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## Research Article

# Adipose Tissue Elastography, Anthropometric Parameters and Non-Alcoholic Fatty Liver Disease in Obese Adults: A Cross-Sectional Study

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**Abstract**

***Background***: Obesity is recognized as a significant global health crisis, with over a third of the world's population affected, posing severe health and economic challenges. ***Objectives***: To investigate the differences in subcutaneous adipose tissue (SAT) characteristics, specifically thickness and stiffness, between young (20-39 years) and middle-aged (40-59 years) obese individuals and examine sex-specific variations and associations with non-alcoholic fatty liver disease (NAFLD). ***Methods***: One hundred obese participants were evaluated using anthropometric measurements (body mass index and waist-height ratio) and ultrasonic shear wave elastography to assess NAFLD and SAT structure across three anatomical sites. ***Results***: Participants in their middle years had stiffer SATs, especially in the upper abdomen and distal triceps. However, there were no significant differences in BMI, waist-to-height ratio, or SAT thickness at the mid-thigh based on age. Additionally, NAFLD prevalence was found in 31 participants, with a notable correlation between its presence and SAT thickness & obesity metrics, although SAT stiffness did not significantly correlate with NAFLD. ***Conclusions***: The dynamic nature of SAT as it relates to aging and sex, emphasizing the need for tailored therapeutic approaches in managing obesity and associated metabolic disorders. According to this study, elastography could be a non-invasive way to check for organ damage due to obesity and could aid in the prediction of NAFLD when combined with routine body measurements. Further research is warranted to refine assessment methodologies and validate anatomical site representativeness.

***Keywords***: Anthropometry, Elastography, Obesity, Non-alcoholic fatty liver, Subcutaneous adipose tissue.

**التصوير المرن للأنسجة الدهنية والمعلمات الأنثروبومترية ومرض الكبد الدهني غير الكحولي لدى البالغين الذين يعانون من السمنة المفرطة: دراسة مقطعية**

**الخلاصة**

**الخلفية**: تعتبر السمنة أزمة صحية عالمية كبيرة حيث يتأثر بها أكثر من ثلث سكان العالم، مما يشكل تحديات صحية واقتصادية خطيرة. **الأهداف**: التحقيق في الاختلافات في خصائص الأنسجة الدهنية تحت الجلد (SAT)، وتحديدا السماكة والتصلب، بين الأفراد الذين يعانون من السمنة المفرطة (20-39 عاما) ومتوسطي العمر (40-59 عاما) وفحص الاختلافات الخاصة بالجنس والارتباطات بمرض الكبد الدهني غير الكحولي (NAFLD). **الطرائق**: تم تقييم مائة مشارك يعانون من السمنة المفرطة باستخدام قياسات الأنثروبومترية (مؤشر كتلة الجسم ونسبة الخصر إلى الطول) وتصوير الموجات المرنة بالموجات فوق الصوتية لتقييم بنية NAFLD و SAT عبر ثلاثة مواقع تشريحية. **النتائج**: كان لدى المشاركين في سنواتهم المتوسطة SAT أكثر صلابة، خاصة في الجزء العلوي من البطن والعضلة ثلاثية الرؤوس البعيدة. ومع ذلك، لم تكن هناك فروق ذات دلالة إحصائية في مؤشر كتلة الجسم أو نسبة الخصر إلى الطول أو سمك SAT في منتصف الفخذ بناء على العمر. بالإضافة إلى ذلك، تم العثور على انتشار مرض الكبد الدهني غير الكحولي في 31 مشاركا، مع وجود علاقة ملحوظة بين وجوده ومقاييس سمك والسمنة في اختبار SAT، على الرغم من أن تصلب اختبار SAT لم يرتبط ارتباطا كبيرا بمرض الكبد الدهني غير الكحولي. **الاستنتاجات**: الطبيعة الديناميكية لاختبار SAT من حيث صلته بالشيخوخة والجنس، مع التأكيد على الحاجة إلى مناهج علاجية مصممة خصيصا في إدارة السمنة واضطرابات التمثيل الغذائي المرتبطة بها. وفقا لهذه الدراسة يمكن أن يكون تصوير المرونة طريقة غير جراحية للتحقق من تلف الأعضاء بسبب السمنة ويمكن أن يساعد في التنبؤ بمرض الكبد الدهني غير الكحولي عند دمجه مع قياسات الجسم الروتينية. هناك ما يبرر إجراء مزيد من البحث لتحسين منهجيات التقييم والتحقق من صحة تمثيل الموقع التشريحي.

