
RESEARCH ARTICLE

Normal Distance and Angle between the Superior Mesenteric Artery and Abdominal Aorta in a Sri Lankan Cohort

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Highlights

- Males have greater SMA-AA distance and angle, suggesting higher SMA syndrome risk
 - Higher BMI linked to greater SMA-AA; lower BMI may increase SMA syndrome risk
 - No age-SMA-AA link found; age may not be a key factor in SMA syndrome risk in the study population
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Normal Distance and Angle between the Superior Mesenteric Artery and Abdominal Aorta in a Sri Lankan Cohort

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Received: 21.04.2025; Accepted: 25.08.2025

Abstract: This study aimed to assess the normal values of the distance and angle between the superior mesenteric artery (SMA) and abdominal aorta (AA) in an asymptomatic Sri Lankan cohort using computed tomography (CT) images. A cross-sectional descriptive study was conducted at three selected government hospitals, involving 100 patients (50 males and 50 females) who underwent contrast-enhanced (CE) CT exams for gastrointestinal reasons, aged 18 to 80 years. Demographic parameters such as age, gender, height (m), and weight (kg) were recorded prior to the scanning. The mean aorto-mesenteric distance (AMD) was 14.49 mm, and the mean aorto-mesenteric angle (AMA) was 57.14°. Significant associations were observed between gender and AMD ($p = 0.014$) as well as gender and AMA ($p = 0.018$), with males exhibiting higher values. Differences in AMD ($p = 0.01$) and AMA ($p = 0.026$) were also significant across BMI groups, with higher values seen in individuals with higher BMI. No significant correlation was found between age and AMD ($p = 0.827$) or age and AMA ($p = 0.307$). This study highlights significant gender and BMI-related differences in the anatomical relationship between the SMA and AA. Age, however, does not appear to significantly impact these measurements within the studied range. Future research should explore additional demographic factors to further understand these variations.

Keywords: Aorto-mesenteric angle; Aorto-mesenteric distance; Computed tomography; Superior Mesenteric Artery; Vascular anatomy

INTRODUCTION

The compression of the third part of the duodenum between the Superior Mesenteric Artery (SMA) and the Abdominal Aorta (AA) is a significant cause of duodenal obstruction (Sinagra et al., 2018). This condition is known as Superior Mesenteric Artery Syndrome (SMAS), also referred to as Willkie's syndrome, Cast syndrome, duodenal vascular compression, or arterial-mesenteric duodenal compression. (Chrysikos et al., 2019; Fazio et al., 2015). Although the accurate prevalence of SMAS is unknown, the incidence is estimated at 0.1% to 0.3% of the world population, with a higher prevalence in women compared to men at a ratio of 3:2 (Jafarpisheh et al., 2019).

Superior Mesenteric Artery Syndrome results in notable clinical symptoms such as weight loss, nausea, vomiting, abdominal pain, and other gastrointestinal issues, making

an accurate diagnosis and understanding of its anatomical basis is critical. (Felton et al., 2012; Gozzo et al., 2020; Shi et al., 2019). The anatomical relationship between the SMA and AA, specifically the aorto-mesenteric distance (AMD) and aorto-mesenteric angle (AMA), is crucial in the development of SMAS (Felton et al., 2012; Gozzo et al., 2020; Shi et al., 2019). Research indicates that the normal mean value of AMD ranges from 10 to 34 mm, while AMA varies from 28° to 65° (Lamba et al., 2014; Santer et al., 1991). A reduction of 5–11 mm in distance and 6°–16° in angle significantly increases the risk of development of SMAS (Laffont et al., 2002). However, studies suggest that AMD and AMA vary across different populations and demographic groups (Hadi et al., 2022; Kalyani et al., 2017).

