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Identification of vertebral deformities in the Polish population by morphometric X-ray absorptiometry — results of the EPOLOS study

Identyfikacja zniekształceń trzonów kręgowych w populacji polskiej przy użyciu morfometrii densytometrycznej — wyniki badań programu EPOLOS

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Abstract

Introduction: The aim of the study was the determination of the prevalence of asymptomatic vertebral deformities in healthy persons of the Polish population, based on morphometric X-ray absorptiometry (MXA), and comparison of the results with data from literature, obtained by other techniques.
Material and methods: The study involved 829 persons, including 520 women and 309 men, aged 18–79 years, untreated for osteoporosis before. The Th_4 to L_4 vertebrae were examined. Lateral scans of the thoracic-lumbar spine were made by an Expert-XL densitometer. Six-point digitization was used to calculate the anterior (Ha), central (Hc), and posterior (Hp) height of the Th_4-L_4 vertebral bodies. The vertebrae were defined as having prevalent deformities when at least one ratio value (Ha/Hp, Hc/Hp, Hp/Hp up, or Hp/Hp low) fell 3 SDs below or even more than the reference mean of that ratio at any vertebral level.
Results: The analysis was performed on 9629 vertebrae, of which 167 (1.75%), evaluated as deformed and considered as fractures, were observed in 113 patients (13.63 % of the examined patients). In 81 persons (74% of the patients with fractures; 9.7% of the studied population), single fractures were demonstrated, while in 28 persons, multiple deformities prevailed. Fractures occurred in 108 women (20.7% of the examined women) and 42 men (13.5% of the examined men). The highest incidence of deformities was observed in women over 55 years of age. First-degree deformities dominated. Deformities of the Th_8 and Th_6 vertebrae were most frequently observed.
Conclusions:
1. Using MXA, it was found that in the Polish population deformities of vertebrae are common, as was demonstrated in X-ray morphometric studies in the European Vertebral Observation Study (EVOS).
2. Densitometric morphometry, as a non-invasive technique, may become a useful tool in the diagnostics of vertebral fractures.
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Key words: *vertebral deformities, vertebral fractures, morphometric X-ray absorptiometry*

Streszczenie

Wstęp: Celem badania było określenie częstości występowania bezobjawowych zniekształceń trzonów kręgowych u zdrowych osób populacji polskiej przy wykorzystaniu morfometrii densytometrycznej (MXA) i porównanie wyników z danymi z piśmiennictwa uzyskanymi innymi technikami.
Materiał i metody: Badaniu poddano 829 osób, w tym 520 kobiet i 309 mężczyzn w wieku 18–79 lat, dotąd nieleczonych z powodu osteoporozy. Uwidoczniono kręgi od Th_4 do L_4. Boczne skany kręgosłupa piersiowo-lędźwiowego wykonano aparatem Expert-XL. Oznaczono sześć punktów w celu wyznaczenia przedniej (Ha), środkowej (Hc) i tylnej (Hp) wysokości trzonów kręgowych Th_4–L4. Kręg uznawano za zniekształcony, jeśli którakolwiek z wartości Ha/Hp, Hc/Hp lub Hp/Hp kręgu następnego lub Hp/Hp kręgu poprzedniego była niższa niż 3 odchylenia standardowego od średniej wartości referencyjnej.
Wyniki: Analizie poddano 9629 kręgów. Jako zniekształcone, uznane za złamane oceniono 167 kręgów, występowały one u 113 pacjentów (13,63% badanych osób). U 81 osób (74% osób ze złamaniami; 9,7% populacji badanej) wykazano pojedyncze złamanie, a u 28 osób występowały mnogie deformacje. Złamania występowały u 108 kobiet (20,7%) i 42 mężczyzn (13,5%). Dominowały zniekształcenia pierwszego stopnia. Największa częstość deformacji występowała w grupie kobiet po 55. roku życia. Dominowały zniekształcenia pierwszego stopnia. Najczęściej obserwowano deformacje kręgu Th_8 i Th_6.

