Original Article

Ultrasonographic Measurements of the Liver, Gallbladder, and Hepatic Vessels among University-aged Youth in Baghdad, Iraq

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Abstract

Background: Ultrasound measurements of the liver, gallbladder, and hepatic vessels are important for clinicians as these measurements can be affected anatomically, physiologically, and pathologically. The objective of this study was to determine the correlation between ultrasound measurements and anthropometric measures. **Methods:** A prospective observational design was carried in this study. A total of 135 university-aged youth with ages ranging between 18 and 24 years were examined sonographically. Ultrasound measurements include liver length and thickness, gallbladder length, width, thickness, volume and wall thickness, portal and hepatic veins' diameter, and subcutaneous tissue thickness. **Results:** A significant and positive correlation was observed between liver length with height ($P < 0.001$), weight ($P = 0.006$), body mass index (BMI) ($P = 0.025$), waist circumference (WC) ($P = 0.048$), and waist-to-hip circumference ratio (WHR) ($P = 0.004$). A significant and positive correlation was found between gallbladder volume and portal vein diameter with height ($P = 0.034$, $P < 0.001$), weight ($P = 0.028$, $P = 0.032$), and BMI ($P = 0.047$, $P = 0.041$), respectively. Furthermore, liver length and liver thickness were positively and significantly related with gallbladder volume ($P = 0.038$, $P = 0.047$), portal vein diameter ($P = 0.029$, $P = 0.040$), and subcutaneous tissue thickness ($P = 0.017$, $P = 0.049$), respectively. Gallbladder length and volume were negatively and significantly correlated with gallbladder wall thickness ($P = 0.037$, $P = 0.041$, respectively). A significant increase in the liver length, liver thickness, and portal vein diameter was observed in favor of the central obesity group. **Conclusion:** Ultrasound measurements confirmed a physiological correlation between liver size with gallbladder volume, portal vein diameter, and subcutaneous tissue thickness. Anthropometric measurements, particularly BMI, are considered determinants for increasing the liver size, gallbladder volume, and portal vein.

Keywords: Gallbladder, hepatic vessels, Iraq, liver, ultrasonography

Introduction

The liver is the largest organ in the human body, contributing in many substantial biological functions such as detoxication, metabolism, regulation of the blood volume, homeostasis of lipid, protein and carbohydrates, bile production and excretion, triglycerides, cholesterol, and bilirubin excretion.[1] Due to its essential function in the human body, it is important to assess liver size as precisely as possible during the basic physical examination or during medical imaging such as ultrasonography.[2] Assessment of the liver size is reflection of its function. Focal or diffuse changes in the liver parenchyma may lead to change in its size.[3] Ultrasonography is widely used for evaluation the liver size due to high accuracy, safety, noninvasive, availability, portability, and lower cost as compared to other medical imaging such as computed tomography and magnetic resonance imaging.[4] Ultrasonography provides precise information about its dimensions such as length (craniocaudal), thickness (anteroposterior [AP]), and width (laterolateral) diameter.[5] Previous literature showed that liver size is also depended on race, gender, and body mass index (BMI).[6,7] Numerous studies showed that liver size can be affected by many factors, including age, gender, dietary pattern, and body surface area.[8-10] Gallbladder dimensions such as volume can reflect functional status and probably pathophysiological mechanisms of gallbladder diseases.[11] Changing in the gallbladder size is, therefore, likely to be indicative of gallbladder conditions.

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A recent study showed that gallbladder volume is strongly associated with gender, BMI, metabolic equivalent of task, and history of cardiovascular disease.[12]

Ultrasonography helps evaluate the gallbladder length, transverse and AP diameters, and volume. It is the first-line technique for assessment patients with suspected gallbladder diseases by measuring its dimensions and wall thickness.[13] In the same context, portal vein should also be assessed for imaging, identifying, and follow-up of portal hypertension.[14] However, it is still unknown if the portal vein diameter is likely to be affected by demographic and anthropometric variables. Thus, it is an essential to evaluate the portal vein diameter and its correlation with these variables to avoid false-negative diagnosis of portal hypertension and hepatomegaly. Therefore, the objectives of this study are to evaluate the correlation between sonographic measurements of liver, gallbladder, portal, and hepatic veins and anthropometric data among university-aged youth in Baghdad, Iraq.

Materials and Methods

Design, setting, and study population

An observational cross-sectional study was prospectively carried in this survey. The study was conducted in accordance with the Declaration of Helsinki and was approved by Institutional Review Board of College of Health and Medical Techniques with approval number: 7/27/7608; approval date: 25/09/2023. A total of 135 consecutive youth were screened sonographically who met inclusion criteria. A systematic sampling method was applied over 6 months from October 2023 to March 2024. The data were recruited at department of radiology techniques, college of health, and medical techniques. The study population consisted of physically active youth with both normal and high BMI (over than 23 kg/m^2) without known disease. This explains that participants in this study engage in regular physical activity and exhibit good cardiovascular fitness. Youth who were fasting for 8 h before the ultrasound examination were included in the study. The youth who had focal or diffuse liver diseases such as fatty liver, viral hepatitis B or C, cirrhosis, liver tumor or metastases, previous liver surgery, portal hypertension, tropical hepatomegaly and schistosomiasis, cholecystectomy, gallbladder stone(s), gallbladder sludge, acute or chronic cholecystitis, anatomical variations in the organs/structures involved, hematological, congestive, collagenous diseases, or heavy alcohol consumed (>140 g/week for men and > 70 g/week for women)[15] were excluded from the study. Each respondent was verbally informed about the study, and informed consent forms were signed by all individuals before the commencement of the study. In this study, "youth" refers to individuals aged 18–24 years (university-aged), encompassing both adolescents and young adults.

