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RESEARCH

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Establishment of *Z* score reference of liver, spleen, and kidney parameters for Egyptian children and adolescents: a cross-sectional randomized study

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Abstract

Background Among various growth parameters, liver and spleen size is an important parameter used for the evaluation of patients with certain disorders and abnormalities in these organs.

Aim To determine the normal dimensions for the liver, spleen, and kidney in Egyptian infants, children, and adolescents from birth to 18 years.

Methods This cross-sectional randomized study was conducted on 1861 Egyptian infants, children, and adolescents from birth to 18 years for the establishment of *Z* score reference of liver, spleen, and kidney parameters.

Results Egyptian children of both sexes (51.5% boys and 48.5% girls) from birth to 18 years old were studied. Then *Z* scores reference for liver, spleen, and kidney parameters for both sexes were represented in detailed tables and graphs. There was no statistically significant difference between both sexes, so we used unisex tables and graphs ($P > 0.05$).

Conclusions Determination of pathologic changes in the size of the liver, spleen, and kidney necessitates knowing the normal range of dimensions for these organs. So, our study established a *Z* score chart for normal values of liver, spleen, and kidney size for children and adolescents from birth to 18 years.

Keywords Children, Kidney, Liver, Spleen, *Z* score

Background

Similar to other organs, the liver, spleen, and kidneys grow with age. It has been found that between birth and maturity, these organs increase by a factor of ten or more [1]. During the clinical evaluation liver, spleen, and kidneys are examined. It is essential to know the average size of these organs for different age groups to detect any abnormalities in these organs, a condition which will need further evaluation [2, 3].

The size of the liver fluctuates greatly with age. Its size can be affected by a variety of illnesses, from infectious diseases to malignant conditions. On the other hand, a palpable liver may not always be diseased clinically. Visceroptosis and pushed-down liver caused by lung or subdiaphragmatic disease are two examples of palpable liver without any apparent clinical significance [4].

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Palpation and percussion of the liver and spleen have been shown to be less accurate, particularly when attempting to detect minute increases in organ size. It found that the typical liver edge can be felt at the mid-clavicular line up to 2 cm below the right costal margin and up to 3.5 cm below the costal margin in a newborn. The spleen is only palpable when it is two to three times its normal size even though it may be palpable in 10% of healthy children and 15% of newborns. Examinations are unable to determine the size of the kidneys, and ballottement can only find huge enlargements [5, 6].

These intrabdominal organs' diameters are frequently evaluated using ultrasonography, which is a simple, affordable, noninvasive, and accurate technique. When young children are breathing quietly or when older children are holding their breath, the liver is measured at the mid-clavicular line while the right kidney is simultaneously demonstrated. The sonographic image's upper and lower points are measured. The longitudinal coronal view is used to measure the spleen. The spleen length is calculated as the maximum distance between the sites that are the most supero-medial and inferolateral [7, 8]. It is preferable to measure the kidney diameters when in the lateral decubitus position [9].

The majority of research findings on children's liver, spleen, and kidney size are either rather old or only apply to a limited number of children. To our knowledge, neither Arab children and adolescents in general, nor Egyptian children and adolescents in particular, have any data on the size of the liver, spleen, or kidney. As a result, we provided Z score references for kidney, liver, and spleen parameters for young, healthy Egyptians from birth to 18 years in this work.

Methods

Study design

This cross-sectional randomized study was conducted to determine the normal dimensions for the liver, spleen, and kidney in neonates, infants, and children from birth to 18 years.

Our primary outcome was to establish a Z score reference of liver, spleen, and kidney size in neonates and children up to the age of 18.

The secondary outcome was the establishment of a single chart for organ size for both sexes and this can facilitate the examination of organs in daily practice, the correlation between clinical and ultrasound examination of liver span, and demonstration of the difference between left and right kidney length.

Study population

We initially enrolled 1861 children aged from birth to 18 years, divided into groups according to age, from several Egyptian geographic discrete that were chosen by computerized randomized method to include nurseries, primary schools, secondary schools, tertiary schools, primary and secondary health care units from January 2022 to March 2023.

Our inclusion criteria were healthy infants and children aged from birth to 18 years from both sexes, who were term and appropriate for gestational age with normal anthropometric parameters: weight, length/height, and BMI for age according to Egyptian Z score [10, 11]. Patients with chronic or acute diseases, congenital metabolic disorders, liver or kidney diseases, and systemic diseases were excluded from the study.

So, from all participants we excluded 55 according to our exclusion criteria 27 of them were undernutrition, 7 of them were with single kidneys, 6 of them were with fatty liver, 2 of them was with splenectomy, 5 of them were diabetic, 3 of them were with thalassemia, 5 of them were with acute follicular tonsillitis.

