Effect of visceral fat tissue on superior mesenteric artery configuration: Is it superior to BMI?

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ABSTRACT

Background/Aims: *To determine the effect of visceral fat volume measured via computed tomography (CT) images of umbilical slices on superior mesenteric artery (SMA) configuration, as compared with body mass index (BMI). In addition, this study aims to determine the effect of lumbar lordosis angle (LLA) on SMA configuration.*

Materials and Methods: *The study included 310 patients who underwent abdominal CT. On CT images, the aortomesenteric angle (AMA), the distance between SMA and aorta at three levels, and LLA were measured. Visceral fat volume was measured using three consecutive images obtained at the level of the umbilicus. The relationship among AMA, and distances measured between SMA and aorta, and visceral fat tissue volume were determined. The effect of LLA on AMA and distances measured between SMA and aorta was analyzed.*

Results: *There was a significant positive correlation between visceral fat volume, and patient age, AMA, distances between SMA and aorta, LLA, and BMI ($p<0.001$). There were not any significant differences in AMA, distances between SMA and aorta, BMI, or visceral fat volume between the patients with an LLA of 20°-45° and those with an LLA >45° ($p>0.05$). There was a significant positive correlation between BMI, and AMA, distances between SMA and aorta ($p<0.001$). There was a significant positive correlation between visceral fat volume, and AMA, distances between SMA and aorta ($p<0.001$).*

Conclusion: *Visceral fat tissue volume is more valuable than BMI for evaluating the SMA configuration.*

Keywords: *Visceral fat, body mass index, superior mesenteric artery, superior mesenteric artery syndrome, renal nutcracker syndrome*

INTRODUCTION

Vascular structures can compress adjacent visceral organs or can be compressed by adjacent anatomical structures. Such anatomical changes may be clinically symptomatic depending on the degree of compression or can be detected incidentally. Superior mesenteric artery (SMA) as one of these vascular structures, leads to compression syndromes because of its close relationship with the third part of the duodenum and left renal vein (LRV). The third part of the duodenum and LRV are protected from compression by the surrounding fat and lymphatic tissue in the triangular area formed by the SMA when it leaves the aorta. (1). Loss of the retroperitoneal fat pad situated between the SMA and the abdominal aorta diminishes cushioning of the duodenum and LRV when it passes through this narrow area, which can lead to superior mesenteric artery syndrome (SMAS) and/or nutcracker syndrome (NCS) (1-3).

In patients with SMAS, also known as Wilkie's syndrome or cast syndrome, the third part of the duodenum is compressed between the SMA and the abdominal aorta. This rare clinical condition presents with symptoms of upper gastrointestinal system obstruction and was first described in 1861 by Rokitansky (4). In 1927, Wilkie (5) described the syndrome as chronic duodenal ileus as well as its pathophysiology and clinical findings. The prevalence of SMAS is roughly 0.1%-0.3% (6). Its incidence is approximately 0.013%-0.3% in the general population,but is more common in patients following scoliosis surgery and those in a hypercatabolic state (7).

NCS is characterized by compression of the LRV between the SMA and abdominal aorta. The first clinical report of NCS was published by El-Sadr and Mina (8) in 1950, but the term NCS was first used by De Schepper in 1972 (9, 10). Asymptomatic compression of the LRV is known as nutcracker phenomenon (NCP) and can be observed incidentally during abdominal CT examinations, with an approximate prevalence of 51%-72%; however, the frequency with which LRV compression causes pathological symptoms (NCS) remains unknown (3).

Multiple structural and acquired factors are suggested to play a role in the etiology of SMAS and NCS (1, 2). Although rare, SMAS and NCS can occur concomitantly (1, 3). Both syn-

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dromes are difficult to diagnose because of their non-specific clinical symptoms. Therefore, in the presence of suspicion, diagnosis is made with radiological findings along with clinical symptoms (11).

Some studies have examined the correlation between the aortomesenteric angle/distance (AMA/AMD) and body mass index (BMI) (6, 12). Literature frequently states that SMAS and NCS patients have low BMI and weight loss (3, 13, 14). However other studies have declared that BMI may not always be low in these group of patients (3, 15, 16). In fact, BMI does not always provide an accurate estimation of visceral fat tissue volume. The visceral fat volume of two people with the same BMI may vary depending on various variables as body size and composition. Cross-sectional imaging is known to be more accurate than BMI for estimating visceral fat tissue volume (17, 18]). As such, the present study aimed to determine the effect of visceral fat tissue volume measured via CT images of umbilical slices for evaluating the SMA configuration as compared with BMI. An additional aim of the present study was to determine the effect of lumbar lordosis angle (LLA) on AMA and distances measured between the SMA and the abdominal aorta.