This study aimed to determine the normal values of the distance and angle between the SMA and AA in an asymptomatic Sri Lankan cohort using contrast-enhanced computed tomography (CECT). Additionally, this study investigated the association of these anatomical measurements with demographic factors such as gender, age, and body mass index (BMI). The findings provide a critical reference for diagnosing SMA-related conditions and deliver population-specific data essential for accurate clinical assessment. Furthermore, the study offers baseline anatomical insights to support surgical planning. Notably, this is the first study to assess these parameters in the Sri Lankan population, addressing a previously unexplored topic and laying a foundation for future research in this area.

Several studies have validated the effectiveness of CECT in diagnosing and assessing SMAS. The established use of CECT in similar research provides a solid foundation for the methodology in this study, ensuring that it builds on a proven and reliable imaging technique (Hadi et al., 2022; Kalyani et al., 2017).

MATERIALS AND METHODS

A cross-sectional descriptive study was conducted at three selected Government hospitals in Sri Lanka: Kandy

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National Hospital (Hospital A), Teaching Hospital, Peradeniya (Hospital B), and Sirimavo Bandaranayake Specialized Children's Hospital, Peradeniya (Hospital C). The study received ethical clearance from the Ethics Review Committee of the Faculty of Allied Health Sciences (AHS/ERC/2022/030) and permission from the respective hospitals. Informed consent was obtained from all participants prior to their inclusion in the study. The study prospectively included CT images of patients aged 18 to 80 years who were referred for CECT abdominal scans for reasons other than direct gastrointestinal complaints during the study period. Exclusion criteria included a history of gastrointestinal surgery, abdominal bowel obstruction, abdominal vascular intervention, anatomical variants of SMA origin, abdominal aortic aneurysm, and abdominal aortic dissection. Additionally, images of poor quality were excluded.

Data collection was conducted over five weeks, from May to July 2022. Sample size calculation was based on information obtained from each hospital registry, utilizing a convenience sampling technique. Before the scan, demographic parameters such as age, gender, height (m), and weight (kg) were recorded. The BMI was calculated using the standard formula: weight (kg)/ height (m²). The patients were divided into four different BMI categories based on the world health organization (WHO) recommendations: Underweight (Category 1) - <18.50 kg/m², Normal weight (Category 2) - 18.50-24.90 kg/m², Pre-obesity (Category 3) - 25.00-29.90 kg/m², Obesity (Category 4) - >30.00 kg/m² (World Health Organization Regional Office for Europe. Everyday Actions for Better Health – WHO Recommendations., 2010). Only images obtained from the arterial phase of abdominal CECT were included. All selected CECT images were assessed for diagnostic quality using visual grading analysis, as shown in Figure 1. Images scoring less than or equal to 2 met the acceptable standard for clinical diagnostic purposes and were included in the study. The selected images were then reviewed and confirmed as representing a healthy cohort in terms of SMA and AA by an experienced consultant radiologist with more than five years of experience.

Digital Imaging and Communications in Medicine (DICOM) images were processed using multi-planar reconstruction (MPR) with the RadiAnt DICOM viewer software (*RadiAnt DICOM Viewer*, 2022). This enabled the acquisition of high-resolution mid-sagittal sections in a soft tissue window, facilitating detailed assessment of the branching configuration of the SMA from the AA. The distance between the posterior wall of the SMA and the anterior wall of the AA was measured on axial images at the level where the third part of the duodenum crosses between the two vessels (Figure 2). To ensure uniformity across all patients, the measurement was taken at the midpoint between the superior and inferior margins of the crossing duodenal loop (Hadi et al., 2022). The AMA was measured at the origin of the SMA using reconstructed sagittal images, as shown in Figure 2. The angle measurement was taken at the point where the lines tracing the posterior wall of the SMA and the anterior wall of the aorta intersected at the SMA origin (Figure 2). To ensure reproducibility, measurements were taken twice by the same investigator on two separate occasions, at least two weeks apart.

