Journal of Basic Research in Medical Sciences

Journal HomePage : https://jbrms.medilam.ac.ir

Ilam University of Medical Sciences Publications

# The Relationship of Thickness of the Subcutaneous Fat of the Anterior Abdominal Wall and the grade of Hepatic Steatosis

**Somayeh Zeynizadeh Jeddi** [1]✉, **Afshan Sharghi** [2], **Sahand Ghorbani Davatgar** [1]

[1] Department of Radiology, School of medicine, Ardabil university of medical science, Ardabil, Iran
[2] Department of Community Medicine and Biostatistics, School of medicine, Ardabil university of medical science, Ardabil, Iran

**Article Info**

***Article type:***
Original Article

***Article History:***
Received: Apr. 30, 2025
Revised: Oct. 15, 2025
Accepted: Nov. 04, 2025
Published Online: Jun. 16, 2026

✉ ***Correspondence to:***
Somayeh Zeynizadeh Jeddi
Department of Radiology, School of medicine, Ardabil university of medical science, Ardabil, Iran

**Email:**
s.zeynizadeh@arums.ac.ir

**A B S T R A C T**

**Introduction**: Non-alcoholic fatty liver disease (NAFLD) is the most frequent cause of fat buildup in the liver, which results in liver disease. This condition is becoming more commonplace worldwide. Knowing the causes of the disease is crucial for preventing and minimizing its effects, especially since the etiology of the condition is not fully understood. The aim of this study was to investigate the relationship between hepatic steatosis grading and the thickness of the subcutaneous fat of the anterior abdominal wall.

**Materials & Methods:** In this descriptive cross-sectional study, all 181 patients underwent ultrasound scanning to determine the grade of their fatty liver, as well as to measure the thickness of the anterior abdominal wall's subcutaneous fat at the RUQ. The fatty liver grading was between 0 and 3. The questionnaire was filled out with the patient's height, weight, age, gender, fatty liver grade, thickness of subcutaneous fat, and underlying medical conditions.

**Results:** This study revealed that the distribution of hepatic steatosis among 47% of participants was normal (grade 0), while 42.5%, 9.4%, and 1.1% were classified as grade 1, grade 2, and grade 3 of fatty liver, respectively, as per ultrasonographic classification. Quantitative analysis of abdominal adiposity showed a mean anterior abdominal wall subcutaneous fat thickness of 16.31±6.45 mm. Crucially, subcutaneous fat thickness showed a significant positive correlation with hepatic steatosis grade ($r = 0.39$, $p = 0.001$), and each additional millimeter of fat thickness raised the likelihood of advanced steatosis. These results substantiate the clinical relevance of abdominal wall fat measurement as a potential surrogate marker for NAFLD severity.

**Conclusion:** The current study showed that more than half of patients had fatty liver in grades 1-3, and programming to change the lifestyle of people to avoid weight gain and manage NAFLD is necessary.

**Keywords**: Fatty Liver, Subcutaneous, Thickness, Ultrasound

➢ **Cite this paper**
Zeynizadeh Jeddi S, Sharghi A, Ghorbani Davatgar S. The Relationship of Thickness of the Subcutaneous Fat of the Anterior Abdominal Wall and the grade of Hepatic Steatosis. *J Bas Res Med Sci*. 2026; 13(3):38-47.

[ Downloaded from demo.medilam.ac.ir on 2026-11-14 ]

© Author(s) retain the copyright

**Publisher**: Ilam University of Medical Sciences

## Introduction

NAFLD is the leading cause of chronic liver disease worldwide (1), with the hallmark feature of fat accumulation in the liver that can evolve from simple steatosis to non-alcoholic steatohepatitis (NASH), fibrosis, and ultimately cirrhosis or hepatocellular carcinoma (HCC). This disease epidemic is paralleled by the worldwide rise of metabolic disorders. Major risk factors are obesity (especially visceral adiposity), type 2 diabetes mellitus (T2DM), insulin resistance, dyslipidaemia and hypertension (2, 3).

NAFLD has become the third most common indication for liver transplantation and the most common cause of hospitalisation for liver disease among gastrointestinal diseases (4–6). In T2DM populations, prevalence of NAFLD is >70%, highlighting diabetes as a risk factor and disease accelerator (7).

Ultrasonography is still the first line diagnostic modality. It is accessible and reliable in detecting hepatic steatosis (sensitivity 85%, specificity 94%) (8). It is helpful to estimate the thickness of the subcutaneous fat, but the current evidence does not conclusively show its association with the severity of NAFLD (9).