Ultrasound techniques and measurements

Ultrasound measurements were performed using B-mode ultrasound scanner (Mindray DC-70, China) equipped with a 3.5 convex-array probe was used in this study. Ultrasound imaging was achieved by a single sonographer with an experience in abdominal ultrasound of more than 7 years. As ultrasonography is considered one of the most operator-dependent imaging methods, the reliability analysis (intraobserver agreement) was tested to assess and confirm the consistency of our measurements. For this purpose, the same operator was repeated the measurements three times on the offline image and the average of these measurements were computed. All participants were fasting 8 h prior ultrasound imaging. Ultrasound procedure was done while the participant was lying in supine position (occasionally in left lateral decubitus for the gallbladder examination). Liver length (craniocaudal measurement) was measured on longitudinal scan at midclavicular line from the diaphragm to the inferior edge [Figure 1]. In the same scan, liver thickness (AP diameter) was measured from anterior to the posterior aspect of the liver [Figure 1]. For gallbladder examination, the probe was placed in both longitudinal and transverse scans at right subcostal region (sometimes at intercostal space). Gallbladder length was measured on longitudinal scan from the tip of the fundus to the neck (at junction with the cystic duct) [Figure 2a]. At this level, the probe is rotated transversely to measure the width and thickness. Gallbladder width was measured from the lateral edge one side to the lateral edge of the other side [Figure 2b$_1$] whereas gallbladder thickness was measured from anterior edge to the posterior edge [Figure 2b$_2$]. Gallbladder wall thickness was measured at three sites: fundus, body, and neck; then, the average was calculated. Gallbladder volume was calculated based on the ellipsoid formula as follows:

Volume (cm^3) = length (cm) × width (cm) × AP diameter (cm) ×0.52.[16]

To locate main portal vein, the probe was placed longitudinally or transversely at epigastric area during normal suspended

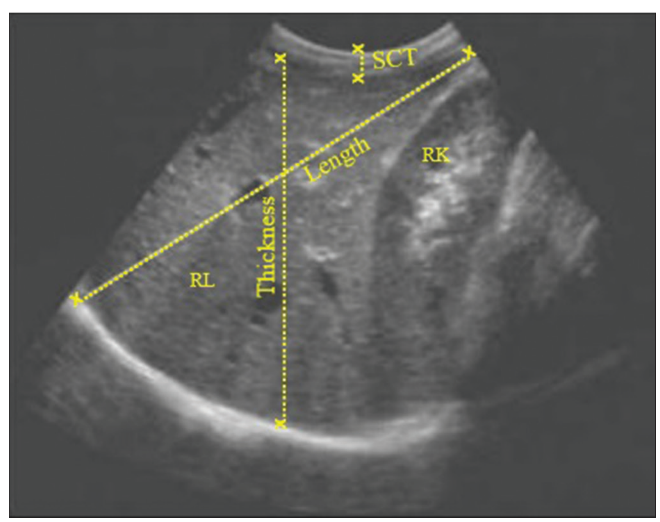

Figure 1: Ultrasound measurements (longitudinal scan) of the liver length, liver thickness, and subcutaneous tissue thickness. RL: Right lobe, RK: Right kidney, SCT: Subcutaneous tissue thickness

respiration at the level where the vein crosses anterior to inferior vena cava. The AP diameter of the portal vein was measured between inner margins of the echogenic walls of the vessel [Figure 3a and b]. Hepatic vein was located by placing the probe longitudinally at epigastric area with slightly angled to the right lobe of the liver during normal respiration [Figure 3c]. The AP diameter of the right, middle, and left hepatic veins was measured near to their confluence with inferior vena cava, and the average of the three measurements of the branches were calculated. A distance between the skin (the margin nearest to the probe) and the liver capsule (the margin farthest to the probe) was reported as subcutaneous tissue thickness.

Anthropometric parameters and measurements

Anthropometric measurements were made for all participants who met the inclusion criteria. The height, waist circumference (WC), and hip circumference (HC) were measured using elastic height measuring tape. Body weight was measured using the Etekcity digital scale. WC was measured at midpoint between the lower costal edge and the iliac crest whereas HC was taken around the buttocks. Moreover, the waist-to-hip ratio (WHR) was computed. WHR of more than 0.90 in males and more than 0.85 in females was classified as central obesity.[17]

Statistical analysis

Data were analyzed by using SPSS program version 22.0, IBM Corporation, Armonk, New York, United States. A mean ± standard deviation was reported for continuous variables whereas numbers and percentages (%) were recorded for categorical variables. Normal distribution of data was tested by a Kolmogorov–Smirnov test. Independent-samples *t*-test was applied to determine the differences between two groups. Pearson's correlation coefficient was applied to determine the correlation between two continuous variables. An intraclass correlation coefficient was done to test the reliability of the measurements with a value ≥0.85 indicating a high level of consistency. $P < 0.05$ was considered statistically significant.

