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A COMPARATIVE ANALYSIS OF THE RELATIONSHIP BETWEEN STATURE AND ULTRASOUND DIMENSIONS OF INTERNAL ORGANS IN ADOLESCENTS

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The *aim* of the study was a comparative characteristic of the size of internal organs according to ultrasonography data in subjects with various deviations in stature, determined using international standardized norms.

Materials and methods. The stature was measured in 93 adolescents, aged 13 to 17 years. Based on the measurements, the *Z*-score of body length was calculated according to the WHO Growth Reference, 2007 and three groups were formed for comparing the sizes of internal organs: "average", "above average", "below average". Ultrasonography data of the internal organs dimensions and thyroid gland was performed using a Toshiba Aplio 500 ultrasound scanner.

Results. There were statistically significantly lower values of the liver span and the longitudinal size of the gallbladder in the examined subjects from the "below average" group compared to the rest of the subjects. The length of the spleen and the total volume of the thyroid gland were statistically significantly different in subjects from all three groups, with the highest values in volunteers from the "above average" group. A weak direct correlation was shown between the *Z*-score of body length and liver span, the length of the cauda of the pancreas, and the width of the spleen. An average direct statistical relationship was found between the *Z*-score of stature and the length of the spleen, as well as the total volume of the thyroid gland.

Conclusion. To a greater extent, body length is associated with the size of the parenchymal organs with a pronounced connective tissue frame - the liver and spleen, as well as the thyroid gland due to the relationship of its volume with hormones that regulate growth and development. Clinical substantiation of the relationship between the structure of the body and internal organs opens up the possibility of creating anatomical standards that allow ultrasound morphometric assessment of internal organs, taking into account the individual characteristics of the patient's body size.

Keywords: *Z*-score; adolescents; body length; dimensions of internal organs; thyroid gland volume.

СОПОСТАВИТЕЛЬНЫЙ АНАЛИЗ ВЗАИМООТНОШЕНИЙ ДЛИНЫ ТЕЛА И РАЗМЕРОВ ВНУТРЕННИХ ОРГАНОВ У ПОДРОСТКОВ

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Цель работы — провести сравнительную характеристику размеров внутренних органов по данным ультрасонографии у испытуемых с различными отклонениями длины тела, определяемых с применением международных стандартизированных норм.

Материалы и методы. Проведено измерение верхушечной длины тела у 93 подростков, юношей в возрасте от 13 до 17 лет. На основании измерений рассчитан *Z*-индекс длины тела по стандартам WHO Growth Reference, 2007, и были сформированы три группы сравнения размеров внутренних органов: «средние», «выше средних», «ниже средних». Исследование органов брюшной полости и щитовидной железы проводили с использованием ультразвукового сканера Toshiba Aplio 500.

Результаты. Выявлены статистически значимо меньшие значения косого вертикального размера правой доли печени и продольного размера желчного пузыря у обследованных субъектов из группы «ниже средних» по сравнению с остальными испытуемыми. Длина селезенки и общий размер щитовидной железы статистически значимо отличались у испытуемых из всех трех групп с наибольшими значениями у добровольцев из группы «выше средних». Показана слабая прямая корреляция *Z*-индекса длины тела и косого вертикального размера печени, длины хвоста поджелудочной железы, ширины селезенки. Обнаружена средняя прямая статистическая связь *Z*-индекса длины тела и длины селезенки, а также общего объема щитовидной железы.

Выводы. В большей степени длина тела связана с размерами паренхиматозных органов с выраженным соединительнотканным каркасом — печенью и селезенкой, а также щитовидной железой в силу взаимосвязи ее объема с гормонами, регулирующим рост и развитие. Клиническое обоснование взаимоотношений строения тела и внутренних органов открывает возможность создания анатомических стандартов, позволяющих вести ультразвуковую морфометрическую оценку внутренних органов с учетом индивидуальных особенностей размеров тела пациента.

Ключевые слова: *Z*-индекс; подростки; длина тела; размеры внутренних органов; размеры щитовидной железы.

INTRODUCTION

The regulation of the growth and development of the skeleton and internal organs is a single humoral mechanism [33]. Thus, it becomes possible to use physical development parameters as predictors of the deviations in the size of internal organs from the standards during ultrasound (US) examination [20, 24, 26, 28, 31, 34].

The anatomical dimension of internal organs is a constant value; therefore, they may be considered as signs that determine the characteristics of a person's somatotype [8]. Studies have discussed the relationship between individual typological characteristics of internal organs, namely, the size of the liver, gallbladder, pancreas, and thyroid, and their relationship with a person's somatotype to create standards for the US assessment of these parameters [9, 18, 19].

