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Liver, Spleen, and Kidney Size in Children as Measured by Ultrasound:

A Systematic Review

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Abstract

Ultrasound is commonly the first-line imaging modality for assessing the pediatric abdomen. An abnormal size of the liver, spleen, or kidneys may indicate disease, but the evaluation is challenging because the normal size changes with age. In addition, published normal value charts for children may vary by population and methods. In this systematic review, we summarized published data on the normal size of the pediatric liver, spleen, and kidneys as measured by ultrasound in which we found similar values across different populations, ages, and sexes.

Keywords

kidney; liver; normal size; pediatric; spleen; ultrasound

Ultrasound (US) is an important imaging modality in children because it is safe, quick, and portable. It is an established diagnostic and screening tool to assess a variety of clinical concerns.[1] 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.[2]

Organ size is crucial to the image interpretation of disease: for example, diseases of the liver, spleen, and kidneys can affect organ size and development, but a physical examination is not enough accurate to detect small increases in organ size.[3] For example, the spleen may be palpable in 15% to 17% of healthy neonates[4] and 10% of healthy children, but in most children, it must be 2 to 3 times its normal size before it is palpable.[1] Ultrasound may therefore first detect organ size abnormalities that indicate disease. Normative data for organ size are challenging in the pediatric population because of changes that occur with growth and development and the effects of the body habitus, including height and weight.

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In contrast to adults, for whom there are established normal ranges of organ size, organ size in children relies on growth and development.[5–8] Studies exist that define the normal ranges of organ size in healthy children.[1,3,4,7–23] For example hepatomegaly is a frequent clinical finding in children that may be caused by intrinsic liver diseases or by other diseases with liver involvement.[16] With the growing epidemic of childhood obesity, early detection of hepatic steatosis is critical to avoiding premature liver failure.[24] In children with kidney disease, the renal size may be increased or decreased.[15] Measurements of renal length and volume reportedly correlate with height and weight, but the exact measurements are not homogeneous in the available literature.[3,9,21] This systematic review was conducted to establish available literature published in indexed journals of US measurements of the liver, spleen, and kidneys in healthy children.

Methods

This study was approved by our Institutional Review Board, as well was registered on the PROSPERO registry, with number CRD42018094714, and performed according to the Preferred Reporting Items for Systematic Reviews and Meta-analyses and the Meta-analysis of Observational Studies in Epidemiology guidelines.[25]

Literature Search and Selection of Studies

A PICO strategy for searching in the databases was used, with P (population): healthy children from 0 to 18 years old; I (intervention): measurement of the spleen, liver, and kidney using US; C (comparison): not applicable; and O (outcome): determination of abdominal organ sizes. The Institutional Review Board at Children's Hospital of Philadelphia approved the study, and a waiver of informed consent was obtained.

A systematic review was performed of all cross-sectional, case-control, and cohort studies, clinical trials, and randomized clinical trials related to the abdominal organ size of the liver, spleen, and kidneys in children published in the English language. A bibliographic search was performed using the following databases: Embase, MEDLINE, PubMed, SciELO, CINAHL, and Lilacs, using medical subject heading key words (spleen, liver, kidney, ultrasonography, child, pediatrics), with search dates up to May 1, 2018. The search terms were entered as shown in the following example used for PubMed: (ultrasonography and organ size) or (ultrasonography and spleen) or (ultrasonography and liver) or (ultrasonography and kidneys) and (children or pediatric). In addition, the reference lists of the retrieved articles were screened for further material for inclusion. In addition, we searched using the same search terms on Google Scholar. For extracting those articles suitable for our research, we performed a number of exclusion steps, as highlighted in the flow diagram (Figure 1). The first exclusion step was removing duplicated studies (using My EndNote Web; Clarivate Analytics, Philadelphia, PA); the second step involved exclusion of studies performed in patients with previous disease in the target organ, studies of contrast-enhanced US, studies using imaging modalities other than US, studies in animals and phantoms, and those studies that included adults who had escaped the age-filtering process of the search.

Assessment of Methodological Quality

The qualitative assessment of articles selected for retrieval was based on methodological validity before inclusion in the review, using standardized critical appraisal instruments from the Joanna Briggs Institute Qualitative Assessment and Review Instrument (Appendix 1). A cutoff score of 70% was used in this review.[26]

Data Extraction

The information extracted from each study included study setting, population demographics and baseline characteristics, US technique, study methods, outcomes, and assessment of the risk of bias. Information was organized in a general table (Appendixes 1 and 2) and in 4 subtables by each organ.