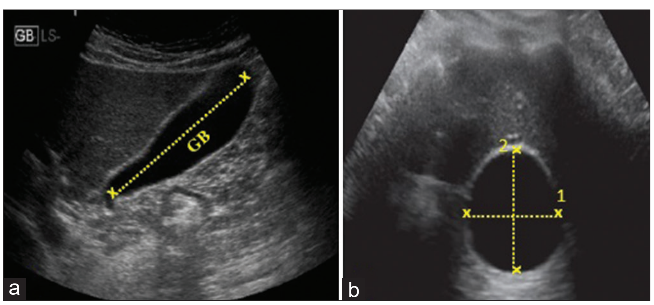

Figure 2: Longitudinal ultrasound measurements of the gallbladder length (a), gallbladder width (b_1) and thickness (b_2). GB: Gallbladder

Results

The characteristics of the study population are shown in Table 1. A total of 135 youth with a mean age of 22.0 ± 1.7 (max–min = 18.0–24.0 years) were recruited and analyzed in this study. The study population was predominantly males (116 males vs. 19 females). The mean of BMI was 23.8 ± 4.0 kg/m^2, weight was 71.2 ± 14.6 kg, height was 172.5 ± 9.1 cm, WC was 84.5 ± 8.9 cm, HC was 89.5 ± 11.2 cm, and WHR was 0.94 ± 0.14. Furthermore, the prevalence of youth with central obesity was reported to be 56.3%.

Table 2 shows the correlation between ultrasound measurements with age and gender. The results showed no significant correlation between liver length (r = 0.129, P = 0.791), liver thickness (r = 0.057, P = 0.514), gallbladder length (r = 0.135, P = 0.118), gallbladder width (r = 0.033, P = 0.700),

Table 1: Distribution of the study population (*n*=135 subjects)

Variables	Mean±SD (maximum–minimum)
Age	22.0±1.7 (18.0–24.0)
Gender, *n* (%)	
Male	116 (85.9)
Female	19 (14.1)
BMI	23.8±4.0 (16.8–41.4)
Weight	71.2±14.6 (41.0–109)
Height	172.5±9.1 (150.0–190.0)
WC	84.5±8.9 (66.0–115.0)
HC	89.5±11.2 (70.0–128.0)
WHR	0.94±0.14 (0.00–1.32)
Central obesity, *n* (%)	
No	59 (43.7)
Yes	76 (56.3)

BMI: Body mass index, WC: Waist circumference, HC: Hip circumference, WHR: Waist to hip ratio, *n*: Sample, SD: Standard deviation

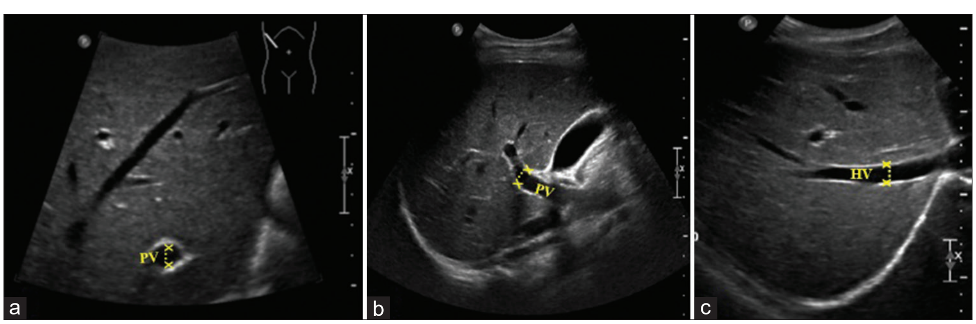

Figure 3: Transverse scan of the portal vein diameter (a). Longitudinal scan of the portal vein diameter (b). Longitudinal scan of the right hepatic vein was measured near to its confluence with inferior venal cava (c). PV: Portal vein, HV: Hepatic vein

gallbladder thickness ($r = 0.072$, $P = 0.405$), gallbladder wall thickness ($r = 0.012$, $P = 0.893$), portal vein diameter ($r = 0.128$, $P = 0.139$), and hepatic vein diameter ($r = 0.007$, $P = 0.936$) with age. Additionally, the mean liver length was higher in males (127.1 ± 13.2 mm) than in females (119.0 ± 11.3 mm), showing significant differences ($P = 0.001$). Nonetheless, there were no significant differences found in the measurements of the liver thickness ($P = 0.783$), gallbladder length ($P = 0.582$), gallbladder width ($P = 0.477$), gallbladder thickness ($P = 0.127$), gallbladder volume ($P = 0.573$), gallbladder wall thickness ($P = 0.171$), portal vein diameter ($P = 0.201$), and hepatic vein diameter ($P = 0.800$) between males and females.

