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A standard for measuring the relative spine values of adults

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The paper proposes a method for using the relative values of linear dimensions for spine structures, which are necessary to compare the results obtained from digital and conventional radiographs having different scales.

The purpose of the study: to develop a method for quantifying the spine structures of adult patients in relative units of measurement.

Materials and methods. Using digital spine radiographs of 141 patients (from 21 to 88 years old), with careful observance of the same magnification, it is shown that the metric length of the segment tangent to the image of the vertebral body C_I lower contour – the órel standard – has no age trend.

Results and discussion. The ratio of segment tangent to the image of sacrum upper contour (segment s) and órel standard dimension also does not depend on age and is on average equal to 2.1. So the segment can be approximately calculated as órel = s/2.1. A group of 64 patients, from 21 to 88 years old, taken from the general cohort is divided into four age subgroups according to the WHO classification. It is shown that relative vertical spine size decreases with age. The difference in average relative vertical spine size for the first and the fourth age subgroups was 3.75 órels. The relative contribution of each spine part to the decrease is also demonstrated.

Conclusion. The proposed relative unit of measurement “órel” can be used as a universal measure of length, independent of the scale and method of obtaining an X-ray image for measuring and comparing the structures of the spine in adults at any age.

Keywords: spine; radiography; “órel” dimensional segment; spine reduction with aging

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Эталон для измерения относительных величин структур позвоночника взрослых

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В работе предложен метод измерения относительных величин линейных размеров структур позвоночника, которые необходимы для сравнения результатов, полученных с цифровых и обычных рентгенограмм, имеющих разный масштаб.

Цель исследования: разработать метод количественной оценки величины структур позвоночника взрослых пациентов в относительных единицах измерения.

Материал и методы. На примере группы из 141 пациента (от 21 до 88 лет) при тщательном соблюдении одинакового увеличения цифровых рентгенограмм было показано, что метрическая длина отрезка касательной к изображению нижнего контура тела позвонка C_I – эталон óрел – не имеет возрастного тренда.

Результаты и обсуждение. Выявлено, что соотношение размеров эталона óрел (отрезка orel) и отрезка касательной к изображению верхнего контура крестца (отрезка s) не зависит от возраста и в среднем равно 2,1, и может быть приблизительно вычислено по формуле orel = s/2,1. На примере группы 64 пациентов, взятых из той же когорты обследованных, (от 21 до 88 лет), разделенной на 4 возрастные подгруппы в соответствии с классификацией ВОЗ, показано, что относительный вертикальный размер позвоночника, уменьшается с возрастом. Разница средних относительных значений вертикального размера позвоночника в первой и в четвертой возрастной подгруппе составила 3,75 óрела. Также продемонстрирован относительный вклад каждого отдела позвоночника в это уменьшение.

Заключение. Предлагаемая относительная единица измерения “óрел” может быть использована в качестве универсальной меры длины, независимой от масштаба и способа получения рентгеновского изображения для измерения и сравнения структур позвоночника у взрослых в любом возрасте.

Ключевые слова: позвоночник, рентгенография, эталон óрел, уменьшение высоты позвоночника при старении

Источник финансирования. Исследование не финансировалось каким-либо источником помимо средств авторов.

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Этическая экспертиза. Исследование проведено в соответствии с Хельсинской декларацией (принята в июне 1964 г., пересмотрена в октябре 2013 г.), от каждого участника исследования получено информированное согласие.

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Introduction

Traditionally, the main task of radiological spine examination was to identify morphological signs of diseases, fractures, developmental abnormalities, dystrophic changes, inflammatory, tumor, and other morphological disorders affecting spine functions, which was used to determine the possibilities of surgical intervention.

Neurosurgeons, traumatologists, orthopedists, vertebrologists, radiologists, specialists in restorative medicine, rehabilitologists, physical therapy doctors, osteopaths, chiropractors and many other specialists engaged in spine diagnosis and treatment are involved in studying spine features.

The issue has a rich history, and studies conducted earlier offer a number of solutions used in practice estimating the spine linear dimensions in neurosurgery using metric units. On the basis of metric measurements of radiographs, classifications of spinal deformities in adolescent idiopathic scoliosis have been developed in neurosurgery clinics. The metric parameters of the spine determining the balance of its arches in the frontal and sagittal planes are investigated. And they still serve to evaluate the results of surgical intervention [1–7]. Other authors also write about this.

However, the use of a relative indicator, a benchmark that would reflect the individual characteristics of each patient's spine, has not yet been proposed. When reviewing the scientific literature, we did not find analogues of such an invention, neither in domestic nor in foreign databases. Such an approach would make it possible to compare the metric characteristics of the spine in patients of different ages, made using both analog and digital X-ray machines.

Modern digital X-ray examination has significantly reduced the dose of radiation exposure and opened up new opportunities for a refined detailed diagnosis of patient's spine condition. However, the digital X-ray examination has a significant problem. The advantage of digital radiography is the ability to proportionally change the scale of the X-ray image on the screen of a personal computer. However, this inevitably leads to a change in the linear dimensions of the studied structures, and it requires the introduction of additional standards into the image itself. The standards make it possible to correctly compare the results of different X-ray studies.