Clinical assessment

All participants underwent full history taking that covered their personal history (age, sex, residence, and consanguinity), perinatal, nutritional, developmental, past medical history, and family history in order to rule out any infectious, inflammatory, hematological, malignant, congestive, or collagenous conditions that could affect the size of the liver, spleen, and kidney.

The children were examined in the supine position. All physicians used a standardized technique in the examination of the liver (percussion and palpation of the upper and lower borders of the right lobe of the liver respectively). The lower border is gently palpated in an upward direction starting from the right iliac fossa and moving gently upward, a transverse line is drawn across the skin at the location of the liver's edge as soon as it is felt. The upper border is percussed in a downward direction and marked when a significant shift in tone towards dullness is noticed. The examiner next uses a stretched metric paper tap to measure the width of the liver, the distance between the two borders (liver span), and the size of the liver below the right costal margin [12]. All measurements were taken along the mid-clavicular line.

Examination of the spleen was done by bimanual examination when the child was relaxed in the supine position as palpation was started in the lower left quadrant in infants and was started in the right lower quadrant in older children [13] and examination of the kidney by ballotement was done.

Sonographic determinations

The participants were examined by an abdominal ultrasound scan using a portable log book equipment with a convex, multi-frequency 3–7 MHz transducer from General Electric Medical Systems. The settings for the equipment were standardized in accordance with the pediatric abdominal protocol. The tests were conducted on the participants while they were supine, with their lower limbs and upper limbs extended along their bodies, without any support under their heads, and without any sedation or preparation. The transducer was positioned in an orthogonal position to the spine plane, below the costal cage, with a longitudinal orientation.

Measurements of the liver were based on external orientation lines in correlation with intra- and extra-hepatic anatomic repairs. The measurements were performed in craniocaudal diameter in the midsternal line (coronal diameter), through a horizontal line parallel to the abdominal wall, extending from the diaphragmatic surface to the lower hepatic border and craniocaudal diameter of the posterior surface of the liver on the mid-clavicular line (anterior–posterior diameter), through an oblique line traced between the upper extremity and the lower hepatic border [7, 12, 14] (Fig. 1).

The measurements of the spleen depend on a coronal view that includes the hilum and the longitudinal distance for sonographic evaluation of spleen size in infants and children [7, 8, 14, 15] (Fig. 1).

The measurements of the kidney were obtained in the sagittal and axial planes passing through the renal hilum with patients in the supine or slightly left or right lateral decubitus positions. A single sonographic measurement of maximum renal length was obtained (distance pole to pole). To ensure that all of the images satisfied the inclusion criteria at the time of the study, a pediatric consultant radiologist checked them all again. The measures had also been adjusted to account for the children's vigorous intense crying and movement [7, 9, 15] (Fig. 1).

Statistical methodology

The data were tabulated on SPSS spreadsheets, which included age and sex in addition to liver span, spleen span, and kidney length. Age was assessed to determine its level of association with liver and spleen span, and kidney length, and the data were viewed as a scatter graph. It was found that the variance in liver and spleen span, and kidney length increased with age. The natural log of liver and spleen span and kidney length was used and the variance was found to be very similar across all levels. To compute the − 2 and + 2 standard deviation of each variable the squared root of the mean square error was used, multiplied by − 2 and + 2, and then added to the constant beta term.

Logarithmic and semilogarithmic adjustments of the three variables were statistically valued by regression analysis for different Z scores (− 2 SD, median, and + 2 SD) and the correlation coefficients with age were assessed.

The significance of the difference between the length of the right and left kidneys was analyzed using Student's t test. Results were considered significant if the p value was < 0.05 for all data analyses.

Correlation between the clinical and ultrasound liver span measurements was studied by Pearson's correlation.

Results

Demographic parameters of the subjects

We started with 1861 infants and children we excluded 55 according to our exclusion criteria, and about 1806