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Wnioski:
1. Stosując metodę MXA, potwierdzono częste występowanie deformacji trzonów kręgowych w populacji polskiej. Dane te są zbliżone do wyników uzyskanych w badaniach morfometrii rentgenowskiej w badaniach EVOS.
2. Morfometria densytometryczna jako badanie nieinwazyjne może stać się przydatnym narzędziem w diagnostyce złamań trzonów kręgowych. **(Endokrynol Pol 2009; 60 (2): 68–75)**

Słowa kluczowe: *złamania trzonów kręgowych, zniekształcenia trzonów kręgowych, morfometria densytometryczna*

Introduction

The introduction of fan-beam X-ray densitometers has improved the quality of obtained images. It has made possible visualization of the thoracic and lumbar lateral spine and offered a new method for the detection of vertebral deformities, considered as fractures [1]. This new tool offers a lot of interesting perspectives: the possibility to image the lateral spine quickly (within as little as 10 seconds), safely (radiation dose is 100 times lower than that of conventional spinal radiography) [2] and minimizing the parallax/obliquity error [1]. Additionally, DXA images can be performed at the same time and location as standard BMD determination [1, 3]. This method was employed in many crucial trials (VERT [Vertebral Efficacy with Risendronate Therapy] [4] and FIT [Fraction Intervention trial with alendronate] [5]) and population studies [6, 7].

Two approaches may be applied to densitometric image of the lateral spine: quantitative (semiquantitative) and/or qualitative [8, 9]. Morphometry is a quantitative method to identify vertebral fractures. It consists of the measurement of vertebral heights (anterior, posterior, and central) and calculation of their height reduction [8]. The approach, which employs morphometry to a fan-beam densitometry, is called morphometric X-ray absorptiometry (MXA) [10]. Although, the best method of diagnosing and defining vertebral fracture is the subject of many ontroversies, we decided to use MXA in a Polish population study, taking into consideration the fact that quantitative vertebral morphometry is an objective tool with reproducible results [10–12]. Thus, we avoided taking X-ray images of the spine, which are the gold standard of vertebral fracture diagnostics but which should be avoided in healthy subjects with no medical indications.

The investigation that we carried out is part of EPOLOS, a multi-centre, population-based, cross-sectional study on osteoporosis and its determinants in Poland. The aim of the present part of the study was to assess the prevalence of vertebral deformities in healthy persons among the Polish population, based on MXA and comparison of results with literature data, obtained by other techniques.

Material and methods

Patient recruitment

EPOLOS is a multi-center, population-based study on osteoporosis and its determinants in Poland. It was established as a result of collaboration between the Ministry of Health and the State Committee of Scientific Research.

Invitation forms to our study, with explanations of its goals, were sent to a random sample of men and women, aged 20–80 years, obtained from the registry of the Ministry of Home Affairs and Administration, Department of National Registry. Participants to that part of the study were enrolled at three clinical sites in the following geographic areas: Warsaw, Łódź, and Bydgoszcz. The response rate was 12%. After short telephone calls, several volunteers were excluded. The exclusion criteria were as follows: personal history of osteoporosis, pregnancy, cancer, fracture during the last year, and being overweight (> 100 kg). The last exclusion criterion was related to densitometry requirements. Informed written consent was obtained from each participant. The study was approved by the Ethics Committee of the Children's Memorial Health Institute.

This part of study involved 829 persons, including 520 women and 309 men at the age of 18–79 years, untreated for osteoporosis before. The characteristics of the study population are shown in Table I.

Study protocol

All the participants were examined by a physician to detect spine deformities (scoliosis, kyphosis) and dysarthrosis. Subsequently, the physician fulfilled an epidemiological questionnaire to assess the following parameters: anthropometric parameters, demographic information, lifestyle information, and detailed history (diseases, accidents, and medications) of medical conditions that could influence bone mass and metabolism. The women were classified as premenopausal if they reported monthly bleeding during 3 months preceding the study onset, and as postmenopausal if they reported the last bleeding at least 1 year before.