Expanding the boundaries of the application for X-ray examination, comparing X-ray images obtained for the same patient at different ages, we are again faced with the technical problem of measuring the spine structures obtained with different X-ray machines, under different conditions of radiography. It is well known that throughout patient life, the position and shape of each vertebra change. Solving the problem of determining norm boundaries, we need to compare linear sizes of the vertebrae, length of entire spine and its sections both for one patient and for different patients. Due to large variability and uncertainty of norm boundaries of anatomical structure and vertebra shape, the quantitative assessment of age-related changes in metric units cannot be recognized as absolutely objective. That is why the task of developing a unit (standard) for relative measurements, acquiring the properties of a universal measure that does not depend on either the magnitude and scale of X-ray image or features of a patient's constitution becomes relevant. The relative dimensions of spine structures measured using such a unit of measurement can be compared.

As a standard, it seems most acceptable to use those bone formations that can be easily found and measured on a spine radiograph. It must be said that such an approach – to measure any dimensions with the help of a standard representing a part of human body, has deep historical roots.

In visual arts, at various times, many systems of typing the size and proportions of the human body have been proposed, which have received the name canon. When using the canon, a length of a part of human body was taken as a unit of measure – a module. The modules were: length of middle finger (in Ancient Egypt), head (in Ancient Greece), foot, face, and others. An author of one of the first literary sources describing the canon was Polycletus, the sculptor of Ancient Greece in classical period. In V century BC, he wrote an essay on the regularity of human body part proportions. Some researchers suppose that Polycletus took palm width at the level of finger bases as a module, while others think that his module was a head longitudinal size. Polycletus applied his canon in the work on the statue of Doriphorus (Spearman). A face in Polycletus sculptures is 1/10, a head is 1/8, and head with neck is 1/6 of the entire human figure [8].

In Russia, since ancient times, it has been accepted to measure the size of any objects in arshins (from the Persian word “arsh” – “elbow”). This is length measure that was equal to the length of the arm. It was equal to 71 cm and measured at arm's length in a straight line from the tip of the middle finger to the shoulder. Another example of a measure of length – a vershok – was equal to the main phalanx length of the index finger. Other length measures based on the size of human body parts were also used [9].

The approach of Chinese traditional medicine is closer to our problem solving. For the purpose of acupuncture specialists search biologically active points on the energy meridians of human body using individual measures of length: individual tsun and proportional tsun. Individual tsun is measured on the patient's middle finger. To measure it, it is necessary to connect the ends of the bent thumb and middle finger of the left hand so that they form a ring. The distance between the outer ends of the transverse folds at the second phalanx of the middle finger is taken as a tsun. Proportional tsun is the distance from the patient's ulnar fold to the fold of the wrist joint divided into 12.5 parts – each of the part is equal to one individual tsun [10].

Concerning the topic of the present study, it is interesting that there is a structure in the human spine that differs in its anatomical structure from other vertebrae, present in all people, clearly defined on radiographs, and does not require complex equipment for its measurement. This is the C_I vertebra – axis. In radiology, it is customary to start counting vertebrae in the spine column from the axis. Even in a baby's X-ray spine image, the axis body is clearly defined. Though the appearance of secondary ossification nuclei in the axis apex area is a subject of significant variations, the axis body ossification nucleus is primary and can be diagnosed already at birth, it is well defined till the first months of a person's life. We believe that this structure reflects the features of patient's anatomical structure, and can serve as an individual measuring unit, a standard for studying the spine size.

The purpose of this work is to develop a method for quantifying the spine structures of adult patients in relative units of measurement.

Type of study: cohort.

Location of the study. The study was conducted at the Moscow Scientific and Practical Center for Medical Rehabilitation, Restorative and Sports Medicine of Moscow Health Department.

Materials and methods

Digital radiographs for patients who applied for dorsopathies were randomly selected. The cohort consisted of 141 patients aged 21 to 88 years, 57 men and 84 women. The patient cohort was divided into four groups according to the WHO age classification [11]: I – 21–44 years (mean age 32.7 years) – 31 people, II – 45–59 years (mean age 52.6 years) – 39, III – 60–74 years (mean age 66.8 years) – 50 and IV – 75–88 years (mean age 81.1 years) – 21 people.

The inclusion criteria to the study cohort were the availability of digital radiographs of all parts of the spine, made simultaneously in accordance with the required standards of radiography. Key conditions of radiography were: focal length of at least 150 cm (telerentgenography), the patient standing barefoot in a natural pose at the vertical rack of X-ray machine, during radiography the patient fixes his gaze at a distant point opposite the eyes [12]. The exclusion criteria were gross violations of spinal statics in the form of scoliosis of the III–IV degree, due to congenital anomalies of vertebral development, as well as the presence of diseases in which treatment with osteopathy is contraindicated [13].

