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Sonographic and Anatomical Evaluation of the Liver and Portal Vein Reference Values

Evaluación Ecográfica y Anatómica de los Valores de Referencia del Hígado y la Vena Porta

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SUMMARY: This paper's aim is a morphometric evaluation of liver and portal vein morphometry using ultrasonography in healthy Turkish population. This study was carried out with 189 subjects (107 females, 82 males). The demographic data and the body surface area were calculated. The longitudinal axis of the liver for two lobes, diagonal axis or liver span, anteroposterior diameter of the liver and portal vein, portal vein transverse diameter, caudate lobe anteroposterior diameter, and portal vein internal diameters as well as longitudinal liver scans in an aortic plane, sagittal plane, transverse plane, and kidney axis were measured. All measurements were analyzed according to age, sex, body mass index, obesity and alcohol consumption. The mean values of the age, height, weight and body mass index were calculated as 44.39 years, 167.05 cm, 74.23 kg, and 27.06kg/m^2 in females, respectively. The same values were 44.13 years, 167.70 cm, 75.93 kg and 26.71 kg/m^2 in males, respectively. There was significant difference between demographic characteristics, gender, and alcohol consumption in terms of anteroposterior diameter of the liver, portal vein transverse diameter of the right side and liver transverse scan. Also, some measurements including portal vein transverse diameter, liver transverse scan and at kidney axis longitudinal scan of liver showed significant difference between the age groups. There was significant difference in diagonal axis and anteroposterior diameter of liver, portal vein internal diameter, and longitudinal liver scans of the aortic plane parameters between obesity situation. The findings obtained will provide important and useful reference values as it may determine some abnormalities related liver diseases. Also, age, sex, obesity and body mass index values can be effective in the liver and portal vein morphometry related parameters.

KEY WORDS: Liver and portal vein reference values; Ultrasonography; Obesity; Age-sex related changes.

INTRODUCTION

The liver is the largest abdominal viscera and gland located at the right hypochondriac region, and regio epigastrica, and lying into the left hypochondriac region. Its structural unit divides into 4 lobes: right lobe, left lobe, quadrate lobe and caudate lobe. The caudate lobe is a central structure and has independent vessels in the form of portal venous, and hepatic arterial branches. Also, it may be important in metastasis, cirrhosis, and hepatic resections. The quadrate lobe is quadrilateral in outline bounded on the left by fissure for ligamentum teres, on the right side by fossa for gall bladder, above and behind by the porta hepatis and caudate process and below and in front by the inferior margin of liver (Walker *et al*., 1990; Guyton & Hall, 2006; Harlod, 2006; Reddy *et al*., 2017; Ahmed Esmeal & Nagla Hussien, 2019). Portal vein (PV;75-80 % of hepatic blood flow) and hepatic artery (HA; 20-25 % of hepatic blood flow) are the liver's blood supply (Usman *et al*., 2015; Luntsi *et al*., 2016). Moreover, the portal vein, which is formed by the union of the superior mesenteric vein and splenic vein, is a unique vein that drains from the capillaries of the intestinal walls and spleen to the capillaries of the hepatic sinusoids (Usman *et al*., 2015; Geleto *et al*., 2016; Luntsi *et al*., 2016). Portal vein diameters are both a significant element and a reasonable accuracy diagnose structure (Luntsi *et al*., 2016), and it has essential anastomoses with oesophageal, rectal venous plexus and superficial veins of the abdomen (Singh *et al*., 1998). Portal hypertension is a prevalent clinical syndrome and its main reason is known as cirrhosis and hepatic vascular abnormalities (Geleto *et al*., 2016). Furthermore, the inferior vena cava (IVC) is the

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basic structure for venous return from the pelvis, abdominal viscera, and lower limbs, and also, many congenital anomalies, and acquired pathologies can affect this important structure. For this reason, radiologists should carefully evaluate the image of IVC in assessing tumor size or distinguishing tumor extension, whether benign or malignant (Li *et al*., 2021). The liver carries out some special vital functions related to metabolic homeostasis, digestion, immunity, and storage of nutrients, for maintain a normal blood glucose concentration, and the special functions are important for body tissues' alive. Moreover, the liver size is approximately 5 cm span at 5th year of a child. Liver size increases during development until reaching 15 years and that is adult liver size. Many factors including age, sex, body size, shape, and liver related diseases, or liver transplantation may affect the liver sizes which should be known especially in liver transplantation (Walker *et al*., 1990; Guyton & Hall, 2006; Harlod, 2006; Ahmed Esmeal & Nagla Hussien, 2019). The Ultrasonography (US) is one of the effective diagnostic tools and contributes to assesment of several conditions such as size, texture, follow-up patients with portal vein abnormalities, and pathology of the liver. Additionally, US is preferred mostly because of its many features such as the use of non-ionizing radiation, accessibility, use of non-invasive, low cost, portability, rapid, safe, and readily available diagnostic tool (Rosenfield *et al*., 1974; Singh *et al*., 1998; Hawaz *et al*., 2012; Usman *et al*., 2015; Babu Naik *et al*., 2017; Ahmed Esmeal & Nagla Hussien, 2019).

The liver and portal vein dimensions provide important and useful knowledge and reference data as it may determine some abnormalities related liver diseases. For this reason, it was aimed to determine the normal values of liver and portal vein dimensions and to investigate whether age, sex, obesity or body mass index, and alcohol consumption parameters affect the liver related parameters or not.

MATERIAL AND METHOD

The present study was performed with 189 subjects (107 females, and 82 males) aged between 18 and 80 years in Adana Ortadogu Hospital Radiology Department. The oral and written statement was obtained from participants. All the test procedures were approved by the our university ethics committee (no: 2020;105-35). Inclusion criteria were no history of disease-related gall bladder, the venous system, liver, pancreas or hepatic enlargement, and hematologic, oncologic, or no history of a diagnosing of cancer, and metastasis, lesions, anatomical abnormalities related to the these areas. All examinations were performed with abdominal ultrasonography using a commercially available high-resolution real-time US scanner (GE Voluser,730 USA) with a 3.5 MHz sector transducer.