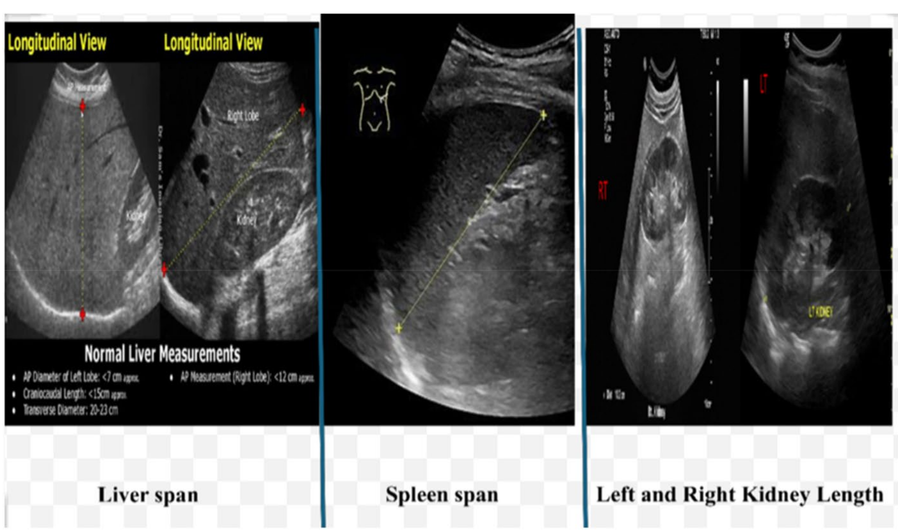

Fig. 1 Ultrasound examination of the liver, spleen, and both kidney

who completed the study were males (51.5%) and females (48.5%), their ages ranged from 0 to 18 years; 13.5% less than 1 year, 16.6% from 1 to 5 years, 22.5% from 5 to 10 years, 29.4% from 10 to 15 years and 18% from 15 to 18 years. 49.3% were urban residents and 50.7% were living in rural areas.

On assessing the difference in measures between males and females, there was no statistically significant difference in abdominal organ sizes between boys and girls. Therefore, we depicted percentiles of diameters by including both males and females for each age and evolved unisex diagrams.

Liver assessment

The Z score of liver span (cm) for Egyptian children from birth to 18 years was established based on both clinical and ultrasound data with a positive correlation between both values ($r = 0.952$; P value $= < 0.01$) (Fig. 2). There was minimal difference in the clinically and ultrasound measurements especially in children older than 6 years of age, differences ranged from 0 to 2 mm. On observing the growth pattern of the liver with the advancement of age, it was observed that by the age of 18 years, the liver reaches nearly double its birth size.

The longitudinal dimensions of the liver on clinical and ultrasound examination showed a significant positive correlation with the age ($r = 0.927$, $r = 0.914$; respectively), body weight ($r = 0.89$, $r = 0.894$; respectively), and height ($r = 0.93$, $r = 0.912$ respectively), $P < 0.0001$ for all correlations.

Spleen assessment

After birth, the measures of the liver size were near that of the spleen, while by the age of 18 years, the spleen reached triple its birth size. Descriptive statistics for spleen length by ultrasound within each age group are given.

The same as the liver, the splenic length showed a significant positive correlation with the children's ages ($r = 0.836$), body weight ($r = 0.824$), and height ($r = 0.883$), $P < 0.0001$ for all correlations.

Kidney assessment

In the current study; the Z score of both kidney lengths by ultrasound showed just minimal variation between the sizes of both kidneys ranging from 0 to 4 mm in the same individual in the different age groups.

The length of the right and left kidney significantly correlated with the age ($r = 0.882$, $r = 0.864$;

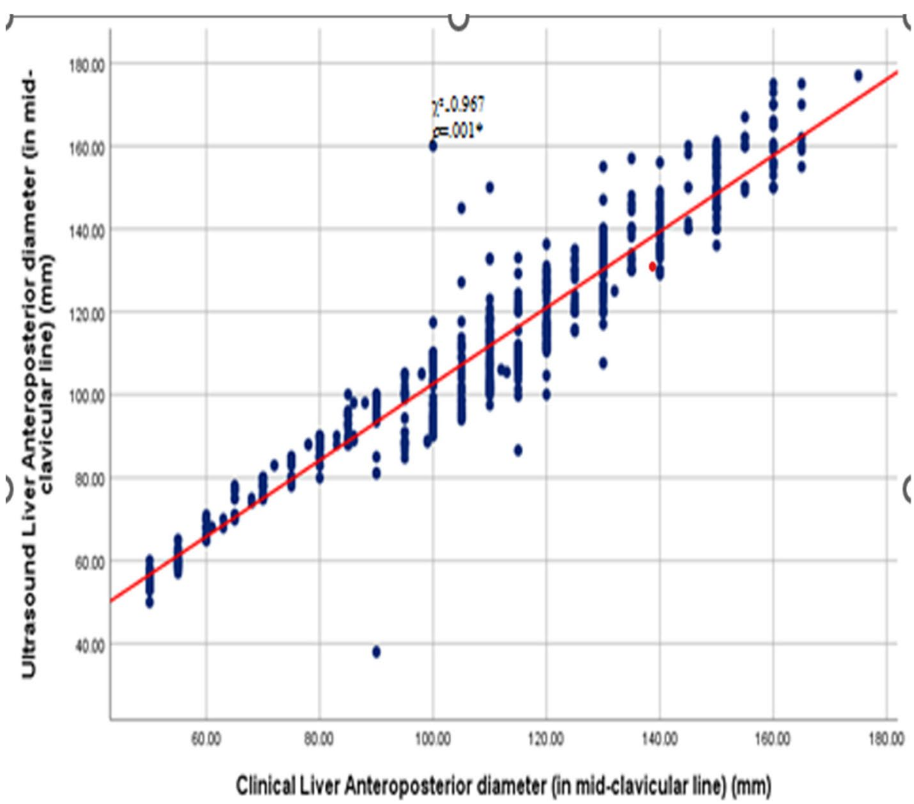

Fig. 2 Scatter plot showing positive correlation between clinical liver diameter and ultrasound liver measurements