Statistical analysis

Statistical analysis of the measurements was performed using SPSS version 20 statistical software. Minimum, maximum, Mean, and standard deviations (SD) were calculated for all the continuous variables. The intraclass correlation coefficient (ICC) was used to evaluate the reproducibility of the reading of the continuous variables. According to the Shapiro-Wilk normality test, age and AMD were not found to be normally distributed ($p < 0.001$), while AMA was found to be distributed normally ($p = 0.121$). Therefore, group comparisons were conducted using Student's T-test and ANOVA for normally distributed data. The Mann-Whitney and Kruskal-Wallis tests were used for not normally distributed data. The Spearman's rank correlation test was used to assess the correlation between age and AMD, as well as between age and AMA. To predict the value of a dependent variable based on independent variables, regression analysis was performed.

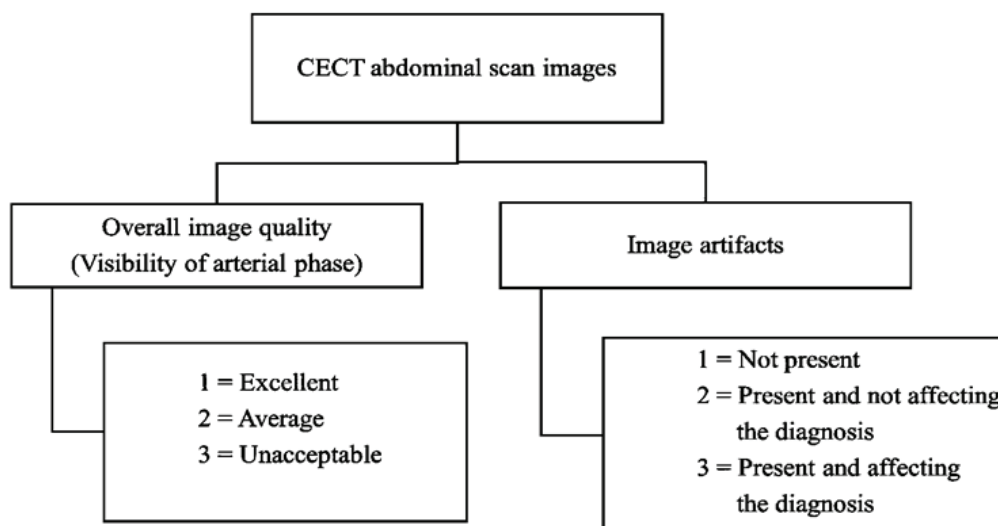


Figure 1: Image Quality Evaluation (Visual grading Analysis)

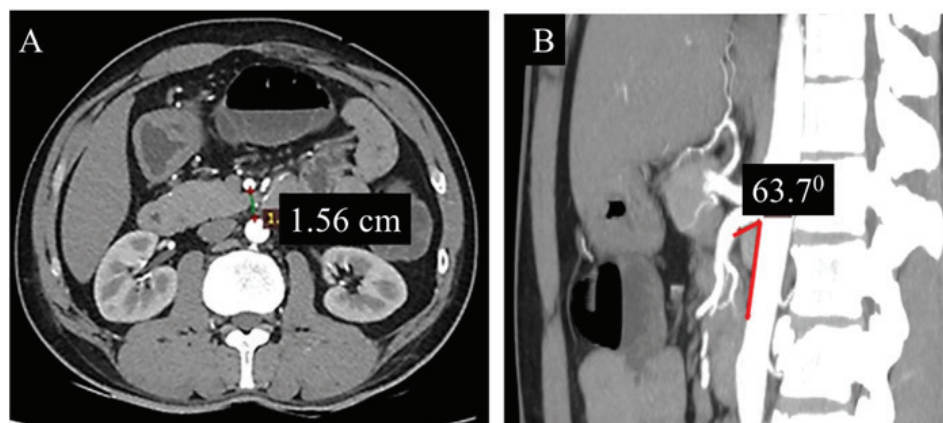


Figure 2: Measurement of (A) the distance between the superior mesenteric artery (SMA) and the abdominal aorta (AA) using an axial image, and (B) the angle between the SMA and AA using a sagittal image

RESULTS

Out of 147 abdominal CECT images, 21 were excluded due to poor quality, and 8 were excluded due to an age mismatch. Additionally, 18 images were excluded due to pathological conditions in the region of interest, as determined by the consultant radiologist. Therefore, the final sample size was 100, selecting a gender balanced sample of 50 males and 50 females.