Demographic data, including age, height, and weight were measured, and body mass index, and body Surface Area (BSA) were calculated according to the special formulas (BMI= weight/height2), [BSA=(weight x height) / 3600]1/2, respectively. Also, using the abdominal USG image, the following parameters of liver and portal vein dimensions were evaluated below:

- Right Longitudinal Axis (RLA): Longitudinal axis of the liver was defined between the right hepatic dome to the inferior hepatic tip for the right lobe in the midclavicular line.

- Left Longitudinal Axis (LLA): It was defined from the highest to the lowest point of the liver for the left lobe in the mid-sagittal plane.

Diagonal Axis (DA): The diagonal axis of the liver is measured from its most inferior aspect on the right to the most lateral aspect on the left (as the liver span).

- Anterior-Posterior Diameter (APD): Antero-posterior diameter of the liver is defined that a vertical line drawn between the aorta and inferior vena cava.

- Portal Vein Transverse Diameter-Right (PVTDR) and Left sides (PVTDL): The anteroposterior diameter and transverse diameter of the Portal vein were measured at its midpoint, while the values for the right PV(PVTDR) and left PV were measured at the level of their bifurcation.

- Longitudinal Liver Scans of the Aortic Plane (LLSAP): Longitudinal scans of the liver were obtained along the sagittal plane of the aortic plane: A-line parallel to the aorta axis was drawn 3 cm vertically to the anterior aortic Wall. The upper margin of this line was used as the upper limit of the longitudinal diameter while the inferior edge of the liver as the lower limit.

- Longitudinal Liver Scans of the Sagittal Plane (LLSSP): Longitudinal scans of the liver were obtained along the sagittal plane of the plane. A similar ventral line was drawn 2 cm from the inferior vena cava axis. The upper limit of this line touching the diaphragmatic surface of the liver served of the lower limit for the second longitudinal diameter.

- Longitudinal Liver Scans Axis of the Kidney (LLSAK): A third longitudinal diameter was drawn parallel to the long axis of the kidney and the diaphragm serves as the upper limit while the inferior liver edge as the lower limit (LLSKA).
- Liver Transverse Scan (LTS): Transverse scan of the liver

was obtained in the midline measuring the anterior-posterior diameter of the liver transected by a vertical line drawn between the aorta and inferior vena cava.

- Caudate Lobe Anterior Posterior Diameter (CLAP): Transverse scan of the liver was also obtained in the midline measuring the anteroposterior diameter of the liver transected by a vertical line drawn between the aorta and inferior vena cava (LTS). The anterior posterior diameter of the caudate lobe is also derived from this line (CLAP)

- Portal Vein Internal Diameter (a) (PVIDa): The internal diameter of the portal vein was measured at 2 points: (a) at the point where the right hepatic artery crosses over the portal vein (PVIDa), (b) at the splenoportal confluence (PVIDb).

The data were divided into two groups: healthy adult females and males. Furthermore, the data were divided also into five groups according to age and the age group ranges were noted in Table IV. The measurements were made on the computer screen with an electronic caliper and estimations were expressed as millimeters. Also, data were divided into four groups according to Body mass index (BMI). BMI is less than 18.5, underweight; BMI is 18.5 to <25, healthy weight; BMI is 25.0 to <30, overweight and BMI is 30.0 or higher, obesity range. Also, subjects were evaluated according to obesity and alcohol consumption.

Statistical analysis. SPSS 22.0 version was used for statistical analysis of the measurement results. From these measurements, means, standard deviations (SD), minimum and maximum values were calculated; p< 0.001, p<0.01 and p<0.05 were considered statistically significant.

RESULTS

Sonographic measurements of the liver and portal vein of the 189 healthy subjects were evaluated. The sex-related changes in demographic characteristics were shown in Table I. In females, the means of age, height, weight, and body mass index were measured as 44.39 years, 167.05 cm, 74.23 kg, and 27.06 kg/m^2, respectively. The same values were 44.13 years, 167.70 cm, 75.93 kg, and 26.71 kg/m^2 in males, respectively. There was no significant differences between demographic features and sexes (p>0.05). Moreover, the mean, standard deviation, minimum and maximum values of liver and portal vein morphometric measurement, and BSA in females and males were shown in Table II, and all parameters showed no significant difference. Moreover, some values including BSA, PVTDR, PVIDa, and LLSSP were higher in males than females, whereas the RLA and LLA values were lower in males. Also, some values such as DA, APD, PVIDb, PVTDL, LLSAP, LLSKA LTS, and CLAP were close to both females and males (p>0.824). When we analyzed the effects of alcohol consumption on liver and portal vein measurement results, significant difference was seen in APD, PVTDR, and LTS dimensions. Additionally, some parameters including APD, PVTDR, LLA, DA, PVTDL, PVIDa, PVIDb, and LLSAP were lower in subjects with no use alcohol. A striking finding was that LLSSP finding was similar in two groups. BSA, RLA, LLSKA, LTS, and CLAP were higher in subjects used alcohol than subjects no used alcohol (Table III). The distribution of the diameters according to age groups of females and males was shown in Table IV. Especially, PVTDR's highest value was obtained in Decade 3, while the lowest value was in Decade 4. From Decade 4 until Decade 6, the PVTDR values increased. However, the PVTDL obtained the highest and lowest values in Decade 3 and Decade 5. The PVIDb obtained the highest value in Decade 3, whereas the lowest value was in Decade 2. FromDecade 4 until Decade 6, the PVIDb value increased. The LLSKA dimension was the lowest in Decade 5 and the highest in Decade 6. Conversely, the highest value of LTS was in Decade 4, whereas the lowest value was in Decade 1. Also, the LTS values increased from Decade 1 to Decade 5. After, from Decade 5 to Decade 6, this dimension decreased. In Table V, liver and portal vein dimensions according to obesity condition were given. The BMI values of 68.39 % of subjects were lower than "30 or higher". The subjects with underweight were no found. In obese subjects

Table I. The sex related changes of the demographic characteristics.