MATERIALS AND METHODS

This retrospective study included 310 patients who underwent abdominal CT owing to various complaints between January and May 2018. The Institutional Review Board approved the study protocol, and informed consent for abdominal CT was obtained from all individual participants included in the study. Mean age of the patients was 47.46±19.05 years (range 16-95 years). Patients with any intra-abdominal inflammatory conditions, intra-abdominal fluid collection, retroperitoneal mass, abdominal aortic aneurysm at the level of the origin of the SMA, and a history of abdominal surgery were excluded. Age, gender, weight, and height were recorded, and BMI was calculated as BMI=weight/(height)^2. The study population was divided into four subgroups according to BMI as follows: underweight subgroup (UW subgroup) BMI<18.50 kg m^{-2}; normal weight subgroup (NW subgroup) BMI=18.50-24.99 kg m^{-2}; pre-obese subgroup (PO subgroup) BMI=25-29.99 kg m^{-2}; obese subgroup (O subgroup) BMI>30 kg m^{-2} (19). As the UW subgroup included only 5 patients, the UW and NW subgroups were combined as the UW-NW subgroup for further statistical analysis.

Abdominal CT was performed using GE Optima CT660 Freedom Edition/128 slices (GE Healthcare, WI, USA) with the following parameters: voltage 120 kV; tube current 100-400 mA; gantry rotation 0.6 s; detector coverage 40 mm; helical thickness 5 mm; and pitch and speed 1.531 mm and 61.25 rotation, respectively. Using a power injector, 45-90 mL of contrast material was injected at a rate of 2.5-3 mL s^{-1}.

CT image data were evaluated using a GE Advantage Workstation (GE Healthcare, Buc, France) with Volume Share 7 software version. All distances and angle measurements were made by the same radiologist experienced in abdominal evaluation. On axial images, the distance between the SMA and aorta was measured at 3 levels: D1 (the level at the superior border of the duodenum where the duodenum passes between the aorta and SMA); D2 (the level at the midpoint of the duodenum where the duodenum passes between the aorta and SMA); R (the level where the LRV crosses this region) (Figures 1, 2). Measurements were made between the outer walls of the aorta and SMA. Fifteen patients whose LRV passed posterior to the aorta were excluded from R measurement analysis. Sagittal multi-planar

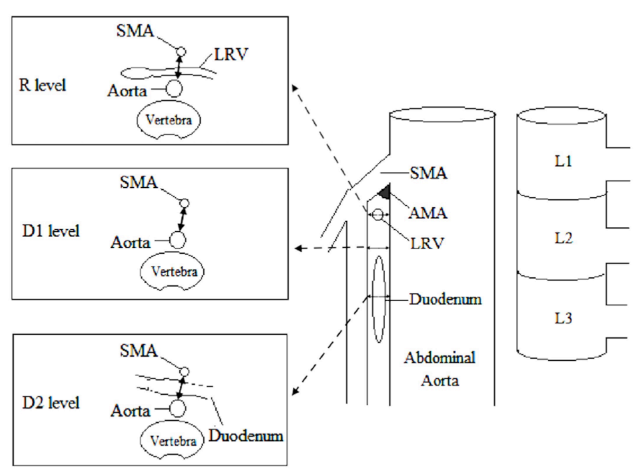

Figure 1. Pictorial image of anatomical relationships of duodenum and LRV between the abdominal aorta and SMA. On the left, we see the axial anatomical sections passing through the levels R, D1 and D2 as indicated in the sagittal drawing. On axial anatomical sections, the small double arrows show the distances between aorta and SMA at R, D1, and D2 levels.
AMA: aortomesenteric angle; LRV: left renal vein; SMA: superior mesenteric artery.

MAIN POINTS

- *BMI does not always provide an accurate estimation of visceral fat tissue volume.*
- *Cross-sectional imaging is known to be more accurate than BMI for estimating visceral fat tissue volume.*
- *In patients with SMAS and/or NCS, the amount of visceral adipose tissue should be taken into consideration when evaluating the SMA configuration.*