Given the importance of liver health and the lack of similar studies in Ardabil, we decided to investigate the relationship between the grade of fatty liver and the thickness of the subcutaneous fat of the anterior abdominal wall in patients referred to the ultrasound department of Alavi Hospital in Ardabil.

## Materials and methods

### *Study Design*

This descriptive cross-sectional study was conducted to investigate the relationship between the thickness of the anterior abdominal wall subcutaneous fat and the grade of hepatic steatosis among patients referred to the ultrasound department of Ardabil University of Medical Sciences-affiliated hospitals in 2021.

### *Setting and Participants*

The study population consisted of outpatients referred to the ultrasound department of Alavi Hospital for complaints unrelated to liver diseases. A convenience sampling method was used to recruit participants.

The inclusion criteria were age ≥15 years, referral for abdominal ultrasonography for non-hepatic complaints, and willingness to participate in the study. The exclusion criteria included known liver diseases (such as cirrhosis, hepatic masses, hepatitis, or liver failure), previous abdominal wall surgery (e.g., liposuction or abdominoplasty), current treatment for fatty liver disease, use of lipid-lowering medications, pregnancy, and incomplete clinical information. All the participants underwent abdominal ultrasonography by an expert radiologist after written informed consent. Hepatic steatosis was graded based on ultrasonographic findings as follows: grade 0, normal liver echogenicity; grade 1, mild steatosis; grade 2, moderate steatosis; grade 3, severe steatosis.

### *Sample Size*

The sample size was calculated for correlation studies considering a confidence level of 95%, statistical power of 80%, and an expected correlation coefficient of 0.25 based on previous studies investigating the relationship between abdominal fat thickness and NAFLD severity. The minimum required sample size was estimated to be 170 participants. Considering possible incomplete data, 181 participants were finally included in the study.

### Measurements & Validity and Reliability

### *Demographic and Clinical Characteristics Checklist*

[ Downloaded from demo.medilam.ac.ir on 2026-11-14 ]

Demographic and clinical data were collected using a researcher-developed checklist. The checklist included variables such as age, gender, height, weight, body mass index (BMI), history of diabetes mellitus, hypertension, thyroid disorders, heart failure, anemia, multiple sclerosis, hepatic steatosis grade, and anterior abdominal wall subcutaneous fat thickness.

### *Assessment of Hepatic Steatosis by Ultrasound*

Hepatic steatosis grading was evaluated by ultrasonography performed by an experienced radiologist using a Voluson E6 ultrasound machine. Liver echogenicity was assessed using a curvilinear probe, and hepatic steatosis was graded 0–3 according to standard ultrasonographic criteria. Ultrasonography is a reliable and valid method for detection of fatty liver disease with a reported sensitivity and specificity of about 85% and 94%, respectively (5).

All ultrasonographic examinations were performed under standardized conditions by the same radiologist to ensure the reliability of measurements.

### *Measurement of Subcutaneous Fat Thickness of Anterior Abdominal Wall*

A linear ultrasound probe was used to measure the subcutaneous fat thickness at the anterior abdominal wall in the right upper quadrant (RUQ). Measurements were made in millimetres with the patient in supine position during quiet respiration.

### *Statistical and Data Analysis*

After collection of data, data were entered in SPSS V.26 and analysed with analytical statistical techniques including logistic regression, T-test and chi-square for quantitative and qualitative data and descriptive statistics presented in tables and graphs. Significance level was less than 0.05.

## Results

Out of the 181 participants in the study, 19 individuals (10.5%) were men and 162 (89.5%) were women. The average age of patients was 37.98 ± 15.02 in the range of 15 to 92 years. Thyroid dysfunction was the most common underlying condition, affecting 14 individuals (7.7% of the population), whereas anemia and multiple sclerosis were the least common, affecting 1 individual each (0.6%) (Figure 1). In terms of BMI, the highest frequency was related to the overweight group (39.8%), and the lowest frequency was related to severe obesity (Figure 2).