Data Synthesis

The data analysis was conducted from the findings of the included studies, structured according to the type of intervention, the target population characteristics and outcome measures. It was anticipated that there would be a small number of studies on this topic.

Results

We selected from the 504 studies only those suitable for our research as summarized in the flow diagram (Figure 1). The first exclusion step was for duplicated studies (195), resulting in 309 abstracts for review. A total of 272 studies in patients with prior disease in the target organ, studies performed with contrast-enhanced US, studies using imaging modalities other than US, studies in animals and phantoms, and those studies that included adults who had escaped the age-filtering process of the search were excluded. This resulted in 37 full-text studies remaining for complete review. From these, 27 were further excluded for 1 of 3 reasons: the organ size was reported by volume instead of a linear measure; the study focused on preterm neonates and fetuses; or the study assessed patients with a previous organ disease. The 10 studies remaining for evaluation in this review were published between 1991 and 2018 (Figure 1). Five studies included data of the liver,[7,8,17,27,28] 6 of the spleen,[1,7,8,22,28,29] and 4 of both kidneys.[7,28,30,31]

The studies included patients from 0 to 20 years of age; however, only data from those aged 0 to 18 years are included here because those 19 years and older are considered young adults. Two studies included patients from 0 to 18 years[1,7]; 1 study included infants from 0 to 1 year[30]; and the remainder included groups between 0 and 16 years.[7,8,17,27–29,31]

Most were prospective studies (6 or 10), and none were multicenter. Application of the Joanna Briggs Institute Qualitative Assessment and Review Instrument tool for assessment of study quality showed that 8 of 10 studies had at least 80% of the required characteristics for a good-quality research study; the other 2 had scores of 70% and 75%, respectively (Appendixes 1 and 2).

In general, similar organ sizes were reported between the included studies. The liver was measured in the sagittal plane longitudinally in all 5 studies included for liver measurement and ranged from 7 cm[7] in younger patients, to a maximum of 12.1 cm[7] in older patients

(Table 1), although not all of them used the same technique to measure the liver size (Figure 2), and the craniocaudal measurement was the most commonly used.[32,33] The spleen in all studies was measured in the sagittal plane longitudinally and ranged from 5.2 cm[18,22] in younger patients, to a maximum of 12.5 cm[7] in older patients (Table 2). The right kidney in all studies was measured in the sagittal plane longitudinally, and the reported measurements ranged from 4.5 cm[23] in younger patients, to a maximum of 10.7 cm[23] in older patients (Table 3). The left kidney size ranged from 4.5 cm[23] in younger patients to a maximum of 10.7 cm[7] in older patients (Table 4).

Discussion

Normative liver, spleen, and kidney sizes as measured by US change with the child's age, which is expected because of the normal growth and development in a healthy child. Currently published evidence demonstrates that there is no difference in abdominal organ size between boys and girls.[1,4,7,9–11,14,15,18–20,22,23,27,31,34–36] However, a correlation was demonstrated between the organ length and the child's weight, height, body mass index, and body surface area,[12,27,28,37] in which patients with a higher weight, height, body mass index, and body surface area tended to have larger organs.[1,13,21,22,27,30,31,38]

In clinical practice, differences of just a centimeter may make a difference between a read of "normal" versus "hepatomegaly," with the latter prompting further testing and even biopsy. Standard practice in our institution and many others is to only measure the craniocaudal dimension.[39] Radiologists and their ordering clinicians need valid measurements that account for variability in the organ measurement, patient size, and statistical analysis. Although we cannot be sure of the technical differences in transducer placement and the technique descriptions provided, taken as a true representation, we have provided an image (Figure 2).

This review had several strengths: there were no restrictions regarding the year of publication; quality criteria were based on the available evidence and were agreed on independent of the reviewers; and the use of a quality score form allowed an objective rather than empirical assessment of quality for determining the risk of bias.

However, we recognize several limitations: the data were entirely from observational studies; different inclusion and exclusion criteria were used in the studies, including different patient populations and ethnicities; and only English-language studies were included for practical reasons. Additionally, the tool that was used to rate the quality of each study was developed more recently than some of the article publication dates.