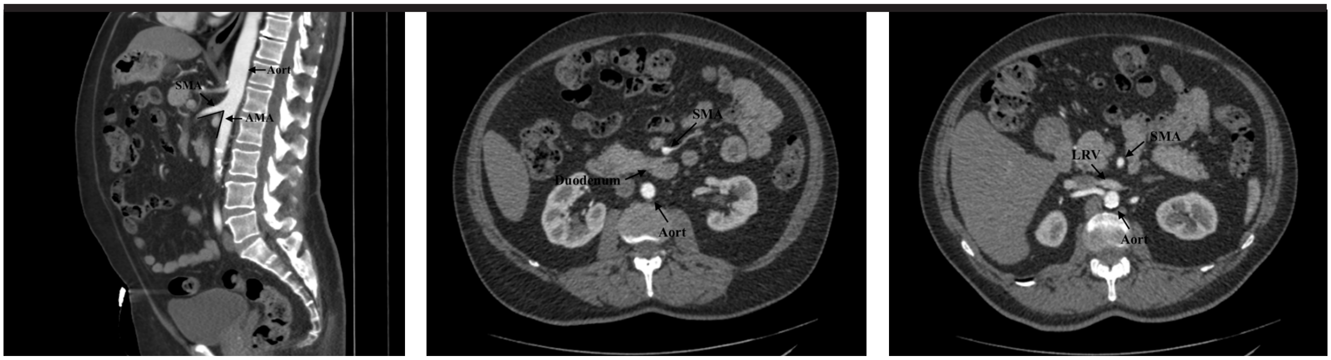

Figure 2. Contrast enhanced CT images shows the measurement of AMA in sagittal plane and AMD between the abdominal aorta and SMA at D2 and R levels in axial planes.
AMA: aortomesenteric angle; AMD: aortomesenteric distance; SMA: superior mesenteric artery

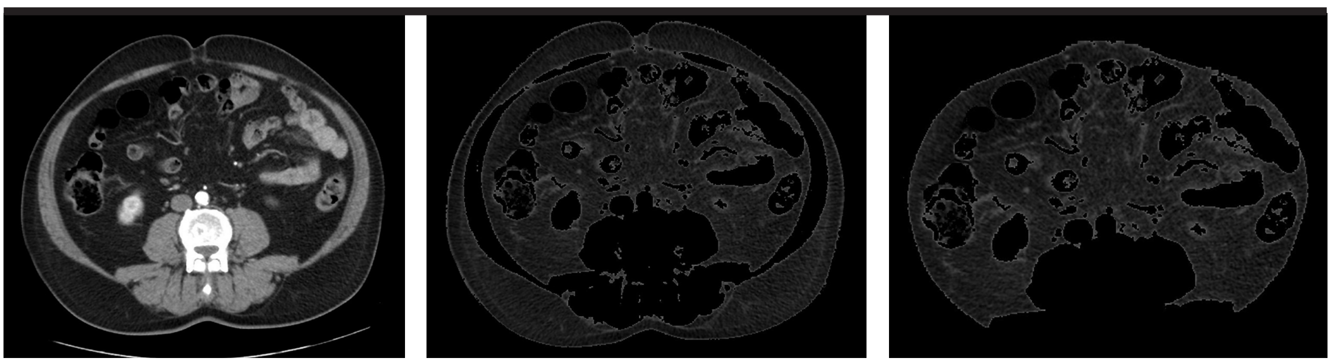

Figure 3. Axial CT images at the level of the umbilicus show the steps used to measure visceral fat tissue after removal of non-fat tissue via a threshold technique (range from −190 to −30 HU). Native image, processed image and visceral fat image can be seen respectively.

reformat (MPR) images were used to assess the AMA. The AMA was measured at its origin via manual tracing (Figure 2). Sagittal images were also used to assess the LLA. Patients were divided into three subgroups according to LLA: lumbar hypolordosis subgroup (LhypoL subgroup) LLA <20; neutral lumbar lordosis subgroup (NLL subgroup) LLA = 20-45; and lumbar hyperlordosis subgroup (LhyperL subgroup) LLA >45 (20). As the LhypoL subgroup included just 1 patient, it was not included in any further analysis.

Visceral fat tissue volume was measured using semi-automated measurement tools. In total, three consecutive 10-mm cross-sectional images were generated at the level of the umbilicus via the MPR images, and 0.625-mm image data were used for 10-mm cross-sectional image generation. A threshold range between –190 and –30 HU was used for semi-automated non-fat tissue removal from 10-mm volume images as the standard of reference. In addition, the intra-abdominal fat tissue layer was acquired via manual contouring with a scalpel tool following non-fat tissue removal via the threshold technique. Volume measurement in cross-sectional fat tissue images was performed using an automatic volume tool (Figure 3). Subcutaneous fat tissue volume was measured using the same technique via manual contouring through the abdominal wall and removing the intra-abdominal fat tissue from the total fat tissue and non-fat tissue on the axial images.

