the African American and others. Family predisposition includes a history of low BMD in the family. Adjustable risk factors are smoking, alcohol, inactivity, malnutrition, malnutrition.

1.7. Osteoporosis

Osteoporosis (OP) is a metabolic bone disease and according to the World Health Organization (WHO) is among the diseases of the greatest social significance. Due to the aging trend of the population, reduced physical activity, poor nutrition and abuse of cigarettes and alcohol, OP disease is becoming more frequent and becoming an increasingly important problem. Bone mass is reduced due to disturbed balance between bone formation and bone resorption. Subsequently, the bone beams become thinner, the bone strength decreases and as a result the fracture risk increases. The diagnosis of OP can also be made on the basis of a fracture that occurred with minimal trauma that would not cause a bone fracture of normal strength. Osteoporous fractures lead to a deterioration in the quality of life of patients, and the economic burden of osteoporotic fractures, calculated on the basis of data for European countries, is in the order of 37 billion euros.

1.8. Lumbar scoliosis

The word "scoliosis" (Greek σκολιός - "curve", Latin scoliōsis) was proposed in medicine in the second century AD by K. Galen and combines all

kinds of permanent lateral curvatures of the spine. According to various authors, the prevalence of this pathology is from 3.2% to 30% of the population. The large variation in the numbers is due to the lack of a unified approach in diagnosing this disease during the examination.

Usually today we call scoliosis the deformation of the spine in the frontal plane, which is defined as a lateral deviation of the normal vertical line of the spine.

The frontal deformation can be:

1. idiopathic spinal deformity in adults or also called adult spinal deformity (ASD), which is most often the result of untreated adolescent idiopathic scoliosis, preserved in adults.

2. degenerative ASD, defined as progressive deformity in an adult caused by:

- degenerative changes
- iatrogenic
- paralytic injuries
- trauma

In Bulgaria the used clinical-radiological classification of scoliosis in the practice, including in dispensary observation, is the classification of V.D. Chaklin (1958). It defines 4 degrees of scoliosis according to the angle of the curvature of the spine:

I degree: 5 - 10 °

II degree: 10 - 25 °

III degree: 25 - 45 °0

IV degree: 45 - 75 °

1.9. Scoliosis assessment studies based on the DEXA study

The study of the relationship between degenerative changes in the spine and osteoporosis has been the subject of a number of scientific publications. Spinal degenerative changes in patients with pain symptoms do not differ from those in patients without pain symptoms. However, significant inactivity in patients with pain caused by a compression fracture against the background of degenerative changes in the spine leads to subsequent bone loss with the risk of developing more fractures, subsequent pain and even deeper inactivity. The presence of osteoporosis of the spine against the background of degenerative changes favors the appearance of compression fractures and the development of deformity and stenosis. Clinicians are responsible for recognizing the presence of degenerative changes in imaging studies accompanied by clinical symptoms. It is accepted that the spine with degenerative changes may be completely asymptomatic. Imaging (radiography, computed tomography, magnetic resonance imaging) reveals the presence of degenerative changes in the intervertebral joints and discs. However, sometimes these studies have limited use, especially in adult patients without symptoms. Osteoarthritis of the spine, degenerative changes in the discs, narrowing of the joint spaces together with bone remodeling due to osteoporosis are changes associated with the aging of the spine. These degenerative changes caused by vertebral deformities, changes in the distribution of forces and weights, as well as the normal order of the vertebral column, lead to the appearance of degenerative segmental instabilities and subluxations such as spinal stenosis, spondylolisthesis and scoliosis. Degenerative spondylolisthesis and scoliosis are mostly asymptomatic, but may be associated with a worsening of a pre-existing problem.

2. Aim and tasks

The aim of the study was to evaluate the effect of lumbar scoliosis on the DEXA result of the axial skeleton.

Tasks:

1. To determine whether women with spinal curvature have a significant difference in BMD and T-score of lumbar spine and femur compared to those without curvature.

2. To examine whether women with lumbar curvature have a significant difference in age, height and weight compared to those without curvature.

3. To determine whether women with lumbar curvature have a more frequent difference in T-scores between adjacent vertebrae of more than 1.0 SD.

4. To determine whether there is a significant difference between the T-scores of the lumbar spine and femur in women with spinal curvature compared to those without curvature.

5. To investigate whether women with lumbar curvature have a higher fracture risk than women without lumbar curvature.

3. Material and methods

3.1. Study design

This study examined data from 1,019 patients who underwent axial DEXA osteodensitometry of the spine and hip on the same day for the period from January 2017 to July 2019. in the Clinic of Imaging Diagnostics of the University Hospital "Dr. G. Stranski" in Pleven. DEXA osteodensitometry was performed with a dual-energy X-ray absorber QDR 4500 C from Hologic, USA, based in the same Clinic. The result obtained from osteodensitometry is evaluated for the presence of lumbar scoliosis and the data for BMD. Only women over the age of 40 were studied.

Three groups of patients were formed, divided according to the angle of spinal curvature. The first group is without spinal curvature and includes a Cobb angle <5 °. The second group has a spinal curvature and includes two subgroups - one with a Cobb angle of 5 ° to 10 ° and the other with a Cobb angle above 10 °. According to the total T-score of L1-L4, women can be divided into those with osteoporosis, osteopenia and normal BMD. Osteoporosis is defined at a total T-score of L1-L4 below -2.5 SD; osteopenia at a T-score between -2.5 and -1.5 SD; normal BMD we have at a total T-score of L1-L4 above -1.5 The same division can be applied to the T-score of the hip.

3.2. Measured parameters and definitions

The parameters included in the study are: age, weight, height, total BMD of L1-L4, total T-score of L1-L4, maximum difference in T-score between L1 to L4, BMD of the hip, T-score of hip, difference between L1-L4 T-score and hip, Cobb angle, FRAX Major Osteoporotic and FRAX hip fracture. Weight and height data are determined in advance. After a spinal scan, the values for total L1-L4 BMD, total L1-L4 T-score, total hip BMD, and total hip T-score are presented. DEXA of the lumbar spine provides BMD and T-score values for each individual vertebra from L1 to L4, as well as total BMD and total T-score. The maximum difference in the T-scores of adjacent vertebrae is defined as the value of the difference between the T-scores of the two vertebrae with the largest one. For each pair of vertebrae, the difference in the T-score is calculated, and if any of these pairs has a difference greater than 1 SD, the patient falls into the corresponding group. Groups of patients with a difference of <1 SD and> 1 SD are formed.

For each patient, previous data are checked and measurements for hip BMD and hip T-score are entered. The difference between the T-score of L1-L4 and the T-score of the hip is calculated from the corresponding values in the presence of a DEXA examination of the hip. FRAX Major Osteoporotic and FRAX hip fracture are patents of FRAX® and are calculated according to a special algorithm published on the website of the University of Sheffield.

3.3. Cobb angle measurement from DEXA image

The measurement of the Cobb angle of the lumbar curvature was made on the basis of the image from the DEXA study of the lumbar spine using DICOM software. Tangents are drawn to the upper surface of the first terminal and the lower surface of the last vertebra in the curved arc. The intersection of the two lines determines the angle of deformation. The magnitude of the deformity of the apical vertebra is similar.

We use the clinical-radiological classification of scoliosis according to V.D. Chaklin (1958), which is recognized in Bulgaria and determines 4 degrees according to the angle of the arc of curvature of the spine:

I degree: 5 - 10 °

II degree: 10 - 25 °

III degree: 25 - 45 °

IV degree: 45 - 75 °

Although according to Chaklin's classification there are four degrees of scoliosis, in the present dissertation two subgroups are formed in the group of patients with scoliosis - with a Cobb angle from 5 ° to 10 ° and with a Cobb angle above 10 °. The reason for this is the small number of patients in the group with third degree scoliosis according to Chaklin's classification and the lack of those with fourth degree.

The values of BMD, measured at different anatomical places of the human body, most often correlate with each other, but in determining the diagnosis they

do not always coincide. T-score mismatch between lumbar spine and hip is a common phenomenon in osteodensitometry. This discrepancy represents a variation in a patient's T-score at different key measurement sites. This phenomenon is divided into two groups: maximum and minimum difference or also called maximum and minimum discordance. We observe minimal difference or discordance when the classes of diagnoses are adjacent to each other: for example, from the measurement of the spine we have osteoporosis, and of the hip - osteopenia and vice versa. However, if the diagnosis is osteoporosis in one place and BMD in the other is normal, then we have a maximum difference or discordance. Although the presence of a discrepancy may affect the patient's final diagnosis and treatment plan, measurement of BMD in several anatomical areas is routinely recommended.