Demographic characteristics

Table 1 presents the demographic data of participants. The mean age of the participants was 55 years. The mean BMI was 23 kg/m², indicating that the majority of the participants were in the normal weight category. The mean AMD was 14.49 mm, and the mean AMA was 57.14°.

Reliability of measurements

Since all the ICC values were greater than 0.9, the reliability

of the measurements was well within acceptable limits.

Gender with AMD and AMA

As indicated in Figure 3, the median values for AMD and AMA are slightly higher in males compared to females, suggesting that, on average, males exhibit higher AMD and AMA measurements. According to the Independent-Samples Mann-Whitney U-test, a significant association was found between gender and AMD, as well as gender and AMA ($p < 0.05$), with higher values observed in males compared to females (Table 2).

BMI with AMD and AMA

The Kruskal-Wallis test indicated significant differences in AMA and AMD between different BMI groups. Higher AMD values were observed with increasing BMI categories (Figure 4, Table 3). Pairwise comparisons revealed that the AMD in the underweight group was significantly

Table 1: Descriptive statistics (minimum, maximum, mean, and standard deviation) of age, BMI, weight, height, aorto-mesenteric distance (AMD), and aorto-mesenteric angle (AMA) among the study participants.

	Minimum	Maximum	Mean	Std. Deviation
Age (year)	18	80	55	14.83
BMI (kg/m ²)	14.08	34.57	23.06	4.55
Weight (kg)	33	96	57.65	12.02
Height (m)	1.30	1.83	1.58	0.097
AMD (mm)	5.17	36.92	14.49	7.12
AMA (o)	11.30	116.00	57.14	25.65

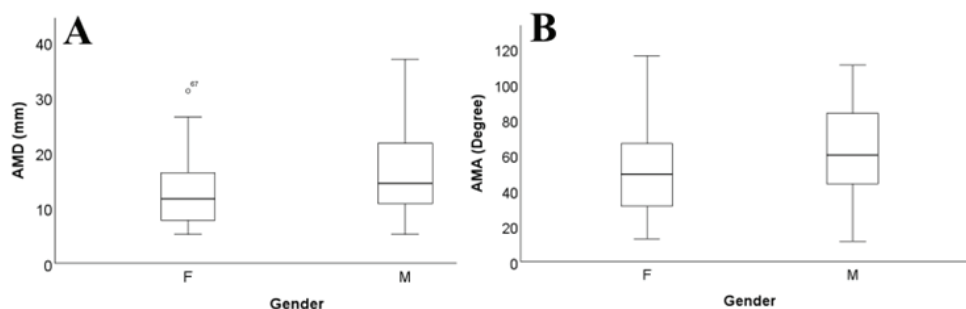


Figure 3: (A) Distance between the superior mesenteric artery (SMA) and the abdominal aorta (AA) by gender, and (B) angle between the SMA and AA by gender

Table 2: Distribution of Aortomesenteric Distance (AMD) and Aortomesenteric Angle (AMA) according to gender

Variable	Gender	N	Mean	Std. Deviation ($\pm$)	p
AMD	Female	50	12.62 mm	6.95	0.014
	Male	50	16.35 mm	7.67	
AMA	Female	50	51.09 ⁰	24.78	0.018
	Male	50	63.20 ⁰	25.30	