respectively), body weight ($r = 0.855$, $r = 0.851$; respectively), and height ($r = 0.902$, $r = 0.900$ respectively), $P < 0.0001$.

The median of organ sizes was plotted against the age and a *Z* score reference for liver, spleen, and kidney were established for healthy Egyptian children and adolescents from birth to 18 years (Figs. 3, 4, and 5).

Discussion

The period between birth and childhood is critical for the development of numerous organ systems. One of the growth markers for the clinical examination and evaluation of illnesses and abnormalities in these organs is the size of these organs as liver, spleen, and kidney size [16].

In the initial phases of parenchymal diseases, the only finding would be increased size. Therefore, being aware of normal organ size for each age would facilitate the management of the subjects in terms of treatment, further evaluation, or follow-up [17]. However, a physical examination is not enough accurate to detect small increases in organ size [5]. For example, the spleen may be palpable in 15% to 17% of healthy neonates and 10% of healthy children, but in most children, it must be 2 to 3 times its normal size before it is palpable. Ultrasound may therefore first detect organ size abnormalities that indicate disease [6].

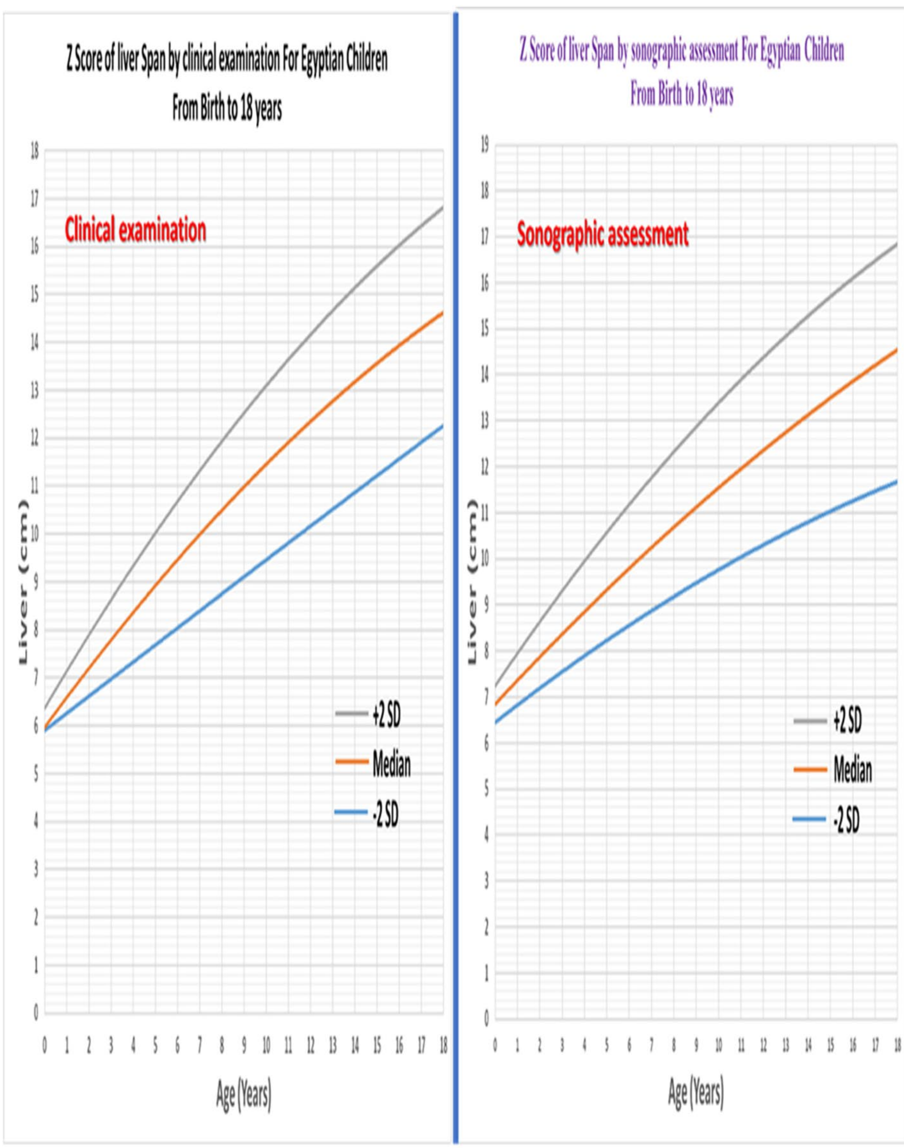

Fig. 3 Liver span (cm) charts for Egyptian children from birth to 18 years by clinical and ultrasound examination