It is important to note that the study was conducted on a personal computer monitor screen without the participation and without additional irradiation of patients. The graphical capabilities of the Microsoft Office Word 2007 software package were used. Digital images of each spine section in the sagittal projection were superposed at the edges, and then attached one to the other at a fivefold magnification. At the first step image of the cervical spine was attached to the X-ray image of the thoracic spine. And then the image of the thoracic spine was attached to the image of the lumbosacral-coccygeal section. We achieved a complete coincidence of the sizes and contours of the combined vertebrae. Therefore, a compounded digital X-ray image in proportions and shape corresponded to the whole spine image of the patient.

In order to measure the average size of spine sections and entire spine, 64 compounded radiological spine images for patients aged 21 to 88 years were selected from the general cohort. The selection criterion was the presence of X-ray images for all spine parts in sagittal projection, from skull base to sacrum apex. Combined spine radiographs of patients who did not have an X-ray image of sacrum apex were excluded from the study group. There were four age subgroups: 21–44 years – 21 people, 45–59 years – 14 people, 60–74 years – 21 people and 75–88 years – 8 people.

Tangent to axis body lower contour (segment órel) as well as tangent to sacrum base contour (segment s) were applied to the combined digital X-ray spine image of each patient (Fig. 1). In order to study the dependence of average vertical spine size on age, a vertical straight line was applied to the combined X-ray spine images of 64 patients, coming from the outer contour of the external tubercle of the occipital bone – the occipital vertical. Several horizontal lines were drawn to intersect with occipital vertical: from the dens apex of axis (C_{II}), from the posterior lower corner of the C_{VII} vertebra body image, from the posterior lower corner of the T_{XII} vertebra body image, from the posterior upper corner of sacral base image (S_I) and from the sacral apex (S_V). The screen ruler Window Ruler 1.1 and the standard transparent ruler were used for measurements. The values of órel segments and s segments were measured in millimeters for all 141 patients. Projection values of spine vertical dimensions, cervical C_{II}–C_{VII}, thoracic C_{VII}–T_{XII}, lumbar T_{XII}–S_I and sacral S_I–S_V, cut off by horizontal lines on the occipital vertical, were measured in millimeters for 64 patients. The data are recorded in the study protocol. Statistical data processing was carried out using Microsoft Office Excel 2007 and the STATISTICA 12 software package.

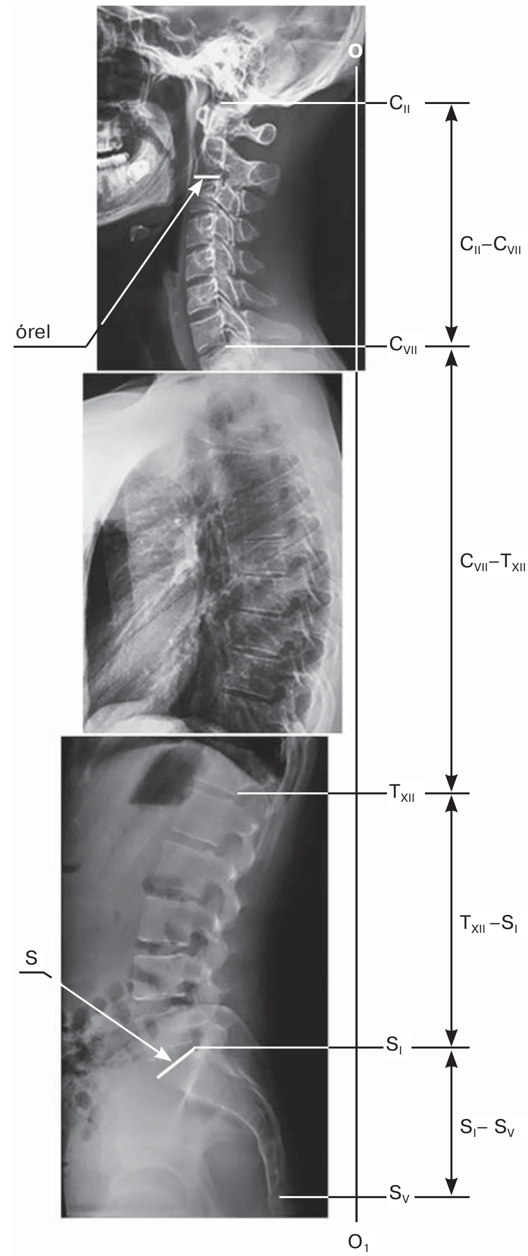

Fig. 1. Combined digital radiological image of patient X., 31 years. OO_1 – occipital vertical, órel – dimensional segment órel; s – segment sacrum; C_{II}, C_{VII}, T_{XII}, S_I, S_V – horizontals drawn from the corresponding vertebrae; C_{II}–C_{VII} –vertical size of the cervical spine, C_{VII}–T_{XII} – vertical size of the thoracic spine, T_{XII}–S_I – vertical size of the lumbar spine, S_I–S_V – vertical size of the sacral spine. This patient has a normal position of the sacrum. Lumbar lordosis, thoracic kyphosis and cervical lordosis are within normal limits. There are retrolistesis of the vertebrae C_{III}, T_{XII}, L_I and L_{II}. The sacrum is segmented. The signs of chondrosis are differentiated with a decrease in intervertebral space height at the level of C_{III}–C_{IV}. There are manifestations of arthrosis of the arcuate joints at all levels, as well as arthrosis of the anterior atlanto-axial and sacrococcygeal joints. A large osteophyte, the occipital spur, grows from the external occipital protuberance. The occipital vertical passes behind the spine.