Diagnostic equipment

Lateral scans of the thoracic-lumbar spine were performed by means of an Expert-XL densitometer (Lunar,

Table I. *Characteristics of examined population*

Tabela I. *Charakterystyka populacji badanej*

	Age [years]	Number of persons	Mean height ± SD [cm]	Mean weight ± SD [kg]	BMI [kg/m²]
Women N = 520	18–45	167	163.69 ± 10.28	61.12 ± 10.54	22.81
	46–55	109	161.82 ± 6.36	65.47 ± 10.91	25.01
	> 55	244	158.90 ± 6.47	68.11 ± 11.28	26.97
Men N = 309	18–45	79	177.47 ± 6.4	78.76 ± 12.53	25.00
	46–55	56	175.93 ± 6.47	83.80 ± 11.62	27.08
	> 55	174	171.73 ± 5.9	80.03 ± 11.76	27.14

SD — standard deviation; BMI — body mass index

Corp.) - a fan-beam densitometer based on dual-energy X-ray absorptiometry. During examination, the patient is in the supine position with the knees slightly raised and hands over the head. Daily calibration and quality control were performed regularly, according to the manufacturer's instruction. In all the study centres, bone densitometers were calibrated daily using a phantom of the lumbar spine for the QDR 1500. At the beginning of the study and at the end, after 12 months, cross calibration with two phantoms was done [13]. Vertebrae from Th_4 to L_4 were examined. Six-point digitization was used to calculate the anterior (Ha), central (Hc), and posterior (Hp) height of the Th_4–L_4 vertebral bodies. The software automatically placed the points onto the inferior and superior endplate of the vertebrae, in the anterior, middle (central), and posterior positions. An experienced operator (PP) manually corrected the position of the point, if incorrect. The following heights and ratios were automatically obtained from the Expert-XL software: Ha, Hc, Hp, the anterior/ /posterior (A/P) ratio, the middle/posterior (M/P) ratio, and the average of the three heights (Fig. 1).

Definition of vertebral deformity

We employed the method described by Eastell et al. [14]. The vertebrae were defined as having prevalent deformities when at least one ratio value (Ha/Hp, Hc/Hp, Hp/ /Hp up, or Hp/Hp low) fell 3 SDs (Grade1) below or even more (Grade 2) *vs.* the reference mean of that ratio at any vertebral level.

Three types of deformities were defined:

Wedge deformity:

- Grade 1 4.0 SD < Ha/Hp < 3.0 SD
- Grade 2 Ha/Hp < 4.0 SD

Biconcave deformity:

- Grade 1 4.0 SD < Hc/Hp < 3.0 SD
- Grade 2 Hc/Hp < 4.0 SD

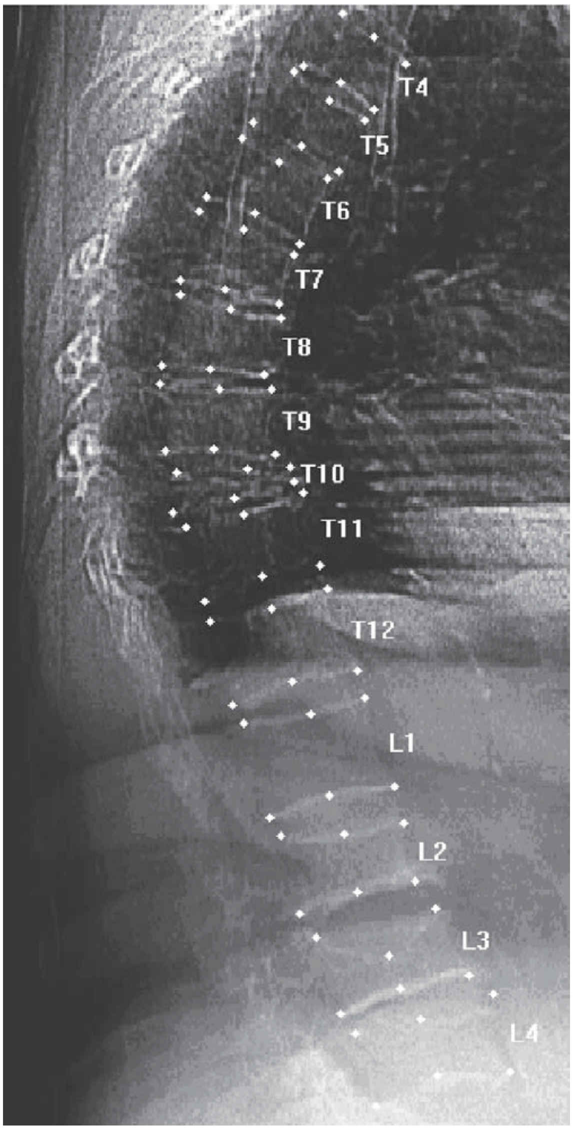

Figure 1. *MXA — placement of six digitization points. Deformations of* Th_{10} L_2–L_4

Rycina 1. *MXA — umieszczanie sześciu punktów cyfrowych. Deformacje kręgów* Th_{10} L_2–L_4

Table II. *Morphometric vertebral values of posterior, central, and anterior heights, average heights ± SD, and number of identified vertebrae*

Tabela II. *Parametry morfometryczne trzonów kręgowych (wysokość ± SD) oraz liczba uwidocznionych kręgów*

Region	Anterior height ± SD [mm]	Posterior height ± SD [mm]	Central height ± SD [mm]	Average height ± SD [mm]	Nr of identified vertebrae
Th4	17.78 2.85	19.04 2.88	17.26 2.46	18.03 2.67	314
Th5	17.86 2.67	19.31 2.67	17.46 2.30	18.21 2.48	556
Th6	18.50 2.68	20.01 2.61	18.07 2.31	18.86 2.46	760
Th7	18.33 1.61	19.90 1.62	17.78 1.52	18.67 1.46	781
Th8	19.17 1.73	20.43 1.62	18.23 1.51	19.28 1.49	812
Th9	20.43 1.87	21.36 1.74	19.10 1.70	20.30 1.66	822
Th10	21.67 1.99	22.74 2.11	20.24 1.88	21.55 1.87	756
Th11	22.97 2.34	24.46 2.17	21.57 2.04	23.00 2.04	759
Th12	24.71 2.15	26.10 2.12	23.06 2.08	24.62 1.98	760
L1	26.17 2.26	27.04 2.12	24.20 2.05	25.80 1.95	829
L2	27.23 2.15	27.19 1.94	24.63 2.10	26.35 1.87	829
L3	27.49 2.06	26.82 2.02	24.87 2. 00	26.39 1.82	829
L4	27.40 2.22	25.34 2.30	24.49 2.04	25.74 1.92	822
				Total number	9629

SD — standard deviation

Crush/collapse deformity:

Grade 1 4.0 SD < Hp/Hp_{up} or Hp/Hp_{low} < 3.0 SD

Grade 2 Hp/Hp_{up} or Hp/Hp_{low} < 4.0 SD

Data were statistically tested using *t*-Student's-test (analysis of influence of sex) and two-way analysis of variance (ANOVA) (analysis of influence of age groups).

Results

The analysis was performed on 9629 vertebrae. Incorrect image quality excluded 1148 vertebrae from the analysis. Data on vertebral heights (mean ± SD) and the number of identified vertebrae are shown in Table II. In the analysis, 167 vertebrae (1.75% of the total number) were evaluated as deformed and considered as fractured; these were found in 113 patients (13.63 % of the examined patients). In 81 persons (74% of patients with fractures; 9.7% of the studied population), single fractures were demonstrated, while in 28 persons, multiple deformities prevailed. Fractures occurred in 108 women (20.7% of the examined women) — Table III, and 42 men (13.5% of the examined men) — Table IV. First degree deformities dominated. The highest incidence was observed in the oldest patients: in women, 86 fractures (37%) were found in the group over 55 years of age ($p < 0.0001$ *vs.* younger women and $p < 0.05$ *vs.* men in the same age), 13 (9%) in the group of patients at 18–45 years of age, and 9 (8%) in the group at the age of 45–55 years. Ten deformities (12.8%) were diagnosed in the group of male patients at the age of 18–45 years ($p < 0.05$ *vs.* women in the same age and $p < 0.01$ *vs.* men aged over 55 years old), in the 45–55 years old group there were 4 (7.27%) deformities, and 45 (26, 69%) deformities were found in the age group above 55 (Fig. 2). Deformities of the Th_8 and Th_6 vertebrae were most frequently observed (Fig. 3), both in men and in women (Fig.4).