Demographic Features	Females (n=107)				Males (n=82)			
	Mean	S.D.	Min.	Max.	Mean	S.D.	Min.	Max.
Age	44.39	14.31	16.00	80.00	44.13	15.57	18.00	78.00
P	>0.05 (p=0.906)							
Height	167.05	9.53	150.00	186.00	167.70	8.74	150.00	187.00
P	>0.05 (0.632)							
Weight	74.23	12.91	51.00	102.00	75.93	12.16	51.00	102.00
P	>0.05 (p=0.632)							
Body Mass Index	27.06	4.31	19.59	36.57	26.71	4.74	18.61	36.14
P	>0.05 (p=0.595)							

determined with BMI values, the DA, APD, PVIDb, and LLSAP values were significantly higher in obese subjects than in non-obese subjects. Only two parameters including PVTDL and LTS were higher in non-obese subjects than in obese subjects. Furthermore, the body mass index parameter's effects on measurements related to the liver and portal vein were shown in Table VI and Post Hoc test were performed to evaluate the BMI related changes (p<0.05).

Table II. The sex related changes of liver morphometric measurements.

Measurements	Female (n=107)				Male (n=82)			
	Mean	S.D.	Min.	Max.	Mean	S.D.	Min.	Max.
BSA	17.39	1.11	15	19.40	17.46	1.11	15.20	19.40
P	>0.05 (p=0.668)							
RLA	13.02	1.02	10.20	14.40	12.94	1.04	10.40	14.30
P	>0.05 (p=0.586)							
LLA	9.32	1.04	7.20	11.40	9.25	1.09	7.20	11.20
P	>0.05 (p=0.618)							
DA	9.32	1.21	7.00	12.40	9.30	1.20	7.40	12.40
P	>0.05 (p=0.914)							
APD	7.86	0.80	6.30	9.50	7.84	0.77	6.30	9.50
P	>0.05 (p=0.918)							
PVTDR	6.85	0.94	5.40	8.50	7.01	0.87	5.40	8.50
P	>0.05 (p=0.221)							
PVTDL	6.56	0.84	5.00	7.80	6.54	0.92	5.00	7.90
P	>0.05 (p=0.873)							
PVIDa	9.79	1.08	8.00	12.30	10.08	1.23	8.10	12.30
P	>0.05 (p=0.084)							
PVIDb	10.02	1.57	7.50	14.00	10.08	1.73	7.50	13.60
P	>0.05 (p=0.824)							
LLSAP	9.94	1.44	7.30	13.60	9.97	1.42	7.30	13.60
P	>0.05 (p=0.870)							
LLSSP	9.74	1.02	7.30	12.40	9.79	1.11	7.80	11.60
P	>0.05 (p=0.745)							
LLSKA	13.21	0.83	11.00	14.70	13.19	0.79	11.00	14.70
P	>0.05 (p=0.848)							
LTS	7.06	0.55	6.10	8.10	7.04	0.53	6.10	8.10
P	>0.05 (p=0.835)							
CLAP	3.84	0.34	3.00	4.50	3.83	0.39	3.00	4.50
P	>0.05 (p=0.975)							

BSA: Body Surface Area, RLA: Right Longitudinal Axis, LLA: Left Longitudinal Axis, DA: Diagonal Axis, APD: Anterior-Posterior Diameter, PVTDR: Portal Vein Transverse Diameter-Right, PVTDL: Portal Vein Transverse Diameter-Left, LLSAP: Longitudinal Liver Scans of the Aortic Plane, LLSSP: Longitudinal Liver Scans of the Sagittal Plane, LLSAK: Longitudinal Liver Scans Axis of the Kidney, LTS: Liver Transverse Scan, CLAP: Caudate Lobe Anterior Posterior Diameter, PVIDa: Portal Vein Internal Diameter at the point where the right hepatic artery crosses over the portal vein and PVIDb: Portal Vein Internal Diameter at the splenoportal confluence.

DISCUSSION

There are many imaging methods determining of the liver, and one of them is ultrasonography (US). Ultrasonography has noninvasive, and high-resolution imaging technique features. It has high reliability in many diagnostic placements and no side effects. It is inexpensive, nonionizing, noninvasiveness (Patzak *et al*., 2014). Also, the most important feature of the US is the principal imaging technique used for diagnostically determination of the liver (Lewin, 2004; Hawaz *et al*., 2012; Patzak *et al*., 2014). Liver US is one of the most common routine applications to assesment of several conditions such as size, texture, follow-up patients with portal vein abnormalities, and pathology of the liver. Additionally, US is preferred mostly because of its many features such as the use of non-ionizing radiation, accessibility, use of non-invasive, low cost, portability, rapid, safe, and readily available diagnostic tool (Rosenfield *et al*., 1974; Singh *et al*., 1998; Hawaz *et al*., 2012; Usman *et al*., 2015; Babu Naik *et al*., 2017; Ahmed Esmeal & Nagla Hussien, 2019).

In the present study, it was aimed to determine the normal values of liver and portal vein dimensions and to

Table III. Distribution of liver measurements according to alcohol consumption.