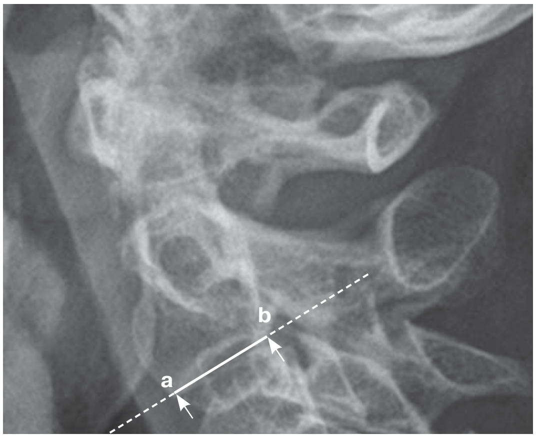

Fig. 2. X-ray image of atlas and axis (C_I and C_{II}) in sagittal projection. a is the distal point of body C_{II} anterior contour; b is the distal point of body C_{II} the posterior contour; ab is the absolute value of the measuring unit “órel”.

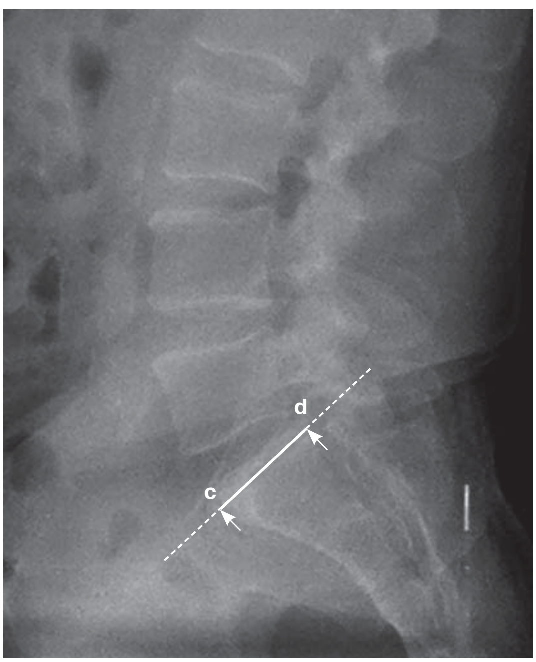

Fig. 3. X-ray image of the lumbosacral spine in sagittal projection. c is the front point of the sacrum base contour; d is the back point of the sacrum base contour; cd is the absolute value of the segment “sacrum”.

As a unit of measurement to assess the relative size of the spine structures, we propose to take the lower contour of the second cervical vertebra body. To do this, on the radiograph of the cervical spine in the sagittal projection, it is necessary to find the axis body and draw a tangent line to its lower contour. As a unit of measurement, we propose to take a straight line segment between distal points of anterior and posterior contours in the X-ray shadow of the axis body (Fig. 2). This segment was named “órel”. We noticed that the size of the segment differs slightly from one person to another, but at the same time reflects individual characteristics of each person.

The measuring segment “órel”, as well as all other sizes, was measured on the screen of a personal computer in millimeters. We relate any measured parameters on the combined digital radiological image of the spine, without changing image scale, with the órel measuring unit. Thus we get a dimensionless relative value, and these relative values can be compared for different people, at different ages and during various studies.

It is important to emphasize that the same scale of images was observed during the study, both during a single study and throughout the entire series of studies. Therefore, the data obtained made it possible to compare the linear dimensions of the studied structures, both on a single combined image of the spine, and in the entire group of studied images.

As an example of using the órel standard, the size segment of the tangent drawn on the combined spine radiograph in sagittal projection to the base of the sacrum was studied for all 141 patients. This segment was called “sacrum” and was designated by the letter “s”. The sacrum is well defined on radiographs and on any radiation images of this area. As well as the axis, the sacrum has a characteristic structure (Fig. 3).

Results

The value of órel segment was measured on combined digital radiological spine images of all 141 patients. It should be said that the absolute values of the órel segment, as well as the sacrum segment, measured in mm, given in this paper play the role of only indicative data. They were measured on the screen of a personal computer and depended on the scale of the image. On the other hand, these data reliably reflect the true size ratios of the studied structures. The average value of the órel segment on the digital X-ray images studied in all age groups was 9.55 ± 1.08 mm.

The true dimensions of the órel segment can be determined by direct measurements of the anterior-posterior size on the lower surface of the axis body on dry anatomical preparations. This kind of research has been conducted repeatedly and is presented in scientific sources of different countries, Table 1, the data of the table are quoted by source: [14].

