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ORIGINAL ARTICLE

Relationship between ultrasound-measured spleen, liver and anthropometry of children living in a rural community in southwest Nigeria: a cross-sectional study

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Abstract
Background Ultrasonography is noninvasive, relatively inexpensive and useful for resource-poor settings. US spleen and liver sizes have been observed to differ among populations, so there is a need for reference values for different geographic populations.
Objective To describe the sizes of the spleen and liver of children living in a rural community in southwest Nigeria and assess the relationship between these measurements and the children's anthropometry.
Materials and methods We conducted a community-based cross-sectional study among 358 apparently healthy children ages 1–14 years. We obtained the participants' weights, heights, body mass index and body surface area. They underwent US imaging to obtain longitudinal measurements of their spleen and liver. We used independent *t*-test to compare means, and linear regression analysis to assess relationships between continuous data. The significance level was set as $P<0.05$.
Results There were more girls (181; 50.6%). Most children were ages 1–5 years (172; 48.0%). The body surface area had significantly strong positive relationships with US spleen size ($r=0.769$; $R^2=0.592$; $P<0.0001$) and US liver size ($r=0.819$; $R^2=0.671$; $P<0.0001$) but body mass index had weak positive relationships.
Conclusion This study contributes to data on US spleen and liver sizes of Nigerian children. The findings buttress observations that body surface area strongly correlates with US spleen and liver measurements. It is recommended that more studies be conducted among Nigerian children to generate a robust pool of data that are useful for creating homogeneous formulae to ease interpretation of US measurements of these intraabdominal organs.

Keywords Anthropometry · Children · Liver · Nigeria · Spleen · Ultrasound

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Introduction

The spleen and the liver are intraabdominal organs with important functions including hemopoietic, immunologic, metabolic and storage, among others [1, 2]. A clinical assessment of these organs is essential for optimal care. US is a relatively inexpensive and noninvasive method of investigating the spleen and the liver [2]; it is often used in resource-poor settings.

The US measurements of these organs have been observed to increase with age and with some anthropometric measurements in children, especially body surface area [3–10]. These organ sizes have been observed to differ among populations [3], hence clinical inferences using data from communities with widely variable characteristics must be made with caution. There are only a few Nigerian studies in this regard among children [7, 8, 11–13] and there is no consensus on reference values or formulae for the clinical interpretation of US measurements of the spleen and the liver among Nigerian children. Furthermore, a recent systematic review by Calle-Toro et al. [14] did not include any African country; as such, there is paucity of data to compare the spleen and liver measurements among Nigerian children with children in other parts of the world. These observations raise the need for regional reference values for US measurements in Nigerian children.

In this paper we describe the sizes of the spleen and liver in apparently healthy children ages 1–14 years living in a rural community in Ire-Ekiti, southwest Nigeria. We also assess the relationship between the children's anthropometry and the US measurements of their spleen and liver.

Materials and methods

Study setting

This community-based cross-sectional study was conducted in April 2019 in Ire-Ekiti, a rural community in southwest Nigeria. The community is known for rice farming and brickmaking. The annex of the government-owned Ekiti State University Teaching Hospital is located within this community in partnership with the privately owned Joan Taiwo Daramola Memorial Hospital.

Participants

We included 358 apparently healthy children ages 1–14 years who were selected during a house-to-house survey. A list of children within the age group of interest was drawn during the survey, and participants were randomly chosen from the list. The caregivers of selected children who were not available at the point of recruitment were contacted a maximum of three times and if no response could be obtained, the children were replaced. Children who had chronic diseases were excluded from the study.

Measurements

The participants were weighed in kilograms on a digital weighing scale. Their heights were measured in centimetres using a stadiometer while barefoot, standing with their occiputs, buttocks and heels touching the stadiometer, and their eyes looking horizontally straight ahead. The chest circumferences were measured in centimetres during inspiration, with a non-elastic tape around the chest at the nipple line, or just below the breasts in post-pubertal girls. The measurements were taken three times and the average for each participant was recorded.