The correlation between ultrasound measurements and anthropometric measures is illustrated in Table 3. The present study showed a positive and significant correlation between liver length and height ($r = 0.297$, $P < 0.001$), weight ($r = 0.237$, $P = 0.006$), BMI ($r = 0.405$, $P = 0.025$), and WC ($r = 0.537$, $P = 0.048$) whereas correlation was not significant between liver length and HC ($P = 0.342$). The liver thickness was significantly correlated with weight ($r = 0.267$, $P = 0.002$) and BMI ($r = 0.260$, $P = 0.002$) whereas it was not significantly correlated with height ($P = 0.350$), WC ($P = 0.693$), and HC ($P = 0.233$). No significant correlation was found between gallbladder length, width, and thickness with height, weight, BMI, WC, and HC ($P > 0.05$). A positive and significant correlation was found between gallbladder volume with height ($r = 0.183$, $P = 0.034$), weight ($r = 0.189$, $P = 0.028$), and BMI ($r = 0.421$, $P = 0.047$) whereas no significant correlation was observed between gallbladder volume and WC ($P = 0.101$) and HC ($P = 0.288$). Similarly, there was no significant correlation between gallbladder wall thickness and height ($P = 0.393$), weight ($P = 0.315$), BMI ($P = 0.823$), WC ($P = 0.341$), and HC ($P = 0.952$). In the light of this, the present findings revealed that portal vein diameter was significantly correlated with height ($r = 0.365$, $P < 0.001$), weight ($r = 0.185$, $P = 0.032$), BMI ($r = 0.339$, $P = 0.041$), and WC ($r = 0.204$, $P = 0.032$) whereas it was no significantly correlated with HC ($r = 0.134$, $P = 0.120$). However, the correlation between the hepatic vein diameter with height ($P = 0.145$), weight ($P = 0.109$), BMI ($P = 0.272$), WC ($P = 0.241$), and HC ($P = 0.477$) was not reported to be statistically significant.

The current findings also revealed a significant and positive correlation between gallbladder volume with liver length ($r = 0.543$, $P = 0.038$) [Figure 4a] and thickness ($r = 0.290$, $P = 0.047$) [Figure 4b]. In the light of this, a correlation between gallbladder wall thickness with gallbladder volume [Figure 5a] and gallbladder length [Figure 5b] was significant and negative ($r = -0.394$, $P = 0.041$ and $r = -0.179$, $P = 0.037$, respectively). In this context, portal vein diameter was significantly correlated with liver length ($r = 0.304$, $P = 0.029$) [Figure 6a] and thickness ($r = 0.177$, $P = 0.040$) [Figure 6b]. Liver length and liver thickness were significantly correlated with

Table 2: Correlation between ultrasonographic measurements with age and gender

Variables	Age	Gender	Mean±SD	P
Liver length	r=0.129	Male	127.1±13.2	0.001
	P=0.791	Female	119.0±11.3	
Liver thickness	r=0.057	Male	98.6±27.6	0.783
	P=0.514	Female	98.7±31.0	
GB length	r=0.135	Male	60.0±18.8	0.582
	P=0.118	Female	62.7±15.0	
GB width	r=0.033	Male	26.3±5.8	0.477
	P=0.700	Female	22.1±5.3	
GB thickness	r=0.072	Male	21.3±7.0	0.127
	P=0.405	Female	24.1±10.3	
GB volume	r=0.059	Male	14.3±5.5	0.573
	P=0.405	Female	13.5±5.6	
GB wall thickness	r=0.012	Male	2.5±0.8	0.171
	P=0.893	Female	2.2±0.6	
Portal vein	r=0.128	Male	9.4±1.7	0.201
	P=0.139	Female	8.9±1.2	
Hepatic vein	r=0.007	Male	6.7±2.0	0.800
	P=0.936	Female	6.6±1.6	

r: Pearson's correlation coefficient. GB: Gallbladder, SD: Standard deviation

Table 3: Correlation between ultrasound measurements and anthropometric measures

Variables	Height	Weight	BMI	WC	HC	WHR
Liver length						
r	0.297	0.237	0.405	0.537	0.267	0.245
P	<0.001	0.006	0.025	0.048	0.342	0.004
Liver thickness						
r	0.081	0.267	0.260	0.034	0.103	0.028
P	0.350	0.002	0.002	0.693	0.233	0.749
GB length						
r	0.143	0.104	0.048	0.074	0.008	0.083
P	0.749	0.228	0.580	0.396	0.923	0.339
GB width						
r	0.127	0.045	0.016	0.008	0.002	0.032
P	0.143	0.604	0.854	0.923	0.997	0.712
GB thickness						
r	0.013	0.044	0.065	0.210	0.068	0.092
P	0.880	0.613	0.714	0.114	0.433	0.290
GB volume						
r	0.183	0.189	0.421	0.142	0.235	0.048
P	0.034	0.028	0.047	0.101	0.288	0.577
GB wall thickness						
r	0.074	0.087	0.019	0.083	0.005	0.026
P	0.393	0.315	0.823	0.341	0.952	0.761
Portal vein						
r	0.365	0.185	0.339	0.204	0.134	0.076
P	<0.001	0.032	0.041	0.032	0.120	0.379
Hepatic vein						
r	0.126	0.139	0.095	0.102	0.062	0.168
P	0.145	0.109	0.272	0.241	0.477	0.052

r: Pearson's correlation coefficient. BMI: Body mass index, WC: Waist circumference, HC: Hip circumference, WHR: Waist to hip ratio, GB: Gallbladder