We investigated the absolute dimensions of órel segment depending on the age of the patients (Fig. 4). In the course of this study, it was shown that there was no age trend in the size of órel segment. That is, its value does not depend on patient age and does not change with age, it’s just a feature of this patient spine constitution.

Table 1. Morphometric analysis of the anterior-posterior diameter of inferior axis vertebra surface, values in mm ± DP (Marques Filho, Gustavo de Souza, et al., 2021)

Authors	Country	Year	Number of vertebrae examined	Anterior-posterior length of inferior vertebral body CII surface
Filho M., Gustavo de Souza et al.	Brazil	2021	58	15.29± 2.02
Lalit M., Piplani S., et al.	North Italy	2020	60	15.10± 1.56
Mukesh Singla et al.	India	2015	30	15.42± 1.78
Morales-Avalos et al.	Mexico	2012	576	15.11± 1.88
Gosavi and Swamy et al.	India	2012	100	14.77± 1.73
Naderi et al.	Turkey	2006	80	15.8± 1.7
Xu R., Nadaud M.C. et al.	USA	1995	50	(male) 16.1±1.5 (female) 15.0±1.7
Doherty B.J., Heggeness M.H.	Houston, Texas	1994	51	16.6± 1.6

The average value of sacrum segments on the combined digital X-ray images studied in all age groups was 20.0 ± 2.55 mm.

When analyzing the segment size of tangent drawn to the base of the sacrum (segment s) in the entire cohort of 141 patients, as well as for absolute órel length, no age trend was found (Fig. 5).

The study suggested that both segments are interchangeable and can equally be used to assess the relative sizes of spinal structures. Therefore, at the next stage of the study, we studied the relationship between them. It was revealed (Table 2) that the ratio between average segments s and órel was approximately equal to 2.1 for patients of all age categories.

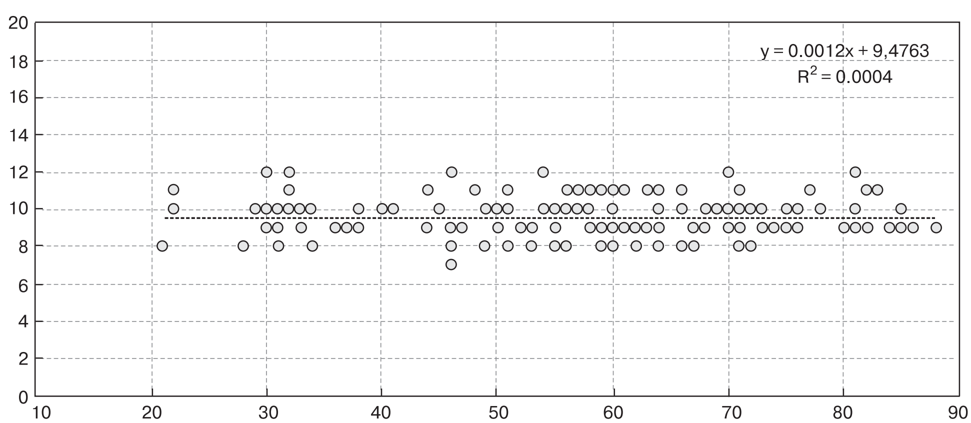

Fig. 4. Absolute órel segment dimensions depending on patient age.

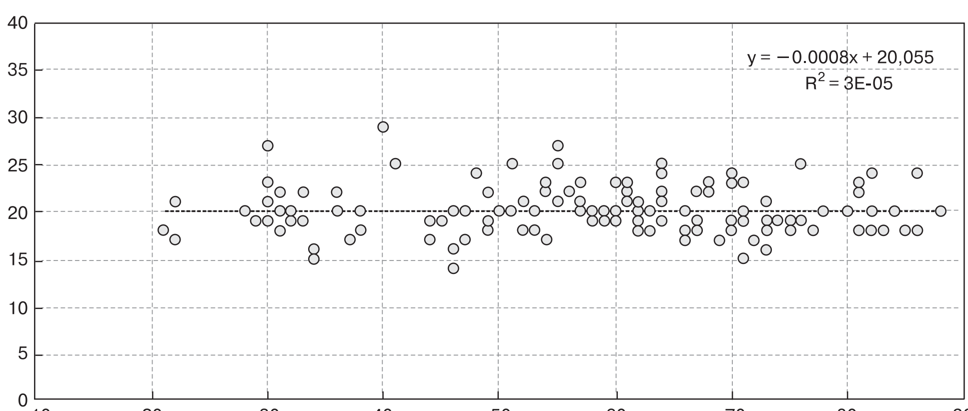

Fig. 5. Absolute sacrum segment dimensions depending on patient age.