3.4. Data analysis and statistics

Statistical analysis is performed using SPSS software version 19. For the purposes of descriptive statistics, the following parameters are used: mean, standard deviation, standard error, minimum and maximum value. Using the descriptive statistics, we present the data in tables and figures. Descriptive statistics summarize the samples and observations. Univariate analysis involves describing the distribution of a variable by its mean, median, and mode. The variance is expressed in the values of range, quartiles and standard deviation. In the present dissertation the ANOVA test and the chi-square test for performing the univariate analysis are applied.

4. Results

4.1. General characteristics of patients

After conducting a descriptive statistical analysis, it was found that 1019 women had a mean age of 60.84 years (years) ± 9.5 years SD with a minimum age of 40 years and a maximum age of 89 years (Fig. 1). The mean height of the patients was 160.22 cm ± 9.3 cm SD (range from 140 cm to 185 cm) and the mean weight was 70.56 kg. ± 15.3 kg. SD (range 48 - 165 kg). According to the studies of the lumbar spine, the total BMD of L1-L4 and the total T-score of L1-L4 were measured for all 1019 women. The total BMD of L1-L4 is on average 0.865g / cm2 ± 0.194 g / cm2 SD (minimum value 0.44 g / cm2 and maximum

value 2.70 g / cm2), and the total T-score of L1-L4 is on average - 1.65 SD ± 1.752 SD (range -5.6 SD to 14.80 SD). The mean value of the maximum difference in the T-score of L1-L4 is 1.38 SD ± 0.894 SD with a range from 0 to 7.3 SD. BMD and T-score of the whole hip were estimated for 1009 patients. The total BMD of the whole hip averaged 0.805g / cm2 ± 0.284g / cm2 SD (minimum value 0 g / cm2 and maximum value 4.3 g / cm2), and the total T-score of the hip averaged 1.19 SD ± 1.21SD (range of -4.2 SD to 7.6 SD). The mean difference in the T - scores of the lumbar spine and hip was calculated for 998 women and averaged 1.102 SD ± 1.034 SD and ranged from 0 to 15.9 SD. The Cobb angle was measured for all 1019 patients and had a mean value of 2.76 ° ± 2.53 ° SD and ranged from 0 ° to 30 °, (Table 1).

	Count (N)	Min. value	Max. value	Mean value	Standard deviation (SD)
Age (yrs.)	1019	40	89	60.84	9.501
Height (cm)	1019	140	185	160.22	9.265
Weight (κg)	1019	48	165	70.56	15.265
Total BMD L_1-L_4 (g/cm^2)	1019	.44	2.70	.8645	.19437
Total T-score L_1-L_4 (SD)	1019	-5.60	14.80	-1.6532	1.75174
T-score max. difference between L_1-L_4 (SD)	1019	.0000	7.3000	1.376840	.8938413
Hip BMD (g/cm^2)	1009	.00	4.26	.8050	.28416
Hip T-score (SD)	1003	-4.20	7.60	-1.1894	1.20826
Difference in T-scores between L_1-L_4 and hip (SD)	998	.0000	15.9000	1.101603	1.0343632
Cobb angle (°)	1019	.0000	30.0388	2.762553	2.5269054

Table 1. General characteristics of patients; min. - minimal; max. - maximum

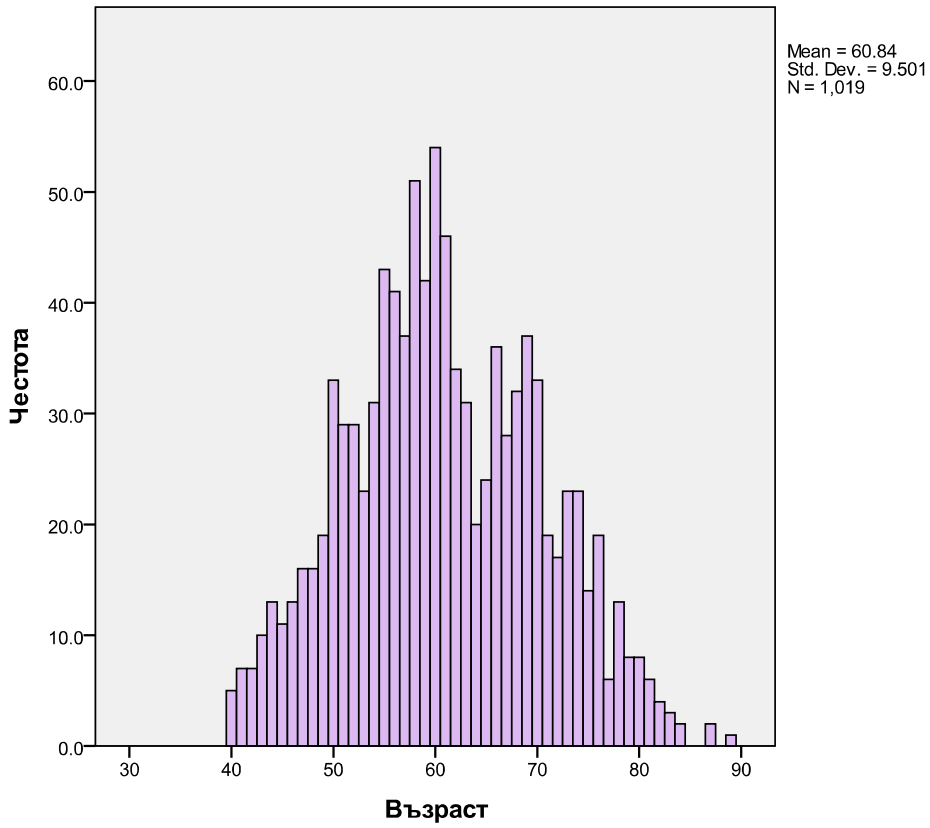

Fig. 1. Distribution of the patients by age

4.2. Distribution of patients with spinal curvature according to the Cobb angle

Three groups of patients were formed, divided according to the angle of spinal curvature. The first group is without spinal curvature and includes a Cobb angle <5 degrees. The second group has a spinal curvature and includes two subgroups - one with a Cobb angle of 5 ° to 10 ° and the other with a Cobb angle above 10 °. After measuring the Cobb angle, it was found that out of a total of 1019 women, 894 women (87.7%) had a Cobb angle <5 °, 106 (10.4%) women had a Cobb angle of 5-10 ° and 19 (1.9%) females have a Cobb angle> 10 °, (Fig. 2). The incidence of lumbar spinal curvature amounts to 125/1019 women (12.3%).