Statistical Analysis

Statistical analysis was performed using the Statistical Packages for the Social Sciences (SPSS) for Windows v.22.0 (IBM Corp., Armonk, NY, USA). Descriptive statistical methods (frequency, percentage, and mean±SD) and the Shapiro-Wilk normality test were used to evaluate the study data. One-way analysis of variance (ANOVA) was used to compare parameters between study subgroups and Tukey's HDS and Tamhane's T2 tests were used to identify the subgroups that caused the difference in pairwise comparisons between subgroups. Student's t test was used to compare normally distributed parameters between two subgroups. Pearson's correlation analysis was used to identify correlations between parameters. The level of statistical significance was set at $p<0.05$.

Table 1. Distribution of study parameters.

	n	Range	Mean±SD
AMA (°)	310	10-123.1	47.78±25.54
R (mm)	295	2.3-42.1	14.23±7.11
D1 (mm)	310	3.8-49.5	15.65±8.35
D2 (mm)	310	3.3-57.3	16.34±9.46
LLA (°)	310	15-81.6	48.72±12.21
BMI (kg m^{-2})	310	17.93-57.09	27.91±5.5
Visceral fat volume (cm^3)	310	11.99-533.31	180.14±103.08

AMA: aortomesenteric angle; R the distance between the aorta and superior mesenteric artery at the level where left renal vein passes, D1 the distance between the aorta and superior mesenteric artery at the level where the superior border of the duodenum passes, D2 the distance between the aorta and superior mesenteric artery at the level where the midpoint of the duodenum passes, LLA: lumbar lordosis angle;, BMI: body mass index.

Table 2. Distribution of study population according to BMI and LLA subgroups.

		n	%
LLA Subgroups	LhypoL	1	0.3
	NLL	128	41.3
	LhyperL	181	58.4
BMI Subgroups	UW	5	1.6
	NW	81	26.1
	PO	139	44.8
	O	85	27.4

LLA: lumbar lordosis angle; LhypoL: lumbar hypolordosis; NLL: neutral lumbar lordosis; LhyperL: lumbar hyperlordosis; BMI: body mass index; UW: underweight; NW: normal weight; PO: pre-obese; O: obese.

RESULTS

Among the 310 patients, 163 were male (52.6%) and 147 were female (47.4%) (p>0.05). Study parameters are shown in Table 1. The distribution of the study population according to BMI and LLA subgroups is shown in Table 2. There was a significant positive correlation between patient age, and AMA (r=0.212, p<0.001), R (r=0.345, p<0.001), D1 (r=0.368, p<0.001), D2 (r=0.388, p<0.001), LLA (r=0.243, p<0.001), BMI (r=0.201, p<0.001), and visceral fat volume (r=0.468, p<0.001). AMA, R, D1, and D2 were significantly lower in the females than males (p=0.007, p<0.001, p<0.001, and p<0.001, respectively). LLA was significantly higher in the females than in males (p<0.001). There was no significant difference in visceral fat volume between the females and males (p=0.175). Subcutaneous fat volume was significantly higher in the females than in males (females 389.85±178.24 cm^3, males 271.78±159.28 cm^3; p<0.001).

Comparison of the study parameters between the BMI subgroups is shown in Table 3. Patient age, AMA, R, D1, D2, LLA, and visceral fat volume were significantly lower in the UW-NW subgroup than in the PO and O subgroups (p<0.001). There was a significant difference in gender distribution between some of the BMI subgroups (p=0.009). The percentage of females in the O subgroup (61.2%) was significantly higher than in the UW-NW subgroup (45.3%) (p=0.038) and PO subgroup (40.3%) (p=0.002). There was no significant difference in gender distribution between the UW-NW and PO subgroups.

Comparison of the study parameters between the LLA subgroups is shown in Table 4. Patient age was significantly lower in the NLL subgroup than in the LhyperL subgroup (p<0.001). There was no significant difference in AMA, R, D1, D2, BMI, or visceral fat volume between the NLL and LhyperL subgroups (p>0.05). The percentage of male patients in the NLL subgroup (60.2%) was significantly higher than in the LhyperL subgroup (47%).

The correlations between BMI and visceral fat volume, AMA, R, D1, and D2 are shown in Table 5. There was a significant positive correlation between BMI and AMA (r=0.284, p<0.001), R (r=0.377, p<0.001), D1 (r=0.385, p<0.001), and D2 (r=0.407, p<0.001). There was a significant positive correlation between visceral fat volume and AMA (r=0.347, p<0.001), R (r=0.586, p<0.001), D1 (r=0.700, p<0.001), and D2 (r=0.703, p<0.001).