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## INTRODUCTION

The World Health Organization (WHO) considered obesity as a major non-communicable disease pandemic affecting more than a third of the world's population and leading to major negative health and economic consequences [1]. Most national institutes of health (NIH) follow the WHO lead in classifying obesity according to the body mass index (BMI) into class-I (BMI 30-34.9 kg/m$^2$), class-II (BMI 35-39.9 kg/m$^2$) and class-III (BMI ≥40 kg/m$^2$) [2]. Socio-environmental factors (e.g., dietary & physical lifestyle) are the main factors predisposing to the development of obesity. However, genetic/ethnic factors, endocrinological disorders, and psychological or drug-related causes contribute to a considerable degree to the etiology of worldwide obesity [3]. About 80%-90% of obese individuals

have a phenotype known as metabolically unhealthy obesity (MUO), which is associated with a high risk of developing metabolic syndrome (including diabetes), cardiovascular disease, non-alcoholic fatty liver disease (NAFLD), arthropathy, and certain malignancies (e.g., colorectal, pancreatic, breast) [4]. The increase in obesity prevalence in the last four decades has prompted the implementation of more accurate measures for detection and analysis of causative factors, better diagnostic and therapeutic approaches, and more feasible preventive measures [5]. Anthropometric tools like body mass index (BMI), waist-hip ratio (WHR), and waist-height ratio (WHtR) are popularly used for assessment of obesity even though each has its own disadvantages and limitations [6]. Despite being rarely used in clinical practice, imaging techniques like CT scans, DXA scans, and MRI can provide accurate assessment of body fat distribution and body composition, making them somewhat superior to anthropometric measures in disease prediction. However, these techniques are costly, not readily accessible, require trained personnel, and may carry the risk of radiation exposure [7]. Elastography has emerged as a readily accessible, cheap and non-invasive imaging tool to evaluate tissue thickness/stiffness, offering critical insights into obesity-related organ damage [8]. Ultrasonic shear wave elastography (SWE) works by focusing ultrasound beams that go deeper and deeper. This makes an acoustic radiation pressure that moves across the ultrasound beam at a faster speed than the shear waves it creates. The speed of shear waves in a supersonic mode (usually more than 5,000 images per second) can be used to measure how flexible or stiff tissue is (in kPa) [9]. Adipose tissue, as a regenerative endocrine and energy-storing organ, goes through age- and sex-related changes regarding its structure and anatomical distribution [10]. The aim of the current study is to address critical gaps by (1) comparing subcutaneous adipose tissue (SAT) thickness and stiffness between young and middle-aged obese individuals at different anatomical sites, (2) analyzing sex-specific differences, and (3) exploring associations with NAFLD.

## METHODS

### *Study design and setting*

One hundred obese individuals (BMI ≥30 kg/m²) were randomly selected at a tertiary clinic to participate in the study over a period of ten months (January 2024-October 2024). The participants were divided into two age groups (50 individuals each): a young group (20-39 years) and a middle-aged group (40-59 years). Exclusion criteria included current pregnancy, endocrine disorders causing weight gain, alcohol intake or drug-induced obesity (e.g., corticosteroid), and known genetic or autoimmune diseases causing obesity/fatty liver.

### *Anthropometric Examination*

Body weight was recorded with minimal clothing using a VE-200RT VELAB™ (USA) digital scale (d = 0.1 kg), standing height was measured using a fixed stadiometer, and waist circumference was measured with the subject standing using a tape measure; then BMI and WHtR were calculated.