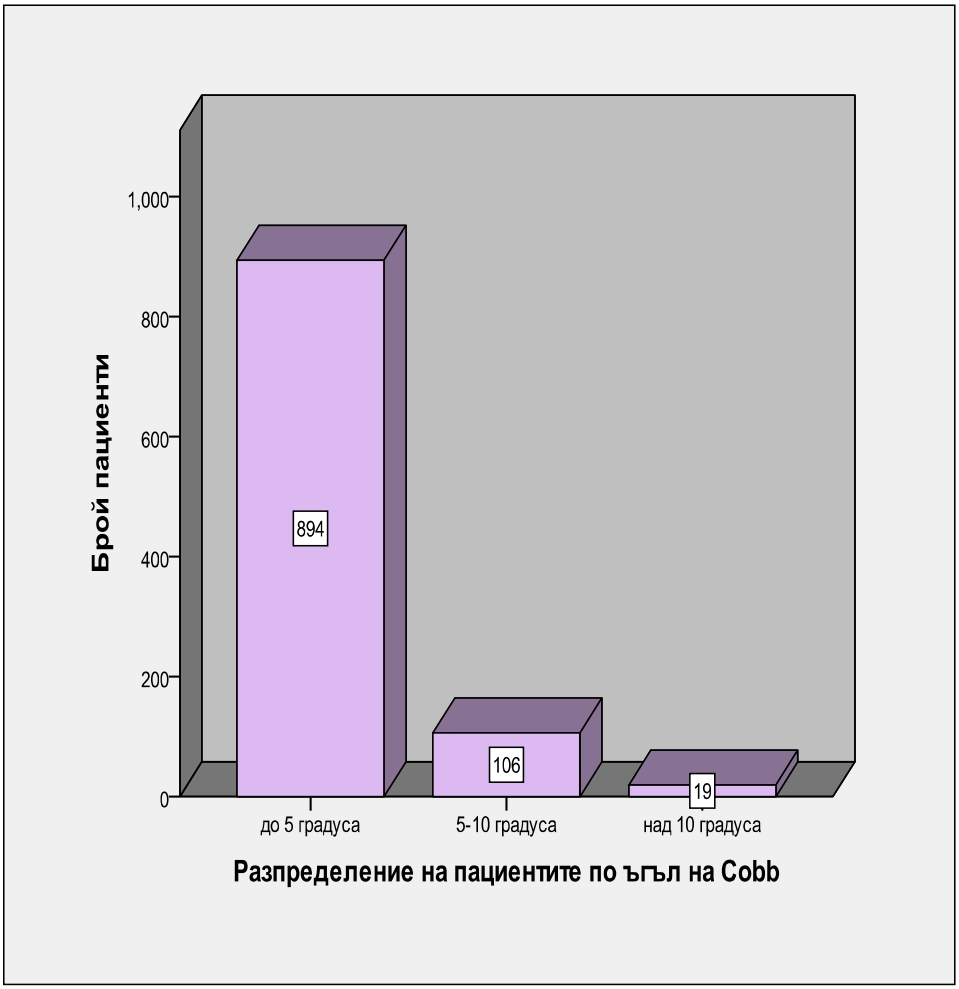

Fig. 2. Distribution of patients according to the Cobb angle

4.3. Characteristics of patients in the individual groups according to the Cobb angle

Patients in the Cobb angle <5 ° group had a mean age of 60 years (years) ± 9 years SD with a minimum age of 40 years and a maximum age of 87 years with a standard error of 0. The mean height of the patients was 160 cm. ± 10 cm SD (range from 140 cm to 185 cm) and the average weight is 71 kg. ± 15.3 kg. SD (range 48 - 165 kg). According to the studies of the lumbar spine, the total BMD of L1-L4 and the total T-score of L1-L4 for all 894 women were measured. The total BMD of L1-L4 is on average 0.86 g / cm2 ± 0.19 g / cm2 SD (minimum value 0.44 g / cm2 and maximum value 2.70 g / cm2), and the total T-score of L1-L4 is on average 1.68 SD ± 1.74SD (range -5.6 SD to 14.80 SD). The mean value of the maximum difference in the T-score of L1-L4 is 1.34 SD ± 0.87 SD with a range from 0 to 7.3 SD. BMD and T-score of the whole hip were estimated for 882 patients. The total BMD of the whole hip averaged 0.79 g / cm2 ± 0.15 g / cm2 SD (minimum value 0 g / cm2 and maximum value 1.86 g / cm2), and the total T-score of the hip averaged 1.17 SD ± 1.20 SD (range of -4.1 SD to 7.6 SD). The mean difference in the T - scores of the lumbar spine and hip was calculated for 894 women and averaged 1,091 SD ± 0.035 SD and ranged from 0 to 15.9 SD, (Table 2).

	Characteristics					
	Mean value	Max.	Min.	Count (N)	SD	Standard error
Age (yrs)	60	87	40	894	9	0
Height (cm)	160	185	140	894	10	0
Weight (kg)	71	165	48	894	15	1
Total BMD L1-L4 (g/cm^2)	.86	2.70	.44	894	.19	.01
Total T-score L1-L4 (SD)	-1.68	14.80	-5.60	894	1.74	.06
T-score max. difference between L1-L4 (SD)	1.3412	7.3000	.0000	894	.8701	.0291
T-score of the hip (SD)	-1.17	7.60	-4.10	882	1.20	.04
BMD of the hip (g/cm^2)	.79	1.86	.00	882	.15	.01
Difference in T-scores between L1-L4 and hip (SD)	1.0912	15.9000	.0000	882	1.0243	.0346

Table 2. Characteristics of patients with Cobb angle <5 °

Patients in the group with a Cobb angle of 5 ° - 10 ° were with mean age 65 years (years) ± 10 years. SD with a minimum age of 41 years and a maximum age of 87 years with standard error 1. The mean height of the patients was 161 cm ± 6 cm SD (range 146 cm to 174 cm) and the average weight was 70 kg. ± 15 kg. SD (range 42 - 110 kg). According to the measurements of the lumbar spine, the total BMD of L1-L4 and the total T-score of L1-L4 for all 106 women were measured. The total BMD of L1-L4 is on average 0.90g / cm2 ± 0.21g / cm2 SD (minimum value 0.54 g / cm2 and maximum value 1.61 g / cm2), and the total T-score of L1-L4 is on average 1.31 SD ± 1.88 SD (range -4.6 SD to 5.10 SD). The mean value of the maximum difference in the T-score of L1-L4 is 1,623 SD ± 0.93 SD with a range from 0.3 to 5.4 SD. BMD and T-score of the entire hip were assessed for 106 patients. The total BMD of the whole hip averaged 0.78 g / cm2 ± 0.15 g / cm2 SD (minimum 0.42 g / cm2 and maximum 1.29 g / cm2), and the total T-score of the hip averaged 1.22 SD ± 1.24 SD (range of -4.2 SD to 2.9 SD). The mean difference in lumbar spine and hip T-scores was calculated for 106 women and averaged 1,224 SD ± 1,153 SD and ranged from 0 to 5.9 SD, (Table 3).

	Characteristics					
	Mean value	Max.	Min.	Count (N)	SD	Standard error
Age (yrs)	65	87	41	106	10	1
Height (cm)	161	174	146	106	6	1
Weight (kg)	70	110	42	106	15	1
Total BMD L1-L4 (g/cm^2)	.90	1.61	.54	106	.21	.02
Total T-score L1-L4 (SD)	-1.31	5.10	-4.60	106	1.88	.18
T-score max. difference between L1-L4 (SD)	1.6236	5.4000	.3000	106	.9250	.0898
T-score of the hip (SD)	-1.22	2.90	-4.20	105	1.24	.12
BMD of the hip (g/cm^2)	.78	1.29	.42	105	.15	.01
Difference in T-scores between L1-L4 and hip (SD)	1.2238	5.9000	.0000	105	1.1533	.1126

Table 3. Characteristics of patients with a Cobb angle of 5 ° - 10 °

Patients in the group with a Cobb angle> 10 ° had a mean age of 66 years (years) ± 10 years. SD with a minimum age of 43 years and a maximum age of 89 years with a standard error of 2. The mean height of the patients was 159 cm ± 7 cm SD (range from 159 cm to 170 cm) and the average weight was 63 kg. ± 15 kg. SD (range 41 - 105 kg). According to the studies of the lumbar spine, the total BMD of L1-L4 and the total T-score of L1-L4 for all 19 women were measured. The total BMD of L1-L4 is on average 0.78 g / cm2 ± 0.12 g / cm2 SD (minimum value 0.60 g / cm2 and maximum value 1.10 g / cm2), and the total T-score of L1-L4 is on average 2.45 SD ± 1.11 SD (range -4.1 SD to 0.50 SD). The mean value of the maximum difference in the T-score of L1-L4 is 1.679 SD ± 1.45 SD with a range from 0.3 to 5.3 SD. BMD and T-score of the entire hip were assessed for 19 patients. The total BMD of the whole hip averaged 0.66 g / cm2 ± 0.09 g / cm2SD (minimum value 0.43 g / cm2 and maximum value 0.82g / cm2), and the total T-score of the hip averaged -2.24 SD ± 0.80 SD (range of -4.1 SD to - 0.9 SD). The mean difference in the lumbar spine and hip T-scores was calculated for 19 women and averaged 0.869 SD ± 0.675 SD and ranged from 0.1 to 2.2 SD, (Table 4).

	Characteristics					
	Mean value	Max.	Min.	Count (N)	SD	Standard error
Age (yrs)	66	89	43	19	10	2
Height (cm)	159	170	148	19	7	2
Weight (kg)	63	105	41	19	15	3
Total BMD L1-L4 (g/cm^2)	.78	1.10	.60	19	.12	.03
Total T-score L1-L4 (SD)	-2.45	.50	-4.10	19	1.11	.25
T-score max. difference between L1-L4 (SD)	1.6789	5.3000	.3000	19	1.4562	.3341
T-score of the hip (SD)	-2.24	-.90	-4.10	16	.80	.20
BMD of the hip (g/cm^2)	.66	.82	.43	16	.09	.20
Difference in T-scores between L1-L4 and hip (SD)	.8688	2.2000	.1000	16	.6750	.1688

Table 4. Characteristics of patients with Cobb angle> 10 °

4.4. Comparison of BMD and T - score of spine and hip between the different groups according to the angle of Cobb

To determine whether women with spinal curvature had a significant difference in BMD and T-score of the lumbar spine and hip compared to those without curvature, an ANOVA test was performed to compare the differences in mean values between groups according to the Cobb angle, (Table 5).