One limitation of US is the user-dependent image acquisition, resulting in interobserver variability.[5,6,40–46] Novel problems include improved visualization of different anatomic layers resulting from more advanced US scanners, which can lead to erroneous placement of measurement markers.[2,45] Biometric studies in children by means of US have been reported; however, some of them used different measurement methods.[9,13,14,19]

In conclusion, the size of the liver, spleen, and kidneys increases consistently as the patient grows, and according to the data from the included studies, dimensions of these organs have a similar growth pattern. A true meta-analysis of available data from around the globe would be of international value.

Appendix

Appendix 1.

Critical Appraisal Results for Included Studies Using the Joanna Briggs Institute Qualitative Assessment and Review Instrument Critical Appraisal Checklist

Author	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Total %
Amatya et al	Y	Y	Y	Y	N	N	Y	Y	U	U	75
da Rocha et al	Y	Y	Y	Y	Y	Y	Y	NA	NA	Y	80
Dhingra	Y	Y	Y	Y	Y	Y	Y	NA	NA	Y	80
Konuş, et al	Y	Y	Y	Y	Y	Y	Y	Y	NA	Y	90
Megremis et al	Y	Y	Y	Y	Y	Y	Y	NA	NA	Y	80
Otiv et al	Y	Y	Y	Y	Y	Y	Y	NA	NA	N	70
Özdikici	Y	Y	Y	Y	N	Y	Y	Y	U	U	88
Rosenberg et al	Y	Y	Y	Y	Y	Y	Y	Y	NA	Y	90
Thapa et al	Y	Y	Y	Y	Y	Y	Y	Y	U	U	100
Vujic et al	Y	Y	Y	Y	Y	Y	Y	NA	NA	Y	80
Average score											83

N indicates no; NA, not applicable; U, unclear; and Y, yes.

Appendix 2.

Included Studies List

Year	Journal	1st Author	Country	Age Range, y	Organ	n	Modality
2018	*J Ultrasound*	Özdikici	Turkey	0–16	Spleen	310	Retrospective
2016	*Kathmandu Univ Med J*	Thapa	Nepal	0–15	Left kidney, right kidney, liver, spleen	272	Prospective
2014	*Indian J Pediatr*	Amatya	India	0–15	Liver	500	Cross-sectional
2012	*Indian Pediatr*	Otiv	India	0–12	Left kidney, right kidney	1000	Cross-sectional
2009	*Radiol Brasil*	da Rocha	Brazil	0–7	Right kidney,	584	Prospective
2010	*Indian Pediatr*	Dhingra	India	1–12	Liver, spleen	597	Cross-sectional
2007	*Pediatr Nephrol*	Vujic	Serbia	0–1	Left kidney, right kidney	992	Prospective
2004	Radiology	Megremis	USA	0–18	Spleen	512	Prospective
1998	*AJR Am J Roentgenol*	Konuş	Turkey	0–16	Left kidney, right kidney, liver, spleen	307	Prospective
1991	*AJR Am J Roentgenol*	Rosenberg	USA	0–20	Spleen	230	Prospective

Abbreviation

US ultrasound

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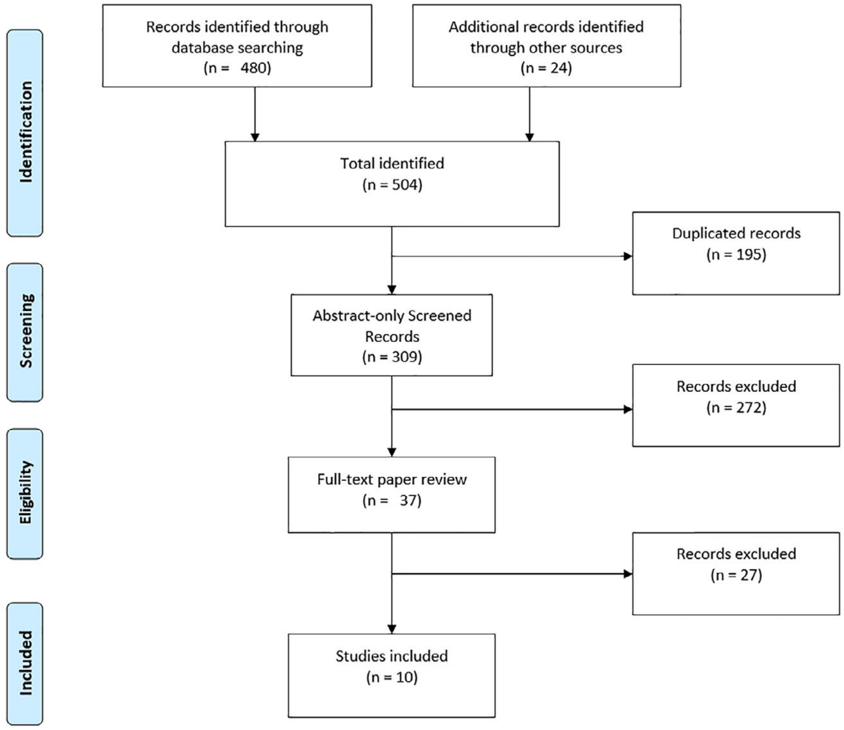