### *Ultrasonic examination and elastography*

Sonoscape SSI-5000® (China) with the TriVu platform was used to measure SAT thickness (mm) and stiffness (kPa) in B-mode with a 12 MHz curvilinear probe at three anatomical areas: distal triceps (70% of arm length), upper abdomen (1 cm above the umbilicus), and front thigh (50% of thigh length) [11]. The thickness was measured from the line of high echo at the junction of the dermo-hypodermal layer to the topmost layer of the multilayered echogenic band in the deep fascia of the skeletal muscle. Three readings were averaged for each anatomical site. A diagnosis of NAFLD was made upon finding a hepatorenal index ≥1.34 with diffused liver enhanced near-field echo, accompanying higher echoes in the hepatic parenchyma compared to the kidney; a blurred intrahepatic duct structure; and an attenuated dirty liver far-field echo, all coupled with increased stiffness on point shear wave elastography [12,13].

### *Ethical consideration*

The study design/purpose was approved by the College of Medicine, Mustansiriyah University Institutional Review Board (IRB-2024-2552). and written informed consent was obtained from all participants

### Statistical analysis

Data analysis was performed using SPSS v.26 (IBM© Corp., 2019), and results were tabulated using Microsoft Office Excel LTSC Professional (Microsoft© Corp., 2021). Independent-samples t-test, chi-square test, Fisher exact test, and linear regression analysis were applied with a 95% confidence interval. The p-value of < 0.05 was considered statistically significant.

## RESULTS

Of the 100 participants, 57 were males (27 young, 30 middle-aged) and 43 were females (23 young, 20 middle-aged). Their age distribution is shown in Figure 1. Body mass index (BMI), waist-height ratio (WHtR), and SAT thickness in the mid-thigh region did not show statistically significant differences between young and middle-aged groups. Distal triceps SAT thickness increased in middle-aged participants while upper abdominal SAT thickness showed marked reduction.

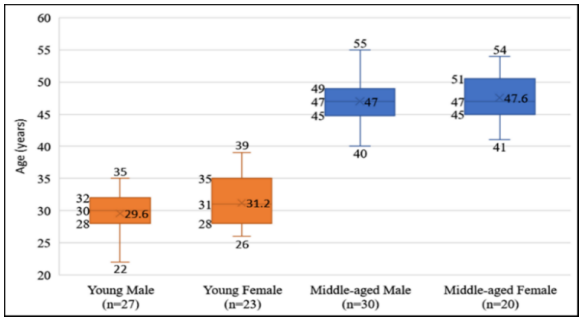


**Figure 1**: Distribution of obese participants according to sex and age group.

SAT stiffness was significantly greater in all three anatomical sites in middle-aged individuals as compared to the young group measurements (Table 1). The linear relationship between age and SAT stiffness showed that as age went up, there was a moderately positive relationship with the upper abdominal (R= 0.753) and distal triceps (R= 0.746) areas. The correlation with mid-thigh SAT stiffness was also moderately positive (R= 0.592), though to a lesser degree (Figure 2)

**Table 1**: Age-related distribution of anthropometric measurements of obesity in young & middle-aged obese individuals

| Anthropometric parameter | | Age group | | *p*-value |
|---|---|---|---|---|
| | | Young | Middle-aged | |
| BMI (kg/m$^2$) | | 35.7±2.8 | 35.6±2.9 | 0.910 |
| Waist-Height Ratio | | 0.58±0.03 | 0.60±0.03 | 0.087 |
| SAT thickness (mm) | Distal triceps | 21.2±2.4 | 22.9±3.1 | 0.003 |
| | Upper abdomen | 40.2±3.9 | 38.1±4.4 | 0.013 |
| | Mid-thigh | 28.7±4.6 | 28.3±4.6 | 0.676 |
| SAT stiffness (kPa) | Distal triceps | 7.6±1.3 | 11.2±1.8* | 0.000 |
| | Upper abdomen | 20.2±2.7 | 29.5±3.1* | 0.000 |
| | Mid-thigh | 14.3±1.9 | 18±2.2* | 0.000 |

Values were expressed as mean±SD. SAT: Subcutaneous Adipose Tissue.