ANOVA test								
		(N)	Mean value	SD	SE	95% Confidential interval (CI)		P - value
						Lower	Upper	
BMD and T-score	Cobb angle							
Total T-score L1-L4 (SD)	< 5°	894	-1.6775	1.74046	.05837	-1.7921	-1.5629	0.016
	5 - 10°	106	-1.3057	1.87966	.18257	-1.6677	-.9437	
	>10°	19	-2.4526	1.10824	.25425	-2.9868	-1.9185	
	Total	1019	-1.6532	1.75174	.05501	-1.7611	-1.5452	
Total BMD L1-L4 (g/cm^2)	< 5°	894	.8618	.19320	.00648	.8491	.8745	0.016
	5 - 10°	106	.9031	.20803	.02021	.8630	.9431	
	>10°	19	.7769	.12257	.02812	.7178	.8360	
	Total	1019	.8645	.19437	.00610	.8526	.8765	

BMD and T-score	Cobb angle	(N)	Mean value	SD	SE	95% Confidential interval (CI)		P - value
						Lower	Upper	
T-score of the hip (SD)	< 5°	882	-1.1662	1.20358	.04053	-1.2458	-1.0867	0.002
	5 - 10°	105	-1.2248	1.23559	.12058	-1.4639	-.9856	
	>10°	16	-2.2375	.80156	.20039	-2.6646	-1.8104	
	Общо	1003	-1.1894	1.20826	.03815	-1.2643	-1.1146	
BMD of the hip (g/cm^2)	< 5°	882	.7891	.15226	.00513	.7790	.7991	0.004
	5 - 10°	105	.7845	.15011	.01465	.7555	.8136	
	>10°	16	.6604	.09885	.02471	.6078	.7131	
	Общо	1009	.7865	.15208	.00480	.7771	.7960	

Table 5. ANOVA test for comparison of BMD and T-score between the 3 groups of patients according to the Cobb angle; N - number; Wed. st-t - average value; SD - standard deviation; SG - standard error

After the ANOVA test in the individual groups according to the Cobb angle, a significant difference was found in the total T-score of L1-L4 (p = 0.016) and in the total T-score of the hip (p = 0.002). Patients with a Cobb angle> 10 ° have a significantly lower mean T-score of L1-L4 (-2.5 SD) and hip (-2.2 SD) than patients with a Cobb angle of 5 ° - 10 ° score of L1-L4 = -1.3 SD and T-score of hip = -1.2 SD) and those with Cobb angle <5 ° (T-score of L1-L4 = -1.6 SD and T score of hip = -1.2 SD). The L1-L4 BMD and hip BMD in patients with a Cobb angle> 10 ° were also significantly lower (0.777 g / cm2 for L1-L4

and 0.660 g / cm2 for the hip) compared to those in patients with a Cobb angle of 10 °. Cobb 5 ° - 10 ° (0.903g / cm2 for L1-L4 and 0.785 g / cm2 for hip) and Cobb angle <5 ° (0.862 g / cm2, respectively 0.789 g / cm2), (p = 0.016 for L1-L4 and p = 0.004 for hip).

4.5. Estimation of the incidence of Osteopenia and Osteoporosis of the spine and hip in the individual groups according to the Cobb angle

The group of patients with a Cobb angle> 10 ° showed the highest incidence of osteoporosis in L1-L4 - 10/19 women (52.6%). This frequency decreased by about 20% in the group of patients with a Cobb angle of 5 - 10 ° (31/106 women - 29.2%) and in the group of patients with a Cobb angle <5 ° (287/889 - 32.3%). The incidence of osteopenia was similar in all three groups - 38.4% (341/889) in the group of patients with a Cobb angle <5 °, 29.3% (31/106) in the group of patients with a Cobb angle 5 ° - 10 ° and 36.8% (7/19) in the group of patients with a Cobb angle> 10 °, (Fig. 4).

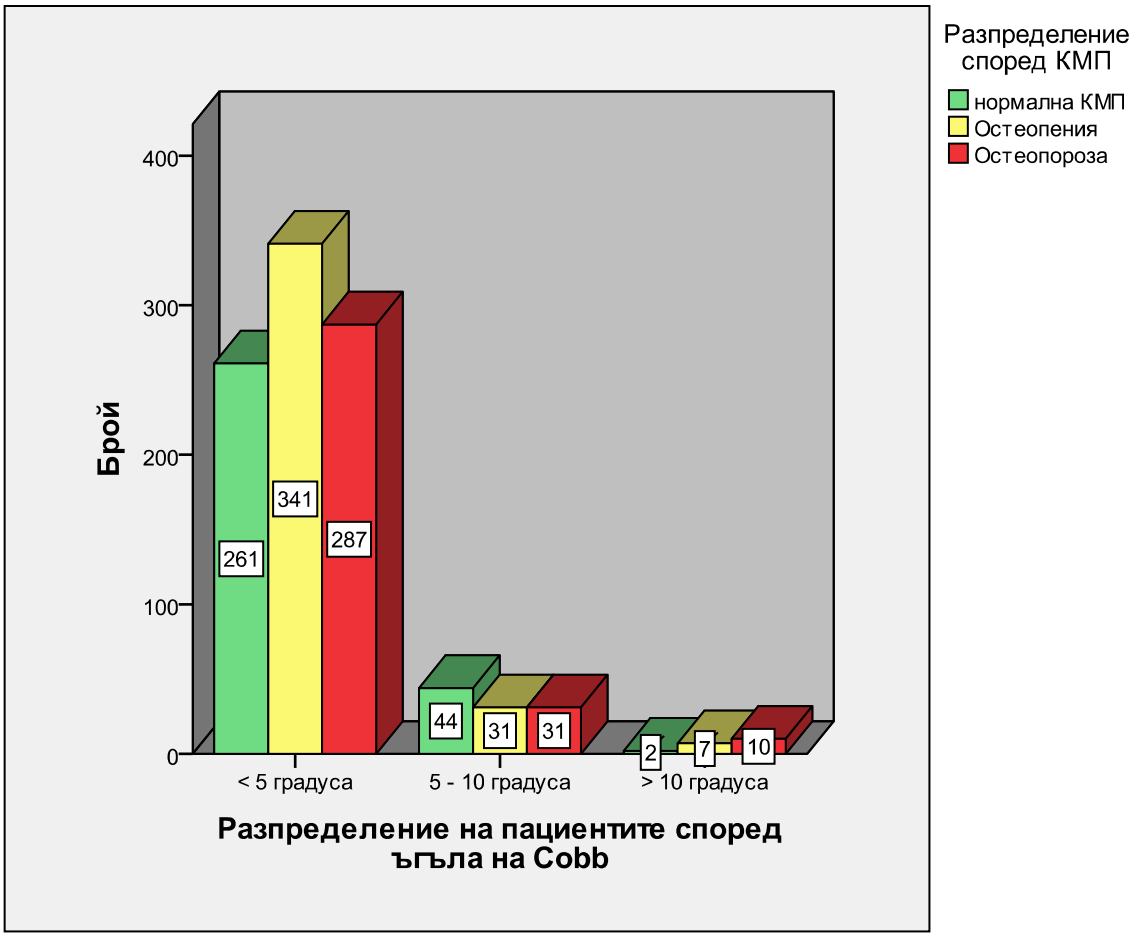

Fig. 4. Distribution of patients with normal BMD, osteopenia and osteoporosis of the lumbar spine in different groups according to the angle of Cobb

According to the total hip T-score, the incidence of osteopenia and osteoporosis increased in the following groups, respectively: Cobb angle <5 ° (osteopenia - 49.9% (444/889 women) and osteoporosis - 8.9% (70/889 women)),

Cobb angle 5 ° - 10 ° (osteopenia - 51.9% (55/106 women) and osteoporosis - 9.4% (10/106 women)) and Cobb angle> 10 ° (osteopenia - 75% (12/16 women) and osteoporosis - 18.8 % (3/16 women), (Fig. 5).