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Table III. *Number and type of deformed vertebrae in women*

Tabela III. *Liczba i rodzaj zniekształceń kręgów u kobiet*

Women	Wedge	Biconcave	Crushed	Total
Grade 1	44	17	22	83
Grade 2	12	8	5	25

Table IV. *Number and type of deformed vertebrae in men*

Table IV. *Liczba i rodzaj zniekształceń kręgów u mężczyzn*

Men	Wedge	Biconcave	Crushed	Total
Grade 1	22	8	17	47
Grade 2	5	4	3	12

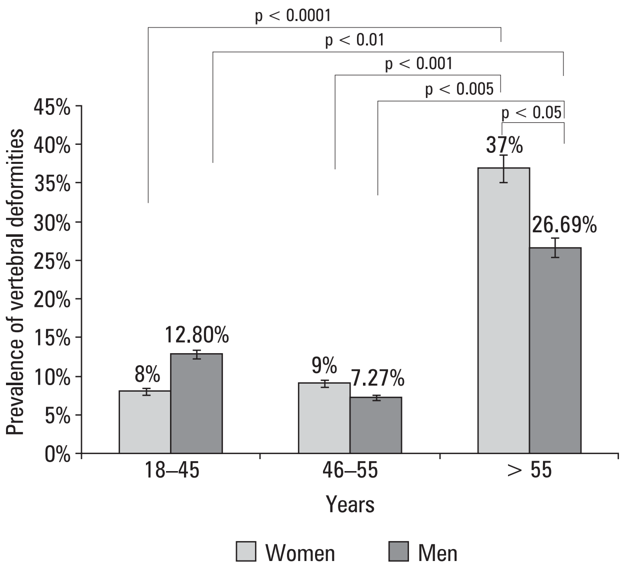

Figure 2. *Prevalence of vertebral deformities in men and women according to age*

Rycina 2. *Występowanie deformacji kręgowych u kobiet i mężczyzn zależnie od wieku*

Discussion

The reported study was the first attempt, undertaken in the Polish population, to assess the prevalence of vertebral deformities by MXA. Vertebral fractures, recognized as the hallmark of osteoporosis, are clinically significant because they are very common [15], associated with marked mortality, morbidity, and impaired life quality [16, 17]. Patients with vertebral fractures are at risk of osteoporotic fractures later, including subsequent vertebral fractures [18–20] and hip fractures [19, 20], independently of bone mineral density. Applying MXA (the morphometric method) to the diagnostics of vertebral deformities, we were conscious of certain discrepancies in the appropriate terminology. Some authors consider that, regarding the vertebrae, "deformity" is a better term than "fracture" because it better describes the anatomical changes in the vertebral body [21]. Other authors [22] reserve the term "fracture" for clinically apparent deformities. Besides, the term "deformity" is much broader than fracture; every fracture is a deformity but not every deformity is a fracture [8]. Vertebrae may be deformed not only because of fracture but also by other conditions, including normal anatomical variants, congenital anomaly, degenerative disease — disc space narrowing, infection — tuberculosis, osteomyelitis, Paget's disease, Scheuermann's disease (the presence of Schmorl's nodes), and malignancy [8]. Because of all those reasons, we decided to use the term "deformity" in our study. Trying to diminish the number of false positive deformities, all the participants were examined by a physician to detect spine scoliosis and other skeletal pathologies.

