

Rethinking anthropometric risk: non-linear associations between body indices and carotid plaque

Ignas Badaras

`ignas.badaras@santa.lt`

Vilnius University

Roma Purnaite

Vilnius University

Egidija Rinkuniene

Vilnius University

Vytautas Kasiulevicius

Vilnius University

Jolita Badariene

Vilnius University

Vilma Dzenkeviciute

Vilnius University

Research Article

Keywords: atherosclerosis, carotid plaque, anthropometric indices, A Body Shape Index, Body Roundness Index, body mass index, cardiovascular risk, non-linear association

Posted Date: July 10th, 2026

DOI: <https://doi.org/10.21203/rs.3.rs-10116402/v1>

License:   This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

Additional Declarations: No competing interests reported.

Abstract

Background:

This study aimed to explore the associations between various anthropometric indices—a body shape index, body roundness index, and body mass Index —and the prevalence of carotid plaque in a Lithuanian primary prevention population

Methods:

Data were obtained from a national cardiovascular disease prevention program, including men aged 40–54 years and women aged 50–64 years. After exclusions, 6,718 individuals were analyzed. Carotid ultrasound was performed to assess plaque presence. ABSI and BRI were categorized into quartiles, while BMI was grouped according to standard clinical categories. Analyses were performed separately for males and females.

Results:

In males, significant associations were observed between carotid plaque prevalence and ABSI ($P = 0.011$) and BRI ($P = 0.047$). The relationship for ABSI was non-linear, with the highest plaque prevalence in Q4 (50.2%), but also elevated prevalence observed in Q1 (44.4%). Similarly, BRI demonstrated an inverse pattern, with the highest plaque prevalence observed in Q1 (49.9%). BMI showed a significant inverse association, with the highest plaque prevalence observed among normal-weight individuals (56.3%).

In females, only BMI was significantly associated with plaque prevalence ($P < 0.001$), again with the highest prevalence observed in the normal-weight group (64.0%). Lower quartiles were characterized by a higher burden of metabolic abnormalities.

Conclusion:

Anthropometric indices demonstrated complex and non-linear associations with carotid plaque prevalence, particularly in males. Lower index values were not consistently associated with lower cardiovascular risk, suggesting that favorable anthropometric profiles may mask underlying metabolic impairment. These findings highlight the importance of comprehensive cardiovascular risk assessment beyond traditional body composition measures.

Introduction

Despite improvements in recent years, cardiovascular (CV) diseases remain the leading cause of death worldwide. Atherosclerosis is a complex chronic disease and is considered one of the most important preventable causes of ischaemic stroke. The earliest structural abnormality indicative of carotid artery atherosclerosis is an increase in intima-media thickness (IMT). Obesity is a well-established risk factor

for atherosclerosis and cardiovascular disease, particularly due to the metabolic activity of visceral adipose tissue (4, 5). The release of fatty acids and cytokines from adipose tissue into the circulation is the most widely accepted explanation for the association between abdominal fat and the development of carotid atherosclerosis (7).

Detecting atherosclerosis in asymptomatic individuals using various strategies helps predict and prevent future CV events. Carotid ultrasound has been suggested as a potential technique to assist in CV risk stratification, as it is a safe, low-cost, and commonly available method that directly evaluates arterial atherosclerosis. Multiple previous studies have demonstrated that carotid IMT and carotid plaques are associated with the incidence of CV events and with CV risk factors..

Traditionally, anthropometric measures such as body mass index (BMI), waist circumference (WC), and waist-to-hip ratio (WHR) have been used in clinical practice to assess obesity-related risk (11). However, these indices have important limitations, as they do not adequately reflect fat distribution or distinguish between metabolically healthy and unhealthy phenotypes.

In recent years, novel anthropometric indices, including the A Body Shape Index (ABSI) and the Body Roundness Index (BRI), have been proposed as more precise markers of body fat distribution and cardiometabolic risk (11–14). These indices have been linked to metabolic syndrome and cardiovascular outcomes across diverse populations. However, their relationship with subclinical atherosclerosis, particularly carotid plaque formation, remains inconsistent and incompletely understood.