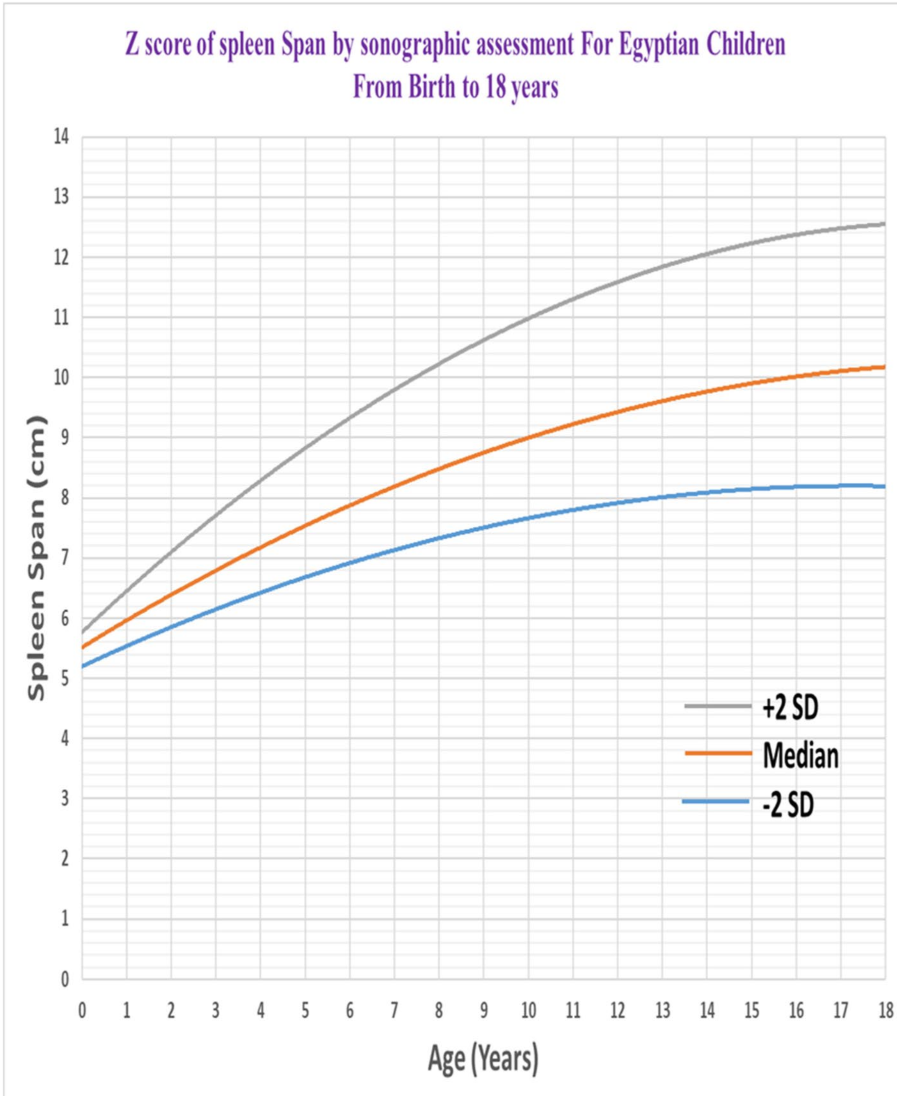

Fig. 4 Spleen span (cm) chart for Egyptian children from birth to 18 years by ultrasound examination

Ultrasound is an important imaging modality in children because it is a safe, quick, portable, and accurate method for the measurement of liver, kidney, and spleen size [7]. It is an established diagnostic and screening tool to assess a variety of clinical concerns. Ultrasound is used in everyday practice for emergency, inpatient, and outpatient care. Measurement of abdominal organ dimensions in children of all ages is performed in the monitoring of abdominal organ growth patterns, diagnosis, and follow-up of patients with a variety of diseases [15].