Because most vertebral fractures are clinically silent, they are often missed in the course of routine medical care [23] and underdiagnosis of vertebral fractures is a worldwide problem [24]. There is a small amount of data regarding the prevalence and incidence of vertebral fractures in Poland [22, 25]; all the data are derived from the EVOS study (the European Vertebral Osteoporosis Study), the main European study dedicated to the prevalence of vertebral fractures [22]. Two Polish centres, Warszawa and Szczecin, participated in the study. The prevalence of morphometrically assessed vertebral deformities varied from 10.2 to 18.7% among women in the Warszawa region (n = 280) and 12.7 to 19% among women in the Szczecin region (n = 254), and from 12.5 to 22.3% among men in the Warszawa region (n = 286) and from 10.4 to 17.5% among men in the Szczecin region (n = 233), depending on the strictness of the morphometric criteria [22]. In our study, vertebral deformities were approximately at the level of 13% (520 women and 309 men). That incidence was higher in women than in men (20.7% *vs.* 13.6%) and, as we expected, it was highest in the oldest group. The prevalence of vertebral deformities in young men was higher than in women in the same age group (Fig. 3). Probably, most of the deformities observed in that group of patients were the consequence of injury rather than osteoporosis, related to greater trauma [21, 22, 25]. Unfortunately, MXA is characterized by lower resolution than X-ray; consequently, it can be more difficult to differentiate aetiologies for vertebral deformities other than fractures. The difficulties in the identification between non-osteoporotic short vertebral height and vertebral fractures were also observed in the MrOS study [26].

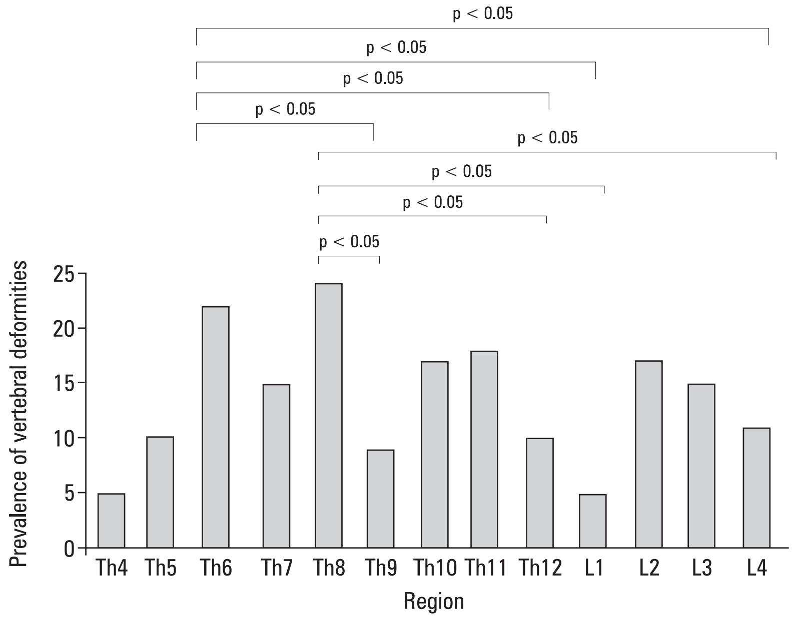

Figure 3. *Prevalence of vertebral deformation by region*
Rycina 3. *Występowanie deformacji kręgowych w zależności od lokalizacji*