Table 2. Measured values of órel and sacrum segments on combined spine radiographs, 141 patients

Age group	Number of people	The average value of órel segment, mm	The average value of the s segment, mm	The ratio of average s and average órel values
21–44	31	9,61 ± 1,1	20,00 ± 3,0	2,1
45–59	39	9,51 ± 1,2	20,23 ± 2,6	2,1
60–74	50	9,48 ± 1,0	19,80 ± 2,4	2,1
75–88	21	9,67 ± 0,9	20,10 ± 2,3	2,1

Table 3. The average relative vertical dimensions of spine parts and entire spine, in órels, 64 patients

Age group	Number of people	Vertical dimensions of the spine parts, in órels				Vertical size of the entire spine, in órels
		C_{II}–C_{VII}	C_{VII}–T_{XII}	T_{XII}–S_I	S_I–S_V	C_{II}–S_V
21–44	21	7,64 ± 0,67	16,60 ± 1,87	10,02 ± 2,02	5,99 ± 1,32	40,25 ± 5,13
45–59	14	6,82 ± 0,68	15,92 ± 2,05	9,13 ± 1,38	5,85 ± 1,07	37,72 ± 3,99
60–74	21	6,55 ± 0,78	15,51 ± 2,04	8,58 ± 1,65	6,26 ± 1,26	36,90 ± 5,10
75–88	8	6,38 ± 0,41	14,97 ± 1,93	8,74 ± 1,29	6,41 ± 1,21	36,50 ± 3,47

Thus, based on the study results, we consider it possible to assert that the value of dimensional segment órel correlates with the value of sacrum segment, with the same coefficient. And the value of the segment s, in órels, can be approximately calculated by the formula:

$$s = 2.1 \text{ órel}$$
$$\text{órel} = s / 2.1$$

Órel standard application for measuring spine vertical dimensions

It was important not only to offer a relative unit, a standard for measurement, but also to make sure that this approach can be applied in practice. We assumed that the study carried out using a relative standard allows us to reliably compare the dimensions of the spine structures on uniform X-ray images for persons of different genders and ages. It means that the method made it possible to investigate the age trend in average vertical size of entire spine as well as the size of each spine part. The measurement results in relative units are shown in Table 3.

The comparison of the average relative vertical dimensions in the group of 64 patients showed that there is a relative change in the vertical size of both the entire spine and its parts. When comparing the cervical spine for young and senile patients, a decrease of 1.26 órels was noted. The thoracic spine decreased by 1.63 órels. The lumbar spine decreased by 1.28 órels. In contrast, the relative vertical size of the sacral spine increased slightly by 0.42 órels.

The study demonstrated a decrease in average vertical size of entire spine for senile patients compared with young patients by 3.75 órels.

At the same time, during the study it was revealed that the decrease in the relative vertical dimensions of entire spine occurred unevenly (Fig. 6). The greatest differences were found when comparing the first (21–44 years) and the second (45–59 years) age subgroups, where the difference in average size of entire spine was 2.52 órels. In the next age subgroup (60–74 years), the average size of entire spine decreased by another 0.83 órels. And at the age of 75–88 years, the vertical size of spine decreased by another 0.40 órel.

A more rigorous test of the statistical hypothesis about the significance of the difference in the mean

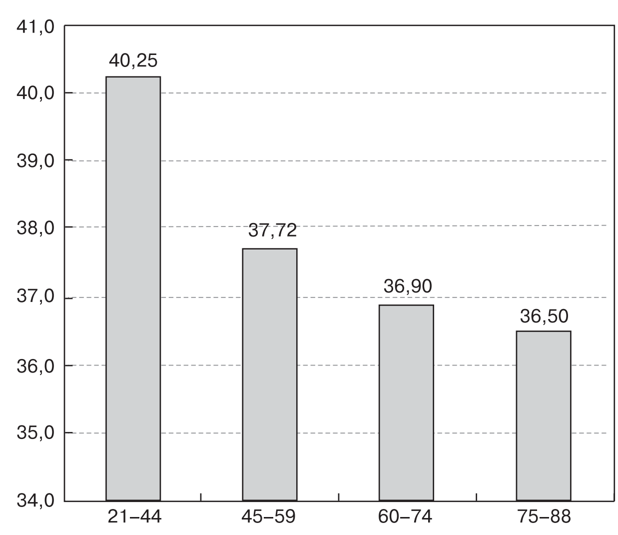

Fig. 6. The average relative vertical size of spine, C_{II}–S_V, four age groups.