Importantly, emerging evidence suggests that the relationship between anthropometric indices and cardiovascular risk may be non-linear, with lower index values not necessarily indicating lower risk, potentially due to underlying metabolic impairment or sarcopenia-related phenotypes.

Therefore, this study aimed to investigate associations between ABSI, BRI, and BMI and the prevalence of carotid plaque in a large Lithuanian primary-prevention population, with a particular focus on potential non-linear patterns and sex-specific differences.

Methods

The data for this study were drawn from a national Lithuanian ASCVD primary prevention programme. Our study population comprised men aged 40–54 and women aged 50–64. Individuals with a history of major cardiovascular events, including myocardial infarction or stroke, were excluded. Participants who were unable to undergo carotid ultrasound or had missing data for key variables, such as waist circumference, height, or weight, were also excluded from the analysis.

After applying these criteria, the study sample consisted of 6,718 individuals, including 3,886 females.

Data Collection: All patients participating in the Lithuanian national ASCVD primary prevention programme undergo a Duplex Doppler ultrasonographic examination of the carotid arteries as part of their screening. A patient was classified as having carotid plaque if any carotid artery showed localized

arterial wall thickening exceeding 1.5 mm, or if the intima-media thickness was more than 50% greater than that of the adjacent vessel segment. During the same visit, patients had their weight, height, and waist circumference measured, their smoking status assessed, and blood samples collected for testing. Waist circumference was measured in centimetres (cm) around the smallest area below the rib cage and above the belly button.

Weight, height, and waist circumference were used to calculate ABSI, BRI, and BMI. The indices were computed using the following formulas:

$$1) \text{ BRI} = 364.2 - 365.5 \times \sqrt{\left(1 - \left(\frac{\left(\frac{WC(m)}{2\pi}\right)^2}{(0.5 \times \text{Height}(m))^2}\right)\right)}$$

$$2) \text{ ABSI} = WC / \text{BMI}^{2/3} * \text{Height}^{1/2}$$

$$4) \text{ BMI} = \text{weight(kg)} / \text{height (cm)}^2$$

Participants were categorised into quartiles based on their BRI and ABSI scores. For BMI analysis, individuals were grouped into four categories: 18.5–25, 25–30, 30–35, and 35 or higher. These quartiles were then examined for statistically significant differences in the prevalence of carotid atherosclerotic plaque. Separate analyses were conducted for the female and male populations.

Statistical Analysis:

Statistical analysis was performed using R software (version 4.4.2). Continuous variables are presented as means with standard deviations (SD), while categorical variables are expressed as percentages. Participants were categorised into sex-specific quartiles based on ABSI and BRI values, while BMI was analysed using predefined categories (18.5–25, 25–30, 30–35, and ≥ 35 kg/m²). The prevalence of carotid plaque was compared across these groups.

Analyses were conducted separately for male and female populations. A P-value of less than 0.05 was considered statistically significant.

Results

Baseline characteristics

The median age of the study population was 52.9 years. Due to differing inclusion criteria, females were older than males (57.1 vs. 47.2 years). Females comprised 57.8% of the cohort.

Hypertension was highly prevalent (93%), and 17.7% of participants had diabetes mellitus. Smoking was reported by 28.6% of participants. Carotid plaque was detected in 49.1% of the overall population, with a

higher prevalence in females than in males (52.0% vs. 45.2%). Detailed clinical and biochemical characteristics are presented in Table 1