Measurements	Alcohol Consumption Group (n=80)				No Alcohol Consumption Group (n=109)			
	Mean	S.D.	Min.	Max.	Mean	S.D.	Min.	Max.
BSA	17.38	0.89	15.00	19.00	17.44	1.25	15.20	19.40
P	>0.05 (p=0.700)							
RLA	12.91	0.74	10.40	14.20	13.04	1.19311	10.20	14.40
P	>0.05 (p=0.378)							
LLA	9.40	1.02	7.20	11.20	9.20	1.09	7.20	11.40
P	>0.05 (p=0.195)							
DA	9.47	1.21	7.30	12.40	9.20	1.18	7.00	12.40
	>0.05 (p=0.124)							
APD	8.10	0.79	6.30	9.50	7.68	0.74	6.30	9.30
	<0.05 (p<0.001)							
PVTDR	7.21	0.76	5.50	8.50	6.71	0.95	5.40	8.40
	<0.05 (p<0.001)							
PVTDL	6.64	0.90	5.00	7.90	6.50	0.85	5.00	7.60
	>0.05 (p=0.270)							
PVIDa	9.98	0.99	8.10	11.40	9.88	1.26	8.00	12.30
	>0.05 (p=0.551)							
PVIDb	10.15	1.50	7.50	13.50	9.97	1.74	7.50	14.00
	>0.05 (p=0.447)							
LLSAP	10.17	1.38	7.80	13.50	9.80	1.45	7.30	13.60
	>0.05 (p=0.078)							
LLSSP	9.76	1.08	7.80	12.40	9.76	1.04	7.30	11.60
	>0.05 (p=0.993)							
LLSKA	13.10	0.96	11.00	14.70	13.28	0.66	12.00	14.70
	>0.05 (p=0.115)							
LTS	6.89	0.45	6.10	8.10	7.17	0.56	6.10	8.10
	<0.05 (p<0.001)							
CLAP	3.78	0.40	3.00	4.50	3.88	0.32	3.00	4.50
	>0.05 (p=0.060)							

BSA: Body Surface Area, RLA: Right Longitudinal Axis, LLA: Left Longitudinal Axis, DA: Diagonal Axis, APD: Anterior-Posterior Diameter, PVTDR: Portal Vein Transverse Diameter-Right, PVTDL: Portal Vein Transverse Diameter-Left, LLSAP: Longitudinal Liver Scans of the Aortic Plane, LLSSP: Longitudinal Liver Scans of the Sagittal Plane, LLSAK: Longitudinal Liver Scans Axis of the Kidney, LTS: Liver Transverse Scan, CLAP: Caudate Lobe Anterior Posterior Diameter, PVIDa: Portal Vein Internal Diameter at the point where the right hepatic artery crosses over the portal vein and PVIDb: Portal Vein Internal Diameter at the splenoportal confluence.

investigate whether age, sex, obesity or body mass index, and alcohol consumption parameters affect the liver related parameters or not using US.

The US evaluation of liver size enables diagnose of some diseases, and also, important and useful souce of information. The liver size increases in some diseases including viral hepatitis, alcoholic liver disease, congestive cardiac failure, and metabolic disorders. Conversely, some conditions as in acute fulminant hepatitis, cirrhosis leads to decrease in liver size. It is determined clinically by liver span: The vertical distance between the uppermost and lowermost points of hepatic dullness estimated by percussion in the right midclavicular line. A length over 16 cm frequently is a significant sign for critical hepatomegaly. If the liver length is 13 cm or less, it is accepted as normal in size in 93 percent of cases. Additionally, liver size varies widely according to age. Many diseases can affect its size ranging from infective processes to malignant disorders (Ahmed Esmeal & Nagla Hussien, 2019).

The liver span may change due to some factors including used method, height, age, sex, or race. It is commonly used in determination of the hematologic disorders, Epstein-Barr virus infection patients, and patients having bone marrow transplantation before to the administration of granulocyte colony-stimulating factor (Babu Naik *et al.*, 2017). There are many studies about liver span. In a study including German subjects (mean age 41.8 years), the liver span was found as 15.1 cm and 14.9 cm in males and females, respectively. In the same study increased age, the liver span decreased significantly until 18 to 65 years. Conversely, increase in body mass index was directly proportional to iver span. There was no significant difference between alcohol consumption, and liver span measurements (Patzak *et al.*, 2014). The corresponding value was measured as 12.86 cm and 14.27 cm in Sudanese healthy and patients having malaria, respectively (Moawia *et al.*, 2015). Indian males and females' liver span size were reported as 13.93 cm and 13.99 cm. Also, there was no found significant difference between

Table IV. Liver and portal vein measurements according to age groups of females and males.