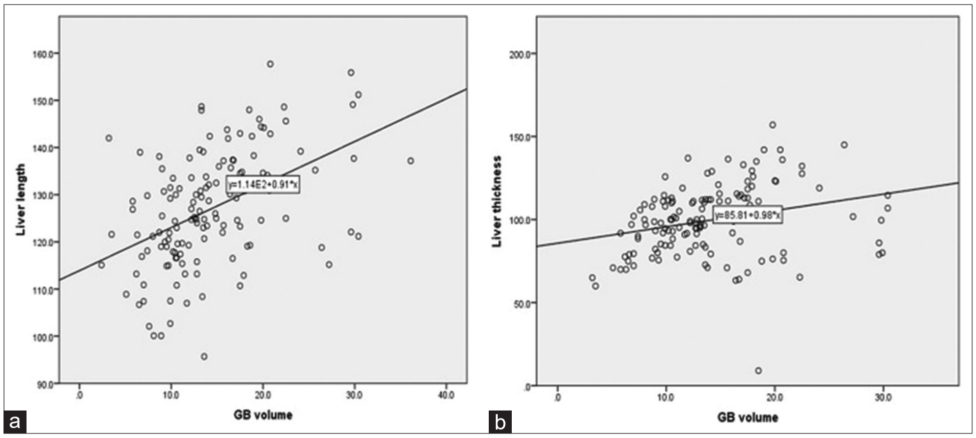

Figure 4: Scatter plot shows (a) correlation between liver length and gallbladder volume, (b) correlation between liver thickness and gallbladder volume. GB: Gallbladder

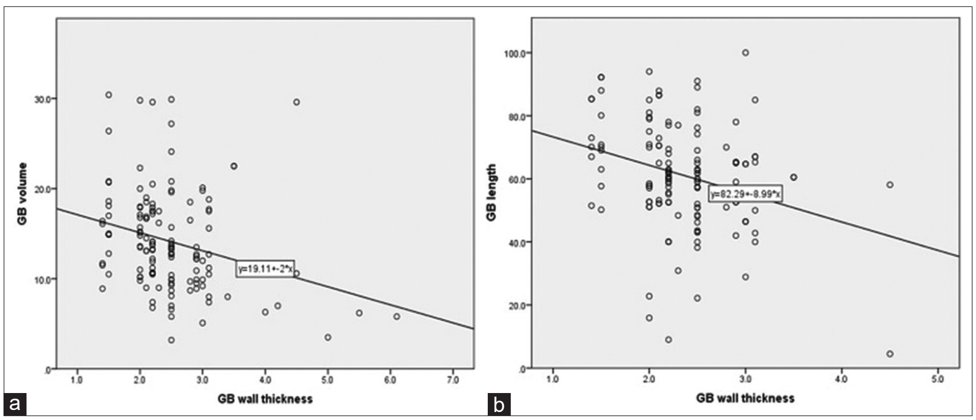

Figure 5: Scatter plot shows (a) correlation between gallbladder wall thickness and gallbladder volume, (b) correlation between gallbladder wall thickness and gallbladder length. GB: Gallbladder

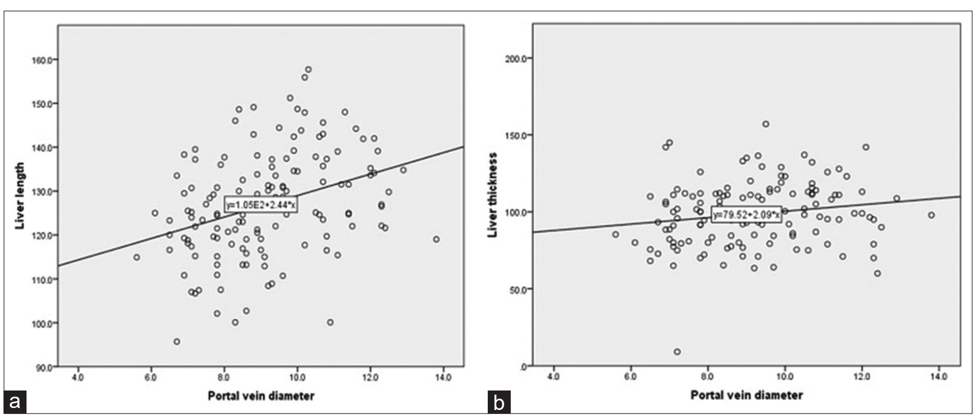

Figure 6: Scatter plot shows (a) correlation between liver length and portal vein diameter, (b) correlation between liver thickness and portal vein diameter

subcutaneous tissue thickness ($r = 0.206$, $P = 0.017$; $r = 0.115$, $P = 0.049$, respectively) [Figure 7a and b]. The correlation; however; of the following ultrasound measurements was not found to be statistically significant: liver length versus gallbladder length ($P = 0.958$), liver length versus gallbladder width ($P = 0.509$), liver length versus gallbladder thickness ($P = 0.691$), liver length versus gallbladder wall thickness ($P = 0.218$), and liver length versus hepatic vein ($P = 0.290$). Likewise, liver thickness was not significantly correlated with gallbladder length ($P = 0.653$), gallbladder width ($P = 0.604$), gallbladder thickness ($P = 0.223$), gallbladder wall thickness ($P = 0.776$), and hepatic vein ($P = 0.812$). There were no significant correlation found between gallbladder length with portal vein ($P = 0.198$), hepatic vein ($P = 0.823$), and subcutaneous tissue thickness ($P = 0.194$). In this line, gallbladder width, gallbladder thickness, gallbladder volume, and gallbladder wall thickness were not significantly correlated with portal vein diameter, hepatic vein, and subcutaneous tissue thickness ($P > 0.05$). The correlation of portal vein diameter with hepatic vein diameter ($r = 0.040$, $P = 0.646$) and subcutaneous tissue thickness ($r = 0.072$, $P = 0.404$) was not found to be significant. No significant correlation was observed between hepatic vein diameter and subcutaneous tissue thickness ($r = 0.048$, $P = 0.582$) [Table 4].