Table 1
Clinical and Biochemical Characteristics of the Study Population

	Total	Female	Male	p
	N = 6718	N = 3886	N = 2832	
Age, year	52.9 (6.50)	57.1(4.28)	47.2 (4.33)	<0.001
Hypertension	93%	94.5%	91.0%	<0.001
Diabetes	17.7%	20.1%	14.5%	<0.001
Smoking	28.6%	17%	44.6	<0.001
Total cholesterol, mmol/l	6.27 (1.36)	6.40 (1.35)	6.09 (1.36)	<0.001
LDL-Cholesterol, mmol/l	4.04 (1.17)	4.19 (1.18)	3.83 (1.11)	<0.001
HDL-Cholesterol, mmol/l	1.20 (0.30)	1.30 (0.29)	1.06 (0.25)	<0.001
Triglycerides, mmol/l	2.30 (2.21)	1.97 (1.20)	2.74 (3.04)	<0.001
Fasting glucose, mmol/l	6.37 (1.49)	6.37 (1.50)	6.37 (1.49)	0.843
CRP, mg/l	3.07 (3.72)	3.31 (3.80)	2.75 (3.58)	<0.001
Creatinine, mmol/l	11.4 (5.98)	9.41 (5.02)	14.0(6.16)	<0.001
LDL-cholesterol – low density lipoprotein cholesterol, HDL- cholesterol - low density lipoprotein cholesterol, CRP – C reactive protein				

Association of ABSI and Carotid Plaque:

The male population was divided into ABSI quartiles as follows: Q1 (0.064–0.078), Q2 (0.078–0.081), Q3 (0.081–0.084), and Q4 (0.084–0.105). Meanwhile, the female population was categorised into ABSI quartiles as follows: Q1 (0.048–0.076), Q2 (0.076–0.079), Q3 (0.079–0.083), and Q4 (0.083–0.105).

In males, a statistically significant difference in carotid plaque prevalence was observed across ABSI quartiles ($P = 0.011$). The highest prevalence was in Q4 (50.2%), while the lowest was in Q2 (41.5%). The relationship was non-linear, with plaque prevalence also higher in Q1 than in Q2 (44.4% vs 41.5%).

In females, no statistically significant differences in carotid plaque prevalence were observed across ABSI quartiles ($P = 0.457$) (Table 2).

Table 2
Prevalence of carotid plaque across anthropometric indices quartiles

ABSI	Q1	Q2	Q3	Q4	p
Carotid plaque (Males)	44.4%	41.5%	45.0%	50.2%	0.011
Carotid plaque (Females)	49.9%	51.8%	53.2%	53.0%	0.457
BRI					
Carotid plaque (Males)	49.6%	43.9%	44.1%	43.0%	0.047
Carotid plaque (Females)	54.8%	52.6%	50.0%	50.2%	0.110
ABSI – a body shape index, BRI – body roundness index,					

Association of BRI and Carotid Plaque:

The male population was grouped into BRI quartiles: Q1 (2.1–4.8), Q2 (4.81–5.5), Q3 (5.51–6.3), and Q4 (6.31–12.8). For females, quartiles were Q1 (1.5–5), Q2 (5.01–6), Q3 (6.01–7), and Q4 (7.01–15.1).

In males, carotid plaque prevalence differed significantly across BRI quartiles ($P = 0.047$). The highest prevalence was observed in Q1 (49.6%), whereas the prevalence in Q2–Q4 was relatively similar (43.9%, 44.1%, and 43.0%, respectively).

In females, a similar distribution was observed, with the highest prevalence in Q1 (54.8%); however, the differences were not statistically significant ($P = 0.110$) (Table 2).

Association of BMI and Carotid Plaque:

Significant differences in carotid plaque prevalence were observed across BMI categories in both males ($P = 0.003$) and females ($P < 0.001$).

In males, the highest prevalence was observed in the normal-weight group (56.3%), with prevalence decreasing across overweight (49.2%), obese (43.5%), and severely obese individuals (41.4%).

A similar trend was observed among females, with the highest prevalence in normal-weight individuals (64.0%), followed by overweight (53.6%), obese (53.2%), and severely obese participants (46.3%) (Table 3).

Table 3
Prevalence of carotid plaque in different BMI groups

	BMI				p
	< 25	25–30	30–35	> 35	
Carotid plaque (Males)	56.3%	49.2%	43.5%	41.4%	0.003
Carotid plaque (Females)	64.0%	53.6%	53.2%	46.3%	<0.001
BMI – body mass index					

Association between anthropometric indices and carotid plaques

Three of the four indices (ABSI, BRI, BMI) showed statistically significant differences in carotid plaque prevalence among the male population. BRI and BMI displayed paradoxical trends: the lower quartiles, typically associated with healthier individuals, had higher prevalence rates. By contrast, ABSI followed the expected pattern, with Q4 showing the highest prevalence (50.2%). However, the relationship was not linear, as Q1 (44.4%) had a higher prevalence than Q2 (41.5%).