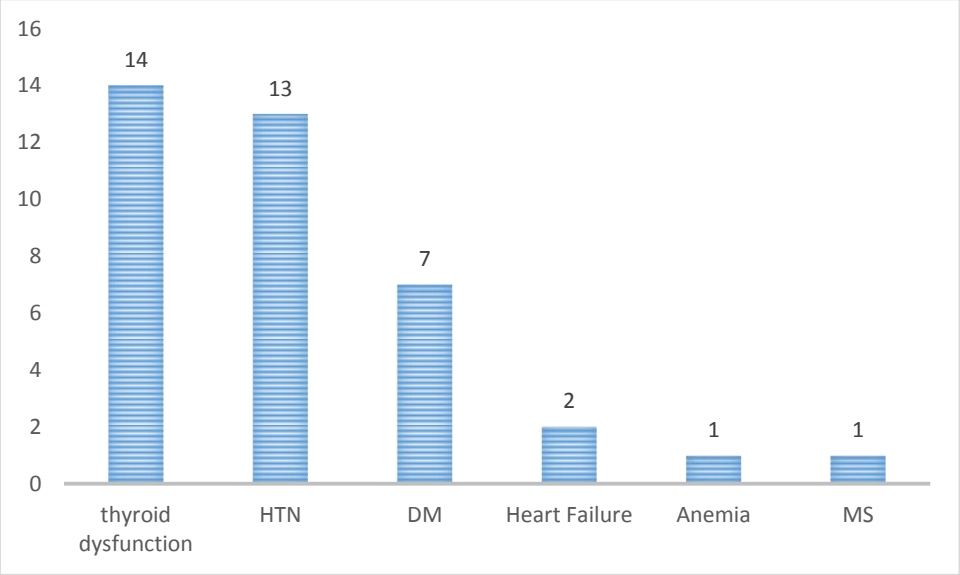



**Figure 1.** Distribution of underlying disease history in the study subjects.

[ Downloaded from demo.medilam.ac.ir on 2026-11-14 ]

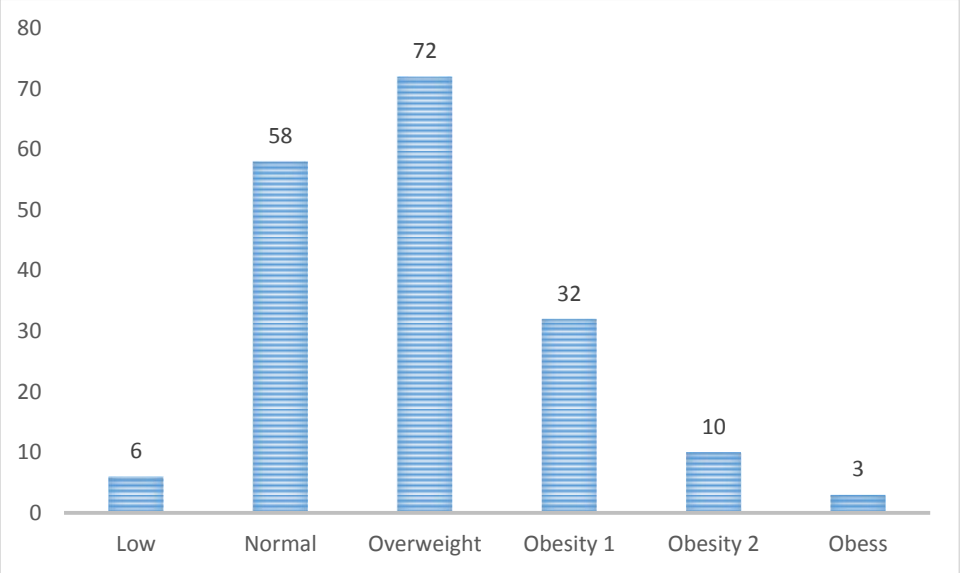



**Figure 2.** BMI distribution in study subjects.

Among 181 patients, 85 patients (0.47%) had normal liver and 77 patients (42.5%) had mild fatty liver (grade 1). The average thickness of the subcutaneous fat of the anterior abdominal wall was 16.31±6.45 mm (Figure 3).