Table 5 shows that the mean liver length was higher in patients with central obesity (132.5 ± 11.8 mm) than those without central obesity (119.1 ± 9.6 mm), showing significant differences ($P < 0.001$). Similarly, a significant increase in liver thickness was observed in favor of central obesity group ($P = 0.003$). Meanwhile, portal vein diameter was significantly higher in patients with central obesity (9.7 ± 2.0 mm) compared with their counterpart who

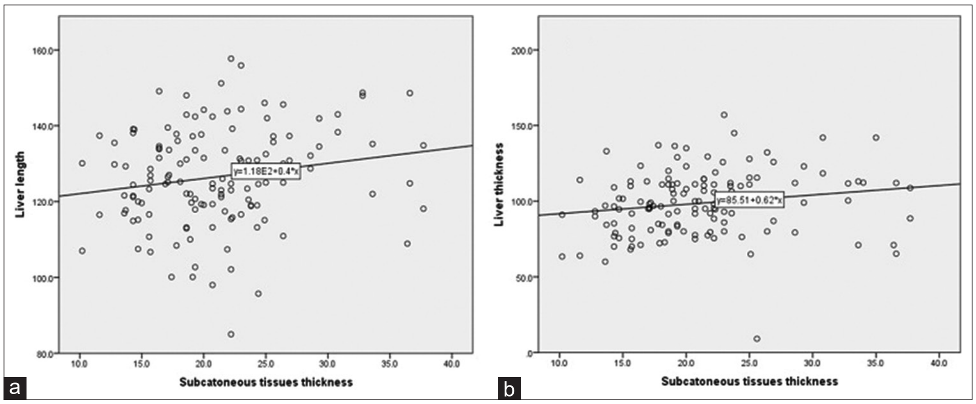

Figure 7: Scatter plot shows (a) correlation between liver length and subcutaneous tissue thickness, (b) correlation between liver thickness and subcutaneous tissue thickness

Table 4: Correlation between ultrasound measurements

Variables	GB length	GB width	GB thickness	GB volume	GB wall thickness	Portal vein	Hepatic vein	Subcutaneous tissue thickness
Liver length	0.005	0.057	0.035	0.543	0.107	0.304	0.092	0.206
r								
P	0.958	0.509	0.691	0.038	0.218	0.029	0.290	0.017
Liver thickness	0.039	0.045	0.106	0.290	0.025	0.177	0.021	0.115
r								
P	0.653	0.604	0.223	0.047	0.776	0.040	0.812	0.049
GB length					−0.179	0.111	0.019	0.112
r								
P					0.037	0.198	0.823	0.194
GB width					0.068	0.049	0.159	0.050
r								
P					0.434	0.574	0.065	0.568
GB thickness					0.025	0.040	0.033	0.003
r								
P					0.776	0.642	0.706	0.972
GB volume					−0.394	0.020	0.067	0.118
r								
P					0.041	0.819	0.440	0.171
GB wall thickness						0.042	0.022	0.108
r								
P						0.630	0.803	0.212
Portal vein							0.040	0.072
r								
P							0.646	0.404
Hepatic vein								0.048
r								
P								0.582

r: Pearson's correlation coefficient. GB: Gallbladder

Table 5: Differences of the ultrasound measurements between central obesity categories

Variables	Central obesity (by WHR)		*P*	Central obesity (by BMI)		*P*
	No	Yes		Normal weight central obesity	Obese central obesity	
Liver length	119.1±9.6	132.5±11.8	<0.001	126.5±11.9	126.6±14.0	0.956
Liver thickness	86.2±18.8	96.7±21.0	0.003	95.8±21.8	100.9±20.1	0.157
GB length	66.4±12.2	59.3±15.2	0.344	58.3±15.2	63.0±17.3	0.101
GB width	22.8±6.1	28.0±10.1	0.157	29.4±5.3	22.8±6.7	0.146
GB thickness	21.3±7.5	21.9±7.6	0.659	21.6±6.8	21.8±8.2	0.913
GB volume	15.1±8.2	16.4±10.2	0.427	13.9±5.5	14.4±5.6	0.561
GB wall thickness	2.3±0.5	2.4±0.6	0.242	2.4±0.8	2.5±0.7	0.358
Portal vein	8.6±1.7	9.7±2.0	<0.001	9.3±1.7	9.1±1.7	0.500
Hepatic vein	6.7±1.9	6.7±2.0	0.849	6.7±1.6	6.7±2.2	0.986

GB: Gallbladder, BMI: Body mass index, WHR: Waist to hip circumference ratio

did not have central obesity (8.6 ± 1.7 mm) ($P < 0.001$). On contrary, no significant differences were found in the mean of gallbladder length ($P = 0.344$), gallbladder width ($P = 0.157$), and gallbladder thickness ($P = 0.659$) between patients with and without central obesity. The mean gallbladder volume, gallbladder wall thickness, and hepatic vein were not found to be statistically different ($P = 0.427$, $P = 0.242$, and $P = 0.849$, respectively). When central obesity (by BMI) was analyzed, the findings revealed no significant differences of the ultrasound measurements between youth with normal weight central obesity and obese central obesity ($P > 0.05$).