Figure 1.
Systematic review flowchart: organ size study selection process.

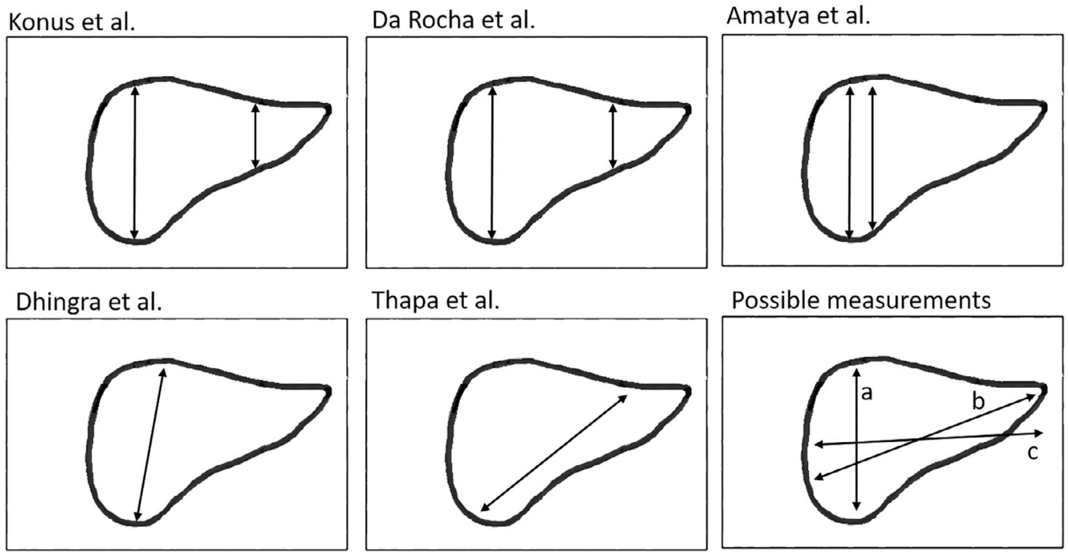

Figure 2.
Custom representation of the linear measurements performed in the longitudinal plane in 5 of the main studies as well as a diagram of possible methods, with a being the ventrodorsal dimension (depth), b the maximum dimension, and c the craniocaudal dimension.

Table 1.