DISCUSSION

Originating from the anterior aspect of the abdominal aorta, the SMA forms a triangular area including the third part of the duodenum, LRV, and the uncinate process of the pancreas. Among these structures, the mesenteric fat pad and retroperitoneal lymphatic tissue prevents compression of the duodenum and LRV while crossing this narrow area. Loss of fat pad between the abdominal aorta and SMA further narrows this area and causes a decrease in measurements related to SMA configuration. Normally, the AMD measures 10-28 mm and the AMA varies between 38° and 65° (21); when these values are lower SMAS and NCS, both of which are the result of compression of the duodenum and LRV, can occur (1-3). As the narrowness of this area is associated with the amount of visceral fat, it is essential to obtain ac-

Table 3. Comparison of study parameters between the BMI subgroups.

	BMI			
	UW-NW	PO	O	
	Mean±SD	Mean±SD	Mean±SD	p
Age (years)	40.65±19.72	48.58±19.09	52.54±16.35	[1]0.001
AMA (°)	34.88±24.89	50.84±25.37	55.84±21.51	[1]0.001
R (mm)	9.76±4.6	15.3±7.13	17.08±7.13	[1]0.001
D1 (mm)	10.54±5.52	16.23±8.05	19.88±8.57	[1]0.001
D2 (mm)	10.73±5.45	16.72±8.81	21.39±10.65	[1]0.001
LLA (°)	45.79±10.57	49.72±12.92	50.07±12.21	[1]0.031
Visceral fat volume (cm^3)	99.88±65.21	188.93±89.79	246.97 ± 101.47	[1]0.001
Gender n (%)				
Male	47 (54.7%)	83 (59.7%)	33 (38.8%)	[2]0,009
Female	39 (45.3%)	56 (40.3%)	52 (61.2%)	

[1]One-way ANOVA test
[2]Chi-square test $p<0.05$
AMA: aortomesenteric angle; R the distance between the aorta and superior mesenteric artery at the level where left renal vein passes, D1 the distance between the aorta and superior mesenteric artery at the level where the superior border of the duodenum passes, D2 the distance between the aorta and superior mesenteric artery at the level where the midpoint of the duodenum passes, LLA: lumbar lordosis angle; BMI: body mass index; UW: underweight; NW: normal weight; PO: pre-obese; O: obese.

Table 4. Comparison of study parameters between the LLA subgroups.

	LLA subgroup		
	NLL	LhyperL	
	Mean±SD	Mean ± SD	p (Student's t test)
Age (years)	42.18±17.77	51.28±19.1	<0.001
AMA (°)	46.9±23.96	48.6±26.58	0.566
R (mm)	14.62±7.36	14.01±6.91	0.472
D1 (mm)	16.19±8.47	15.34±8.24	0.380
D2 (mm)	16.63±9.33	16.2±9.55	0.698
BMI (kg m^{-2})	27.29±5.36	28.37±5.58	0.089
Visceral fat volume (cm^3)	175.22±114.21	184.52±94.1	0.450

AMA aortomesenteric angle, R the distance between the aorta and superior mesenteric artery at the level where left renal vein passes, D1 the distance between the aorta and superior mesenteric artery at the level where the superior border of the duodenum passes, D2 the distance between the aorta and superior mesenteric artery at the level where the midpoint of the duodenum passes, BMI body mass index, LLA lumbar lordosis angle, NLL neutral lumbar lordosis, LhyperL lumbar hyperlordosis

curate information about the visceral fat volume than BMI while evaluating SMA configuration. In this study, we aimed to compare the effect of visceral fat measured by abdominal CT and BMI on SMA configuration.

Compression of the duodenum caused by the SMA is a rare clinical entity characterized by non-specific findings of upper gastrointestinal obstruction. This condition, which is generally called SMAS, most commonly occurs in females aged 10-39 years (7, 22). Anorexia nervosa, malabsorption, hypercatabolic states (burns, major surgery, etc.), increased spinal lordosis, scoliosis surgery, high insertion of the ligament of Treitz, use of a body cast, and low origination of the SMA can predispose a person to the development of SMAS (7, 22).

Entrapment and compression of the LRV between the SMA and aorta—commonly known as NCS—results in hematuria, left flank pain, and varicocele. As the asymptomatic form of NCS, known as NCP, is a common incidental abdominal CT finding, it is difficult to accurately estimate the frequency of NCS. According to the literature, NCS is more common in females than in males and is usually diagnosed in those aged 20-40 years (3, 13).

Table 5. The correlations between BMI and visceral fat volume, and AMA, R, D1, and D2.