Discussion

Ultrasonography represents valuable diagnostic imaging in the evaluation of the liver. Liver size is considered important parameter during assessment of this organ. In daily practice, the three dimensions (length, width, and thickness) of the liver should be measured.[5] Liver length is the most common measurement depended in the evaluation of hepatomegaly. However, liver volume is still impossible to measure routinely due to overtime and software technique. There are numerous published studies around the world conducted on normal and hepatobiliary diseases.[18-20] Previous sonographic survey showed that age advances had a strong impact on liver span.[21] Anthropometric parameters, particularly BMI, are considered important while measuring the extent of the liver size.[22] In addition, some studies were conducted to state effect of the BMI on liver diseases but not the effect on its size among healthy individuals.[21,23] Moreover, understanding portal vein diameter and anatomy is significant for interventional radiologists and surgeons.[24] Dilatation of the portal vein can be caused by any disease that interferes with blood stream.[14] Over 95% of portal vein dilatation may due to intrahepatic diseases such as cirrhosis.[25] However, a correlation between portal vein diameter with liver size and anthropometric measures was not well studied. Thus, this study has taken into consideration this research gap. In the meantime, the correlation between gallbladder dimensions and anthropometric measures is still limited. Ultrasound measurement of gallbladder size is one of the main criteria in the assessment of biliary system diseases. It can provide substantial details about its morphology.[12] Previous literature stated that changes in gallbladder size and volume may be related to functional impairment.[26]

Previous literature from Germany and Turkey were conducted among healthy subjects over 18 years old. The studies revealed that craniocaudal liver span was significantly correlated with age and gender.[27,28] In this line, the study from Turkey also showed that liver size in females, unlike males, was closely correlated with age.[28] Nevertheless, another study from India by Ravi and Roopa confirmed that portal vein diameter in females was not found to have correlation with age.[9] Furthermore, Bora *et al*. found that gallbladder volume was significantly increased with age advancing as well as it was significantly greater in males than in females.[29] Similarly, Ewunonu showed that length, width, thickness, wall thickness, and volume of the gallbladder were not changed with age advancing. The author also confirmed a significant increase in the length, wall thickness, and volume of the gallbladder in males compared to the females.[30] Akanni *et al*. observed a significant correlation between portal vein diameter with age and gender. In contrast, Galda *et al*. found a significant correlation of the portal vein diameter with gender but not with age.[31] Surprisingly, previous literature did not address a correlation between liver thickness and hepatic vein with age and gender. This study showed that following ultrasonographic measurements, liver length, liver thickness, gallbladder length, gallbladder width, gallbladder thickness, gallbladder wall thickness, and portal vein and hepatic vein diameters were not observed to change with age. This may be attributed to that age ranges including in this study were typically narrow (between 18 and 24 years). Therefore, variations within this age range are very limited to show a significant correlation with measurements of the organs/structures. In addition, the measurements of the organs/structures are influenced by genetic factors which may not change considerably with age in a young adult population. In young adults, moreover, the organs/structures may be relatively stable in sizes in comparison with other stages of life. In the other words, significant variations in measurements of the organs/structures may be developed earlier in life or later in adulthood, instead during the university age. Apart from that, the present findings revealed that liver length was significantly increased in the favor of males. Other ultrasonographic measurements (liver thickness, gallbladder length, gallbladder width, gallbladder thickness, gallbladder wall thickness, gallbladder volume portal vein, and hepatic vein) were not different significantly between both genders.

This study showed that liver length is significantly affected by the body height, weight, BMI, WC, and WHR. Liver thickness, however, was significantly correlated with weight and BMI only. In this line, Özmen *et al*. revealed a significant correlation between liver size and body weight, height, BMI, and body surface area.[28] An explanation of this correlation is that high caloric intake, common in obesity, leads to an excess of nutrients that the liver must process. This can overwhelm the liver's capacity, causing fat buildup and increasing liver size.[32] To the best of our knowledge, there are numerous intrinsic and extrinsic factors such as anthropodermic measures and community-associated factors can impact the liver size. However, previous studies were designed to determine whether a single factor mainly affects the liver size.[22,33] Silva *et al*. revealed that weight was found to be a major determinant for liver size.[34] The liver size was significantly correlated with height and BMI.[22,33] Konuş *et al*. found a significant correlation between liver size and height[35] whereas Safak *et al*. reported a significant correlation between liver size and weight.[36]