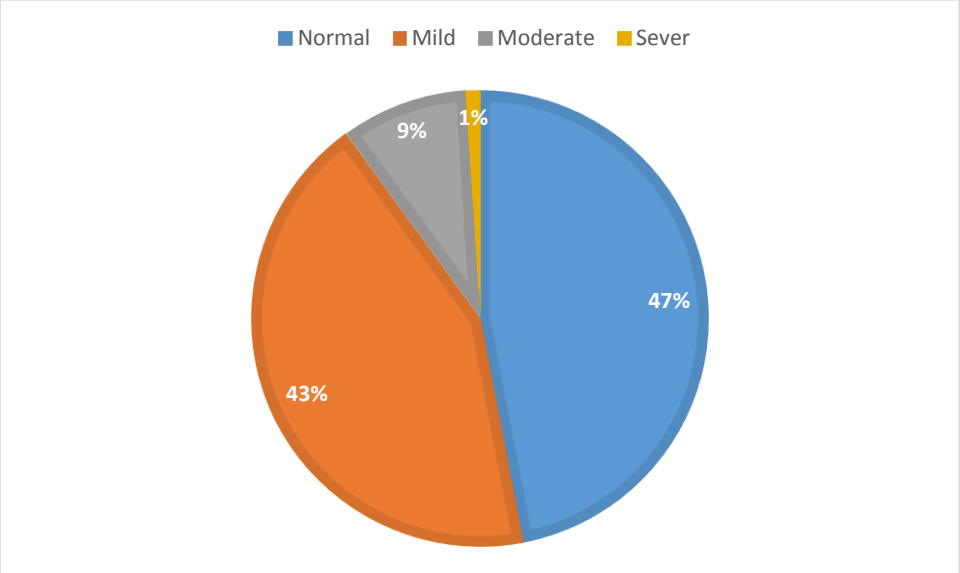



**Figure 2.** Fatty liver distribution of study subjects.

Age and the study participants' fatty liver grade did not significantly correlate. Furthermore, most of the males and females had normal grades, and the gender of participants doesn't have a significant relation with the grading of fatty liver (Table 1).

**Table 1.** Relation between gender and hepatic steatosis grading.

| Grading | Gender | | p-value |
|---|---|---|---|
| | male | female | |
| Normal | 7 (36.8) | 78 (48.1) | 0.16 |
| Mild | 7 (36.85) | 70 (43.3) | |

[ Downloaded from demo.medilam.ac.ir on 2026-11-14 ]

| | | | |
|---|---|---|---|
| Moderate & Sever | 5 (26.4) | 14 (8.6) | |
| Total | 19 (10.5) | 162 (89.5) | |

Chi-square test

A significant relation was found between BMI and fatty liver grading in the studied subjects (P=0.001) (Table 2). There was no significant relationship between the history of diabetes and fatty liver grading in the studied subjects (Table 3).

**Table 2.** relation between BMI and fatty liver grading.

| Grading | BMI | | | | p-value |
|---|---|---|---|---|---|
| | low | normal | overweight | Obesity | |
| Normal | 6 (7.1) | 38 (44.7) | 33 (38.8) | 8 (9.4) | 0.001 |
| Mild | 1 (1.1) | 19 (21.8) | 31 (35.6) | 26 (29.9) | |
| Moderate & Sever | 1 (4.6) | 2 (9.1) | 8 (36/4) | 11 (50) | |
| Total | 6 (3.3) | 58(32) | 72(39.8) | 45(24.9.7) | |

Chi-square test

**Table 3.** Relation between DM and fatty liver grading.

| Grading | DM | | p-value |
|---|---|---|---|
| | - | + | |
| Normal | 82 (96.5) | 3 (3.5) | 0.94 |
| Mild | 74 (96.1) | 3 (3.9) | |
| Moderate & Sever | 18 (94.7) | 1 (5.3) | |
| Total | 174 (96.1) | 7(3.9) | |

Chi-square test

There was no discernible relation between the participants' fatty liver grades and their histories of hypertension, heart failure, or thyroid conditions (p=0.94). In the participants under study, the degree of fatty liver was shown to be significantly correlated with the thickness of the front abdominal wall's subcutaneous fat. in a way that made the severity of fatty liver worse by making the subcutaneous fat thicker. Also, Spearman's correlation coefficient showed that the severity of fatty liver increased with the increase of subcutaneous thickness (the correlation coefficient (r) was positive and equal to 0.391) (Table 4).

**Table 4.** Relation between subcutaneous thickness and grading of hepatic steatosis.

| Grading | subcutaneous thickness (mm) | | p-value | r |
|---|---|---|---|---|
| | mean | SD | | |
| Normal | 13.75 | 5.43 | 0.001 | 0.392 |
| Mild | 16.4 | 6.6 | | |
| Moderate | 20.06 | 6.76 | | |

Pearson correlation and analysis of variance (ANOVA) were used

## Discussion

In the present study, 181 participants were included and 85 subjects (47%) had normal liver findings and 77 patients (42.5%) had mild fatty liver (grade 1). These findings are in good agreement with previous epidemiological reports that NAFLD is currently the

[ Downloaded from demo.medilam.ac.ir on 2026-11-14 ]

most common chronic liver disease worldwide, affecting nearly one-third of adults in developed countries (7). The rise in NAFLD has been mainly associated with sedentary lifestyle, obesity, poor dietary habits and decreased physical activity. It has also been reported in previous studies that the prevalence of fatty liver disease increases with age and is generally more common in men before the age of 60 (8-12). After menopause, however, women become more susceptible to NAFLD, owing to hormonal and metabolic changes (13–15). In our study, there was no statistically significant association between age and fatty liver grade, suggesting that factors other than age may be more dominant in the studied population.