	AMA		R		D1		D2	
	r	p	r	p	r	p	r	p
BMI	0.284	<0.001	0.377	<0.001	0.385	<0.001	0.407	<0.001
Visceral fat volume (cm^3)	0.347	<0.001	0.586	<0.001	0.700	<0.001	0.703	<0.001

Pearson's correlation analysis.
BMI: body mass index; AMA: aortomesenteric angle.
R the distance between the aorta and superior mesenteric artery at the level where left renal vein passes, D1 the distance between the aorta and superior mesenteric artery at the level where the superior border of the duodenum passes, D2 the distance between the aorta and superior mesenteric artery at the level where the midpoint of the duodenum passes

SMAS and NCS are two syndromes which are difficult to diagnose because their characteristic symptoms are difficult to differentiate from other diseases. SMAS is diagnosed based on a combination of clinical and radiological findings in the presence of a high index of suspicion (11). An AMA <22° and AMD <8 mm, based on CT or angiography, are diagnostic of SMAS (23). The most reliable method for diagnosing NCS is renal venography, which can discern pressure gradients between the LRV and inferior vena cava (10, 24). However, because renal venography is an invasive procedure, non-invasive modalities such as Doppler ultrasonography and cross-sectional imaging are used (10, 24). The radiographic findings that are diagnostic of NCS include a significantly reduced AMD (3 mm), an AMA <16°, LRV compression, and the presence of collaterals or a pressure gradient >3 mmHg (1, 25).

Low BMI and weight loss are frequently reported in patients diagnosed with SMAS, and NCS patients are reported to be tall and thin (resulting in low BMI) and have experienced weight loss (3, 13, 14). Bhagirath Desai et al. (6) reported a strong positive correlation between BMI and AMA (r=0.95). Ozkurt et al. (12) observed a significant positive correlation between BMI and AMA (r=0.29, p<0.001) and between BMI and AMD (r=0.35, p<0.001); however, other studies have shown that BMI is not always low in patients with SMAS and NCS (3, 15, 16). In addition, it remains unclear if weight loss is the cause of compression of the duodenum or if weight loss is a result/complication of SMAS (3, 22). Biank et al. (26) reported that low BMI and weight loss are not necessary for the development of SMAS but that they are commonly associated with the development of SMAS in the pediatric population. Lee et al. (16) reported that 19 of 80 SMAS patients, with an age range of 11-92 years, had normal BMI; and Wee et al. (15) reported an SMAS patient with normal BMI. Moreover, Wang et al. (27) reported an NCS patient with normal BMI.

Although BMI is frequently used in the routine clinical practice to estimate the amount of abdominal fat, it does not provide a precise measurement of visceral fat tissue volume. Visceral fat tissue volume varies in individuals with the same BMI according to body size. In addition, BMI does not help in evaluation and differentiation of the distribution of subcutaneous and visceral fat tissue (17). Furthermore, BMI does not differentiate fat tissue from muscle tissue. The BMI in an athletic person might be high because muscle tissue is heavier than fat tissue.

Ozbulbul et al. (28) reported that visceral fat areas correlate with BMI and that AMD is more strongly associated with visceral fat area than with BMI, but an important limitation of their study was that the population had a higher mean BMI than the general population. The present study's findings show that although there is a positive correlation between BMI and AMA, R, D1, and D2 measurements, the correlation between visceral fat tissue volume and AMA, R, D1, and D2 measurements is higher (Table 5).

The gold standards for measurement of visceral fat tissue volume are CT and MRI. BMI indirectly measures visceral fat tissue, whereas quantitative measurement of visceral fat tissue via cross-sectional imaging can do so directly and more accurately. The advantage of CT is that it has excellent fat tissue resolution, and cross-sectional imaging can easily differentiate between subcutaneous and visceral fat. Single or multiple slices taken from predetermined levels are well correlated with visceral fat tissue volumes (17); according to the literature, the umbilical level is the most commonly used (28). Mizui et al. (29) reported a strong positive correlation between visceral fat volume of the entire abdomen and the visceral fat area at the umbilicus. Literature states that single-slice evaluation is not very accurate because intra-abdominal soft tissue is constantly in motion (17); therefore, in the present study, visceral fat tissue measurement was performed using three consecutive slices at the umbilical level.

In our study AMA, R, D1, D2, and visceral fat volume were significantly lower in the UW-NW BMI subgroup than in the PO and O BMI subgroups (p<0.001). Similar to our results Ozkurt et al. (12) and Bhagirath Desai et al. (6) found a positive and significant correlation between BMI and distance and angle measurements between aorta and SMA. In our study, there was a significant difference in gender distribution between some of the BMI subgroups (p=0.009). The percentage of females in the O BMI subgroup (61.2%) was significantly higher than in the UW-NW BMI subgroup (45.3%) (p=0.038) and PO BMI subgroup (40.3%) (p=0.002). However, we did not find any significant difference in visceral fat volume between the females and males (p=0.175). Unlike our results, Ozbulbul et al. (28) found that visceral fat area is smaller in females.