We calculated each participant's body mass index (kg/m^2) by dividing their weight (in kilograms) by the square of their height (in metres) [15]; we calculated body surface area using the formula by Mosteller [16, 17]: (height [cm] × weight [kg]/3,600)^{½}. Body mass index was further classified as underweight (z-scores below −2 standard deviations), normal (z-scores between −2 standard deviations and +2 standard deviations) or obese (z-scores above +2 standard deviations), based on the World Health Organization classifications [15, 18, 19] using z-scores for age and gender.

The abdomen of each participant was palpated in supine position (by O.A.T.F. and T.O.F., clinicians with 13 years and 10 years of working experience, respectively). They examined the spleen and the liver at the left and right hypochondriac regions, respectively, as described by Rochford and Glynn [20]; participants were said to have splenomegaly or hepatomegaly when their spleen or liver was palpable below the respective subcostal margins [20]. The liver span was measured in centimetres at the mid-clavicular line, by percussing for and measuring the distance between the upper and lower borders of the liver [21].

Ultrasonography of the participants' spleen and liver was performed in supine position (by A.S.O., an ultrasonographer with 5 years of working experience) and checked (by G.O.A., a consultant radiologist with 35 years of working experience) using a device with a 3.5-MHz convex transducer (ZQ-6601; Wuhan Zoncare BioMedical Electronics, Wuhan, China). The longitudinal measurements of the spleen and liver were obtained as described by Konuş et al. [4]. The splenic measurements were taken from the most superomedial to the most inferolateral points of the spleen, while the liver measurements were taken in the midclavicular planes from the uppermost edge under the dome of the diaphragm to the most inferior edge of the liver.

Ethics

The ethics committee of Ekiti State University Teaching Hospital, Ado-Ekiti, approved this study and we obtained permission from the Ekiti State Ministry of Health. Informed consent was obtained from the participants' caregivers and assent from children ages 7 years or older. The procedures used in this study adhered to the tenets of the Declaration of Helsinki. Children with hepatomegaly or splenomegaly were referred for further evaluation.

Data management and analyses

Data were analysed using SPSS version 25 (IBM, Armonk, NY). Participants were grouped by age into one of three groups: 1–5 years, 6–10 years and 11–14 years. We used the chi-square test to compare categorical data and the independent *t*-test to compare means. We used linear regression to analyse relationships between US measurements and anthropometric measurements. The significance level was set at $P<0.05$.

Results

Of the 358 participants, 181 (50.6%) were girls, 172 (48.0%) were in the age group 1–5 years, 121 (33.8%) were in the age group 6–10 years and 65 (18.2%) were in the age group 11–14 years. The average weight, height, body mass index, body surface area and chest circumference of the participants are displayed in Table 1. These parameters increased with the participants' ages.

Of the 358 participants, 326 (91.1%) had normal body mass index, 28 (7.8%) were underweight and four were obese. More than half of the participants who were underweight belonged to the age group 1–5 years (16/28, $P=0.16$) and were girls (18/28, $P=0.20$).

Hepatomegaly and splenomegaly occurred in 43 (12.0%) and 48 (13.4%) participants, respectively. Most of the children with either hepatomegaly (42/43, 97.7%) or splenomegaly (46/48, 95.8%) had normal body mass index, while none of the obese participants had either hepatomegaly or splenomegaly. These findings were insignificant ($P>0.05$).

The mean (standard deviation) spleen and liver sizes of the participants for their age and gender are displayed in Table 2. The participants' liver spans as measured by palpation are also shown in Table 2.

The participants' spleen and liver sizes generally increased with age, with a few exceptions (Table 2). Meanwhile, the mean sizes did not differ significantly with gender ($P>0.05$). The mean US liver measurements were higher than both the mean measurements of US spleen sizes and the liver span measurements. In addition, there was a weak but significant positive relationship between the participants' liver span and the US measurements of their liver ($r=0.349$; $R^2=0.122$; $P<0.0001$).