Fan et al. reported a dramatic increase in the prevalence of NAFLD in Asian populations, especially in urban and affluent areas where obesity rates have increased substantially. The results showed that NAFLD affected about 15% of the people in developed areas of China and the prevalence has doubled in the last decade due to the obesity epidemic. Moreover, many studies have verified that weight loss could remarkably improve hepatic steatosis. In diabetic and non-diabetic subjects, a 5–10% loss of body weight can reduce the content of liver fat by almost 40% (16-17). Aerobic exercise has been demonstrated to independently decrease hepatic fat accumulation independently of weight loss through mechanisms such as improved insulin sensitivity, increased fatty acid oxidation, and suppression of peripheral lipolysis (18–19). Dietary restriction and exercise may improve hepatic steatosis in obese patients, but the effects on liver fibrosis and inflammation remain unclear (20), as shown by Sugawara et al. Similarly, lifestyle interventions have been shown to enhance physical fitness, serum cholesterol, insulin sensitivity, and blood pressure in older adults (21). Overall, these results are in line with the strong association between BMI and hepatic steatosis found in our study and support the role of obesity and metabolic dysfunction in the pathogenesis and progression of NAFLD.

The association of NAFLD with metabolic syndrome has been widely discussed in the literature. Lenzi et al. pointed out that insulin resistance, the main mechanism of metabolic syndrome recognised today, is strongly associated with the progression of NAFLD (22). They found that the prevalence of metabolic syndrome increases significantly with increasing BMI from about 18% in normal-weight to more than 60% in obese patients. Our results also demonstrated a significant correlation between BMI and the grade of fatty liver, in support of the hypothesis that obesity and accumulation of adipose tissue are major contributors to the severity of hepatic steatosis. However, other factors such as ethnicity, genetic predisposition and coexisting disease may also play a role in the evolution of NAFLD and may account for the discrepancy between different populations.

Cardiovascular diseases represent another important concern in patients with NAFLD. NAFLD patients often suffer from multiple cardiovascular risk factors like obesity, hypertension, dyslipidaemia and insulin resistance (23). Various mechanisms have been proposed to explain the association between NAFLD and cardiovascular disease including systemic inflammation, oxidative stress, endothelial dysfunction, altered adipokine secretion and abnormal lipid metabolism (24). In the present study, no significant relationship was found between the grade of fatty liver and history of hypertension or heart failure. Esposito et al. (25) reported that even non-obese NAFLD patients without diabetes or hypertension may show early signs of left ventricular dysfunction detected by echocardiography. Targher et al. also suggested that NAFLD may be not only a marker of cardiovascular disease, but also an active contributor to the development of atherosclerosis through pro-inflammatory and proatherogenic mechanisms (23). We did not observe a direct association of

[ Downloaded from demo.medilam.ac.ir on 2026-11-14 ]

cardiovascular disease with the degree of hepatic steatosis; nevertheless, patients with NAFLD should be considered as being at increased cardiovascular risk and should be regularly monitored for metabolic and cardiovascular health.

Diabetes mellitus is another major metabolic disorder closely associated with NAFLD. While previous studies reported this relationship, our investigation was unable to show significant association between fatty liver grading and history of diabetes. An association between fatty liver and increased risk of future hyperglycemia and type 2 diabetes was found by Okamoto et al. (26). Similarly, Yamazaki et al. showed that improvement of NAFLD is independently associated with reduced incidence of type 2 diabetes (27). Salehi et al. also reported that high triglyceride levels and low HDL concentrations are associated with worsening of glycaemic indices in patients with fatty liver disease (28). In addition, the incidence of type 2 diabetes was also significantly higher in those with fatty liver than in those without fatty liver according to Yamada et al. (29). Similarly, Williams et al. concluded that diabetic patients are most likely to develop NAFLD and non-alcoholic steatohepatitis (30). Thus, although in our study, no statistically significant association was found between diabetes and NAFLD severity, the role of insulin resistance and glucose metabolism abnormalities in the pathogenesis of NAFLD is well established in the literature (31).

Our results further support the close association between the components of metabolic syndrome and the severity of NAFLD. Obesity, hypertension, dyslipidaemia and insulin resistance have been repeatedly proved in previous studies to be closely associated with the progression of hepatic steatosis (14-15, 32-34). Specifically, insulin resistance causes an increase in fatty acids accumulation in the hepatocytes, resulting in oxidative stress, inflammation, and cellular injury. Although our study was largely based on BMI and not on detailed metabolic parameters, the strong association of obesity with fatty liver grading in our participants is in line with these pathogenic mechanisms. The lack of robust associations with diabetes and cardiovascular diseases in our study could be due to differences in population characteristics, sample size or study design.