Our results showed that AMA, R, D1, and D2 were significantly lower in the females than males. Although the number of women in our study's O BMI subgroup was high, the females had less visceral fat volume and more subcutaneous fat volume when compared with that of males like reported in literature (28). This may explain lower values of AMA, R, D1, and D2 and higher frequency of SMAS and NCS in females (7, 13).

Arthurs et al. (24) reported a wide range of normal duodenal distances in a pediatric population and observed a significant but weak correlation between visceral fat volume and AMA (r=0.30, p<0.001), LRV distance (r=0.37, p<0.001), and duodenal distance (r=0.32, p<0.001). Generalizing the findings of this group is not recommended because rapid growth in children might affect SMA configuration and lead to SMAS and NCS without weight loss (16). The present study's patient group did not include children or adolescents.

It has been reported that a history of scoliosis surgery and neurological injury can be observed in patients with SMAS or NCS. Craniocaudal extension in post-scoliosis surgery patients and hyperextension of the spine in patients with neurological injury are causes of SMAS and NCS (16, 30). None of the present study's patients had a history of scoliosis surgery or neurological injury.

According to the literature, one of the pathophysiological mechanisms that play a role in the development of SMAS and NCS is increased lumbar lordosis (2, 6, 7, 13, 24). To date, the effect of LLA on SMA configuration has not been investigated, and as such, an additional aim of the present study was to determine the effect of LLA on AMA and the distances measured between the SMA and aorta. There were no significant differences in AMA, R, D1, D2, BMI, or visceral fat volume between the present study's LLA subgroups (p>0.05).

The present study has some limitations. Because of the retrospective nature of the study, we did not have the clinical information of patient population included in the study. Thus, we do not know if the patients had a diagnosis of SMAS or NCS. From this study, we cannot determine the diagnostic value of visceral fat tissue for SMAS and NCS. Further studies should be planned to compare the diagnostic value of the BMI and visceral fat tissue in patients with a diagnosis of SMAS and/or NCS. A second limitation was that we did not have post-scoliosis surgery patients and/or patients with neurological injury. Although the prevalence of these patients in general population is low, this may have affected the results of the correlation between the LLA and study parameters.

The present study's findings show that visceral fat volume strongly correlates with AMA, R, D1, and D2 measurements than does the BMI. Therefore, the amount of visceral fat tissue should be taken into consideration while evaluating SMA configuration. Further studies should be planned to incorporate the visceral fat volume into diagnosis of SMAS and NCS in suspected patients who have already had an abdominal cross-sectional examination.

Ethics Committee Approval: Ethics committee approval was received for this study from the Ethics Committee of Fatih Sultan Mehmet Training and Research Hospital approved this study protocol (Approval Date: 14.12.2018, Decision Number: 23380).

Informed Consent: Informed consent was obtained from the patients who participated in this study.

Peer-review: Externally peer-reviewed.

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REFERENCES

1. Lamba R, Tanner DT, Sekhon S, McGahan JP, Corwin MT, Lall CG. Multidetector CT of Vascular Compression Syndromes in the Abdomen and Pelvis. RadioGraphics 2014; 34: 93-115. [Crossref]
2. Rabie ME, Ogunbiyi O, Al Qahtani AS, Taha SBM, El Hadad A, El Hakeem I. Superior Mesenteric Artery Syndrome: Clinical and Radiological Considerations. Surg Res Pract 2015; 2015: 628705. [Crossref]
3. Heidbreder R. Co-occurring superior mesenteric artery syndrome and nutcracker syndrome requiring Roux-en-Y duodenojejunostomy and left renal vein transposition: a case report and review of the literature. J Med Case Rep 2018; 12: 214. [Crossref]
4. Rokitansky C. Handbuch der pathologischen Anatomie, ed 1. Wien, Braunmüller &Seidel; 1842, 3: pp. 187.