Our study provided a standard set of normal ranges of liver, kidney, and spleen size according to the age of Egyptian children, as determined by ultrasonography and clinical examination. Developing growth charts from our measures defining the normal range of measures for the liver (clinical and ultrasound), spleen, and both kidneys in Egyptian children from birth to 18 years (Tables 1, 2 and 3), (Figs. 3, 4 and 5) will be a helpful tool for radiologists and clinicians who need valid measurements that account for variability in the organ measurement to avoid overestimation of cases with enlarged organs.

On clinical and ultrasound examination, the liver span, splenic length, and kidney size were positively correlated with the patient's age, weight, and height. The significant correlation between the sizes of the internal organs with the child's age, weight, and height is an expected physiological correlation related to the normal growth and development pattern with advancement of the age in children.

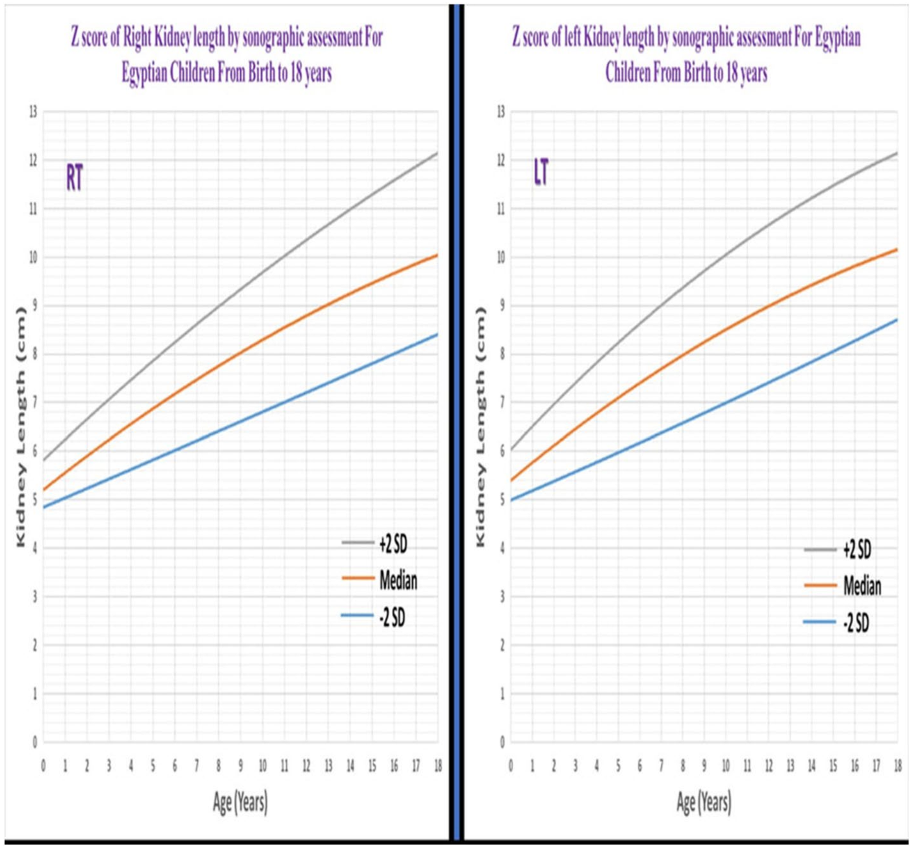

Fig. 5 Left and right kidney length (cm) charts for Egyptian children from birth to 18 years by sonographic assessment

Concomitant with our results Dhingra et al. on determining the normal values of liver and spleen size by ultrasonography in 650 Indian children, declared that the liver and spleen length significantly correlated with the patient's age and height/length of the subjects ($P = 0.0001$) [3].

Huang Y et al., Kim JH et al., and Megremis S et al. demonstrated that there was no difference in abdominal organ size between boys and girls [17–19]. This finding was concomitant with our results as we did not find any significant differences in measures between males and females, the measures were nearly comparable so we used unisex charts.

Despite that, the study of Warnakulasuriya et al. supported our results in the absence of significant difference in the longitudinal measurements of the spleen and kidneys between both sexes, they found a significant difference in the longitudinal length of the liver between the two sexes [20].

In addition, Umeh et al. on assessing the normal sonographic dimensions of the liver, spleen, and kidneys in healthy southwest Nigerian children, found a significant correlation between the organ length and the child's weight, height, body mass index, and body surface area, in which patients with a higher weight, height, body mass index, and body surface area tended to have larger organs [21].

The *Z* score of liver span (cm) for Egyptian children from birth to 18 years was assessed both clinically and by ultrasound with differences between both readings not exceeding 1 cm in the same age group, the difference was minute, especially in children above the age of 6 years.

After birth, the measures of the liver size were near that of the spleen. On observing the growth pattern of the liver and spleen with the advancement of age, it was observed that by the age of 18 years, the liver reached nearly double its birth size, while by the age of 18 years, the spleen reached triple its birth size.