Among the female population, only BMI showed statistically significant differences, with normal-weight individuals exhibiting the highest plaque prevalence (64%), a paradoxical finding. Among the indices analysed, only ABSI showed an expected increase in carotid plaque prevalence across higher quartiles, though this trend was not statistically significant. All the analysed body indices (ABSI, BRI) showed statistically significant differences between male and female populations. This is demonstrated in Table 4.

Table 4
Average anthropometric indices in male and female populations

	Total	Female	Male	p.overall
	N = 6718	N = 3886	N = 2832	
WC	105 (10.4)	102 (10.3)	109 (9.28)	<0.001
BMI	31.9 (4.40)	32.1 (4.72)	31.7 (3.90)	<0.001
ABSI	0.08 (0.0049)	0.079 (0.0052)	0.081 (0.0041)	<0.001
BRI	5.93 (1.47)	6.13 (1.57)	5.66 (1.26)	<0.001

ABSI – a body shape index, BMI – body mass index, BRI – body roundness index, WC – waist circumference.

Metabolic impairment and carotid plaques

Within ABSI quartiles, individuals in Q1 had higher rates of elevated triglycerides (79.5% vs. 72.3%), low HDL-cholesterol (63.2% vs. 60.3%), elevated fasting glucose (83.1% vs. 78.1%), and hypertension (97.1% vs. 95.4%) than those in Q2. BRI quartiles showed similar trends. The high prevalence of carotid plaques in Q1 may result from sarcopenia-related metabolic impairment.

Discussion

In this study, anthropometric indices—ABSI, BRI, and BMI—were significantly associated with carotid plaque prevalence, particularly among males. However, these relationships were non-linear and differed between the sexes. Among the indices evaluated, ABSI showed the most consistent association with carotid plaque prevalence, whereas BRI and BMI demonstrated more complex patterns.

ABSI is considered a marker of central adiposity and has been shown in previous studies to be more closely associated with cardiometabolic risk than traditional indices such as BMI (12). In our study, ABSI demonstrated a statistically significant association with carotid plaque prevalence in males, with the highest prevalence observed in the highest quartile. This finding supports the hypothesis that central fat distribution plays a key role in the development of subclinical atherosclerosis.

In contrast, BRI and BMI showed non-linear associations with carotid plaque prevalence. In both indices, higher plaque prevalence was observed in the lowest categories. For BRI, the highest prevalence in males was observed in the lowest quartile, while BMI demonstrated the highest plaque prevalence in normal-weight individuals in both sexes. These findings indicate that lower anthropometric values were not consistently associated with lower cardiovascular risk.

One possible explanation for these findings is the presence of underlying metabolic impairment in individuals with lower anthropometric indices. In our study, lower quartiles of ABSI and BRI were characterized by a higher prevalence of metabolic abnormalities, including elevated triglycerides, low HDL-cholesterol, elevated fasting glucose, and hypertension. This suggests that individuals in these groups may represent a metabolically unfavorable phenotype despite having lower body size measurements.

These results highlight the limitations of traditional and simplified anthropometric measures in cardiovascular risk assessment. While indices such as BMI and BRI are commonly associated with obesity-related risk, they may fail to capture important aspects of body composition and metabolic status. In contrast, ABSI may better reflect the distribution of visceral adiposity and its impact on vascular health.

Sex-specific differences were also observed in our study. Significant associations between anthropometric indices and carotid plaque prevalence were primarily found in males, whereas in females only BMI showed statistically significant differences. These findings may reflect differences in fat distribution, hormonal factors, or other biological mechanisms between sexes, which influence the relationship between body composition and atherosclerosis.