Many studies have identified a mosaic distribution of differences in the size of internal organs in children with different somatotypes [3–5]. Thus, the focus on the constitutional characteristics of the organism as a factor capable of influencing the results of US morphometry of internal organs should be optional until the mechanisms and structure of these characteristics are clarified in detail. However, the results of these studies were less meaningful in the clinic because of the limited use of somatotyping in routine healthcare practice, that is, even if specialists determine the somatotype, they often do it by guesswork, without using special techniques [8]. Thus, comparing the dimensions of internal organs in individuals with different levels of physical development, that is, a certain length and body weight, ranked according to some generally accepted classifications, becomes necessary. The literature provides no unequivocal opinion on the problem of which approach to assess physical development should be considered a reference [6, 10, 11]. Several experts insist on the creation of updated standards in Russia, taking into account the ethnic, regional, and constitutional characteristics of the physical development of the population [6], and consider the method of centile tables by Mazurin and Vorontsov obsolete because of the accelerated development of children [10]. However, most authors [10, 11] suggest following the recommendations of the World Health Organization (WHO) for these purposes [25]. This method is easy to use, and the materials for its application are publicly available [11].

Reference values of US dimensions of the liver, spleen, kidneys, and thyroid gland, normalized for the length and body weight, were obtained when examining children living in Europe, Asia, and North America [20–24, 26–28, 31, 34]. In Russian scientific publications, such information is nearly nonexistent.

This study aimed to compare characteristics of the dimensions of internal organs according to US data in individuals with various deviations in body length, determined using international standardized norms.

MATERIALS AND METHODS

The study was performed during a routine preventive examination of children, which was conducted according to Order No. 27-O* in the Children's Polyclinic Department No. 3 of the Saint Petersburg City Polyclinic No. 109. All study participants signed voluntary informed consent for preventive examinations and processing of personal data. In total, 93 adolescent boys aged 13–17 years participated in the study. Apical body length was measured using a floor-standing medical stadiometer PM-2 Diakoms (Diakoms, Russia) with a measurement accuracy of up to 5 mm. The *Z*-index of body length was calculated according to the WHO Growth Reference standards (2007) using the WHO AnthroPlus program [25]. The body length of each participant was assessed not only by determining the significance of differences from the *Z*-indices in the indicated groups but also individually. If the *Z*-scores were within the range of –1 SD to +1 SD, body length values were qualified as "average," and their correspondence to ranges of less than –1 SD or more than +1 SD was accepted as "below-average" and "above-average" deviations, respectively [25]. Thus, three groups were formed for the comparison of US measurements of internal organs.

For US examination of the thyroid gland, a Toshiba Aplio 500 US scanner with a linear probe was used with a central frequency of 8.0 MHz (Toshiba Medical System Corporation, Japan). The volume of each lobe was estimated according to a generally accepted method by measuring the width, thickness, and length of each lobe, followed by calculating the lobe volume by multiplying its width, thickness, and length with an ellipsoidal correction factor, K = 0.479. The total volume of the thyroid gland was calculated by adding the volumes of the two lobes. Abdominal organs were examined using a Toshiba Aplio 500 US scanner with a convex probe with a central frequency of 3.75 MHz (Toshiba Medical System Corporation). Oblique vertical dimensions of the right liver lobe, longitudinal and transverse dimensions of the gallbladder, length of the head, body, and tail of the pancreas, as well as the length and width of the spleen, were measured.

The significance of the differences in the *Z*-index of the body length and size of internal organs in groups with different levels of deviations in body length ("below-average values," "average values," and "above-average values") was tested using the Kruskal–Wallis test. If the three samples demonstrated significant differences, pairwise comparison was performed using the Mann–Whitney test, with the Bonferroni correction for the multiplicity of comparisons. The ratio of the *Z*-index of the length and size of internal organs was assessed by calculating the Spearman correlation coefficient (ρ). When the ρ value was equal to 0, the relationship was considered absent; 0.01–0.29 (–0.01 to –0.29), weak direct correlation (reverse); 0.3–0.69 (–0.3 to –0.69), average direct correlation (reverse); 0.7–0.99 (–0.7 to –0.99), strong direct correlation (reverse); and 1 (–1), full direct correlation (reverse) [16]. The results were considered significant at $p < 0.05$. Calculations were performed using built-in Excel functions from the Microsoft Office 2010 application package, past version 2.17 (Norway, Oslo, 2012) software, and StatXact-8 statistical data processing algorithm with Cytel Studio version 8.0.0 software shell. Values are presented as mean (μ) of the *Z*-index of body length or size of the internal organ as well as the lower and upper bounds of the 95% confidence interval.