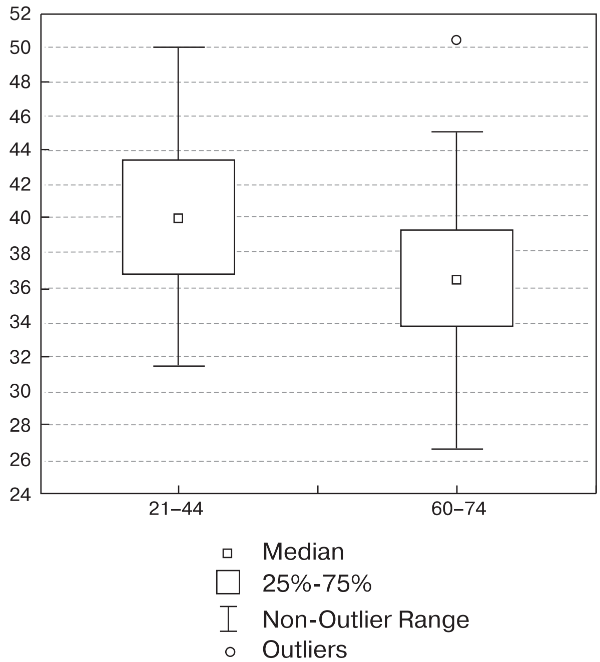

Fig. 7. Relative vertical size of the spine C_{II}–S_{V} in the first and third age groups. Box plot.

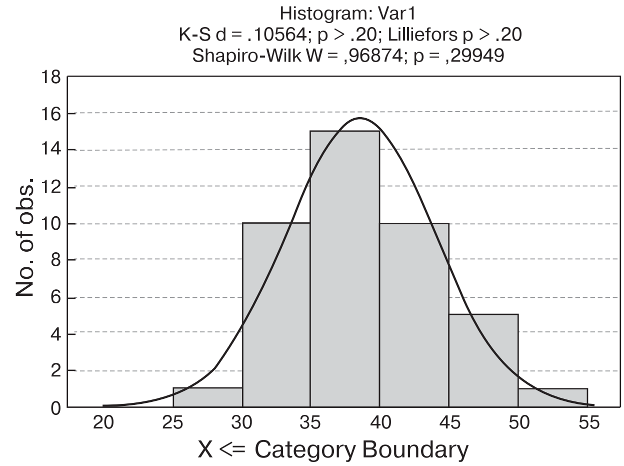

Fig. 8. Assessing data normality for relative vertical spine size C_{II}–S_{V} in the first age subgroup. Histogram.

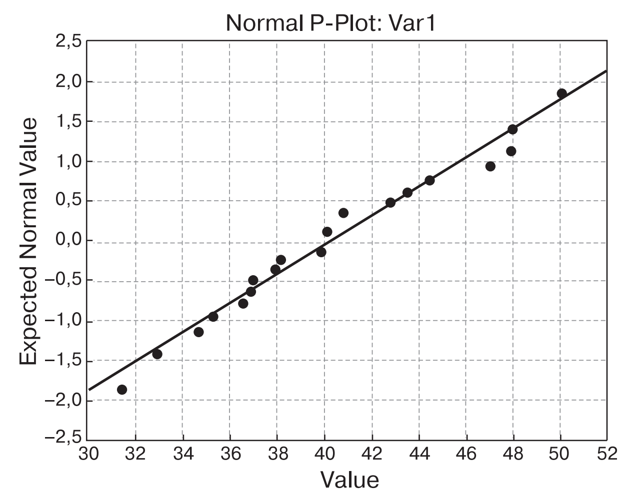

Fig. 9. Assessing data normality for relative vertical spine size C_{II}–S_{V} in the first age subgroup. Normal probability plot.

value (median) of the spine vertical size for different age categories was carried out in several stages using the STATISTICA package. Patients of the first age category (21–44 years), a total of 21 people, and patients of the third age category (60–74 years), also 21 people, were taken as subgroups for comparison from 64 patients. It should be noted that the subgroups were independent, that is, in this case, the indicators were compared for 42 patients. As a null hypothesis, the variant of insignificant median difference for two subgroups was considered, as an alternative – the presence of a statistically significant difference (age trend). Fig. 7 shows boxplot for the relative vertical dimensions of C_{II}–S_{V}, calculated in órels, for patients of two age subgroups.

Before proving the significance of the difference in median values for two subgroups, it was necessary to choose a suitable method, for which, first of all, the data normality of the value we were interested in should be assessed. According to the type of box diagrams, it was impossible to reject the hypothesis of normality, since the graphs demonstrated a fairly symmetrical appearance.

A more thorough check of data normality included the histogram as well as normal probability plot analysis. An example of such a graphical assessment for the first age subgroup of 21 people (21–44 years) is shown in Fig. 8, 9.

The verification was also carried out according to the criteria of Kolmogorov–Smirnov and Shapiro–Wilk. The hypothesis of the data normality could not be rejected, and therefore, when checking the statistical significance of the difference in mean values, it was possible to use a parametric method, in this case the Student's t-criterion for independent samples. As a result, the null hypothesis that the differences in mean values for the two age subgroups were insignificant had to be rejected (p = 0.040). Thus, based on the analysis done, it should be concluded that decrease in relative vertical spine size with age is statistically significant.

Discussion

The widespread use of digital radiography, along with the obvious advantages, has put in agenda the issue of objective measurement and comparison of linear dimensions using spinal structure images, both digital and made on X-ray film.