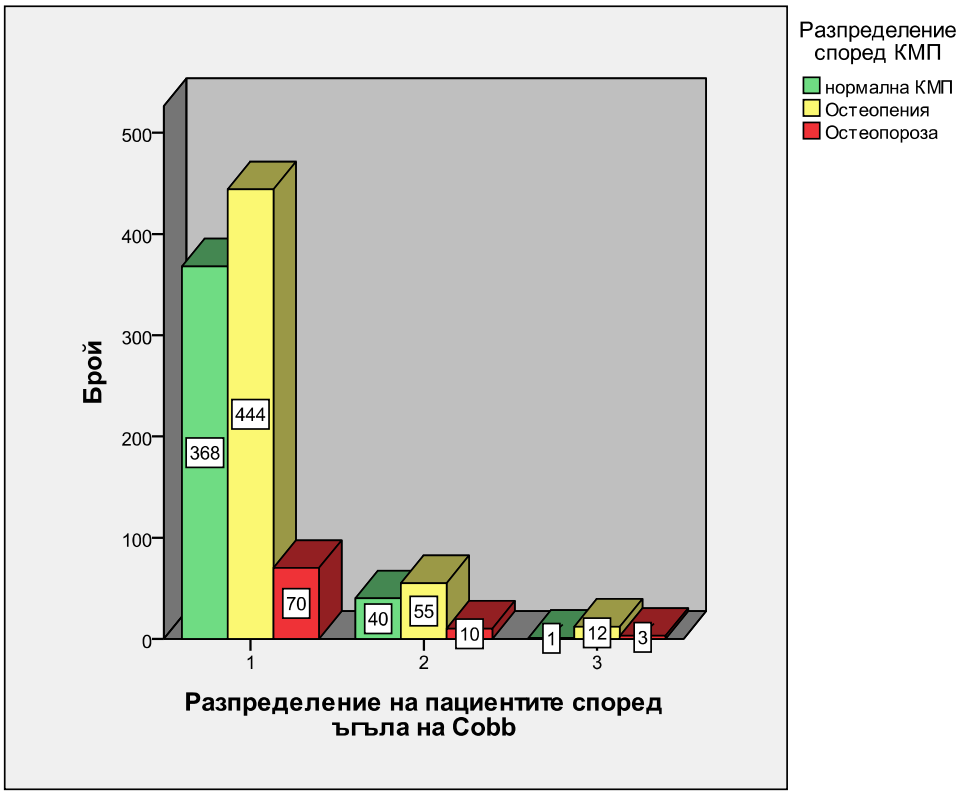

Fig. 5. Distribution of patients with normal BMD, Osteopenia and Osteoporosis of the hip in different groups according to the Cobb angle

4.6. Estimation of differences in age, height and weight in the individual groups according to the Cobb angle

After examining the factors age, weight and height with the ANOVA test, it was found that only the age differed significantly in the individual groups according to the Cobb angle ($p = 0.000$). Women with a Cobb angle> 10 ° are the oldest (mean age 66 years) compared to the mean age of the other two groups with a smaller scoliosis angle (65 years for patients with a Cobb angle of 5 ° - 10 ° and 60 years for patients with a Cobb angle <5 °), (Fig. 6). Weight and height did not differ significantly between groups according to the Cobb angle ($p = 0.078$ for weight and $p = 0.774$ for height), (Table 6)

ANOVA test										
		(N)	Mean value	SD	SE	95% Confidential interval (CI)		P - value	(N)	Mean value
						Lower	Upper			
Characteristics	Cobb angle									
Age (yrs)	< 5°	894	60.25	9.278	.310	59.64	60.86	40	87	0.000
	5° - 10°	106	64.75	10.091	.980	62.80	66.69	41	87	
	>10°	19	66.37	10.062	2.308	61.52	71.22	43	89	
	Общо	1019	60.84	9.501	.298	60.25	61.42	40	89	
Height (cm)	< 5°	893	160.19	9.587	.321	159.56	160.82	58	185	0.774
	5° - 10°	106	160.65	6.432	.625	159.41	161.89	146	174	
	>10°	19	159.11	7.133	1.636	155.67	162.54	148	170	
	Общо	1019	160.22	9.265	.290	159.65	160.79	58	185	
Weight (kg)	< 5°	893	70.77	15.296	.512	69.76	71.77	38	165	0.078
	5° - 10°	106	70.17	14.851	1.442	67.31	73.03	42	110	
	>10°	19	62.84	14.796	3.394	55.71	69.97	41	105	
	Общо	1019	70.56	15.265	.478	69.62	71.49	38	165	

Table 6. ANOVA test to assess the difference in age, height and weight between the 3 groups according to the Cobb angle; X-ki - characteristics; N - number;

Wed. st-t - average value; SD - standard deviation; SG - standard error; CI - confidential interval

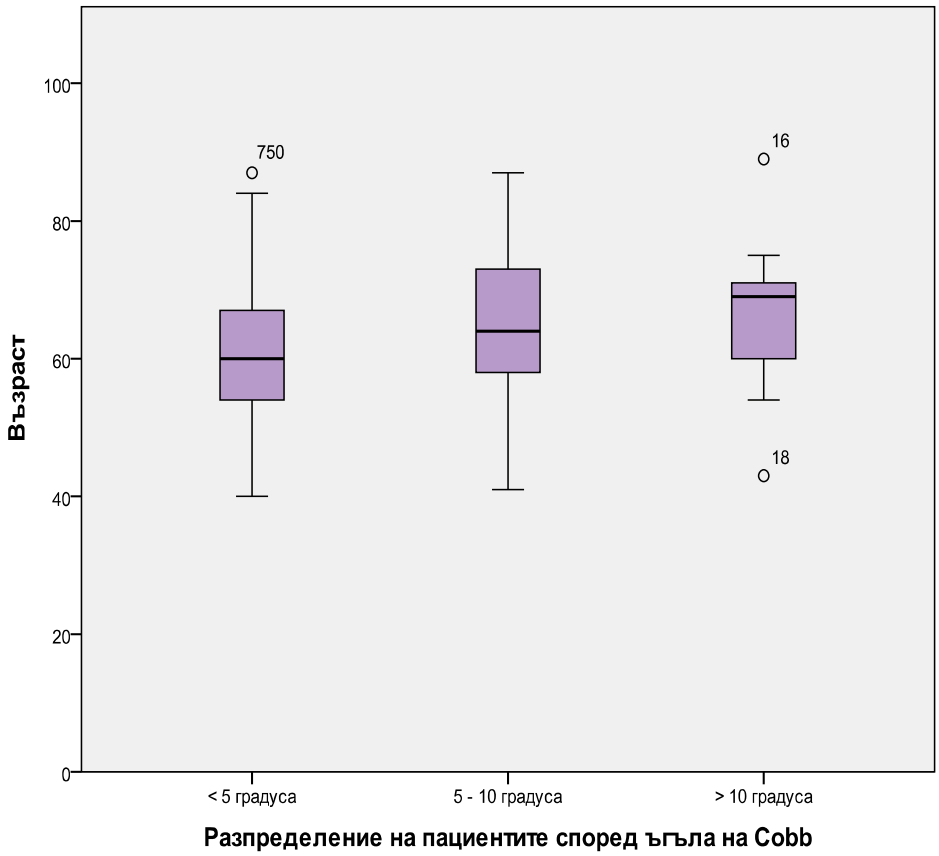

FIG. 6. Distribution of patients by age in the 3 groups according to the Cobb angle

4.7. Estimation of the relationship between the difference in the T-scores of the adjacent vertebrae and the Cobb angle

According to the maximum difference in the T-scores of the adjacent vertebrae, 2 groups are formed - one with a difference in the T-scores ≤1 SD (537/1019 women - 52.7%), and the other with a difference in the T-scores> 1 SD (482/1019 women - 47.3%). After performing a chi-square test, it was found that there was a statistically significant relationship between the difference in the T-scores of the adjacent vertebrae and the Cobb angle ($p = 0.004$). The largest number of patients with a difference in the T-scores of adjacent vertebrae> 1 SD in the group of women with a Cobb angle between 5 ° and 10 ° (66/106 women - 62.3%) and with a Cobb angle> 10 ° (7/12 women - 58.3%). Their share is significantly smaller in the group of women with a Cobb angle <5 ° (409/894

women - 45.7%), (Fig. 7).