Included Studies Measuring Liver Size in Healthy Children

	Turkey, Konuş et al, 1998					Brazil, da Rocha et al, 2009					India, Dhingra, 2010					India, Amatya et al, 2014					Nepal, Thapa et al, 2016				
Age	**n**	**Mean**	**SD**	**5th**	**95th**	**n**	**Mean**	**SD**	**5th**	**95th**	**n**	**Mean**	**SD**	**3th**	**97th**	**n**	**Mean**	**SD**	**5th**	**95th**	**n**	**Mean**	**SD**	**5th**	**95th**
0–<3 mo	53	61.0	10.4	48.0	90.0	32	66.0	5.7	47.0	75.0	21	63.5	9.3	48.5	80.5	45	53.0	5.2	44.0	57.0	36	68.0	7.0	54.0	80.0
3–<6 mo	40	73.0	10.8	53.0	86.0	34	76.0	7.2	58.0	90.0	35	71.5	8.6	56.0	84.5	45	64.0	9.2	49.0	83.0					
6–<9 mo	20	79.0	8.0	70.0	90.0	72	84.0	9.1	62.0	101.0	51	77.0	9.0	62.0	95.5						35	76.0	9.3	47.0	75.0
9–<12 mo						36	84.0	6.9	65.0	96.0															
1–<2 y	18	85.0	10.0	68.0	98.0	102	92.3	7.5	77.3	110.3	77	85.5	11.8	67.0	106.5	45	89	8.6	71	103	62	84.0	7.4	69.5	94.5
2–<4 y	27	86.0	11.8	63.0	105.0	48	99.0	6.7	78.0	11.0	132	89.5	11.4	70.5	116.0						43	87.3	8.9	73.4	105.2
4–<6 y	30	100.0	13.6	77.0	124.0	181	104.0	8.2	86.5	126.0	115	100.5	12.6	69.0	140.0	45	92.0	9.1	80.0	108.0	41	92.2	9.1	75.3	106.6
6–<8 y	38	105.0	10.6	90.0	123.0	109	109.0	8.7	91.0	133.0	51	108.5	11.2	86.0	128.0						25	98.7	8.7	84.6	117.6
8–<10 y	30	105.0	12.5	83.0	128.0						62	118.0	11.0	97.0	140.5										
10–<12 y	16	115.0	14.0	95.0	136.0						53	132.5	12.5	103.5	153.5	45	107	11.1	91	129	19	106.3	10.7	92.0	127.0
12–<14 y	23	118.0	14.6	94.0	136.0																11	116.1	8.8	104.0	130.0
14–<18 y	12	121.0	11.7	104.0	139.0																				

Measurements are reported in millimeters

Table 2.

Included Studies Measuring Spleen Size in Healthy Children

	USA, Rosenberg et al, 1991				Turkey, Konus et al, 1998					USA, Megremis et al, 2004					India, Dhingra, 2010					Nepal, Thapa et al, 2016					Turkey, Özdikici et al, 2018				
Age	**n**	**Median**	**10th**	**90th**	**n**	**Mean**	**SD**	**5th**	**95th**	**n**	**Mean**	**SD**	**Min**	**Max**	**n**	**Mean**	**SD**	**3th**	**97th**	**n**	**Mean**	**SD**	**5th**	**95th**	**n**	**Mean**	**SD**	**5th**	**95th**
0–<3 mo	28	45.0	33.0	58.0	53	53.0	7.8	40.0	65.0	57	45.0	7.1	30.0	61.5	21	47.0	9.7	34.5	69.5	36	50.0	7.9	36.1	62.4	21	46	10	33	61
3–<6 mo	13	53.0	49.0	64.0	40	59.0	6.3	47.0	67.0	16	55.0	5.6	47.0	63.0	35	54.5	5.1	45.5	65.5						24	54	5	47	62
6–<9 mo	17	62.0	52.0	68.0	20	63.0	7.6	53.0	74.0	27	63.5	7.3	52.5	74.5	51	58.0	7.4	45.5	77.5	35	60.0	7.9	47.2	75.8	24	62	7	54	74
9–<12 mo																													
1–<2 y	12	69.0	54.0	75.0	18	70.0	9.6	55.0	85.0	35	65.5	7.1	53.5	82.5	77	62.5	8.8	46.0	87.0	62	61.0	8.2	48.5	76.5	30	70	8	57	80
2–<4 y	24	74.0	64.0	86.0	27	75.0	8.4	61.0	88.0	46	75.5	9.5	58.0	94.0	132	68.0	8.8	47.0	88.0	43	68.1	9.2	54.2	81.6	27	75	11	62	89
4–<6 y	39	78.0	69.0	88.0	30	84.0	9.0	70.0	100.0	54	80.5	8.8	65.5	97.0	115	72.5	9.5	51.0	101.0	28	69.3	7.0	55.4	80.6	27	79	10	67	94
6–<8 y	21	82.0	70.0	96.0	38	85.0	10.5	69.0	100.0	51	85.5	9.5	70.0	102.5	51	77.5	9.7	59.0	96.0	38	95.5	9.3	79.0	110.5	31	86	11	74	101
8–<10 y	16	92.0	79.0	105.0	30	86.0	10.7	70.0	100.0	41	88.5	9.7	69.0	108.5	62	82.0	10.2	66.5	103.5						26	92	12	76	107
10–<12 y	17	99.0	86.0	109.0	16	97.0	9.7	81.0	108.0	53	94.5	10.7	70.5	113.5	53	87.0	15.2	65.0	115.0	19	106.3	10.7	92.0	127.0	27	97	14	73	111
12–<14 y	26	101.0	87.0	114.0	23	101.0	11.7	85.0	118.0	48	100.0	9.2	82.0	116.5						11	116.1	8.8	104.0	130.0	38	100	10	85	114
14–<18 y	17	101.0	95.5	121.5	12	101.0	10.3	88.0	115.0	26	130.0	8.0	91.0	117.5											35	104	9	94	118

Measurements are reported in millimeters.