The introduction of relative measurement unit, órel, gives new important possibilities. There is no need to always strictly observe the scale of digital images in a series of studies or to carry out radiography only on the same X-ray machine. It is possible to compare the data of images obtained on a digital X-ray image and on an X-ray film. It is enough just strictly to adhere to the same conditions: always use the same standards of radiography and during a single study, when measuring significant parameters, to keep the same image scale. With the relative unit of measurement órel, it becomes possible to compare the measured parameters for many patients and objectively determine both norm and pathology boundaries for linear dimensions of structures. It means identifying initial stages of diseases manifested by functional disorders of statics – that is, more specifically, to diagnose somatic spinal dysfunctions based on radiation images. It becomes possible to compare linear dimensions of the same structures with multiple repeated measurements. The comparison of the results of spinal examinations for the same patient made after a long time period is simplified and becomes more evidence-based. So it can contribute to improving the means of monitoring treatment results (before and after treatment), as well as in the long term after treatment course. The authors believe that such an approach can be useful for the development of evidence-based medicine.

The present work offers another improvement. Having axis image in sagittal projection, by measuring the size of órel segment, it is possible to calculate the approximate size of sacrum segment s using the proposed formula. Conversely, by measuring the value of the segment s on a radiograph, it is possible to approximate the value of órel segment. Knowing this, it is enough to have an image of only one segment in order to assess linear dimensions in órels of any spine structure, without additional radiography of the cervical spine.

The use of the data obtained allowed us to investigate the age trend of changes in spine structure sizes. Observing people of different ages shows that people after 60 years gradually decrease in height. However, it was not possible to reliably register and verify spine contribution to the decrease, since longitudinal studies with entire spine radiography of the same patient for many years aimed to solve such a problem were not carried out. Which is not surprising, since the duration of such a study would have to be at least 20 years, and the initial age of patients is 60 years and older. The use of a relative unit for measurement made it possible to compare the spine size for people of different ages, taking into account their individual characteristics, and bring these measurements to uniform conditions. That's why we were able to conduct a cross-sectional study of the age trend. It is important to emphasize that the research methodology described in this paper has provided new measurement data for spine sections and entire spine.

The proposed research methodology was carried out for the first time. And since such work using the relative unit of measurement of spinal structures has not been carried out earlier, we could not find similar work and compare the data obtained with the data of other authors.

The data obtained correlate with the earlier results of the authors. Possible explanations for the decrease in the relative vertical size of the cervical and thoracic spine can be found in the works describing the age trend. For example, it was shown that the second cervical vertebra of elderly people deviates from a strictly vertical position and most often occupies a position with a forward tilt (kyphosis) or backward (lordosis), that is, its relative vertical size decreases [15]. For elderly and senile people, an increase in thoracic kyphosis is most often detected mainly due to forward tilt and anterior displacement of the C_{VII}–T_{III} vertebrae, which also contributes to a decrease in relative vertical size of spine [16]. A weakly pronounced increase in the relative vertical size of the sacral spine can be explained by the fact that vertical sacrum position is most often detected for elder people [17].

Conclusion

Digital radiography has significantly reduced the dose of radiation exposure to the patient and improved the quality of the images obtained. It became possible to study digital images of the spine remotely using a personal computer, without the participation and without additional irradiation of the patient.

For the first time, as a measuring standard characterizing the individual features of the patient spine structures, it is proposed to use a dimensional segment, called “órel”, measured on a tangent drawn on a radiograph of the cervical spine in sagittal projection to the lower contour of the axis body. Comparing any linear dimensions of the spine structures with the órel segment allows us to obtain a dimensionless relative size of the spine structure.

For the same patient a stable ratio of the dimensional segment órel (orel segment) and the segment of a straight line drawn tangentially to the upper contour of sacrum base (s segment) was revealed. The research demonstrates the interchangeability of these segments in possible using for practical needs. And in case there is an image of one of the segments on a digital radiograph, it is possible to approximately recalculate the magnitude of the linear dimensions for the studied structures in órels, without additional examination of other spine parts. The approximate ratio between the órel segment and the s segment is presented in the formula: órel = s/2.1.

The use of the unit in measurement solves the problem of comparing the linear dimensions of spinal structures for different patients, including the age trend identifying. The present study shows that people over 45 years old have a gradual decrease in the vertical dimensions of the cervical, thoracic and lumbar sections and at the same time a slight increase in the relative vertical size of sacral spine. It is demonstrated that average vertical size of the spine from the apex dens of axis C_I to the S_V apex for people aged 21 to 88 years decreases in total by 3.75 órels.

Thus, in the course of the study, data were obtained indicating that the spine is a living, constantly developing structure of human body, which undergoes significant changes not only in childhood, but also for adult people, and especially in old age and senility. This opens up prospects and opportunities for actively maintaining his harmonious physiological state based on the principles of evidence-based medicine.

Authors contribution

Aleksander M. Orel – development of research design, scientific management of research, review of publications on the research topic, data collection, participation in the analysis of collected data, writing the text of the article, editing text of the article, translation of the text of the article.

Olga K. Semenova – participation in the design of the study, review of publications on the research topic, statistical analysis of the collected data, editing text of the article, translation of the text of the article.

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