Our findings have important clinical implications. The observed non-linear associations suggest that reliance on a single anthropometric measure may be insufficient for accurate cardiovascular risk stratification. Individuals with apparently favorable anthropometric profiles may still have a substantial burden of subclinical atherosclerosis, highlighting the need for a more comprehensive evaluation that includes metabolic factors and imaging when appropriate.

Several limitations of this study should be acknowledged. First, due to the cross-sectional design, causal relationships cannot be established. Second, the study population consisted of individuals participating in a national prevention program, which may limit generalizability to other populations. Third, the analysis was based on anthropometric indices and did not include direct measures of body composition.

Conclusion

This study demonstrates that anthropometric indices—ABSI, BRI, and BMI—are associated with carotid plaque prevalence, particularly in men; however, these relationships are complex and non-linear. Lower values of these indices were not consistently linked to lower cardiovascular risk.

ABSI showed the most consistent association with carotid plaque, whereas BRI and BMI showed less predictable patterns. The higher plaque prevalence in lower categories may reflect underlying metabolic impairment not captured by conventional anthropometric measures.

These findings highlight the limitations of relying solely on body size indices for cardiovascular risk assessment and underscore the need for a more comprehensive approach that integrates metabolic and imaging markers.

Abbreviations

ABSI	
A body shape index	
ASCVD	
Atherosclerotic cardiovascular disease	
BMI	
Body mass index	
BRI	
Body roundness index	
CV	
Cardiovascular	
IMT	
Intima–media thickness	
WC	
Waist circumference	

Declarations

Ethics approval and consent to participate

This study was conducted in accordance with the ethical standards of institutional and national research. Ethics approval was obtained from the Vilnius Regional Biomedical Research Ethics Committee. All participants provided written informed consent before inclusion in the study.

Consent for publication

Not applicable

Competing interests

The authors declare that they have no competing interests.

Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Author Contribution

I.B. contributed to the study conception and design, data analysis, and drafting of the manuscript.

R.P. contributed to the study data analysis, data interpretation, and manuscript revision.

E.R. and J.B. contributed to data collection and interpretation.

V.D. contributed to study supervision, critical revision of the manuscript, and final approval.

All authors read and approved the final manuscript.

Acknowledgement

The authors would like to acknowledge the Lithuanian national primary prevention program for atherosclerotic cardiovascular disease for providing the data used in this study

Availability of data and materials

The datasets analysed in the current study are not publicly available due to participant privacy concerns and restrictions imposed by the ethics committee. However, they are available from the corresponding author on reasonable request.