. Sexual dimorphism was evident for BMI and SAT thickness but not for SAT stiffness at Table 2. Females had higher levels of BMI and SAT thickness at distal triceps and mid-thigh regions, but males had significantly higher values of WHtR and SAT thickness in the upper abdominal region. NAFLD was detected in thirty-one of all cases. No age-related or sex-related differences in NAFLD occurrence were seen (Table 3). The presence of NAFLD was associated with significantly higher values of WHtR (*p*= 0.000), BMI (*p*= 0.014), and SAT thickness at distal triceps (*p*= 0.013), upper abdominal (*p*= 0.018), and mid-thigh (*p*= 0.028) regions (Figure 3). NAFLD presence was not affected by SAT stiffness whether in distal triceps (*p*= 0.067), upper abdominal (*p*= 0.091), or mid-thigh (*p*= 0.052) regions.

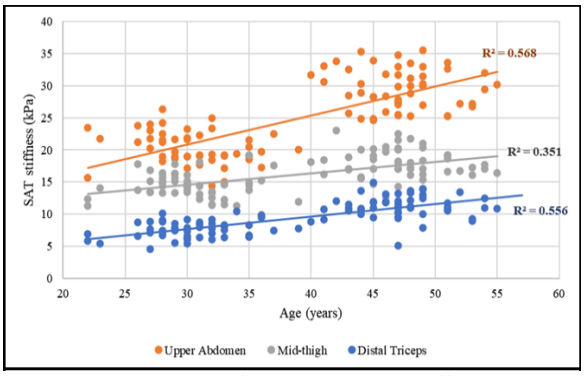


**Figure 2**: Correlation of age with SAT stiffness at three anatomical sites in obese individuals.

**Table 2**: Sex-related differences in anthropometric measurements of obesity in obese individuals ( SAT: Subcutaneous Adipose Tissue)

| Anthropometric parameter | | Sex | | *p*-value |
|---|---|---|---|---|
| | | Female | Male | |
| BMI (kg/m$^2$) | | 37.3±2.1 | 34.4±2.7 | 0.000 |
| Waist-Height Ratio | | 0.57±0.04 | 0.61±0.02 | 0.003 |
| SAT thickness (mm) | Distal triceps | 22.2±2.2 | 20.4±2.6 | 0.000 |
| | Upper abdomen | 38.7±4.2 | 42±3.4 | 0.000 |
| | Mid-thigh | 30.1±4.6 | 27.3±5 | 0.002 |
| SAT stiffness (kPa) | Distal triceps | 9.4±2.2 | 9.5±2.5 | 0.909 |
| | Upper abdomen | 25±6 | 24.8±5.2 | 0.851 |
| | Mid-thigh | 15.8±2.7 | 16.5±2.9 | 0.245 |

Values were expressed as mean±SD. SAT: Subcutaneous Adipose Tissue.

**Table 3**: Distribution of cases of NAFLD according to sex and age group

| | | NAFLD | | *p*-value |
|---|---|---|---|---|
| | | Present n(%) | Absent n(%) | |
| Age group | Young | 11(35.5) | 39(56.5) | 0.052 |
| | Middle-aged | 20(64.5) | 30(43.5) | |
| Sex | Female | 13(41.9) | 30(43.5) | 0.885 |
| | Male | 18(58.1) | 39(56.5) | |

## DISCUSSION

White adipose tissue is considered a continuously changing organ with endocrine, immune, inflammatory, and nutritional functions. Increasing age has an impact on these functions [14]. In children and young adults, adipose tissue has great plasticity that allows it to adapt quickly to both internal and external stimuli and changes. After reaching middle age, this flexibility starts to weaken. This causes fat to move from the subcutaneous to the visceral depots, as well as ectopic fat repositioning (for example, into the liver or between muscle cells), and a decrease in hormone and cold-stress-related thermoregulation [15]. Obesity, as a chronic inflammatory state, can exacerbate these changes and

increase the tendency to develop metabolic disorders like insulin resistance and metabolic syndrome [16].