The mean (standard deviation) measurements of chest circumference, liver span and US measurements of the spleen and liver of the participants were compared between the groups of underweight and normal body mass index children; these are displayed in Table 3. The participants with normal body mass index had higher measurements than the underweight participants. Apart from the liver span, there were significant differences in the other measurements between the groups ($P<0.05$). The measurements obtained from the four obese participants were excluded from this comparison because of their small number.

The participants without splenomegaly or hepatomegaly had wider chest circumferences than those with organ enlargement, though this was not a significant finding, with mean differences (standard deviation) of 0.6 (1.2) cm ($P=0.64$) and 1.6 (1.3) cm ($P=0.21$), respectively. In contrast, participants with splenomegaly or hepatomegaly had larger US measurements of the respective intraabdominal organs than those without. The mean differences (standard deviation) were 1.84 (0.3) cm ($P<0.0001$) for the spleen and 0.22 (0.2) cm ($P=0.37$) for the liver.

The ages of participants without splenomegaly had strong positive relationship with their US spleen sizes ($r=0.763$; $R^2=0.581$; $P<0.0001$); likewise, the age of participants without hepatomegaly had strong positive relationships with their US liver sizes ($r=0.789$; $R^2=0.622$; $P<0.0001$). These are displayed in Figs. 1 and 2, respectively.

The participants' weights had strong positive relationships with their US spleen sizes ($r=0.763$; $R^2=0.582$; $P<0.0001$) and US liver sizes ($r=0.812$; $R^2=0.660$; $P<0.0001$). Similarly, their heights had strong positive relationships with their US spleen sizes ($r=0.741$; $R^2=0.549$; $P<0.0001$) and their US liver sizes ($r=0.793$; $R^2=0.629$; $P<0.0001$).

Among the participants without splenomegaly, there was a weak positive relationship between body mass index and US spleen size ($r=0.402$; $R^2=0.162$; $P<0.0001$) but a strong positive relationship between body surface area and US spleen size ($r=0.769$; $R^2=0.592$; $P<0.0001$), as shown in Fig. 3. Similarly, among the participants without hepatomegaly, there was a weak positive relationship between body mass index and US liver size ($r=0.418$; $R^2=0.174$; $P<0.0001$) but a strong positive relationship between body surface area and US liver size ($r=0.819$; $R^2=0.671$; $P<0.0001$), as shown in Fig. 4.

By comparison, although mean body mass index and body surface area of participants with hepatomegaly or splenomegaly were less than those without enlargement of these intraabdominal organs, there were no statistically significant differences between the means ($P>0.05$) (Table 4).

Discussion

Few data exist on normative values of US liver and spleen measurements among Nigerian children, making it difficult to generate formulae for easy interpretation of US measurements. In this study we describe the US measurements of the spleen and liver among apparently healthy children ages 1–14 years living in a rural community in Nigeria and document the association between the children's anthropometry and their US measurements.

The US scan measurements of the spleen and liver of the participants in this study were quite similar to those in