References

1. Cardiovascular diseases (CVDs). [Internet]. [cited 2025 Jun 29]. Available from: [https://www.who.int/news-room/fact-sheets/detail/cardiovascular-diseases-\(cvds\)](https://www.who.int/news-room/fact-sheets/detail/cardiovascular-diseases-(cvds)).
2. The top 10. causes of death [Internet]. [cited 2025 Jun 29]. Available from: <https://www.who.int/news-room/fact-sheets/detail/the-top-10-causes-of-death>
3. Bots ML, Grobbee DE. Intima media thickness as a surrogate marker for generalised atherosclerosis. *Cardiovasc Drugs Ther.* 2002;16(4):341–51.
4. Volpe M, Gallo G. Obesity and cardiovascular disease: An executive document on pathophysiological and clinical links promoted by the Italian Society of Cardiovascular Prevention (SIPREC). *Front Cardiovasc Med* [Internet]. 2023 Mar 13 [cited 2025 Jun 29];10. Available from: <https://www.frontiersin.org/journals/cardiovascular-medicine/articles/10.3389/fcvm.2023.1136340/full>
5. Blüher M. Obesity: global epidemiology and pathogenesis. *Nat Rev Endocrinol.* 2019;15(5):288–98.
6. Wang W, Lv FY, Tu M, Guo XL. Perirenal fat thickness contributes to the estimated 10-year risk of cardiovascular disease and atherosclerotic cardiovascular disease in type 2 diabetes mellitus. *Front Endocrinol* [Internet]. 2024 Jul 8 [cited 2025 Jun 29];15. Available from: <https://www.frontiersin.org/journals/endocrinology/articles/10.3389/fendo.2024.1434333/full>
7. Alexopoulos N, Katritsis D, Raggi P. Visceral adipose tissue as a source of inflammation and promoter of atherosclerosis. *Atherosclerosis.* 2014;233(1):104–12.
8. Roman MJ, Naqvi TZ, Gardin JM, Gerhard-Herman M, Jaff M, Mohler E. Clinical Application of Noninvasive Vascular Ultrasound in Cardiovascular Risk Stratification: A Report from the American Society of Echocardiography and the Society of Vascular Medicine and Biology. *J Am Soc Echocardiogr.* 2006;19(8):943–54.
9. Jeevarethinam A, Venuraju S, Dumo A, Ruano S, Rosenthal M, Nair D, et al. Usefulness of Carotid Plaques as Predictors of Obstructive Coronary Artery Disease and Cardiovascular Events in Asymptomatic Individuals With Diabetes Mellitus. *Am J Cardiol.* 2018;121(8):910–6.
10. Visseren FLJ, Mach F, Smulders YM, Carballo D, Koskinas KC, Bäck M, et al. 2021 ESC Guidelines on cardiovascular disease prevention in clinical practice: Developed by the Task Force for cardiovascular disease prevention in clinical practice with representatives of the European Society of Cardiology and 12 medical societies With the special contribution of the European Association of Preventive Cardiology (EAPC). *Eur Heart J.* 2021;42(34):3227–337.
11. Mansoori A, Allahyari M, Mirvahabi MS, Tanbakuchi D, Ghoflchi S, Derakhshan-Nezhad E, et al. Predictive properties of novel anthropometric and biochemical indexes for prediction of cardiovascular risk. *Diabetol Metab Syndr.* 2024;16(1):304.

12. Bertoli S, Leone A, Krakauer NY, Bedogni G, Vanzulli A, Redaelli VI, et al. Association of Body Shape Index (ABSI) with cardio-metabolic risk factors: A cross-sectional study of 6081 Caucasian adults. *PLoS ONE*. 2017;12(9):e0185013.
13. Zhang S, Han S, Zheng L, Sun Y, Sun Z. Associations of trajectories in body roundness index with incident cardiovascular disease: a prospective cohort study in rural China. *Front Nutr* [Internet]. 2024 Feb 21 [cited 2024 Nov 13];11. Available from: <https://www.frontiersin.org/journals/nutrition/articles/10.3389/fnut.2024.1291093/full>
14. Geraci G, Zammuto M, Gaetani R, Mattina A, D'Ignoto F, Geraci C, et al. Relationship of a Body Shape Index and Body Roundness Index with carotid atherosclerosis in arterial hypertension. *Nutr Metab Cardiovasc Dis*. 2019;29(8):822–9.
15. Tang L, Zeng L. Comparative efficacy of anthropometric indices in predicting 10-year ASCVD risk: insights from NHANES data. *Front Cardiovasc Med* [Internet]. 2024 Feb 29 [cited 2024 Dec 30];11. Available from: <https://www.frontiersin.org/journals/cardiovascular-medicine/articles/10.3389/fcvm.2024.1341476/full>
16. Westphal SA, Obesity. Abdominal Obesity, and Insulin Resistance. *Clin Cornerstone*. 2008;9(1):23–31.
17. Bagyura Z, Kiss L, Lux Á, Csobay-Novák C, Jermendy ÁL, Polgár L, et al. Association between coronary atherosclerosis and visceral adiposity index. *Nutr Metab Cardiovasc Dis*. 2020;30(5):796–803.
18. Duncan MJ, Mota J, Vale S, Santos MP, Ribeiro JC. Associations between body mass index, waist circumference and body shape index with resting blood pressure in Portuguese adolescents. *Ann Hum Biol*. 2013;40(2):163–7.
19. Chang Y, Guo X, Chen Y, Guo L, Li Z, Yu S, et al. A body shape index and body roundness index: two new body indices to identify diabetes mellitus among rural populations in northeast China. *BMC Public Health*. 2015;15(1):794.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [Lenteles.docx](#)