One of the most important findings of the present study was the significant positive correlation between the anterior abdominal wall subcutaneous fat thickness and hepatic steatosis grade. Ultrasonography measurement of abdominal fat has been suggested as a simple non invasive method for evaluating severity and metabolic risk of NAFLD. Fukuda et al. showed that ultrasonographic estimation of preperitoneal and subcutaneous fat thickness is useful in the diagnosis of NAFLD among diabetic patients and might even predict advanced fibrosis (35). Similarly, our study found that increased subcutaneous fat thickness was significantly associated with more severe grades of fatty liver. These findings support the possible clinical utility of measuring abdominal fat during routine ultrasonography as an accessible marker for screening NAFLD and for assessing its severity.

But the results of previous studies were not all consistent. Murad Hasli et al. showed that the degree of hepatic steatosis was independently associated with mesenteric fat thickness in patients with NAFLD (2). However, Liu et al. found that mesenteric fat thickness was significantly increased in fatty liver patients, while thickness of abdominal subcutaneous fat was not significantly associated with hepatic steatosis (36). The discrepancy in results may be attributed to differences in study populations, imaging modalities, sample sizes or the methods used to quantify adiposity. However, visceral and abdominal adiposity is important in the development and progression of NAFLD according to the weight of evidence. Hence further large and controlled studies are needed to define the exact relationship between the different abdominal fat

[ Downloaded from demo.medilam.ac.ir on 2026-11-14 ]

compartments and the severity of the hepatic steatosis.

## Limitations and Strengths

One of the main strengths of this study was the use of ultrasonography as a non-invasive, accessible, and cost-effective method for simultaneous evaluation of hepatic steatosis and abdominal subcutaneous fat thickness. The evaluation of the relationship between anterior abdominal wall fat thickness and severity of NAFLD in the Iranian population provided useful local data that may be useful for future metabolic and hepatologic research. An additional strength was the inclusion of patients with different grades of fatty liver, allowing comparison across different severities of disease.

However, this study had some limitations as well. First, the cross-sectional design of the study limited the ability to establish causal relationships between the thickness of abdominal fat and the severity of NAFLD. Second, the generalisability of the findings may be limited by the relatively small sample size and the predominance of women. Third, liver biopsy, the gold standard for diagnosis of NAFLD, was not performed. Finally, not all the metabolic and laboratory parameters in detail were completely evaluated.

## Conclusion

The present study shows a significant positive correlation between the thickness of the subcutaneous fat of the anterior abdominal wall and the grade of hepatic steatosis in patients undergoing ultrasound examination. Our results suggest that measurement of subcutaneous fat thickness may be a useful non-invasive parameter of NAFLD severity. This association underscores the clinical importance of measuring abdominal fat in routine work-ups to better identify those at risk of advanced fatty liver disease and guide timely interventions.

### Funding

This study was funded by Ardabil University of Medical Sciences.

### CRediT authorship contribution statement

Conceptualization, Methodology, Validation, Formal Analysis: SZJ, Investigation, Resources, Software: AS, Data Curation, Writing–Original Draft Preparation, Writing–Review & Editing, Visualization, Supervision, Project Administration: SZJ, SGD.

### Declaration of Generative AI and AI-assisted technologies in the writing process

We did not use artificial intelligence programs in this article.

### Conflict of interest

All authors declare that they have no conflict of interest.

### Ethical considerations

Ethical concerns included acquiring the ethics code (IR.ARUMS.REC.1399.549), ensuring integrity in library collection and data reporting, getting signed informed permission from all participants in accordance with the Declaration of Helsinki, and adhering to principles of human intervention.

### Data availability statement

All data of this study can be in access by email with corresponding Author.

### Acknowledgements

Authors would like to thanks all participants in this study.

[ Downloaded from demo.medilam.ac.ir on 2026-11-14 ]