Table 1 Patient characteristics

Age (yrs)	Number of participants		Mean (SD)									
			Weight (kg)		Height (cm)		BMI (kg/m^2)		BSA (m^2)		Chest circumference (cm)	
	M $n=177$	F $n=181$	M	F	M	F	M	F	M	F	M	F
1	11	15	9.5 (1.4)	8.9 (1.3)	77.8 (4.8)	78.0 (4.4)	15.8 (2.5)	14.6 (1.3)	0.45 (0.04)	0.44 (0.04)	45.6 (2.8)	45.7 (3.0)
2	12	16	11.7 (1.5)	10.7 (1.2)	87.5 (4.6)	84.3 (5.5)	15.4 (2.2)	15.1 (1.4)	0.53 (0.04)	0.50 (0.04)	49.8 (2.6)	47.6 (2.4)
3	25	14	14.0 (1.6)	13.2 (1.7)	94.5 (3.7)	94.5 (5.2)	15.6 (1.2)	14.8 (1.6)	0.60 (0.04)	0.59 (0.05)	51.3 (2.4)	49.1 (1.9)
4	25	14	15.9 (2.3)	15.7 (2.0)	103.0 (8.4)	105.8 (8.3)	15.0 (1.6)	14.1 (1.7)	0.67 (0.07)	0.68 (0.06)	52.6 (2.4)	52.5 (2.2)
5	15	25	18.6 (3.5)	17.2 (2.9)	110.3 (7.7)	108.3 (8.1)	15.2 (1.3)	14.6 (1.8)	0.75 (0.10)	0.72 (0.08)	55.2 (3.5)	53.7 (3.4)
6	13	14	19.9 (2.9)	18.8 (3.0)	114.0 (6.8)	116.7 (7.1)	15.3 (1.2)	13.7 (1.3)	0.79 (0.08)	0.78 (0.08)	56.3 (3.7)	55.2 (2.2)
7	11	20	22.9 (2.2)	21.4 (2.7)	123.0 (5.1)	121.8 (8.2)	15.1 (1.0)	14.4 (1.4)	0.88 (0.06)	0.85 (0.08)	57.6 (2.4)	56.9 (2.7)
8	11	13	24.8 (2.5)	22.7 (3.1)	126.0 (5.1)	125.8 (5.9)	15.6 (1.0)	14.3 (1.3)	0.93 (0.06)	0.89 (0.08)	59.7 (3.4)	57.9 (1.9)
9	11	11	27.2 (3.5)	26.0 (4.4)	130.6 (6.6)	127.7 (7.0)	15.9 (1.0)	15.9 (2.2)	0.99 (0.09)	0.96 (0.10)	61.5 (3.1)	59.3 (3.4)
10	9	8	27.0 (4.0)	28.4 (5.2)	132.6 (5.6)	135.2 (9.7)	15.3 (1.4)	15.5 (1.7)	1.00 (0.09)	1.03 (0.13)	62.1 (3.5)	61.0 (4.0)
11	11	3	30.1 (3.0)	29.3 (3.3)	137.6 (5.6)	133.7 (7.5)	15.9 (1.9)	16.4 (1.6)	1.07 (0.06)	1.04 (0.08)	64.2 (1.8)	62.5 (3.1)
12	10	11	34.1 (3.0)	35.0 (6.9)	143.7 (7.7)	144.7 (10.2)	16.5 (1.2)	16.6 (2.2)	1.17 (0.08)	1.18 (1.15)	66.6 (1.0)	66.9 (5.4)
13	8	7	35.1 (5.5)	42.5 (8.4)	144.6 (12.3)	150.0 (9.9)	16.8 (1.9)	18.7 (2.2)	1.19 (1.14)	1.33 (1.17)	67.2 (3.8)	72.3 (7.6)
14	5	10	37.3 (8.3)	44.5 (10.2)	146.1 (13.0)	153.8 (12.6)	17.2 (1.1)	18.7 (2.7)	1.23 (1.19)	1.37 (0.20)	69.4 (6.0)	73.6 (8.7)

BMI body mass index, *BSA* body surface area, *cm* centimetres, *F* females, *kg* kilograms, *m* metres, *M* males, *n* number of participants, *SD* standard deviation, *Yrs* years

Table 2 Ultrasound measurements of participants' spleen and liver and their liver span measured by palpation