In the current study, the *Z* score of both kidney lengths showed just minimal variation between the sizes of both kidneys ranging from 0 to 4 mm in the same individual. In agreement with our results, Warnakulasuriya et al. on assessing the ultrasonographic parameters of the liver, spleen, and kidneys among a cohort of 357 school children in Sri Lanka aged from 5 to 13 years of age, found that the longitudinal length of the left kidney was longer than that of the right one, but the difference was not

Table 1 *Z* score of liver span (cm) for children from birth to 18 years clinically and ultrasound assessment

Age	Liver clinically (cm)				Liver sonographic assessment			
	−2 SD	Median	+2 SD	SD	−2 SD	Median	+2 SD	SD
0–30 days	4.9	5	5.4	0.12	5.3	5.49	5.8	0.18
1–3 months	5	5.4	6	0.28	5.7	6	6.5	0.22
3–6 months	5.5	6.1	6.5	0.23	6.5	6.78	7.1	0.18
6–12 months	6	6.67	7.5	0.47	6.8	7.64	8.5	0.54
1–1.5 years	6.8	7.54	8.5	0.56	7.4	8.14	9	0.46
1.5–2 years	7	7.48	8	0.39	7.5	8.06	8.6	0.34
2–3 years	7.2	8.07	9	0.47	7.6	8.87	9.8	0.55
3–4 years	8	8.78	9.5	0.44	8.5	9.45	10.5	0.55
4–5 years	8.3	9.2	10	0.64	9	9.9	11	0.64
5–6 years	8.4	9.5	10.7	0.83814	9.1	10.2	11.5	0.98461
6–7 years	8.5	10.4	12	0.942793	9.2	10.3	12	1.379153
7–8 years	8.9	10.9	12.5	0.939549	9.2	10.8	12.6	1.04128
8–9 years	9.1	11.1	12.6	1.069512	9.4	11	13	1.067018
9–10 years	9.2	11.2	12.9	0.913808	9.5	11.2	13.2	1.00261
10–11 years	9.5	11.4	13.1	0.983427	9.8	11.4	13.3	1.024571
11–12 years	9.9	11.7	13.5	0.866023	9.8	11.9	13.8	0.918189
12–13 years	10	12.2	13.9	1.073189	9.9	12	14.2	1.238652
13–14 years	10.5	12.9	15	1.350738	10.1	12.9	14.7	1.317661
14–15 years	10.8	13.7	15.9	1.547287	10.9	13.8	15.5	1.377668
15–16 years	11	14.1	16.2	1.559798	11.3	14.2	16.6	1.52566
16–17 years	12.6	14.6	16.6	0.949559	11.8	14.4	16.9	1.166642
17–18 years	13	14.9	17.1	1.035167	12.4	14.8	17.2	1.185213

Table 2 *Z* score of spleen span (cm) for children from birth to 18 years by sonographic assessment

Age	Spleen sonographic assessment			
	−2 SD	Median	+2 SD	SD
0–30 days	3.8	4.55	5.3	0.34
1–3 months	4.5	4.72	5	0.19
3–6 months	5.2	5.55	5.7	0.11
6–12 months	5.3	5.77	6.5	0.34
1–1.5 years	5.8	6.46	7	0.37
1.5–2 years	6.5	6.89	7.4	0.29
2–3 years	7	7.24	7.9	0.28
3–4 years	7.1	7.63	8	0.35
4–5 years	7.2	8	8.8	0.34
5–6 years	7.1	8.1	9.6	0.956418
6–7 years	7.2	8.3	10.2	1.035572
7–8 years	7.2	8.5	10.4	1.04099
8–9 years	7.3	8.6	10.8	0.919684
9–10 years	7.4	8.7	10.9	0.917581
10–11 years	7.5	8.8	11	1.037659
11–12 years	7.5	9.1	11.3	1.231767
12–13 years	7.6	9.1	11.4	1.088343
13–14 years	7.8	9.7	12	1.120104
14–15 years	8	10	12.2	1.02727
15–16 years	8.1	10.2	12.4	1.09491
16–17 years	8.6	10.3	12.6	0.978225
17–18 years	8.7	10.4	12.8	0.735617

Table 3 *Z* score of kidney length (cm) for children from birth to 18 years by sonographic assessment