Furthermore, the present study demonstrated a positive and significant correlation between gallbladder volume with height, weight, and BMI. Nevertheless, the length and width and wall thickness of the gallbladder were not significantly correlated with height, weight, BMI, WC, HC, and WHR. A recent study found that a correlation between gallbladder volume and height and weight was observed to be moderate and significant whereas a correlation between gallbladder volume and BMI was weak but statistically significant.[37] In consistent with the current findings, previous sonographic data showed that gallbladder volume, residual gallbladder volume, and postprandial values with slower emptying rates was noted to be greater in obese fasting patients compared to nonobese controls.[38] A study from Nigeria by Ugwu and Agwu also reported a significant relationship between gallbladder volume and BMI.[39]

The present findings revealed that a correlation between portal vein and height, weight, BMI, and WC was noted to be positive and significant whereas correlation was not significant between the vein and HC and WHR. In contrast, the hepatic vein was not correlated with anthropometric measures. Unfortunately, there was no study evaluated the correlation between hepatic vein and anthropometric measures. Apart from that, a study from Karachi found was partially consistent with the present findings in which the portal vein diameter was increased with BMI increases.[21] This may be attributed to fragmentation of smooth muscles as well as stiffness in the reticular network.[40] Akanni *et al*. reported the correlation between portal vein diameter with weight and BMI during normal respiration. On the contrary, Adeyekun and Tsebi Nigeria and Cosar *et al*. in Turkey observed no parameter correlated with portal vein diameter.[41,42] However, Gareeballah *et al*. in Sudan and Saha *et al*. in India found that weight and height were considered associated factors for portal vein dilatation.[43,44] These variations in the findings between the different studies could be explained by racial variations, sample sizes, ultrasound measurements, and technique.[44-46] This study was also aimed to determine the correlation between liver size with gallbladder dimensions and hepatic and portal veins. The present results confirmed a positive and significant correlation between liver length and thickness with gallbladder volume. An explanation of this correlation is that a larger liver might produce more bile, leading to increase the volume stored in the gallbladder. This can be observed in condition where the liver is has been functioning harder to process fats or detoxify the body, causing an increase in the both gallbladder volume and liver size.[47] Gallbladder wall thickness was reduced with gallbladder volume and gallbladder length increases. In contrast, portal vein diameter was reported to increase with liver length and thickness increases. The cause may be returned to the vascular compliance in which the diameter of the portal vein may adapt to accommodate the liver's needs. Moreover, if the liver is slightly larger than normal, the portal vein may dilate to guarantee proper blood flow. This adaptive process ensures that the liver functions optimally and that nutrients and waste are processed efficiently.[48] Ultrasound measurements showed that length and thickness of the liver were increased in youth who had thickening of the subcutaneous tissues.

Based on the published literature, there is no study yet that has determined the correlation between liver size with gallbladder size and portal and hepatic veins among healthy adults. The gallbladder size, gallbladder wall thickness, and portal and hepatic veins are closely associated with liver disease.[49,50] Therefore, it is an important for clinicians to diagnose whether changes in these structures are physiological or pathological. Future work should be designed to determine the correlation between these structures among healthy adults which can guide a clinician to accurate diagnosis and for further strengthening our outcomes.

Central obesity is considered the most common adverse form of obesity with serious complications.[51] It is the presence of excess of visceral fat in the WC.[52] Excess fat deposits promotes the high dose of adipokines in the portal vein to liver tissues and other organs, causing implication in the form of noncommunicable disease such as nonalcoholic fatty liver disease, diabetes mellitus, organ hyperplasia, renal disease, and other health problems.[53] Up to date, the literature have been still not focused on relationship between central obesity and size of the organs such as liver and related structures. Therefore, this was a motivation for carrying out the present study. The authors found that liver length and thickness were significantly larger in youth with central obesity than those without central obesity. Likewise, the portal vein diameter was a greater for the favor of central obesity group. Nonetheless, gallbladder dimensions, gallbladder wall thickness, and hepatic vein diameter were not significantly affected by the central obesity. Meanwhile, it is unexpected that the present study did not find noticeable differences in the sonographic measurements between youth with normal weight central obesity and their counterparts with obese central obesity. The cause might be returned to that current dataset does not include a sufficient number of participants with high-weight (and high BMI) central obesity to allow for a statistically meaningful comparison with those who have normal-weight central obesity. The sample size in this subgroup is too small to produce reliable results.

The limitations of this study are that sample size was small. Furthermore, university-aged youth tend to be a relatively homogeneous group in terms of age, socioeconomic status, and lifestyle. This lack of diversity might limit to generalize the findings to general population. In addition, the study population often have irregular dietary patterns, including diets high in fat or low in nutrition, which could influence liver size and gallbladder volume. These factors might confound the results if not controlled for or accounted for in the study design.

For future research directions, a further work is needed to carry out a large population-based study to obtain more valid and significant results. We also recommended to use liver volume estimation formula[54] to achieve a more comprehensive assessment of liver size and condition. In the light of this, further researches should include a wide age range (over 18 years) in order to generalize the findings on the general population.

Conclusion

This is the first study could determine the correlation between liver size, hepatic vessels, and gallbladder dimensions among university-aged youth. Ultrasound measurements confirmed a physiological correlation between liver size with gallbladder volume, portal vein diameter, and subcutaneous tissue thickness. Moreover, liver size was closely correlated with anthropometric measurements. Gallbladder volume and portal vein were highly correlated with body height, weight, and BMI.

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Conflicts of interest

There are no conflicts of interest.

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