5. Wilkie DP. Chronic duodenal ileus. Am J Med Sci 1927; 173: 643-9. [Crossref]
6. Bhagirath Desai A, Sandeep Shah D, Jagat Bhatt C, Umesh Vaishnav K, Salvi B. Measurement of the Distance and Angle Between the Aorta and Superior Mesenteric Artery on CT Scan: Values in Indian Population in Different BMI Categories. Indian J Surg 2015; 77: 614-7. [Crossref]
7. Nunn R, Henry J, Slesser AA, Fernando R, Behar N. A model example: coexisting superior mesenteric artery syndrome and the nutcracker phenomenon. Case Rep Surg 2015; 2015: 649469. [Crossref]
8. El-Sadr AR, Mina E. Anatomical and surgical aspects in the operative management of varicocele. Urol Cutan Rev 1950; 54: 257-62.
9. De Schepper A. Nutcracker fenomeen van de vena renalis en veneuze pathologic van de linker nier. J Belge Radiol 1972; 55: 507-11.
10. Shin JI, Park JM, Lee SM, et al. Factors affecting spontaneous resolution of hematuria in childhood nutcracker syndrome. Pediatr Nephrol 2005; 20: 609-13. [Crossref]
11. Ganss A, Rampado S, Savarino E, Bardini R. Superior Mesenteric Artery Syndrome: a Prospective Study in a Single Institution. J Gastrointest Surg 2019; 23: 997-1005. [Crossref]
12. Ozkurt H, Cenker MM, Bas N, Erturk SM, Basak M. Measurement of the distance and angle between the aorta and superior mesenteric artery: normal values in different BMI categories. Surg Radiol Anat 2007; 29: 595-9. [Crossref]
13. Orczyk K, Wysiadecki G, Majos A, Stefańczyk L, Topol M, Polguj M. What Each Clinical Anatomist Has to Know about Left Renal Vein Entrapment Syndrome (Nutcracker Syndrome): A Review of the Most Important Findings. Biomed Res Int 2017; 2017: 1746570. [Crossref]
14. Vulliamy P, Hariharan V, Gutmann J, Mukherjee D. Superior mesenteric artery syndrome and the 'nutcracker phenomenon'. BMJ Case Rep 2013; 2013: bcr2013008734. [Crossref]
15. Wee JW, Lee TH, Lee JS, Kim WJ. Superior Mesenteric Artery Syndrome Diagnosed with Linear Endoscopic Ultrasound (with Video) in a Patient with Normal Body Mass Index. Clin Endosc 2013; 46: 410-3. [Crossref]
16. Lee TH, Lee JS, Jo Y, et al. Superior Mesenteric Artery Syndrome: Where Do We Stand Today? J Gastrointest Surg 2012; 16: 2203-11. [Crossref]
17. Shuster A, Patlas M, Pinthus JH, Mourtzakis M. The clinical importance of visceral adiposity: a critical review of methods for visceral adipose tissue analysis. Br J Radiol 2012; 85: 1-10. [Crossref]
18. Fang H, Berg E, Cheng X, Shen W. How to best assess abdominal obesity. Curr Opin Clin Nutr Metab Care 2018; 21: 360-5. [Crossref]
19. Obesity: preventing and managing the global epidemic. Report of a WHO Consultation (WHO Technical Report Series 894) © World Health Organization 2000 Reprinted 2004.
20. Lin RM, Jou IM, Yu CY. Lumbar lordosis: normal adults. J Formos Med Assoc 1992; 91: 329-33.
21. Raman SP, Neyman EG, Horton KM, Eckhauser FE, Fishman EK. Superior mesenteric artery syndrome: spectrum of CT findings with multiplanar reconstructions and 3-D imaging. Abdom Imaging 2012; 37: 1079-88. [Crossref]
22. Welsch T, Büchler MW, Kienle P. Recalling Superior Mesenteric Artery Syndrome. Dig Surg 2007; 24: 149-56. [Crossref]
23. Agrawal GA, Johnson PT, Fishman EK. Multidetector row CT of superior mesenteric artery syndrome. J Clin Gastroenterol 2007; 41: 62-5. [Crossref]
24. Arthurs OJ, Mehta U, Set PA. Nutcracker and SMA syndromes: What is the normal SMA angle in children? Eur J Radiol 2012; 81: e854-61. [Crossref]
25. Little AF, Lavoipierre AM. Unusual clinical manifestations of the Nutcracker Syndrome. Australas Radiol 2002; 46: 197-200. [Crossref]
26. Biank V, Werlin S. Superior Mesenteric Artery Syndrome in Children: a 20-year experience. J Pediatr Gastroenterol Nutr 2006; 42: 522-5. [Crossref]
27. Wang Y, Zhou Y, Liu CY. A rare case of nutcracker phenomenon with nephrotic syndrome. Int Urol Nephrol 2016; 48: 631-2. [Crossref]
28. Ozbulbul NI, Yurdakul M, Dedeoğlu H, Tola M, Olcer T. Evaluation of the effect of visceral fat area on the distance and angle between the superior mesenteric artery and the aorta. Surg Radiol Anat 2009; 31: 545-9. [Crossref]
29. Mizui M, MIzoguchi Y, Senda Y, Yokoi M, Tashiro T. Visceral Fat Area Evaluation by Computed Tomography Correlates with Visceral Fat Volume. Glob J Health Sci 2017; 9: 78-84. [Crossref]
30. Louie PK, Basques BA, Bitterman A, et al. Superior Mesenteric Artery Syndrome as a Complication of Scoliosis Surgery. Am J Orthop (Belle Mead NJ) 2017; 46: E124-E130.