## References


1. Younossi ZM, Koenig AB, Abdelatif D, Fazel Y, Henry L, Wymer M. Global epidemiology of nonalcoholic fatty liver disease-Meta-analytic assessment of prevalence, incidence, and outcomes. Hepatology. 2016;64(1):73-84.https://doi.org/ 10.1002/hep.28431.
2. Powell EE, Wong VW, Rinella M. Non-alcoholic fatty liver disease. Lancet. 2021;397(10290):2212-2224. https://doi.org/10.1016/S0140-6736(20)32511-3.
3. Rinella ME. Nonalcoholic fatty liver disease: a systematic review. JAMA. 2015;313(22):2263-73. https://doi.org/10.1001/jama.2015.5370
4. Allen AM, Van Houten HK, Sangaralingham LR, Talwalkar JA, McCoy RG. Healthcare Cost and Utilization in Nonalcoholic Fatty Liver Disease: Real-World Data From a Large U.S. Claims Database. Hepatology. 2018;68(6):2230-38. https://doi.org/10.1002/hep.30094.
5. Ilyas F, Ali H, Patel P, Sarfraz S, Basuli D, Giammarino A, et al. Increasing nonalcoholic fatty liver disease-related mortality rates in the United States from 1999 to 2022. Hepatol Commun. 2023;7(7):e00207. https://doi.org/10.1097/HC9.0000000000000207.
6. Friedman SL. Mechanisms of NAFLD development. Nat Med.2018;24(7):908-22. https://doi.org/ 10.1038/s41591-018-0104-9.
7. Mantovani A, Byrne CD, Bonora E, Targher G. Nonalcoholic Fatty Liver Disease and Risk of Incident Type 2 Diabetes: A Meta-analysis. Diabetes Care. 2018;41(2):372-82. https://doi.org/10.2337/dc17-1902.
8. Hernaez R, Lazo M, Bonekamp S, Kamel I, Brancati FL, Guallar E, et al. Diagnostic accuracy and reliability of ultrasonography for the detection of fatty liver: a meta-analysis. Hepatology. 2011;54(3):1082-90. https://doi.org/10.1002/hep.24452.
9. Mustapic S, Ziga S, Matic V, Bokun T, Radic B, Lucijanic M, Marusic S, Babic Z, Grgurevic I. Ultrasound Grade of Liver Steatosis Is Independently Associated with the Risk of Metabolic Syndrome. Can J Gastroenterol Hepatol. 2018;2018:8490242. https://doi.org/10.1155/2018/8490242.
10. Okanoue T, Umemura A, Yasui K, Itoh Y. Nonalcoholic fatty liver disease and nonalcoholic steatohepatitis in Japan. J gastroenterolo hepatol.2011;26:153-62. https://doi.org/10.1111/j.1440-1746.2010.06547.x.
11. Kagansky N, Levy Sh, Keter D, Rimon E, Taiba Z,Fridman Z, et al. Non-alcoholic fatty liver disease–a common and benign finding in octogenarian patients. Liver Int. 2004;24(6):588-94. https://doi.org/10.1111/j.1478-3231.2004.0969.x.
12. Sweeny KF, Lee CK. Nonalcoholic Fatty Liver Disease in Children. Gastroenterol Hepatol (N Y). 2021;17(12):579-587.
13. Hashimoto E, Tokushige K. Prevalence, gender, ethnic variations, and prognosis of NASH. Journal of gastroenterology. 2011;46:63-69. https://doi.org/10.1007/s00535-010-0311-8.
14. FAN JG, Zhu J, Li XJ, Chen L, Lu YS, Li L, et al. Fatty liver and the metabolic syndrome among Shanghai adults.J gastroenterol hepatol.2005;20(12):1825-32. https://doi.org/ 10.1111/j.1440-1746.2005.04058.x.
15. Fan JG, Farrell GC. Epidemiology of non-alcoholic fatty liver disease in China. Journal of hepatology. 2009;50(1):204-210. https://doi.org/10.1016/j.jhep.2008.10.010.
16. Chiang DJ, Pritchard MT, Nagy LE. Obesity, diabetes mellitus, and liver fibrosis. American Journal of Physiology-Gastrointestinal and Liver Physiology. 2011;300(5):G697-G702. https://doi.org/10.1152/ajpgi.00426.2010.
17. Larson-Meyer DE, Heilbronn LK, Redman LM, Newcomer BR, Frisard MI, Anton S, et al. Effect of calorie restriction with or without exercise on insulin sensitivity, β-cell function, fat cell size, and ectopic lipid in overweight subjects. Diabetes care. 2006;29(6):1337-44. https://doi.org/10.2337/dc05-2565.
18. Stewart KJ, Bacher AC, Turner K, Lim JG,Hees PS, Shapiro EP, et al. Exercise and risk factors associated with metabolic syndrome in older adults. Am J Prev Med. 2005;28(1):9-18. https://doi.org/10.1016/j.amepre.2004.09.006.
19. Rafiq N, Younossi ZM. Effects of weight loss on nonalcoholic fatty liver disease. Semin Liver Dis.2008;28(4)::427-33. https://doi.org/ 10.1055/s-0028-1091986.
20. Ueno T, Sugawara H, Sujaku K, et al. Therapeutic effects of restricted diet and exercise in obese patients with fatty liver. Journal of hepatology.1997;27(1):103-107. https://doi.org/ 10.1016/s0168-8278(97)80287-5.
21. Shah K, Stufflebam A, Hilton TN, Sinacore DR, Klein S, Villareal DT. Diet and exercise interventions reduce intrahepatic fat content and improve insulin sensitivity in obese older adults. Obesity. 2009;17(12):2162-2168. https://doi.org/10.1038/oby.2009.126.
22. Marchesini G, Bugianesi E, Forlani G, et al. Nonalcoholic fatty liver, steatohepatitis, and the metabolic syndrome. Hepatology. 2003;37(4):917-23. https://doi.org/10.1053/jhep.2003.50161.
23. Targher G, Day CP, Bonora E. Risk of cardiovascular disease in patients with nonalcoholic fatty liver disease. New England Journal of Medicine. 2010;363(14):1341-50. https://doi.org/10.1056/NEJMra0912063.
24. Liu H, Lu H-Y. Nonalcoholic fatty liver disease and cardiovascular disease. World journal of gastroenterology: WJG. 2014;20(26):8407. https://doi.org/10.3748/wjg.v20.i26.8407.
25. Perseghin G, Lattuada G, De Cobelli F, et al. Increased mediastinal fat and impaired left ventricular energy metabolism in young men with newly found fatty liver. Hepatology. 2008;47(1):51-8. https://doi.org/10.1002/hep.21983.
26. Okamoto M, Takeda Y, Yoda Y, Kobayashi K, Fujino MA, Yamagata Z. The association of fatty liver and diabetes risk. Journal of epidemiology. 2003;13(1):15-21. https://doi.org/10.2188/jea.13.15.