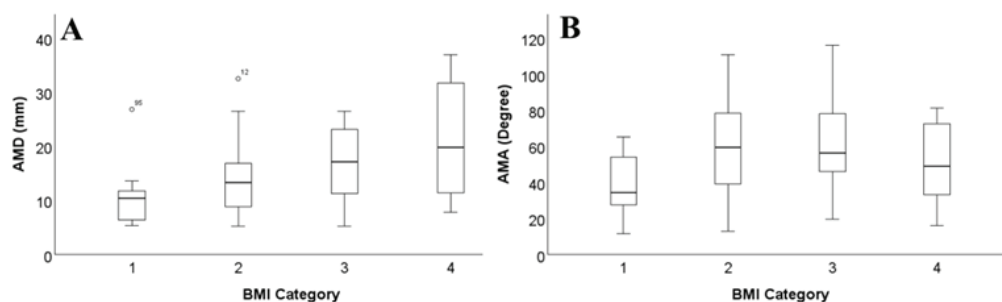
lower than in the normal weight, pre-obesity, and obese categories. Similarly, pairwise comparisons showed that the AMA in the underweight group was significantly lower than that in the normal-weight BMI category (Table 4)

Age with AMD and AMA

According to Spearman's correlation test, there was no significant correlation between age and AMD and age and AMA (Table 5).

Impact of age, gender, and BMI on AMD

An R Square (0.33) indicates that approximately 33% of the variance in AMD (mm) is explained by the independent variables of age, BMI, and gender. Based on the ANOVA table the F-value (15.74) with a p-value (Sig) of 0.000 indicates that the model is statistically significant, meaning that at least one of the predictors significantly explains the variation in AMD. The results show that age has a negative

**Figure 4:** (A) Distance between the superior mesenteric artery (SMA) and the abdominal aorta (AA) by BMI category, and (B) angle between the SMA and AA by BMI category**Table 3:** Distribution of Aortomesenteric Distance (AMD) and Aortomesenteric Angle (AMA) across BMI categories

Variable	BMI Categories	N	Mean (mm)	Std. Deviation	p
AMD	1	13	10.42	5.70	0.01*
	2	61	13.81	6.04	
	3	18	16.71	7.14	
	4	08	21.30	11.15	
Variable	BMI Categories	N	Mean (Degrees)	Std. Deviation	p
AMA	1	13	38.42	19.42	0.026*
	2	61	60.70	26.25	
	3	18	61.41	23.48	
	4	08	50.84	23.62	

*The mean difference is significant at the 0.05 level

Table 4: Pairwise comparison of Aortomesenteric Distance (AMD) and Aortomesenteric Angle (AMA) across BMI categories

Variable	BMI Categories	p	Variable	BMI Categories	p**
AMD	1-2	0.040*	AMA	1-2	0.021*
	1-3	0.004*		1-3	0.059
	1-4	0.004*		1-4	0.682
	2-3	0.128		2-3	0.927
	2-4	0.080		2-4	0.716
	3-4	0.556		3-4	0.748

** Post-Hoc test, *The mean difference is significant at the 0.05 level

Table 5: Correlation of age with Aortomesenteric Angle (AMA) and Aortomesenteric Distance (AMD)

Age		
AMD (mm)	Correlation Coefficient	0.022
	Sig. (2-tailed)	0.827
	N	100
AMA (o)	Correlation Coefficient	-0.103
	Sig. (2-tailed)	0.307
	N	100

relationship with AMD (coefficient = -0.006), but this is not statistically significant ($p = 0.877$). In contrast, the coefficient of 0.831 BMI indicates a statistically significant ($p = 0.000$) positive relationship with AMD, meaning that as BMI increases, AMD tends to increase. Similarly, the coefficient of 5.831 for gender indicates a positive relationship with AMD, and this is highly significant ($p = 0.000$), suggesting that gender is an important predictor of AMD (Table 6). The mean of residuals is zero, indicating

that the model's predictions are unbiased on average.

Impact of age, gender, and BMI on AMA

An R Square (0.108) indicates that approximately 10.8% of the variance in AMA (degree) is explained by the independent variables of age, BMI, and gender. Based on the ANOVA table the F-value (3.894) with a p-value (Sig) of 0.011 indicates that the model is statistically significant, meaning that at least one of the predictors significantly explains the variation in AMA. The results show that age has a negative relationship with AMA (coefficient = -0.223), but this is not statistically significant ($p = 0.192$). In contrast, the coefficient of 1.171 BMI indicates a statistically significant ($p = 0.041$) positive relationship with AMA, meaning that as BMI increases, AMA tends to increase. Similarly, the coefficient of 16.145 of gender indicates a positive relationship with AMA, and this is highly significant ($p = 0.003$), suggesting that gender is an important predictor of AMA (Table 7). The mean of residuals is zero, indicating that the model's predictions are unbiased on average.