Age (yrs)	Spleen				Liver					
	Number of participants		Ultrasound size in cm, mean (SD)		Number of participants		Ultrasound size in cm, mean (SD)		Liver span by palpation in cm, mean (SD)	
	M $n=148$	F $n=162$	M	F	M $n=149$	F $n=166$	M	F	M	F
1	11	13	6.5 (1.1)	6.5 (0.8)	9	13	8.0 (0.7)	8.6 (0.9)	3.4 (1.4)	4.6 (1.4)
2	12	15	6.9 (0.8)	6.7 (0.7)	12	14	8.8 (0.8)	8.4 (0.5)	4.0 (1.0)	4.0 (1.0)
3	24	13	7.5 (1.0)	7.3 (0.6)	21	14	9.2 (0.8)	9.4 (0.8)	5.6 (1.9)	4.2 (0.8)
4	18	13	7.5 (0.8)	7.4 (0.9)	21	13	9.5 (0.8)	9.5 (0.7)	5.0 (2.0)	6.2 (1.7)
5	11	23	8.8 (0.8)	8.2 (1.0)	12	23	10.5 (0.7)	9.9 (1.0)	5.7 (1.4)	5.9 (2.1)
6	9	13	8.7 (1.0)	7.8 (0.8)	11	12	10.2 (0.7)	10.0 (0.6)	5.2 (1.6)	5.8 (0.9)
7	9	15	8.9 (1.0)	8.5 (0.7)	10	16	10.8 (0.9)	10.6 (1.1)	6.1 (1.4)	6.5 (1.6)
8	10	12	9.8 (1.0)	8.5 (1.4)	10	12	11.2 (0.7)	10.3 (0.7)	6.2 (1.4)	6.3 (1.4)
9	9	9	9.5 (0.6)	9.1 (1.4)	6	10	11.2 (0.5)	10.8 (0.7)	6.0 (1.6)	5.6 (1.6)
10	7	6	8.9 (0.8)	8.5 (1.2)	7	8	11.0 (0.7)	11.0 (1.4)	7.5 (2.9)	6.5 (1.6)
11	7	3	10.1 (1.2)	9.5 (1.1)	10	3	11.7 (1.4)	11.1 (0.6)	7.6 (2.2)	8.3 (1.8)
12	9	10	10.6 (0.5)	10.1 (1.6)	8	11	11.9 (0.7)	12.0 (1.4)	6.4 (1.0)	5.1 (2.7)
13	8	7	9.6 (0.9)	11.0 (1.2)	7	7	12.2 (0.4)	13.1 (1.5)	7.9 (1.6)	6.7 (1.5)
14	4	10	10.0 (1.0)	11.0 (1.3)	5	10	12.4 (1.1)	12.5 (1.6)	7.3 (1.4)	7.3 (2.0)

cm centimetres, *F* females, *M* males, *n* number of participants, *SD* standard deviation, *yrs* years

Table 3 Comparison of mean measurements between underweight and normal body mass index (BMI)

Measurements	Mean [SD] in cm		Mean difference [SD], in cm, between underweight and normal BMI	*P*-value[a]
	Underweight ($n=28$)	Normal BMI ($n=326$)		
Chest circumference	52.9 [7.6]	56.9 [7.7]	–3.9 [1.5]	**0.009**
Liver span	5.4 [2.0]	6.2 [2.2]	–0.7 [0.4]	0.08
Ultrasound liver size	9.7 [1.4]	10.4 [1.5]	–0.7 [0.3]	**0.03**
Ultrasound spleen size	7.8 [1.5]	8.7 [1.8]	–1.0 [0.4]	**0.007**

cm centimetre, *n* number of participants, *SD* standard deviation

[a] Independent *t*-test; *P*-values <0.05 are significant (bold)

previous studies among children of similar ages [3–8, 14]. Participants' ages, weights, heights and body surface area had strong positive relationships with their US spleen and liver measurements. Contrary to some studies [3, 4, 12], weight had a relatively stronger relationship than height in this study, supporting the speculation that these observations vary with population. It is therefore reasonable to explore the relationship between the combined anthropometric parameters and US liver and spleen measurements.