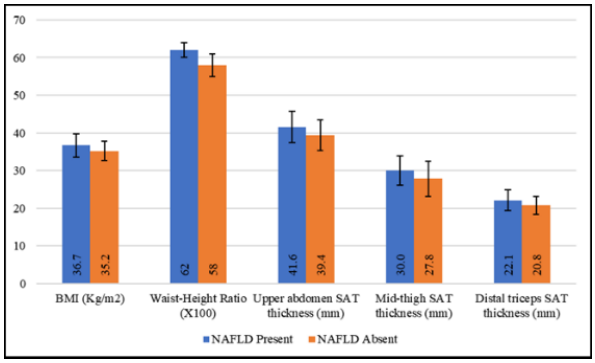


**Figure 3**: Differences in anthropometric measures of obesity and SAT thickness in relation to NAFLD.

The transitional beige/brite adipocytes, which are different from the resident progenitors in white adipose tissue (WAT), also become less active and develop less as people get older [17]. An important limitation of body mass index measurement is its failure to estimate the body fat percentage and distribution and calculate the lean body mass. Similarly, waist-height ratio is greatly dependent on abdominal fat deposition (both subcutaneous and visceral) and is affected by bone mass [18]. For these reasons, BMI and WHtR did not change significantly in the current study in relation to age. The region-specific significant changes in SAT thickness, on the other hand, are due to more visceral fat being stored (abdominal SAT), redistribution (triceps SAT), and less transitional adipocyte turnover. Obesity-related excessive hypertrophic and hyperplastic adipocyte growth and the resulting tissue growth Hypoxia stimulates inflammatory cell migration leading to disruption of extracellular matrix (ECM) collagen [19]. Increased rigidity of the extracellular matrix hampers normal adipogenesis and results in increased tissue stiffness. Aging, coupled with obesity, is also associated with increased ECM fibronectin, promoting SAT fibrosis and increased stiffness with advancing age [20]. Sex-dependent adipose tissue expansion & distribution become evident at puberty as females undergo rapid fat deposition while males gain more lean muscle mass and fat loss. This sexual dimorphism is mainly driven by hormones [21]. Over time, males tend to accumulate fat more at the abdomen and trunk, while females accumulate fat stores around the breasts, gluteofemoral region, and hips [22]. Several studies support the current findings in that obesity is more prevalent in females in many countries, as women have higher levels of body fat, which, when combined with their generally shorter stature and less physical activity, result in greater values for anthropometric parameters of obesity like BMI and WHtR [23-25]. Vilalta *et al.* mentioned that "for a given BMI, women tend to have more body fat than men" [26]. SAT structural properties and stiffness appear to be more age-related than sex-affected, especially when older women reach premenopausal age, and their bodies undergo hormonal changes rendering them more susceptible to android-like changes [27]. NAFLD is linked to obesity, dyslipidemia, and metabolic syndrome. It includes a range of liver diseases, from mild non-alcoholic fatty liver (NAFL) to more severe non-alcoholic hepatic steatohepatitis (NASH), which can lead to hepatic fibrosis and cirrhosis [28]. The ultimate diagnostic tool is liver biopsy histopathology consequential to highly suspicious imaging and biochemical abnormalities [29]. A screening method that uses anthropometric factors of obesity as predictors of NAFLD has been suggested [30]. This is because tissue biopsy is invasive, and some people may not be able to access complicated imaging techniques. As to which parameter is most predictive, it remains controversial. Some authorities found that waist circumference (WC) and waist-hip ratio (WHR) were associated with NASH, but WHR on its own can detect its severity, while BMI, WC, and WHR combined were associated with steatohepatitis [31]. Other studies support the current findings in designating WHtR as the predictor of NAFLD in obese patients [32].

## Conclusion

Elastography provides an effective non-invasive tool for assessing obesity and SAT structure. When coupled with anthropometric parameters of obesity (especially WHtR), it becomes a strong predictor for NAFLD. SAT changes over time, with thickness influenced by aging and structural stiffness influenced by sex. Both factors impact its anatomical distribution. This relationship should be considered when addressing an individual's therapeutic plan for obesity and metabolic dysfunctions. Limitations to SAT assessment arise from the time-consuming repeated measurements of multiple anatomical sites (typically 8) of the human body. The current study used 3 sites from three regions (upper limb, trunk, and lower limb). Whether or not these sites are efficiently representative requires further comparative studies.

### Conflict of interests

The authors declared no conflict of interest.

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The authors did not receive any source of funds.

### Data sharing statement

Supplementary data can be shared with the corresponding author upon reasonable request.

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