Table 6: Multiple regression analysis of Aortomesenteric Distance (AMD) with Age, Body Mass Index (BMI), and Gender

Model Summary					
R	0.574				
R ²	0.330				
Adjusted R ²	0.309				
Std. Error of Estimate	5.919				
ANOVA					
F (df = 3)	15.735				
p-value (Sig.)	0.000				
Predictor	B	Std. Error	Beta	t	p-value
Constant)	-13.070	4.421	—	-2.956	0.004
Age (year)	-0.006	0.041	-0.013	-0.155	0.877
BMI	0.831	0.136	0.532	6.098	0.000
Gender	5.831	1.253	0.412	4.654	0.000

Table 7: Multiple regression analysis of Aortomesenteric Angle (AMA) with Age, Body Mass Index (BMI), and Gender

Model Summary					
R	0.329				
R ²	0.108				
Adjusted R ²	0.081				
Std. Error of Estimate	24.59				
ANOVA					
F (df = 3.96)	3.89				
p-value (Sig.)	0.011				
Predictor	B	Std. Error	Beta	t	p-value
(Constant)	18.240	18.368	—	0.993	0.323
Age (year)	-0.223	0.170	-0.129	-1.315	0.192
BMI	1.171	0.566	0.208	2.068	0.041
Gender	16.145	5.205	0.316	3.102	0.003

DISCUSSION

This study holds particular significance as a timely preliminary investigation within the Sri Lankan context. Given the limited availability of healthcare resources in the country, rapid identification of risk categories becomes crucial for early management and treatment planning. The participants in this study were patients undergoing imaging for non-gastrointestinal conditions, and individuals with known gastrointestinal pathology were excluded to minimize confounding factors. Therefore, while the cohort does not represent a strictly healthy population, it includes individuals without gastrointestinal abnormalities, making the findings relevant for establishing baseline anatomical parameters. Furthermore, due to the scarcity of prior statistical evaluations in Sri Lanka and the variability in findings from similar studies conducted globally, this study contributes valuable region-specific insights. As a preliminary effort, it also highlights the need for further research in this area, given the current lack of published data from Sri Lanka. This study achieved a balanced final sample size of 100 (50 males and 50 females) participants with a mean age of 55 years. The average BMI was 23 kg/m², placing most participants in the normal weight category. Therefore, the results of this study provide a significant baseline understanding of the relationship between the SMA and the AA in a relatively healthy, adult population.

Gender difference

This study found that gender significantly affects both AMD and AMA. Males had higher median values for both AMD and AMA, with these differences being statistically significant ($p < 0.05$). These results are consistent with previous studies that have also reported gender differences in vascular anatomy. For instance, Sakaguchi et al., (2010) observed that males generally exhibit larger vascular structures compared to females, which may be attributed to differences in body size and composition. Additionally, a Brazilian study indicated that females have a higher risk of developing SMAS than males in all age groups except for those aged 20 to 30 years, based on the low mean values of AMD and AMA (Góes Junior et al., 2020). This substantial impact of gender on AMD and AMA underscores the potential physiological differences between genders, highlighting the need for further research into gender-specific factors contributing to variations in AMD and AMA. This also emphasizes the importance of considering gender-specific anatomical variations in clinical evaluations and treatments.