Measurements	Decade 1 (18-30 years) (n=31)	Decade 2 (31-40 years) (n=52)	Decade 3 (41-50 years) (n=33)	Decade 4 (51-60 years) (n=41)	Decade 5 (61-70 years) (n=23)	Decade 6 (71-80 years) (n=9)	Total (18-80 years) (n=189)
BSA	17.70±1.18 (15.20-19.40)	17.05±1.06 (15.00-19.30)	17.56±1.04 (15.20-19.40)	17.61±1.03 (15.80-19.40)	17.23±1.22 (15.20-19.40)	17.63±1.13 (15.70-19.30)	17.42±1.11 (15.00-19.40)
P				0.570			
RLA	12.96±1.08 (10.40-14.30)	12.85±1.04 (10.40-14.30)	12.94±0.87 (11.00-14.30)	13.09±0.99 (10.20-14.40)	13.00±1.26688 (10.40-14.30)	13.47±0.81 (12.20-14.30)	12.98±1.03 (10.20-14.40)
P				0.650			
LLA	9.53±1.05 (7.20-11.20)	9.48±1.03 (7.20-11.40)	9.46±1.10 (7.20-11.20)	9.00±0.91 (7.20-11.20)	9.00±1.18 (7.60-11.20)	8.76±1.12 (7.20-11.20)	9.29±1.06 (7.20-11.40)
P				0.052			
DA	9.24±0.97 (7.40-11.20)	9.10±1.12 (7.00-12.00)	9.30±1.34 (7.30-12.40)	9.72±1.30 (7.80-12.40)	9.22±1.12 (7.80-11.20)	9.24±1.42 (7.40-12.40)	9.32±1.20 (7.00-12.40)
P				0.241			
APD	7.97±0.83 (6.30-9.50)	8.00±0.90 (6.30-9.50)	7.85±0.68 (6.40-9.50)	7.70±0.68 (6.30-9.50)	7.70±0.88 (6.30-9.50)	7.74±0.38 (7.30-8.20)	7.86±0.79 (6.30-9.50)
P				0.423			
PVTDR	7.19±0.76 (5.50-8.50)	7.03±1.09 (5.40-8.50)	7.24±0.78 (5.40-8.50)	6.46±0.74 (5.40-7.80)	6.69±0.83 (5.40-8.30)	6.82±0.76 (5.90-8.40)	6.92±0.91 (5.40-8.50)
P				**0.001**			
PVTDL	6.44±0.79 (5.10-7.70)	6.38±0.89 (5.10-7.80)	6.92±0.92 (5.00-7.80)	6.72±0.71 (5.10-7.80)	6.22±0.97 (5.00-7.90)	6.73±0.76 (5.30-7.80)	6.56±0.87 (5.00-7.90)
P				**0.013**			
PVIDa	9.87±1.25 (8.10-12.30)	9.91±1.12 (8.10-12.30)	10.32±1.10 (8.10-11.90)	9.65±1.02 (8.00-11.90)	10.11±1.30 (8.10-12.30)	9.44±1.13 (8.10-11.40)	9.92±1.15 (8.10-12.30)
P				0.137			
PVIDb	10.42±1.59 (7.50-13.60)	9.67±1.17 (7.50-13.50)	10.79±1.92 (7.50-13.60)	9.74±1.50 (7.50-13.60)	9.86±2.07 (8.10-14.00)	10.12±1.74 (8.10-13.50)	10.05±1.64 (7.50-14.00)
P				**0.023**			
LLSAP	10.22±1.27 (7.80-12.50)	9.95±1.46 (7.30-12.40)	9.91±1.73 (7.50-13.60)	9.75±1.29 (7.30-12.30)	10.22±1.42 (7.30-12.40)	9.42±1.21 (8.10-11.60)	9.95±1.43 (7.30-13.60)
P				0.563			
LLSSP	9.62±0.90 (8.30-11.50)	9.65±0.97 (7.80-12.40)	10.15±1.24 (7.30-11.60)	9.89±1.04 (8.00-11.60)	9.66±1.16 (8.00-11.50)	9.13±0.64 (8.30-10.40)	9.76±1.05 (7.30-12.40)
P				0.081			
LLSKA	13.18±0.86 (11.40-14.70)	13.02±.89874 (11.00-14.70)	13.31±0.66 (11.70-14.30)	13.42±0.79 (11.70-14.70)	12.92±0.71 (11.00-14.30)	13.71±0.45 (12.80-14.30)	13.20±0.81 (11.00-14.70)
P				**0.024**			
LTS	6.83±0.57 (6.10-8.10)	6.97±0.55 (6.10-8.10)	7.10±0.50 (6.10-7.70)	7.20±0.51 (6.10-8.10)	7.19±0.58 (6.10-8.10)	7.11±0.29 (6.80-7.50)	7.05±0.54 (6.10-8.10)
				0.041			
CLAP	3.77±0.30 (3.10-4.50)	3.87±0.32 (3.10-4.50)	3.91±0.49 (3.00-4.50)	3.80±0.35 (3.00-4.50)	3.78±0.38 (3.10-4.40)	3.83±0.17 (3.60-4.00)	3.83±0.36 (3.00-4.50)
P				0.623			

BSA: Body Surface Area, RLA: Right Longitudinal Axis, LLA: Left Longitudinal Axis, DA: Diagonal Axis, APD: Anterior-Posterior Diameter, PVTDR: Portal Vein Transverse Diameter-Right, PVTDL: Portal Vein Transverse Diameter-Left, LLSAP: Longitudinal Liver Scans of the Aortic Plane, LLSSP: Longitudinal Liver Scans of the Sagittal Plane, LLSAK: Longitudinal Liver Scans Axis of the Kidney, LTS: Liver Transverse Scan, CLAP: Caudate Lobe Anterior Posterior Diameter, PVIDa: Portal Vein Internal Diameter at the point where the right hepatic artery crosses over the portal vein and PVIDb: Portal Vein Internal Diameter at the splenoportal confluence.

sexes (Babu Naik *et al*., 2017). Brazilian females and males' same values were 11.9 cm and 11.4 cm, respectively (Silva *et al*., 2010). The same value was in Malaysian male and female subjects aged between 52.6 years, 12.20 cm and 11.7 cm, respectively (Khammas & Mahmud, 2020) and in Indian healthy subjects, 14.07 cm (Balasubramanian *et al*., 2016). Khammas & Mahmud (2020) reported that age, sex, and diseases might be an important element in liver

Table V. Liver and portal vein measurements according to obesity.

Measurements	Non-obese Group (n=132)				The Obese Group (n=57)			
	Mean	S.D.	Min.	Max.	Mean	S.D.	Min.	Max.
BSA	17.38	0.89	15.20	19.30	17.48	1.13	15.00	19.40
p	>0.05 (p=0.602)							
RLA	12.90	1.04	10.20	14.40	13.17	0.97	11.30	14.40
p	>0.05 (p=0.094)							
LLA	9.20	0.95	7.60	11.40	9.49	1.26	7.20	11.20
p	>0.05 (p=0.076)							
DA	8.81	0.89	7.00	11.30	10.47	1.00	8.90	12.40
p	**<0.05 (p<0.001)**							
APD	7.67	0.74	6.30	9.30	8.29	0.73	7.30	9.50
p	**<0.05 (p<0.001)**							
PVTDR	6.90	1.01	5.40	8.50	6.98	0.61	5.50	8.30
p	>0.05 (p<0.577)							
PVTDL	6.56	0.95	5.00	7.80	6.54	0.68	5.00	7.90
p	>0.05 (p=0.890)							
PVIDa	9.89	1.13	8.00	12.30	9.99	1.21	8.30	11.90
p	>0.05 (p=0.573)							
PVIDb	9.67	1.55	7.50	14.00	10.93	1.52	9.00	13.60
p	**<0.05 (p=0.001)**							
LLSAP	9.63	1.36	7.30	13.50	10.70	1.32	8.30	13.60
p	**<0.05 (p=0.001)**							
LLSSP	9.74	1.04	7.30	12.40	9.80	1.10	8.30	11.60
P	>0.05 (p=0.717)							
LLSKA	13.09	0.96	11.00	14.70	13.28	0.66	12.00	14.70
p	>0.05 (p=0.109)							
LTS	7.09	0.57	6.10	8.10	6.96	0.46	6.40	7.90
p	>0.05 (p=0.141)							
CLAP	3.84	0.38	3.00	4.50	3.83	0.34	3.00	4.40
p	>0.05 (p=0.851)							