RESULTS AND DISCUSSION

In the comparison of the values of the *Z*-index of body length, significant differences were revealed in all participants from all three comparison groups (Table 1).

Data analysis showed significantly lower values of the oblique vertical size of the right lobe of the liver and the longitudinal size of the gallbladder from the group with "below-average" deviations in body length compared with groups with "above-average" and "average" deviations in body length. In addition, the length of the spleen and the total size of the thyroid gland were significantly different in all three groups, and their values were the greatest in the group with "above-average" deviations in body length, and the smallest values were noted in the group with "below-average" deviations in body length (Table).

Data analysis revealed no significant differences in the transverse size of the gallbladder, all dimensions of the pancreas, and width of the spleen in all three groups, as well as the oblique vertical dimension of the liver and longitudinal size of the gallbladder in the groups with "above-average" and "average" deviations in body length.

Analysis of the relationship between the size of internal organs and physical development revealed a weak direct correlation between the *Z*-index of

* Order No. 27-O "On the organization of work to fulfill the order of the Ministry of Health of the Russian Federation of August 10, 2017 No. 514-n "On the procedure for conducting preventive medical examinations of minor children" in the children's polyclinic department No. 3 of the St. Petersburg City Polyclinic No. 109."

Table / Таблица

Ultrasound dimensions of internal organs and *Z*-scores of body length in adolescents from three comparison groups (μ; 95% CI)

Размеры внутренних органов и значений *Z*-индекса длины тела у подростков из трех групп сравнения (μ; 95% CI)

Parameter / Параметр	"Above average" / «Выше средних»	"Average" / «Средние»	"Below average" / «Ниже средних»	*p*-value / *p*-значения			
				Kruskal–Wallis test / тест Краскелла–Уоллиса	pairwise comparisons / попарные сравнения		
					"above average"–"average" / «выше средних»–«средние»	"above average"–"below average" / «выше средних»–«ниже средних»	"average"–"below average" / «средние»–«ниже средних»
Z-score / *Z*-индекс длины тела	1.59 (1.40; 1.75)	0.33 (0.20; 0.46)	–1.20 (–1.66; –0.74)	$1.64 \cdot 10^{-16}$	$1.839 \cdot 10^{-13}$	$3.852 \cdot 10^{-13}$	$7.015 \cdot 10^{-7}$
Liver span, cm / Косой вертикальный размер правой доли печени, см	12.95 (12.61; 13.30)	12.88 (12.64; 13.11)	12.07 (11.68; 12.46)	0.00646	1	0.01376	0.006353
Longitudinal dimension of the gall bladder, cm / Продольный размер желчного пузыря, см	6.26 (5.75; 6.76)	6.34 (5.97; 6.72)	5.04 (4.28; 5.81)	0.0154	1	0.03536	0.01487
Transversal dimension of the gall bladder, cm / Поперечный размер желчного пузыря, см	2.25 (1.96; 2.53)	2.27 (2.15; 2.40)	2.09 (1.78; 2.40)	0.1394	0.06766	1	0.1824
Dimension of the pancreas caput, cm / Длина головки поджелудочной железы, см	2.20 (1.04; 3.35)	1.60 (1.54; 1.65)	1.54 (1.39; 1.70)	0.489	1	0.6529	1
Dimension of the pancreas corpus, cm / Длина тела поджелудочной железы, см	1.01 (0.94; 1.08)	1.22 (0.87; 1.58)	0.98 (0.88; 1.09)	0.3597	0.8878	1	0.6505
Dimension of the pancreas cauda, cm / Длина хвоста поджелудочной железы, см	1.79 (1.66; 1.91)	1.71 (1.65; 1.78)	1.66 (1.54; 1.79)	0.4952	1	0.8095	1
Spleen length, cm / Длина селезенки, см	11.50 (11.07; 11.93)	9.82 (9.56; 10.07)	8.99 (8.60; 9.40)	$3.243 \cdot 10^{-10}$	$3.26 \cdot 10^{-8}$	$6.879 \cdot 10^{-6}$	0.01494
Spleen width, cm / Ширина селезенки, см	4.08 (3.84; 4.32)	4.04 (3.86; 4.23)	3.81 (3.65; 3.97)	0.3907	1	0.4098	1
Thyroid gland volume, cm^3 / Общий объем щитовидной железы, $см^3$	9.95 (8.85; 11.05)	8.15 (7.59; 8.71)	6.89 (6.31; 7.47)	0.000124	0.00516	0.001725	0.04273