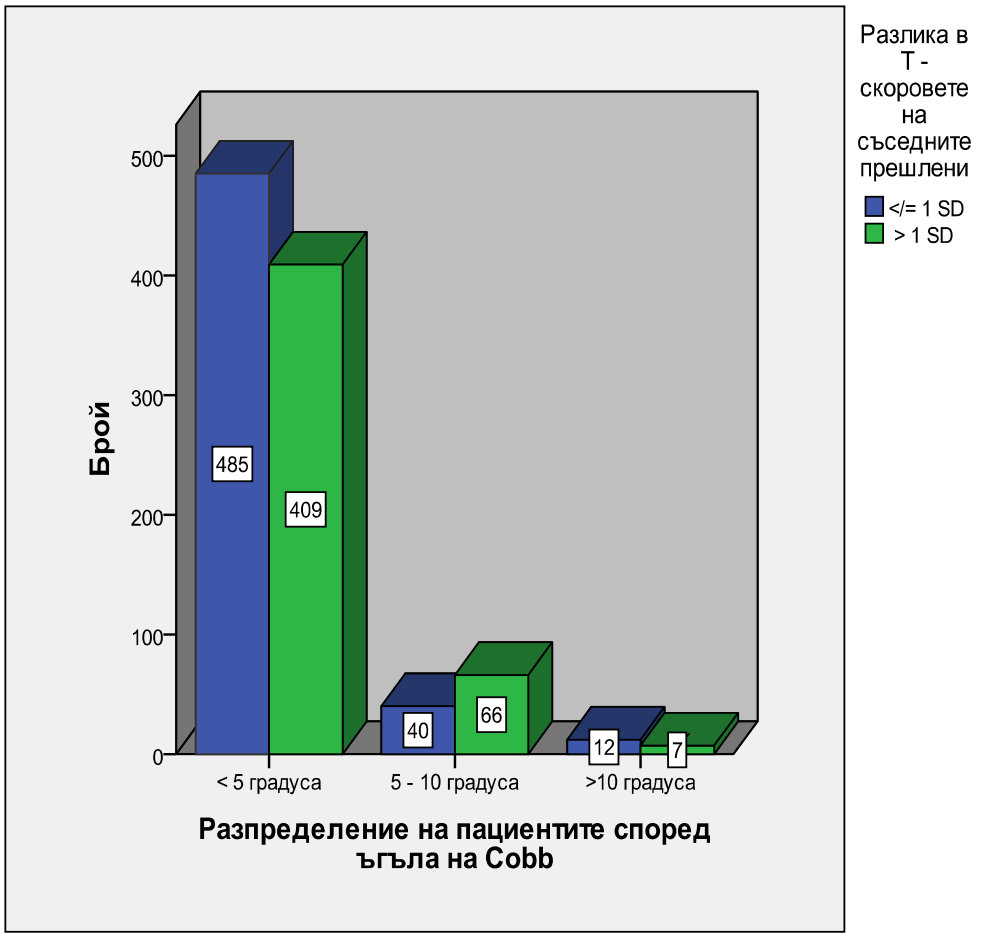

Fig. 7. Difference in the T-scores of the adjacent vertebrae ≤1 SD or> 1 SD, distributed according to the Cobb angle

4.8. Estimation of the relationship between the difference in the T-scores of the spine and hip and the angle of Cobb

To assess the relationship between the difference in the T-scores of the spine and hip and the angle of Cobb, 3 groups were formed according to the difference in the T-scores of the spine and hip. The 1st group has the maximum difference in the T rates of the spine and hip (corresponds to the diagnosis of osteoporosis of the spine and normal BMD of the hip or the diagnosis of osteoporosis of the hip and normal BMD of the spine). In this group the number of patients amounts to 50/998 women - 5%. Group 2 has a minimal difference in the T-scores of the spine and hip (corresponds to a diagnosis of osteoporosis in one area and osteopenia of the other area or osteopenia of one area and normal BMD of the other area) and amounts to 442/998 women - 44.3%. The 3rd group has concordant T-scores (the diagnoses of the two zones are the same) and amounts to 506/998 women - 50.7%. The concordance in the T-score between spine and hip in women with lumbar curvature with a Cobb angle of 5 ° - 10 ° ◦ amounts to 56.2% (59/105 women), in those with a Cobb angle> 10 ° is 56.3% (9 / 16 women), and in those without scoliosis it is 49.9% (438/877). The minimum difference in the T-score in women with a Cobb angle of 5 ° - 10 ° is 41.9% (44/105), with a Cobb angle> 10 ° is 37.5% (6/16), and in those without scoliosis - 44.7% (392/877). The maximum difference in the T-score in women with a Cobb angle of 5 ° - 10 ° is 1.9% (2/105), with a Cobb angle> 10 ° is 6.25% (1/16), and in those without scoliosis is 5.6% (47/877). The 3 groups according to the difference in T-scores between spine and hip were evenly distributed in the three groups according to the Cobb angle and there was no statistically significant difference between them ($p = 0.487$), (Fig. 8).

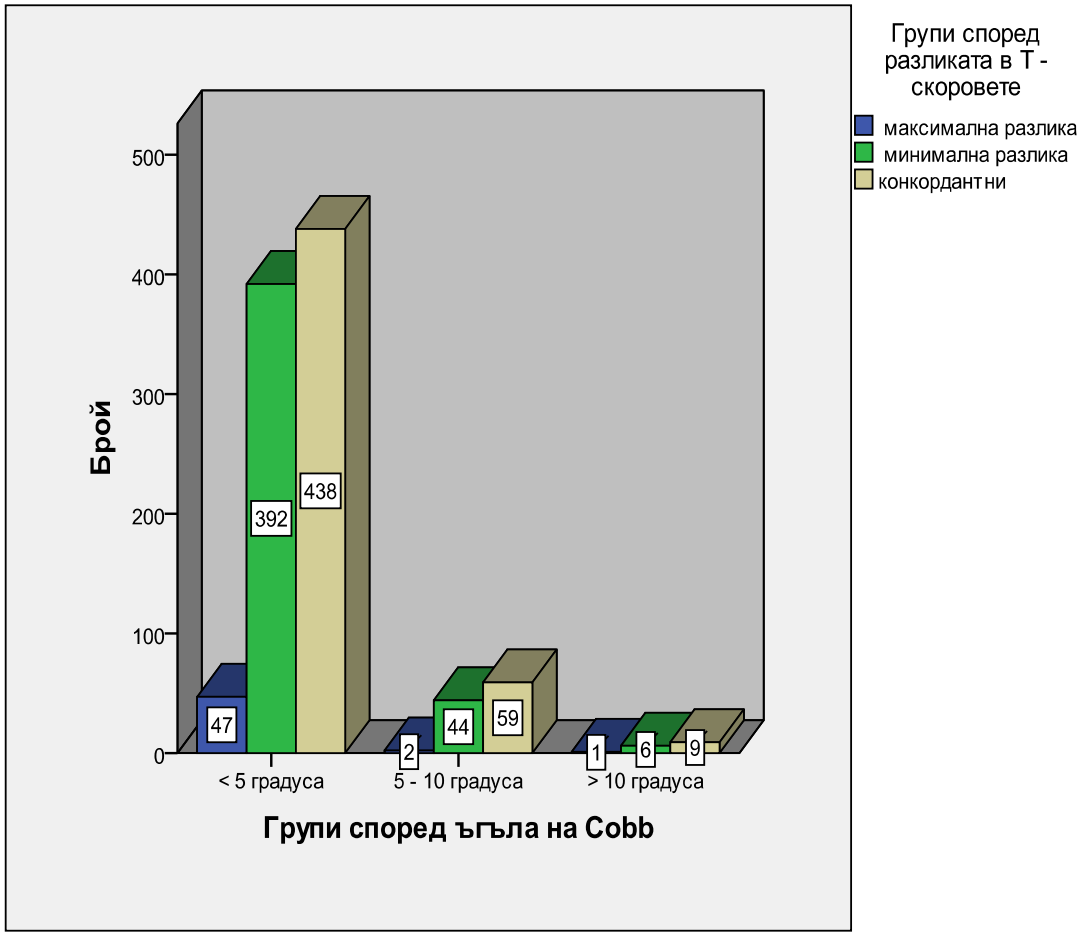

FIG. 8. Distribution of patients according to the difference in T-scores between spine and hip in the three groups according to the Cobb angle

4.9. Assessment of the relationship between total fracture risk and fracture risk of the hip and individual groups according to the Cobb angle

FRAX Major Osteoporotic (FRAX MO) assesses the overall fracture risk of the spine, wrist, humerus, or hip, and FRAX hip fracture (FRAX HF) assesses the fracture risk of the hip. FRAX Major Osteoporotic and FRAX hip fracture are estimated for 997/1019 women. After performing the ANOVA test to compare the mean values of FRAX MO and FRAX HF in the 3 groups according to the Cobb angle, it was found that there was a statistically significant difference ($p = 0.000$ for both fracture indices). The mean value of FRAX MO and FRAX HF increased respectively in the groups with Cobb angle <5 °, with Cobb angle 5 ° - 10 ° and Cobb angle> 10 ° (6.5%, 8.3% and 9.5% for FRAX MO respectively) , (1.3%, 2.1%, and 3.1% for FRAX HF), (Table 7).