BSA: Body Surface Area, RLA: Right Longitudinal Axis, LLA: Left Longitudinal Axis, DA: Diagonal Axis, APD: Anterior-Posterior Diameter, PVTDR: Portal Vein Transverse Diameter-Right, PVTDL: Portal Vein Transverse Diameter-Left, LLSAP: Longitudinal Liver Scans of the Aortic Plane, LLSSP: Longitudinal Liver Scans of the Sagittal Plane, LLSAK: Longitudinal Liver Scans Axis of the Kidney, LTS: Liver Transverse Scan, CLAP: Caudate Lobe Anterior Posterior Diameter, PVIDa: Portal Vein Internal Diameter at the point where the right hepatic artery crosses over the portal vein and PVIDb: Portal Vein Internal Diameter at the splenoportal confluence.

size measurements. In our study, the corresponding value was found 9.32 cm and 9.30 cm in females and males, respectively. The same value was higher in subjects used alcohol than in subjects used no alcohol. Also, there is no significant difference between age and this parameter. However, obesity, and BMI is a critical and significant factors for liver span measurements. The DA value was measured in Group 1 (BMI is 18.5 to <25, healthy weight; 9.06 cm), Group 2 (BMI is 25.0 to <30, overweight; 8.47 cm) and Group 3 (BMI is 30.0 or higher, obesity; 10.47 cm). There was a significant difference between all Groups. There are some diversities between our findings according to the other studies. Several factors may be effective on liver measurements such as weight, height, age, sex, used methods, anatomical abnormalities, obesity, large-volume ascites, cirrhosis, tumors, hepatomegaly, habits and alcohol consumption, or large samples.

In this paper, the detailed analysis of portal vein morphometry was performed at four different points. The mean values of PVTDR, PVTDL, PVIDa, and PVIDb were measured as 6.85 mm and 7.01 mm; 6.54 m and 6.56 mm; 9.79 mm and 10.08 mm and 10.02 mm and 10.08 mm in females and males, respectively. All values of the portal vein measurements were higher in males than females, however, there was no significant difference between sex. The PVTDR, PVTDL, and PVIDb values showed significant changes depending on age. However, obesity and BMI parameters showed a significant difference in PVIDb measurement. The portal vein is related to the liver structure. It transports deoxygenated but nutrient-rich blood from the gastrointestinal system toward the liver by the portal vein (Al-Nakshabandi, 2006; Ozbülbül, 2011). Ultrasonography has a key role in the evaluations of the portal vein such as diameter, a flow rate of blood, and peak systolic velocity.

Table VI. Liver and portal vein measurements according to Body Mass Index.

Measurements	N	BMI	Mean	SD.	Min.	Max.	P value	Groups 2 - 3	Groups 3 - 4	Groups 2- 4
BSA	2.00	77	17.57	1.26	15.20	19.30	0.068	**0.024**	0.094	0.633
	3.00	55	17.13	0.77	15.20	18.40				
	4.00	57	17.48	1.13	15.00	19.40				
	Total	189	17.41	1.11	15.00	19.40				
RLA	2.00	77	12.77	0.85	11.00	14.40	0.064	0.101	0.606	**0.027**
	3.00	55	13.07	1.25	10.20	14.30				
	4.00	57	13.17	0.97	11.30	14.30				
	Total	189	12.98	1.03	10.20	14.40				
LLA	2.00	77	9.15	0.68	8.20	10.30	0.173	0.541	0.249	0.063
	3.00	55	9.26	1.24	7.60	11.40				
	4.00	57	9.49	1.26	7.20	11.20				
	Total	189	9.29	1.06	7.20	11.40				
DA	2.00	77	9.06	0.79	7.30	11.30	**<0.001**	**<0.001**	**<0.001**	**<0.001**
	3.00	55	8.47	0.92	7.00	10.20				
	4.00	57	10.47	1.00	8.90	12.40				
	Total	189	9.31	1.20	7.00	12.40				
APD	2.00	77	7.82	0.73	6.40	9.30	**<0.001**	**0.005**	**<0.001**	**<0.001**
	3.00	55	7.46	0.70	6.30	8.90				
	4.00	57	8.29	0.73	7.30	9.50				
	Total	189	7.86	0.79	6.30	9.50				
PVTDR	2.00	77	6.87	0.86	5.60	8.50	0.807	0.731	0.780	0.516
	3.00	55	6.93	1.19	5.40	8.50				
	4.00	57	6.98	0.61	5.50	8.30				
	Total	189	6.92	0.91	5.40	8.50				
PVTDL	2.00	77	6.56	0.98	5.10	7.80	0.990	0.996	0.905	0.902
	3.00	55	6.56	0.90	5.00	7.70				
	4.00	57	6.54	0.68	5.00	7.90				
	Total	189	6.56	0.87	5.00	7.90				
PVIDa	2.00	77	9.79	1.38	8.00	12.30	0.453	0.261	0.889	0.324
	3.00	55	10.02	0.63	8.40	11.20				
	4.00	57	9.99	1.21	8.30	11.90				
	Total	189	9.91	1.15	8.00	12.30				
PVIDb	2.00	77	9.87	1.71	7.50	13.50	**<0.001**	0.071	**<0.001**	**<0.001**
	3.00	55	9.38	1.24	7.50	14.00				
	4.00	57	10.93	1.52	9.00	13.60				
	Total	189	10.05	1.64	7.50	14.00				
LLSAP	2.00	77	9.58	1.37	7.50	13.50	**<0.001**	0.589	**<0.001**	**<0.001**
	3.00	55	9.71	1.34	7.30	12.40				
	4.00	57	10.70	1.32	8.30	13.60				
	Total	189	9.95	1.43	7.30	13.60				
LLSSP	2.00	77	9.61	0.90	7.80	11.50	0.215	0.087	0.528	0.292
	3.00	55	9.93	1.19	7.30	12.40				
	4.00	57	9.80	1.10	8.30	11.60				
	Total	189	9.76	1.05	7.30	12.40				
LLSKA	2.00	77	13.31	0.48	12.00	14.00	0.218	0.486	0.334	0.081
	3.00	55	13.21	0.90	11.40	14.70				
	4.00	57	13.06	1.03	11.00	14.70				
	Total	189	13.20	0.81	11.00	14.70				
LTS	2.00	77	6.90	0.52	6.10	7.50	**<0.001**	**<0.001**	**<0.001**	0.445
	3.00	55	7.36	0.52	6.10	8.10				
	4.00	57	6.96	0.46	6.40	7.90				
	Total	189	7.05	0.54	6.10	8.10				
CLAP	2.00	77	3.79	0.40	3.00	4.50	0.277	0.112	0.305	0.617
	3.00	55	3.90	0.31	3.00	4.30				
	4.00	57	3.83	0.34	3.00	4.40				
	Total	189	3.83	0.36	3.00	4.50				