	Kidney length							
	Right Kidney				Left kidney			
Age	− 2 SD	Median	+ 2 SD	SD	− 2 SD	Median	+ 2 SD	SD
0–30 days	4	4.2	4.8	2.144	3.9	4.2	4.5	2.2558
1–3 months	4.3	4.6	5	2.241	4.4	4.7	5.1	2.3872
3–6 months	4.5	5.1	6	4.474	4.8	5.3	6.1	3.7142
6–12 months	5	5.9	6.8	6.363	5.3	6.2	7	6.2111
1–1.5 years	5.7	6.2	7.2	5.607	6	6.5	7.7	5.0438
1.5–2 years	5.8	6.5	7.2	5.455	6	6.9	7.9	5.2328
2–3 years	5.9	6.6	7.5	5.896	6.1	6.9	7.9	5.4032
3–4 years	5.9	6.8	7.5	2.0287	6.1	7	7.9	2.6375
4–5 years	6	7	8	2.2961	6.2	7.2	8.4	2.2563
5–6 years	6.1	7.1	8.2	0.66591	6.2	7.2	8.9	1.219
6–7 years	6.2	7.3	8.3	0.55557	6.3	7.4	9	0.7234
7–8 years	6.2	7.6	8.7	0.74785	6.5	7.9	9.3	0.8039
8–9 years	6.4	7.9	9.2	0.68287	6.7	8.2	9.5	0.7472
9–10 years	6.6	8.1	9.5	0.71218	6.8	8.4	9.8	0.726
10–11 years	7	8.5	9.9	0.7878	7	8.6	10	0.8751
11–12 years	7.2	8.8	10.2	0.80298	7.3	8.9	10.3	0.7751
12–13 years	7.2	8.8	10.8	0.90276	7.3	9	10.5	0.9723
13–14 years	7.4	9.3	11.1	0.87219	7.7	9.5	11.3	0.9422
14–15 years	7.9	9.5	11.7	0.91366	8	9.7	11.8	1.4205
15–16 years	8	9.8	11.8	0.96847	8.5	10	12	0.5933
16–17 years	8.3	10	11.8	0.76945	8.6	10.1	12.1	0.6891
17–18 years	8.6	10	11.9	0.61804	8.9	10.1	12.1	0.505

statistically significant [20]. We had a limitation in our study regarding kidney and liver measures; we measured only the length as we had a large sample size so we used it as screening for nephromegaly and when suspected volume should be measured to confirm it.

In addition, Bayramoğlu et al. demonstrated that the size of the left kidney was greater than the right kidney, while according to the constant ratios and considering the maximum kidney size, it is understood that the size difference between the 2 kidneys will not exceed 1 cm [16].

Ethnic differences in the liver, spleen, and kidney measures were reported [22]. So, establishing nomograms for each ethnic group will enable better interpretation of sonographic assessments in the pediatric population.

Our Egyptian reference ranges of age-based liver, spleen, and kidney size were nearly 1 cm larger than that of the children in Turkey as reported in the study of Bayramoğlu et al. [16]. In the study of Waelti et al. on assessing the normal sonographic liver and spleen dimensions in a central European pediatric population**,** the liver sizes were nearly 1 cm larger than our Egyptians measures in the same age group especially those below 10 years [7].

A number of contemporary studies of normative sonographic liver size in children with different ethnicities have been published and include a Turkish population aged 0–16 years in 1998 [23], a Brazilian population aged 0–7 years in 2009 [24], an Indian population aged 0–12 years in 2010 [3], a Nepalese population aged 0–15 years in 2014 [25] and a second Nepalese population aged 0–15 years in 2015 [15].

With changes in nutrition, and genetic and environmental factors between countries, the timing of puberty also differs between ethnicities. African American boys commence puberty the earliest, at around 9 years of age, while Caucasian and Hispanic boys commence on average at age 10 years [26, 27]. This further emphasizes the importance of using charts based on data from the same ethnicity.

Our study had many points of strength, first is that it covered all the pediatric age groups with a considerable number of participants in each age group, which was insufficient in the previous studies. The second is that we checked carefully for inter and intra-observer variability with the elimination of the conflicting cases. As the midclavicular line is known to vary widely when evaluated by different observers, we predetermined it for the sonographic assessments, thus, consistency of measurement was ensured. A single radiologist performing the ultrasonography removed the inter-observer bias.

Conclusions

Determination of pathologic changes in the size of the liver, spleen, and kidney necessitates knowing the normal range of dimensions for these organs. So, our study established a *Z* score chart to normal values of liver, spleen, and kidney size as the first national reference for healthy Egyptian children and adolescents from birth to 18 years.

Authors' contributions

AE and ZO developed the idea and constructed the design. WM, HA, RH, AD and MH were responsible for participant enrolment and data collection. WB and HE interpreted the patient data. RE, AD and MH wrote the manuscript. RE analyzed the data statistically.
AE, WB, HE and ZO contributed to revising the manuscript. All authors contributed to the article and approved the submitted version.

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Declarations

Competing interests

The authors declare that they have no competing interests.

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