ANOVA тест										
		(N)	Mean value	SD	SE	95% Confidential interval (CI)		P - value	(N)	Mean value
						Lower	Upper			
	Cobb angle									
FRAX MO	< 5°	874	6.4584	3.56601	.12062	6.2217	6.6952	.00	22.60	0.000
	5 °-10°	106	8.3174	4.42468	.42976	7.4652	9.1695	2.20	20.44	
	>10°	17	9.5647	5.14571	1.24802	6.9190	12.2104	2.52	23.16	
	Total	997	6.7090	3.75565	.11894	6.4756	6.9424	.00	23.16	
FRAX HF	< 5°	874	1.2690	1.67303	.05659	1.1580	1.3801	.00	13.48	0.000
	5 °-10°	106	2.1482	2.35501	.22874	1.6947	2.6018	.09	9.95	
	>10°	17	3.1141	3.78724	.91854	1.1669	5.0613	.13	15.91	
	Total	997	1.3940	1.84206	.05834	1.2795	1.5085	.00	15.91	

Table 7. ANOVA test to assess the difference in FRAX Major Osteoporotic (MO) and FRAX hip fracture (HF) between the 3 groups according to the Cobb angle; N - number; Wed. st-t - average value; SD - standard deviation; SG - standard error; CI - confidential interval

5. Discussion

5.1. Incidence of lumbar scoliosis

The incidence of lumbar scoliosis in the present study was examined based on DEXA imaging and amounted to 12.3%. This frequency is approximately similar to that found in the study by Urrutia et al. (12.9%), lower than that reported by Makino et al. (32%) who examined lumbar scoliosis in 241 patients with rheumatoid arthritis and higher than that in a study by Pappou et al. (9.5%) on 454 patients. These data show that the prevalence of lumbar scoliosis (with a range of 8.5% -32%) varies between studies that use DEXA images to diagnose it. On the one hand, the mixed results may be due to the differences between the patients included in the cited studies, and on the other hand to the different methods according to which lumbar scoliosis is defined. In previous studies analyzing lumbar scoliosis in adults based on DEXA images, the definition of spinal curvature varied between Cobb angle> 7 °, Cobb angle ≥10 ° and Cobb angle ≥11 °. Our study is the first in which lumbar scoliosis is defined as a Cobb angle ≥5 ° according to Chaklin's classification based on DEXA images. Chaklin's classification is used in the present study, firstly because it is the official classification in Bulgaria for defining scoliosis, and secondly because we suggest that even a mild degree of lumbar scoliosis (Cobb angle 5 ° -10 °) may affect the results of the DEXA scan. A high degree of correlation was reported in previous studies between the angle of lumbar scoliosis measured by DEXA images and the angle obtained from the analysis of radiographs in the upright position. These data prove the possibility of using DEXA images to conduct large-scale studies on the incidence of lumbar scoliosis.

5.2. Comparison of BMD and T-score of spine and hip between groups according to Cobb angle

After performing the ANOVA test, we found a significant difference in the total T-score of L1-L4 ($p = 0.016$) and in the total T-score of the hip ($p = 0.002$) in the individual groups according to the Cobb angle. Women with a Cobb angle> 10 ° have a significantly lower mean T-score of L1-L4 (-2.5 SD - in the area of osteoporosis) and of the hip (-2.2 SD - in the area of osteopenia) than women with an angle of Cobb 5 ° -10 ° (T-score of L1-L4 = -1.3 SD and T-score of hip = -1.2 SD) and those with Cobb angle <5 ° (T-score of L1-L4 = -1.6 SD and T hip score = -1.2 SD). The L1-L4 BMD and hip BMD in patients with a Cobb angle> 10 ° were also significantly lower (0.777 g / cm2 for L1-L4 and 0.660 g / cm2 for the hip) compared to patients with a Cobb angle of 10 °. Cobb 5 ° -10 ° (0.903g / cm2 for L1-L4 and 0.785 g / cm2 for hip) and Cobb angle <5 ° (0.862 g / cm2, 0.789 g / cm2 respectively),, ($p = 0.016$ for L1- L4 and $p = 0.004$ for hip). Studies published to date have contradicted the relationship between scoliosis and BMD of the lumbar spine and hip, with most showing that lumbar scoliosis in the elderly is associated with low BMD of the hip but not low BMD of the spine. A study by Neubauer et al found that scoliosis in the elderly had a negative relationship with the femoral neck T-score and a positive relationship with the lumbar spine T-score. A number of published scientific papers in the elderly show that idiopathic adolescent lumbar scoliosis is associated with lower BMD of the spine, and degenerative lumbar scoliosis is associated more with a false increase in BMD of the lumbar spine.

5.3. Estimation of the incidence of Osteopenia and Osteoporosis of the spine and hip in the individual groups according to the Cobb angle

After examining the incidence of osteopenia and osteoporosis of the spine and hip, we found that the incidence of osteoporosis of the spine and hip, as well as the incidence of osteopenia of the hip increased with increasing angle of Cobb, and the incidence of osteopenia of the spine remained. in the three groups according to the Cobb angle. The prevalence of osteoporosis of the spine in our study was 32.8% (41/125) and was about three times higher than in the study by Yagi et al. (10.2% - 18/176). The incidence of osteoporosis of the hip in our study was 10.7% (13/121) and was similar to that found in the study by Yagi et al. (10.8% - 19/176). The incidences of osteopenia of the spine - 30.4% (38/125) and of the hip - 55.4% (67/121) in our study are similar to those found in the study of Yagi et al. (28.9% (51/176) for lumbar spine and 55.4% (87/176) for the hip). Because the incidence of lumbar spine osteoporosis in women with scoliosis in our study is about 3 times higher than the incidence of osteoporosis in women without scoliosis, we hypothesize that scoliosis and lumbar spine osteoporosis in the elderly are two conditions that have significant connection with each other.

Comparing our results with those of previous studies, we find that there is a contradiction from on the relationship between osteoporosis and lumbar scoliosis. Osteoporosis and degenerative lumbar scoliosis are well-known diseases in the elderly and most often occur together. Unfortunately, published theories about the relationship between osteoporosis and scoliosis in the elderly are quite diverse.

Despite the complex impact of scoliosis on lumbar spine BMD values and therefore on the final results of DEXA studies, we find that women with scoliosis have a higher incidence of osteoporosis than those without scoliosis. The false

increase in spinal BMD in our study affected the group of women with osteopenia due to the lack of a statistically significant difference in the incidence of lumbar spine osteopenia between women with and without scoliosis. Scoliosis has an important influence on the interpretation of the DEXA result. A false increase in BMD or T-score of part of the lumbar spine can lead to an incorrect final diagnosis. In this case, the exclusion of these vertebrae is a good strategy for a more accurate interpretation of the results of DEXA studies performed on the basis of BMD of the lumbar spine.

5.4. Estimation of differences in age, height and weight in the individual groups according to the Cobb angle

After examining the factors age, weight and height with the ANOVA test, it was found that only the age differed significantly in the individual groups according to the Cobb angle ($p = 0.000$). Weight and height did not differ significantly between groups according to the Cobb angle ($p = 0.078$ for weight and $p = 0.774$ for height). The relationship between age and scoliosis has been established in previous studies. A retrospective study by Kebaish et al examined the prevalence of lumbar scoliosis in patients ≥40 years of age, as well as the relationship between the prevalence of scoliosis and the 3 parameters: age, race, and gender. With increasing age in this study, the incidence of degenerative changes in the spine increases.

5.5. Estimation of the relationship between the difference in the T-scores of the adjacent vertebrae and the Cobb angle

It is known that lumbar scoliosis can affect the interpretation of DEXA test results. It is suggested that on the one hand scoliosis predisposes to osteoporosis, and on the other hand degenerative scoliosis can lead to inaccurate values of bone mineral density of the vertebrae. In a study by Xu et al., Regression analysis showed that BMD was an independent risk factor for scoliosis, and adults with BMD corresponding to a T-score <-2.0 SD had a 1.6-fold higher risk of lumbar scoliosis than those with T-score. score> -2.0 SDs. The authors of this study recommend screening for scoliosis in adults over 65 years of age with a spinal T-score <-2.0 SDs. Similar to the Xu study and co-authors in our study, women with a high degree of lumbar scoliosis, defined as a Cobb angle> 10 °, showed a lower mean lumbar spine T-score (-2.5 SDs) compared to those without scoliosis. defined as Cobb angle <5 ° (-1.7 SD). However, the group with mild scoliosis, defined as a Cobb angle of 5 ° -10 °, showed a lower mean lumbar spine T-score (-1.3 SDs) compared to the group without scoliosis (-1.7 SDs). These results suggest that lumbar scoliosis, although mild, may affect the interpretation of DEXA test results and lead to diagnostic difficulties. Previous studies have reported that BMD should increase from L1 to L4, and the presence of a maximum difference in the T-scores of the four lumbar vertebrae greater than 1 SD suggests the presence of structural abnormalities such as degenerative spinal changes and compression fractures.