BSA: Body Surface Area, RLA: Right Longitudinal Axis, LLA: Left Longitudinal Axis, DA: Diagonal Axis, APD: Anterior-Posterior Diameter, PVTDR: Portal Vein Transverse Diameter-Right, PVTDL: Portal Vein Transverse Diameter-Left, LLSAP: Longitudinal Liver Scans of the Aortic Plane, LLSSP: Longitudinal Liver Scans of the Sagittal Plane, LLSAK: Longitudinal Liver Scans Axis of the Kidney, LTS: Liver Transverse Scan, CLAP: Caudate Lobe Anterior Posterior Diameter, PVIDa: Portal Vein Internal Diameter at the point where the right hepatic artery crosses over the portal vein and PVIDb: Portal Vein Internal Diameter at the splenoportal confluence.

This information gives a correct, and reliable for assessment of diagnosing disease conditions of the liver (Hawaz *et al*., 2012; Usman *et al*., 2015). In a studying consisting of Nepals, in the mean value of portal vein diameter was 10.8 mm, respectively (Bhattarai *et al*., 2017). The same value was found as 9.8 mm in females and 10.4 mm in males in Ethiopia (Hawaz *et al*., 2012), Esmael *et al*., determined that the portal vein diameter was 13.00 mm in Sudanese people (Ahmed Esmeal & Nagla Hussien, 2019). The corresponding value was reported as 10.6mm in a study of 195 Ethiopian adults. Additionally, Geleto *et al*. (2016) study showed a significant difference between portal vein dimension and changes in age and sex. Conversely, Siddiqui *et al*. (2014) found no a significant difference in the portal vein diameter by sex in Pakistan subjects, however, BMI or obesity factor and age showed a significant difference in the portal vein diameter. The close finding is that there was no significant difference between portal vein and sex in North East India's portal vein parameter (9.17 mm and 8.55 mm, respectively) (Saha *et al*., 2016). The same parameter was measured 11.2mm in USA. Additionally, there was no significant difference between portal vein diameter and sex in these studies (Weinreb *et al*., 1982). For this reason, in the diagnosis of portal hypertension and hepatomegaly, the diameter of the vein and the hepatic span in relation to age, sex and body mass index (BMI) is essential (Siddiqui *et al*., 2014). Although there has been no proven data yet, If a portal vein diameter is higher than 1.3 mm, portal hypertension can be speculated (Weinreb *et al*., 1982). The enlargement in PVD with aging can be explained by fragmentation of smooth muscles and reduction of elasticity in the reticular network (Adibi & Givechian, 2007). Although the association between BMI and PVD has not been expressed, some studies have shown the presence of a relationship between BMI and PVD (Luntsi *et al*., 2016; Saha *et al*., 2016), while there are also studies that have not reported significance between BMI and PVD (Weinreb *et al*., 1982; Siddiqui *et al*., 2014; Khammas & Mahmud, 2020). In this paper, the portal vein diameters were higher in males than females (exclude PVTDL) however, there is no significant difference between BMI, or obesity situation and portal vein diameters (exclude PVIDb). PVIDb was higher in the obese group than the non-obese group.

The liver has an essential metabolic activity that plays a role in homeostasis, nutrition, and immune defense. It requires blood glucose and lipid levels. The liver rapidly increases in size as increased age or from infancy to adulthood (Babu Naik *et al*., 2017). The craniocaudal length of the right lobe was found as 13.5cm in males and 12.9 cm in females, respectively. In left lobe, this parameter was 5.8 cm in males and 5 cm in females, respectively (Babu Naik *et al*., 2017). In this paper, mean value of APD, RLA and LLA were recorded 8.10cm, 12.91cm and 9.40 cm in females, respectively. The same values were 7.68 cm, 13.04 cm and 9.20 cm in males, respectively. All parameters no showed significance in terms of age and sex (exclude APD). In a studying consisting of Sudanese adults, liver APD of males and females was measured as 13.74 cm and 13.03 cm, respectively. A significant differences were noticed between liver APD and age groups, also with sex ($p<0,05$) (Eltahir *et al*., 2020). In a study of Pakistan healthy subjects, the RLA value of males (11.9 cm) and females (11.7 cm), and LLA of males (7.1 cm) and females (7.4 cm) were recorded, and also, no statistical difference between sex in terms of RLA and LLA values (Siddiqui *et al*., 2014). In another study performed by Gameraddin *et al*., with Sudanese healthy and patients, the RLA value was found as 11.93 cm, and LLA value was 9.07 cm (Moawia *et al*., 2015). Compared to these data, our results are slightly low. It could be due to several factors such as ethnic differences, imaging methods, and examiners. An increase in liver measurements is based on to boost in the workload and physiological adaptation for a rise in metabolic charges with aging (Andrew, 2005). Additionally in a studying consisting of Northwest Indian Punjabi (NWI) population (n = 50) and a United Kingdom Caucasian (UKC) population (n = 25), caudate lobe length mean value was in 5.44±1.24 cm (UKC) and in 5.74±1.41 cm (NWI) (Sagoo *et al*., 2018). Moreover, same value was found to be 2.5±0.07 cm among Sudanese population (Ahmed Esmeal & Nagla Hussien, 2019).