The body surface area of the participants in this study had the strongest relationship and correlated well with US spleen and liver sizes, better in fact than participants' body mass index. This finding corroborates previous reports that body surface area is a better predictor of US measurements of intraabdominal organ sizes than body mass index among children [7, 8, 10], although both are derived from combining the same anthropometric parameters — weight and height. It might thus be necessary to harmonise the measurements from Nigerian studies and generate formulae to ease interpretation of US measurements of the spleen and liver among Nigerian children using their body surface area.

Even though the participants' ages had strong positive relationships with their US spleen and liver measurements, inferences made from anthropometric measurements are likely to be more accurate, especially for children who are genetically small-statured for their ages but otherwise well-nourished. Moreover, children whose ages are unknown in resource-poor settings can have their US measurements easily interpreted from their anthropometry.

Generally, the participants with low body mass index had significantly smaller US spleen and liver measurements than those with normal body mass index. This reflects the fact that the size of intraabdominal organs is proportionate to body weight, as suggested by Lykke et al. [9]. However,

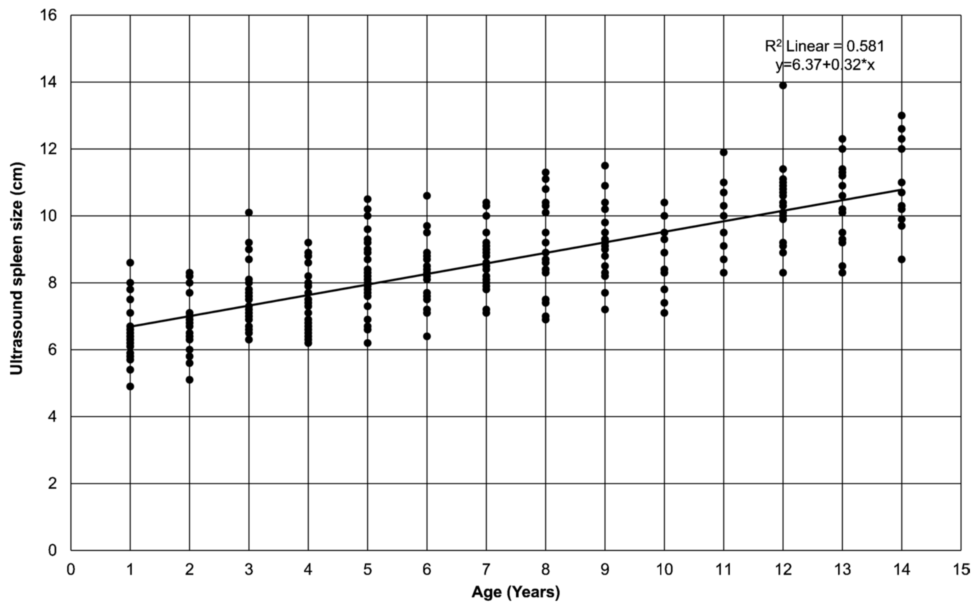

Fig. 1 Linear regression between US spleen size and age