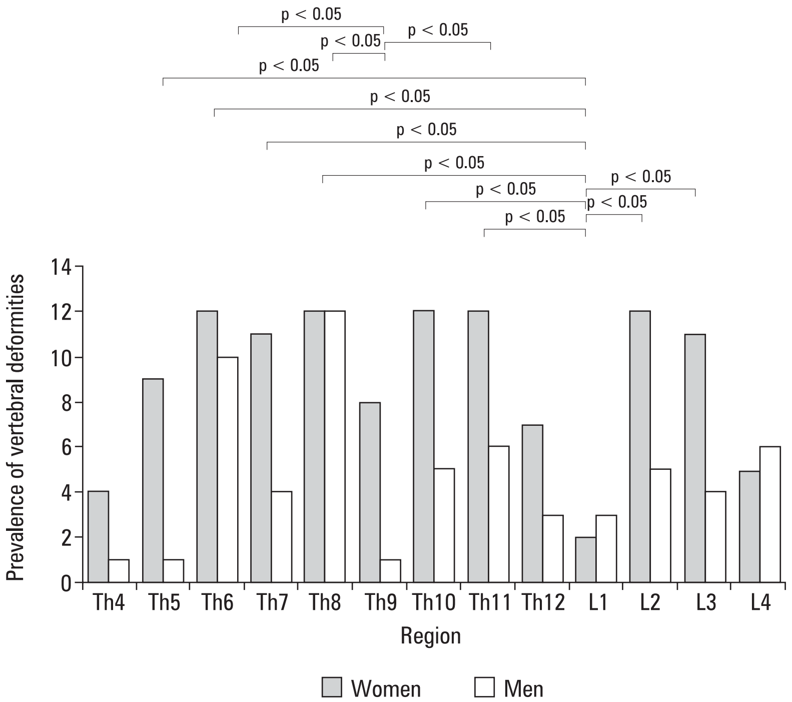

Figure 4. *Prevalence of vertebral deformities in men and women by regions*
Rycina 4. *Występowanie deformacji kręgowych u mężczyzn i kobiet w zależności od lokalizacji*

In several aspects, our results were similar to those from the EVOS study. The obtained results depend on the assumed threshold of fracture identification [27, 28]. Many diagnostic algorithms of morphometric vertebral deformity had been published before [14, 29–31]. We used Eastell's method in our research [14], recommended for its simplicity [28]. Moreover, our data can be modelled using normal distribution, in which case a threshold 3 SDs below the mean represents the limit of normality. The same method was used in the CaMos study (Canadian Multicentre Osteoporosis Study) [21]. In contrast, in the EVOS study, two morphometric definitions of fracture were employed — by Eastell [14] and McCloskey [29]. The latter is less strict, requiring the fulfilment of two criteria to identify the pathology [28]. Obviously, we realize that the EVOS and the CaMos studies were carried out by classic X-ray and analyzed by morphometry, whereas our study was conducted by MXA. However, both techniques represent quantitative methods and the previously high conformity of results was shown between the two modes [32–34]. Comparing the age of the populations between our research and the EVOS and CaMos studies, we examined a younger population, i.e. from 20 years, not only the age group from 50 to 79 years, as our method was safe for women in a child-bearing age [2]. Similarly to others [21, 22], in our study all the images were evaluated centrally and corrected by one operator.

Analyzing the entire population, we found that the most frequent localization of deformities was the mid-thoracic region, but distribution of fracture prevalence differs according to age. Only for women, we observed a higher tendency towards deformation in the lumbar spine and at the thoracolumbar junction (Fig. 4), which was also shown by others [21, 35]. Wedge deformities were the most frequent deformity.

Our study faced some disadvantages due to the applied method. One of the more important limitations of MXA was the difficulty in visualising of the upper thoracic vertebrae, associated with superposition of soft tissue, particularly of the lungs and the bronchial tree. We were able to visualize 38% of Th4, 68% of Th5, and more than 95% below Th7. Our results are similar to the results of other authors [36]. However, fractures of the Th4 to Th6 vertebrae were not common; in the Rotterdam Study, out of 240 new fractures, less than 10 fractures were related to that part of the spine [37].

We treat this publication as preliminary; in future we intend to expand the analysis of our data with other methods applied to detection of fractures, and to compare data according to age in, detail. We think that the impossibility to confirm our results with X-ray images is the main weak point of the study, but we are going to perform visual analysis of the obtained scans.

Conclusions

In conclusion, the application of MXA confirms earlier observations that vertebral deformities are common in the Polish population. The use of densitometric morphometry in clinical practice may be potentially advantageous.

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