5.6. Estimation of the relationship between the difference in the T-scores of the spine and hip and the angle of Cobb

In the present study, the 3 groups according to the difference in T-scores between spine and hip: 1. with concordant T-scores, 2. with minimal discordance in the T-score and 3. with maximum discordance in the T-score are evenly distributed in groups according to the Cobb angle and there is no statistically significant difference between them ($p = 0.487$). Similar to our study, Begum and co-authors investigated the difference in the T-score between the spine and hip in patients with scoliosis, assessed on the basis of a DEXA image. In contrast to our study, the authors of this study included only patients with scoliosis and assessed the incidence of discordance in the T-score between the hip and spine only in patients with scoliosis. This dissertation examines for the first time whether the discordance in the T-score between the lumbar spine and the hip differs significantly between groups according to the Cobb angle. Women with T-score discordance and scoliosis in the current study were 43.8% (53/121) and this frequency was about twice lower than that found in the study by Begum et al., 78.6%, similar to that found in studies by Yagi et al. (43%) and Woodson et al. (44%) and slightly lower than those found in the study by Moayyeri et al. (62.2%). It is likely that the large difference between our study and the study by Begum and co-authors was due to the higher number of patients with scoliosis in our study (121) compared to their study - 70 patients. On the other hand, the two studies may differ in the degree of lumbar curvature, but unfortunately Begum and co-authors do not mention the exact definition of scoliosis in their analysis and do not form groups according to the Cobb angle.

5.7. Assessment of the relationship between total fracture risk and fracture risk of the hip and individual groups according to the Cobb angle

After performing the ANOVA test to compare the mean values of FRAX MO and FRAX HF in the 3 groups according to the Cobb angle, it was found that there was a statistically significant difference (p = 0.000 for both fracture indices). The mean value of FRAX MO and FRAX HF increased respectively in the groups with Cobb angle <5 °, with Cobb angle 5 ° - 10 ° and Cobb angle> 10 ° (6.5%, 8.3% and 9.5% for FRAX MO respectively) , (1.3%, 2.1% and 3.1% for FRAX HF).

The association between lumbar scoliosis and an increased risk of compression fractures has been investigated in previous studies. Multiple vertebral osteoporotic fractures of the spine occur in about 6% of cases and are often associated with lumbar degenerative scoliosis. It has also been found that they can occur as a result of worsening scoliosis after a previous fracture of the corresponding lumbar vertebra.

In the lumbar spine, kyphosis is rare and radiological examination shows that both lateral displacement and mild scoliosis are often the result of uneven degenerative damage to the disc space. In the lumbar spine, the biomechanical effect of degenerative scoliosis alters the load in both the sagittal and axial planes and is associated with loss of normal lumbar lordosis.

Lumbar fractures from L3 to L5 represent 8% - 12% of vertebral fractures. Because these elderly patients often have lumbar stenosis combined with degenerative spondylolisthesis or lumbar degenerative scoliosis, determining the cause of radiculopathy or directly linking it to a fracture can be difficult. Previous scoliosis has been identified as a risk factor for osteoporotic fractures in women

and is found in up to 48% of the study groups. Epidemiological studies of degenerative lumbar scoliosis have shown that asymmetric disc damage and lumbar curvature is a common deformity of the aging spine. Degenerative lumbar scoliosis is much more common in older women who are at higher risk of osteoporosis and vertebral compression fracture. Studies have often found that degenerative scoliosis and subsequently altered biomechanics lead to facet degeneration in the long run. Patients with a Cobb angle ≥10 ° followed for more than 12 years in previous studies showed progression of scoliosis in 20% of cases. Chronic idiopathic scoliosiss in the elderly are more static, but are associated with facet hypertrophy, which may be associated with an increased incidence of fractures in the upper lumbar spine.

Various mechanisms have been identified that are responsible for the increased fracture risk in women with scoliosis. Weakened muscles in older women, combined with altered spinal biomechanics due to lateral displacement of lumbar spine support in the presence of degenerative lumbar scoliosis, make osteoporotic lower lumbar vertebrae and sacrum particularly vulnerable to the development of new fractures. In the lumbar spine, this is more often associated with coronal imbalance and deformity than with sagittal deformity, as is usually seen in the thoracic spine.

Previous vertebroplasty has also been reported as a risk factor contributing to the development of progressive recurrent fractures in patients with underlying degenerative lumbar scoliosis. There are several theories about the occurrence of fractures of adjacent vertebrae in this case. Some suggest that they are due to the increased hardness of the cement-filled vertebrae and the change in balance. Thus, in the case of residual compression, the upper vertebra is affected by a greater anterior load. Other authors through biomechanical studies show that the volume and location of the cement have only a minimal direct effect on the adjacent

vertebra. Experimental studies demonstrate that load-bearing forces can cause fractures to develop at an adjacent level. Mechanical imbalance of the spine due to scoliosis is an important factor in the development of subsequent lumbar fractures. The specific characteristics of this type of lumbar fracture and the high risk of progression often require repeated procedures such as vertebroplasty and kyphoplasty. Avoiding the progression of fractures is an important part of treatment in patients with scoliosis. Recognition of the importance of existing degenerative lumbar scoliosis as a risk factor for fractures, as well as the treatment of osteoporosis and the wearing of special lumbostat belts even after vertebroplasty or kyphoplasty play an important role. When a patient develops subsequent fractures after treatment with either vertebroplasty or kyphoplasty, it is important to distinguish between the worsening of a previously treated fracture and the development of a new fracture at an adjacent or other level of the spine. The relationship between spinal deformities and the occurrence of femoral fractures has also been studied in previous studies. Black and co-authors found that women with existing spinal deformities were at a much higher risk of new deformities as well as various types of nonvertebral fractures. They show that women with pre-existing spinal deformities have approximately four to five times the risk of future deformities and almost twice the risk of femoral fractures. In addition, they found that the risk of future fractures increases with the number and severity of spinal deformities.

All these studies show that spinal deformities, including scoliosis, are associated with an increased risk of fracture. The published results of the previous analyzes are in line with our study. This dissertation is the first to compare FRAX MO and FRAX HF according to the Cobb angle of the spine and show that the values of FRAX MO and FRAX HF increase with increasing Cobb angle.

6. Conclusions:

1. Women with spinal curvature had a statistically significant difference in the total T-score of L1-L4 and the total T-score of the hip compared to women without scoliosis as the group with a Cobb angle> 10◦ showed significantly lower T-scores of lumbar spine and hip compared to groups with a Cobb angle <10◦.

2. Women with lumbar curvature are significantly older than those without curvature.

3. There is no statistically significant difference in height and weight between groups of patients according to the Cobb angle.

4. Women with lumbar curvature, including the group with a Cobb angle between 5◦ - 10◦, show significantly more often a difference in T-scores between adjacent vertebrae of more than 1 SD, which affects the interpretation of DEXA studies.

5. There is no significant difference between lumbar spine and hip T-scores in women with spinal curvature compared to those without curvature, and therefore the discordance between lumbar spine and hip T-scores cannot serve as a criterion for a more accurate interpretation of DEXA result in women with scoliosis.

6. Women with lumbar curvature have a higher fracture risk for major osteoporotic fracture and femoral fracture than women without curvature and this should be taken into account when prescribing treatment in patients with osteopenia or osteoporosis with concomitant lumbar scoliosis.

7. Contributions:

1. For the first time in Bulgaria, a large-scale study was conducted on the prevalence of lumbar scoliosis in women aged ≥40 years based on DEXA images.

2. This is the first study comparing BMD and lumbar spine and hip T-scores between women with and without lumbar curvature.

3. For the first time, the incidence of osteopenia and osteoporosis in patients with spinal curvature is determined on the basis of a DEXA test.

4. For the first time in Bulgaria it has been proven that women with lumbar curvature show significantly more often a difference in the T-scores of the adjacent lumbar vertebrae> 1 SD compared to women without curvature.

5. The present study is the first in Bulgaria to analyze the discordance of T-scores between the lumbar spine and the hip and does not establish a more frequent discordance in women with lumbar curvature compared to those without curvature.

6. For the first time, an increased fracture risk has been identified for a large osteoporotic fracture (FRAX MO) and for a femoral fracture (FRAX HF) in women with lumbar curvature.

8. List of publications with regard to the dissertation:

1. Kirilov, N., Kirilova, E., Todorov, S.,N Nikolov. Effect of the lumbar scoliosis on the results of dual-energy X-ray absorptiometry, 2020, Orthopedic Reviews, 12(1),37- 40 https://doi.org/10.4081/or.2020.8477.

2. Kirilov N, Kirilova E., Nikolov N. Method of simplified risk assessment of osteoporosis in menopausal women. Sience and Technologies, Vol IX, №1, Medical Biology Studies, Social Medicine And Health Care, 2019, 100-105. ISSN 1314-4111.

3. N. Kirilov, S H. Todorov, N G. Nikolov. Prevalence of osteopenia and osteoporosis in adult scoliotic women assessed with Dual-energy X-ray absorptiometry (DXA) Journal Of Biomedical And Clinical Research, MU Pleven, 2020. In press.