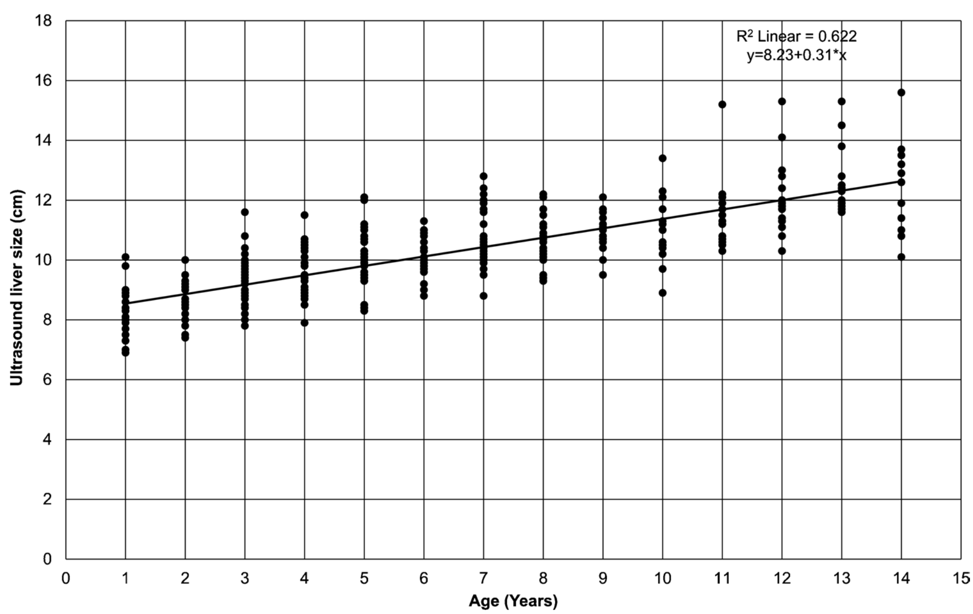

Fig. 2 Linear regression between US liver size and age

because the size of these organs might not necessarily be proportionate to their function, it would be prudent for further studies to compare the biochemical and haematological activities of the liver and spleen between underweight children and those with normal body mass index. The findings from such biochemical and haematological studies might enhance knowledge of evidence-based clinical interpretation of US spleen and liver measurements among children relative to their anthropometry.

The prevalence of hepatomegaly and splenomegaly in this study was low. This is probably because the participants were apparently healthy. Most of those with organ enlargement were well nourished; this is expected because the sizes of these organs has been reported to correlate with anthropometry [9, 22]. In addition, according to Robinson et al. [23], hepatic enlargement partly relies on reasonable vascular supply of dietary fats and carbohydrates, which is expected in well-nourished individuals. However, the small number of obese participants in this study hampers inferences on the observation of organ enlargement within this group of children.

The lack of significant difference between body mass index/body surface area of participants and presence/absence of hepatomegaly or splenomegaly in this study suggests that making a clinical diagnosis of hepatomegaly or splenomegaly by palpation is still reliable because it is not