body length and oblique vertical size of the liver ($\rho = 0.22$; $p = 0.029325$), length of the pancreatic tail ($\rho = 0.21$; $p = 0.042216$), and spleen width ($\rho = 0.24$; $p = 0.018383$). An average significant relationship was found between the *Z*-index of body length and spleen length ($\rho = 0.37$; $p = 0.00030704$), as well as the total volume of the thyroid gland ($\rho = 0.44$; $p = 1.0462 \cdot 10^{-5}$). The correlation coefficient between the *Z*-index of body length, longitudinal ($\rho = 0.14$; $p = 0.19191$) and transverse ($\rho = -0.01$; $p = 0.85438$) dimensions of the gallbladder, as well as the head ($\rho = 0.09$; $p = 0.38561$) and body ($\rho = 0.07$; $p = 0.48775$) of the pancreas were not significantly different from zero.

In this study, the dimensions of the internal organs have the expected characteristic differences, as participants with low *Z*-index values for body length have smaller dimensions of the liver, spleen, and thyroid gland than participants with deviations in body length toward a higher dimension. The liver and spleen are parenchymal organs with a rigid tissue framework; therefore, in this study, stable and expected differences in their dimensions were revealed, which is in good agreement with the data from Russian [9, 18, 19] and international [20, 24, 26, 28, 31, 34] literatures. The obtained patterns of relationships between the volume of the thyroid gland and physical development were also representative [21–23, 27]. Body length and weight have a direct correlation not only with the thyroid gland volume but also with the concentration of insulin-like growth factor 1 in the blood [21–23], as well as protein and calorie supply in adolescents [22]. In addition, the formation of various physique and organ dimensions is partially regulated by thyroid hormones [12], since they can inhibit the proliferation of fibroblasts and the synthesis of collagen by these cells [29, 32]. Children with smaller body dimensions than their peers with body lengths above the average have an increased concentration of thyroid hormones [12].

Based on the data presented, these mechanisms may play important roles in the development of individual characteristics of the dimensions of the thyroid gland and other organs in participants with different levels of physical development.

In the present study, conflicting results were obtained regarding the relationship between physical development and the size of the pancreas. Significant differences were noted only in the gallbladder longitudinal size, not in all comparison groups. The dimensions of the head, tail, and body of the pancreas were not significantly different in adolescents with various deviations in body length as determined by the *Z*-index. The weak direct correlation of the *Z*-index of body length and length of the pancreatic tail cannot be regarded as a cause-and-effect relationship [16].

Methodological errors of the US morphometry of the pancreas and gallbladder dimensions in children with individual typological features of physical development are widely discussed [1, 2, 15, 14, 17]. The dependence of the pancreatic anatomical location on the size of the abdominal cavity [1], its abundant vascularization, deterioration of the US signal [2, 17], and abdominal obesity in children with increased body mass index [2, 17] lead to "blurring" of the image and appearance of optical illusions [2] when visualizing dimensions. Therefore, US data on the length of the head, body, and tail of the pancreas are very contradictory, unstable, and operator-dependent and correlate with the organization of the body [1, 2, 17].

As a result of computer modeling of the topographic location of the gallbladder based on spiral tomography data, significant individual differences were revealed in people with different anthropometric parameters [15]. This leads to the variabilities in the determination of its longitudinal and transverse US dimensions in children with different levels of physical development [2, 15]. The pancreas and gallbladder function continuously, changing constantly the exocrine and tonic activities, even in the "cerebral" phase of the regulation of these processes, which undoubtedly affects their size [7]. Therefore, the methodological organization of experiments to finally resolve the issue of the relationship between the somatotype and size of the pancreas and gallbladder should consider the standardization of nutritional conditions of the individuals examined and determination of the functional activity of these organs [13].

CONCLUSION

This study substantiates the relationship between deviations in body length, determined using international standardized norms, and the size of internal organs. To a greater extent, body length is associated with the size of parenchymal organs with a pronounced connective tissue framework, namely, the liver, spleen, as well as thyroid gland due to the relationship of its volume with hormones that regulate growth and development. Clinical substantiation of the relationship between the organization of the body and internal organs opens up the possibility of creating anatomical standards that enable US morphometric assessment of internal organs, taking into account the individual characteristics of the patient's body size. The application of these standards in clinical practice will help limit erroneous positive and negative conclusions about hypotrophy and hypertrophy of internal organs.

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