Table 3.

Included Studies Measuring Right Kidney Size in Healthy Children

	Turkey, Konuş et al, 1998					Serbia, Vujic et al, 2007[a]					India, Otiv et al, 2012[a]			Nepal, Thapa et al, 2016[a]				
Age	n	Mean	SD	5th	95th	n	SD	Mean	3th	97th	n	Mean	SD	n	Mean	SD	5th	95th
0–<3 mo	50	50.0	5.8	40.0	58.0	582	5.6	48.0	38.0	60.0	71	43.0	6.0	36	48.0	4.8	40.0	60.0
3–<6 mo	39	53.0	5.3	50.0	64.0	448	4	57.0	50.0	65.0	49	47.0	7.0					
6–<9 mo	17	59.0	5.2	52.0	66.0	496.0	4.1	58.0	51.0	67.0	61	55.0	7.0	35	54.0	6.4	44.0	68.0
9–<12 mo						458	5	61.0	50.0	69.0	81	56.0	6.0					
1–<2 y	18	61.0	3.4	55.0	65.0						122	57.0	4.0	62	56.0	5.5	49.1	66.5
2–<4 y	22	67.0	5.1	59.0	75.0						133	64.0	6.5	43	63.0	6.8	52.0	74.0
4–<6 y	26	74.0	5.5	65.0	83.0						129	67.5	6.0	28	69.8	5.6	60.0	80.1
6–<8 y	32	80.0	6.6	70.0	91.0						102	69.5	5.0	38	74.5	6.2	62.5	84.5
8–<10 y	27	80.0	7.0	69.0	89.0						115	78.0	6.5					
10–<12 y	15	89.0	6.2	82.0	100.0						75	82.5	7.5	19	83.0	7.2	68.0	95.0
12–<14 y	22	94.0	5.9	85.0	102.0						62	86.0	8.0	11	91.0	5.3	82.0	97.0
14–<18 y	11	92.0	7.0	83.0	102.0													

Measurements are reported in millimeters.

[a]Study did not divide by side.

Table 4.

Included Studies Measuring Left Kidney Size in Healthy Children

	Turkey, Konuş et al, 1998					Serbia, Vujic et al, 2007[a]					India, Otiv et al, 2012[a]			Nepal, Thapa et al, 2016[a]				
Age	n	Mean	SD	5th	95th	n	Mean	SD	3th	97th	n	Mean	SD	n	Mean	SD	5th	95th
0–<3 mo	50	50.0	5.5	42.0	59.0	582	48.0	5.6	38.0	60.0	71	43.0	6.0	36	50.3	5.0	41.7	59.1
3–<6 mo	39	56.0	5.5	47.0	64.0	448	57.0	4	50.0	65.0	49	47.0	7.0					
6–<9 mo	17	61.0	4.6	54.0	68.0	496.0	58.0	4.1	51.0	67.0	61	55.0	7.0	35	55.8	5.2	48.6	67.2
9–<12 mo						458	61.0	5	50.0	69.0	81	56.0	6.0					
1–<2 y	18	66.0	5.3	57.0	72.0						122	570	4.0	62	59.2	5.4	51.0	67.5
2–<4 y	22	71.0	4.5	610	76.0						133	64.0	6.5	43	66.4	8.0	53.8	81.4
4–<6 y	26	79.0	5.9	70.0	87.0						129	67.5	6.0	28	71.2	5.8	63.0	83.1
6–<8 y	32	84.0	6.6	73.0	93.0						102	69.5	5.0	38	77.1	6.4	64.8	88.5
8–<10 y	27	84.0	7.4	75.0	97.0						115	78.0	6.5					
10–<12 y	15	91.0	8.4	77.0	102.0						75	82.5	7.5	19	85.6	6.2	74.0	98.0
12–<14 y	22	96.0	8.9	84.0	110.0						62	86.0	8.0	11	94.0	6.2	86.0	105.0
14–<18 y	11	99.0	7.5	90.0	110.0													

Measurements are reported in millimeters.

[a]Study did not divide by side.