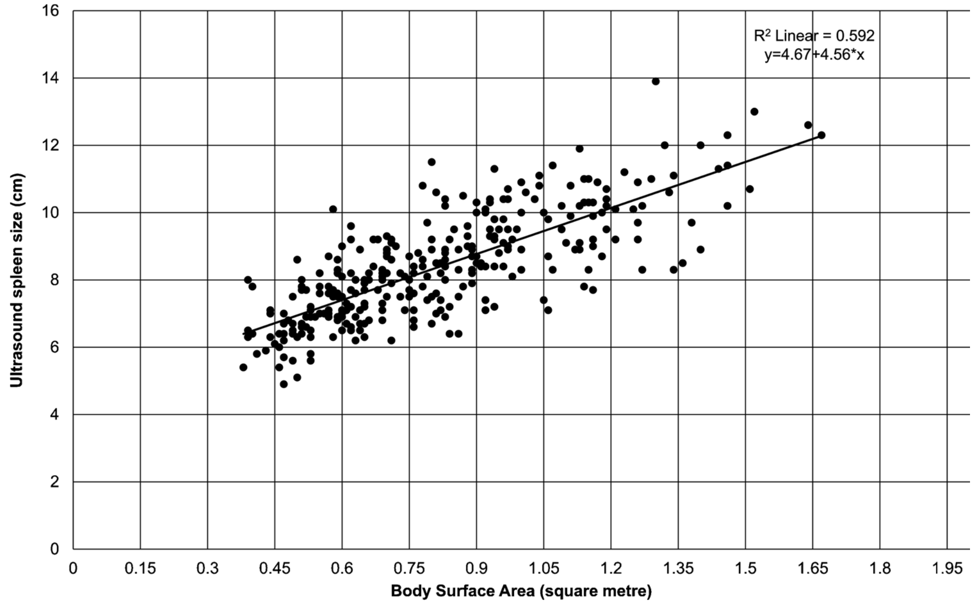

Fig. 3 Linear regression between US spleen size and body surface area

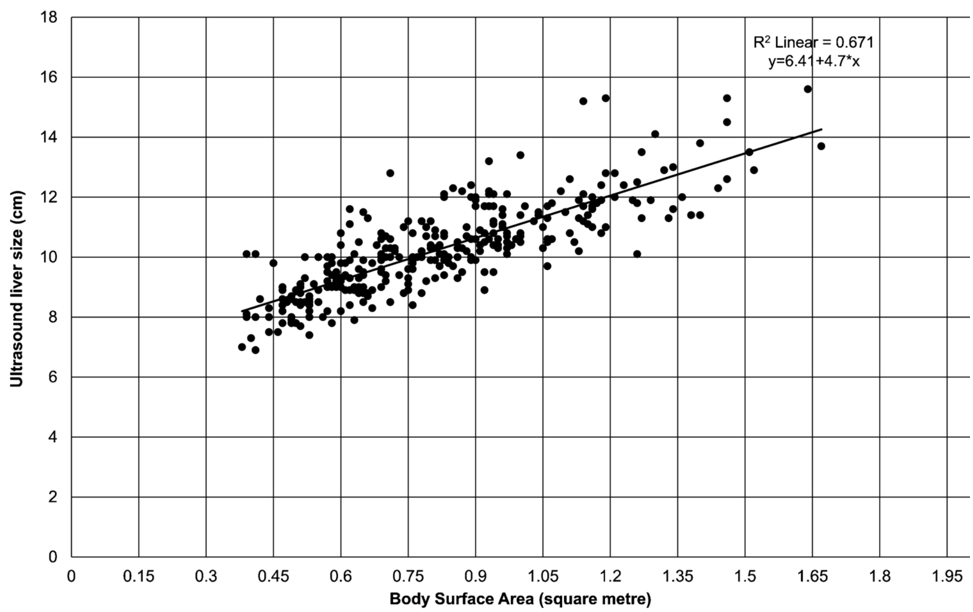

Fig. 4 Linear regression between US liver size and body surface area

Table 4 Mean body mass index (BMI) and body surface area (BSA) measurement differences between participants with and without splenomegaly or hepatomegaly [standard deviation]

	Splenomegaly Yes ($n=48$)	No ($n=310$)	Mean difference [SD] between splenomegaly and no splenomegaly	*P*-value[a]
BMI (kg/m^2)	15.1 [1.3]	15.4 [1.9]	-0.3 [0.3]	0.30
BSA (m^2)	0.81 [0.19]	0.82 [0.27]	-0.01 [0.04]	0.80
	Hepatomegaly Yes ($n=43$)	No ($n=315$)	Mean difference [SD] between hepatomegaly and no hepatomegaly	*P*-value[a]
BMI (kg/m^2)	14.9 [1.4]	15.4 [1.9]	-0.5 [0.3]	0.10
BSA (m^2)	0.76 [0.20]	0.82 [0.26]	-0.06 [0.04]	0.18

kg kilogram, *m* metres, *n* number of participants, *SD* standard deviation

[a] Independent *t*-test; $P<0.05$ is significant

significantly influenced by the child's body mass index or body surface area.

Conclusion

This study contributes to data on US spleen and liver sizes of Nigerian children. Our findings support observations that body surface area strongly correlates with US spleen and liver measurements, better than does body mass index. We recommend that more studies be conducted among children in various communities, to generate a robust pool of data that will be useful for creating homogeneous formulae to ease interpretation of US measurements of these intraabdominal organs in different geographic settings.

Declarations

Conflicts of interest None

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