The caudate lobe an independent anatomical area is bounded on the left and right sides by the ligamentum venosum fissure, and by the groove for the inferior vena cava, respectively. Also, the porta hepatis is located its inferior side. Being an independent unit makes it relatively safer than other areas of the liver. It also has a separate blood supply, and biliary drainage. Its clinically significant emerges in the cirrhosis. Moreover, knowledge of the caudate lobe's morphology or variations may be important to anatomists and morphologists in determination the new variants, embryologists for new developmental defects, clinicians for diseases, surgeons for planning surgery involving the liver, and radiologists for avoiding misinterpretation of CT and Magnetic Rezonans Imaging. In Indians, the caudate lobe length was 3.38cm (Arora *et al*., 2006). Sahni *et al*. (2000) reported that the length ranged from 4.0 to 9.3 cm and 4.0 to 7.2 cm, respectively. These findings were comparable with the results of the present study (length: 3.38 – 7.03 cm and width: 1.20 – 4.24 cm).

We could not find any study on some of the measurements used in the study in which we examined in detail and performed liver morphometric analysis with the US. Therefore, we were not able to make a comparison with the literature, however, we came across a few striking findings: Alcohol consumption affected the LTS measurement significantly. Whereas a significant difference was no found in LLSAP, LLSSP, LLSKA, and LLSAP measurements were higher in subjects who used alcohol. The LLSSP was similar to both groups. The LLSKA parameter was lower in subjects who used alcohol. The other finding is the effect of aging on LLSAP, LLSSP, LLSKA and LTS. The only two parameters called LLSAK, and LTS affected by aging. The LLSKA parameter obtained the highest value in Decade 6 (13.71) and the lowest value in Decades 5 (12.92). Decade 5 to 6 showed a sharp increase. Moreover, the LTS value increased from decade 1 to decade 5 but decreased from decat 5 onwards. The LLSAP value decreased from decade 1 to decade 5. In decade 5, it showed an increase and then decreased again. However, this decrease in decade 6 was the lowest value seen at all ages. When we analyzed the LLSPP value, it reached its highest value in Decade 3 and an increase was observed until this level. From Decade 3 to Decade 6, the value decreased again. However, the value obtained at Decade 6 was the lowest value of the LLSSP at all ages. The effect of the body mass index on these corresponding values was found. Especially, the LLSAP parameter showed a significant difference in Groups (p<0.001). Additionally, the significance was more clear in Groups 2-4 and Groups 3-4. Furthermore, a significant difference was found in LTS parameter. Especially, this was more distinct in Groups 2-3 and Groups 3-4.

The liver and portal vein dimensions provide important and useful knowledge and reference data as it may determine some abnormalities related liver diseases. Also, in literature, there are some points that need to be clarified about the factors affecting the liver. Although the frequency of alcohol consumption is an important determinant of liver and portal vein morphometry. In our study, the frequency of alcohol consumption was 1 or 2 times a month. We think that the values of the liver and portal vein may may be affected many factors age, sex, race, body mass index (obesity) and, alcohol consumption (frequently).

POLAT, S.; ALTINTAS, Y.; TUNÇ, M.; ÇELIKTAS, M.; BAYRAK, M.; ÖZSAHIN, E.; BOLAT, E. & GÖKER, P. Evaluación ecográfica y anatómica de los valores de referencia del hígado y la vena porta. *Int. J. Morphol., 42(1)*:71-81, 2024.

RESUMEN: El objetivo de este artículo fue realizar una evaluación de la morfometría del hígado y la vena porta mediante ecografía en una población turca sana. Este estudio se llevó a cabo en 189 sujetos (107 mujeres, 82 hombres). Se calcularon los datos demográficos y la superficie corporal. Se midió eleje longitudinal del de dos lóbulos del hígado, el eje diagonal o la extensión del hígado, los diámetros anteroposterior del hígado y de la vena porta, el diámetro transversal de la vena porta, anteroposterior del lóbulo caudado y los diámetros internos de la vena porta, así como las exploraciones longitudinales del hígado en un plano aórtico. Se midieron el plano sagital, el plano transversal y el eje del riñón. Todas las mediciones se analizaron según edad, sexo, índice de masa corporal, obesidad y consumo de alcohol. Los valores medios de edad, talla, peso e índice de masa corporal se calcularon como 44,39 años, 167,05 cm, 74,23 kg y 27,06 kg/m^2 en las mujeres, respectivamente. Las mismas variable fueron 44,13 años, 167,70 cm, 75,93 kg y 26,71 kg/m^2. Hubo diferencias significativas entre las características demográficas, el sexo y el consumo de alcohol en términos de diámetro anteroposterior del hígado, diámetro transversal de la vena porta del lado derecho y exploración transversal del hígado. Además, algunas mediciones, incluido el diámetro transversal de la vena porta, la exploración transversal del hígado y la exploración longitudinal del hígado en el eje del riñón, mostraron diferencias significativas entre los grupos de edad. Hubo diferencias significativas en el eje diagonal y el diámetro anteroposterior del hígado, el diámetro interno de la vena porta y los parámetros de las exploraciones hepáticas longitudinales del plano aórtico entre situaciones de obesidad. Los hallazgos obtenidos proporcionarán valores de referencia importantes y útiles ya que pueden determinar algunas anomalías relacionadas con enfermedades hepáticas. Además, los valores de edad, sexo, obesidad e índice de masa corporal pueden ser eficaces en los parámetros relacionados con la morfometría del hígado y la vena porta.

PALABRAS CLAVE: Valores de referencia de hígado y vena porta; Ultrasonografía; Obesidad; Cambios relacionados con la edad y el sexo.

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