BMI difference

The study further identified BMI as a significant factor influencing both AMD and AMA. The Kruskal-Wallis test revealed significant differences across BMI categories, with higher BMI associated with increased AMA and AMD. Specifically, underweight individuals had significantly lower AMD and AMA compared to those in the normal weight, pre-obesity, and obese categories. This finding aligns with the literature, which indicates that higher BMI is often correlated with increased vascular dimensions due to

greater adipose tissue deposition around the vessels (White & Tchoukalova, 2014). Studies from various countries confirm the significant correlation between BMI and both AMD and AMA in the context of SMAS. Lower BMI is associated with decreased AMD and AMA, increasing the risk of SMAS (Adhikari et al., 2019; Desai et al., 2015; Jafarpisheh et al., 2019). This emphasizes the importance of BMI as a key variable in the development of SMAS.

Age difference

Contrary to expectations, age did not show a significant correlation with either AMD or AMA. The Spearman's correlation test indicated no significant relationship, suggesting that within the study's age range (18-80 years), age does not substantially influence the distance and angle between the SMA and AA. This result contrasts with some studies, such as those by Kohn et al. (Kohn et al., 2015) and Cheng et al. (Cheng et al., 2023) which suggested that vascular dimensions could change with age due to arterial stiffening. However, these findings may reflect the specific age range and health status of this sample, indicating that further research is needed to clarify these age-related effects.

Multivariate analysis: Predictors of AMD and AMA

The multiple regression analysis identified BMI and gender as significant predictors of AMD, explaining 33% of its variance. Gender had a substantial positive effect, and BMI also showed a significant positive relationship. Age, however, had a negligible and non-significant impact. For AMA, the regression model explained 10.8% of the variance. Gender and BMI were significant predictors, whereas age was not. These findings are consistent with the broader literature that emphasizes the role of BMI and gender in determining vascular anatomy. Studies by Ahmed et al., (2013) also found similar predictors for vascular measurements, reinforcing the importance of these factors.

The findings of this study have important practical implications. The significant positive relationship of gender and BMI with AMD and AMA suggests that these factors should be considered in medical assessments, interventions, and treatment planning for Sri Lankan populations. Healthcare providers should be aware of the influence of BMI on AMD and AMA, potentially advocating for weight management as part of patient care. Similarly, understanding the gender differences in AMD and AMA could lead to gender-specific medical approaches, enhancing the effectiveness of treatments and interventions.

Limitations and future research

While the model provides valuable insights, it also has limitations. The R Square value of 0.33 indicates that there are other factors not included in the model that account for the remaining 67% of the variance in AMD. Future research should explore additional variables that may influence AMD, such as lifestyle factors, genetic predispositions, and environmental influences. Moreover, the non-significant impact of age in this study suggests that more nuanced age-related variables or interactions might need to be considered. In addition, future studies

could investigate whether the variables examined here also have implications for other compression syndromes, such as Nutcracker syndrome. Exploring potential overlaps between SMA syndrome and other related conditions might reveal common pathophysiological causes. Furthermore, comparing a healthy population with patients diagnosed with SMA syndrome would be an important next step, as it could deepen the understanding of the syndrome and validate the clinical relevance of the variables identified in this study.

CONCLUSIONS

The measured mean AMD was 14.49 mm, and the mean AMA was 57.140 in this study. This study highlights significant gender and BMI-related differences in the anatomical relationship between the SMA and AA, with males and individuals with higher BMI exhibiting greater distances and angles. Age, however, does not appear to significantly impact these measurements within the studied range. These findings are in line with existing literature, yet they contribute new quantitative insights that are crucial for clinical applications such as diagnostic and surgical planning.

DATA AVAILABILITY STATEMENT

The data is available upon request

FUNDING STATUS

No funding is received for the study.

DECLARATIONS/ CONFLICT OF INTEREST

The authors have no relevant financial or non-financial interests to disclose

AUTHOR CONTRIBUTION

Data collection: **S. M. H. W., A. O., M. Vis., M. Vit., B. S. W.**; Data analysis: **S. M. H. W., A. O., B. S. W.**; Manuscript writing: **B. S. W.**; Manuscript editing and reviewing: **S. M. H. W., A. O., M. Vis., M. Vit., B. S. W.** All authors are responsible for the content of the manuscript.

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