[ Downloaded from demo.medilam.ac.ir on 2026-11-14 ]

27. Yamazaki H, Tsuboya T, Tsuji K, Dohke M, Maguchi H. Independent association between improvement of nonalcoholic fatty liver disease and reduced incidence of type 2 diabetes. Diabetes care. 2015;38(9):1673-79. https://doi.org/10.2337/dc15-0140.
28. Salehi M, Islamivaghar M, Nasrabadi T. Evaluation of the relationship between fatty liver disease and diabetes in patients referred to hospitals affiliated to Shahid Beheshti University of Medical Sciences, Tehran, Iran. Journal of Diabetes Nursing. 2016;4(2):25-39.
29. Yamada T, Fukatsu M, Suzuki S, Wada T, Yoshida T, Joh T. Fatty liver predicts impaired fasting glucose and type 2 diabetes mellitus in Japanese undergoing a health checkup. Journal of gastroenterology and hepatology. 2010;25(2):352-6. https://doi.org/10.1111/j.1440-1746.2009.05998.x.
30. Williams CD, Stengel J, Asike MI, et al. Prevalence of nonalcoholic fatty liver disease and nonalcoholic steatohepatitis among a largely middle-aged population utilizing ultrasound and liver biopsy: a prospective study. Gastroenterology. 2011;140(1):124-31. https://doi.org/ 10.1053/j.gastro.2010.09.038.
31. Tohidi M, Harati H, Hadaege F, Mehrabi Y, Azizi F. Association of liver enzymes with incident type 2 diabetes: Tehran lipid and glucose study. Journal of Diabetes and Metabolic Disorders. 2007; 7:5-8.
32. Schmitz-Peiffer C. Signalling aspects of insulin resistance in skeletal muscle: mechanisms induced by lipid oversupply. Cellular signalling. 2000;12(9):583-94. https://doi.org/10.1016/s0898-6568(00)00110-8.
33. Lazo M, Clark JM. The epidemiology of nonalcoholic fatty liver disease: a global perspective. Semin Liver Dis.2008;28(4):339-50. https://doi.org/10.1055/s-0028-1091978.
34. Liu CC, Hung CL, Shih SC, Ko HJ, Lu YT, Wu YJ, et al. Age-related Differences in the Clinical Presentation, Associated Metabolic Abnormality, and Estimated Cardiovascular Risks from Nonalcoholic Fatty Liver Disease: A Cross-sectional Study from Health Evaluation Center in Taiwan. International Journal of Gerontology.2010;4(4):184-91. https://doi.org/10.1016/j.ijge.2010.11.005
35. Fukuda K, Seki Y, Ichihi M, Okada T, Hirata A, Kogita S, et al. Usefulness of ultrasonographic estimation of preperitoneal and subcutaneous fat thickness in the diagnosis of nonalcoholic fatty liver disease in diabetic patients. Journal of Medical Ultrasonics. 2015;42:357-63. https://doi.org/10.1007/s10396-015-0615-7.
36. Liu K, Chan Y, Chan J, Chan W, Kong W. Mesenteric fat thickness as an independent determinant of fatty liver. International journal of obesity.2006;30(5):787-93. https://doi.org/10.1038/sj.ijo.0803201.

[ Downloaded from demo.medilam.ac.ir on 2026-11-14 ]