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Research Article

Association of Sialic Acid with Bmi and Waist Circumference in Coronary Artery Disease

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ABSTRACT

Background: Coronary artery disease (CAD) is one of the leading causes of morbidity and mortality worldwide. Obesity and central adiposity are major risk factors for CAD and are associated with chronic low-grade inflammation. Serum sialic acid, an acute phase reactant, has been considered a potential inflammatory biomarker in cardiovascular diseases.
Aim: To evaluate serum sialic acid levels in patients with coronary artery disease and to study its association with body mass index (BMI) and waist circumference.
Materials and Methods: This hospital-based case-control study included 40 angiographically proven CAD patients and 40 healthy controls of both sexes. Anthropometric measurements including BMI and waist circumference were recorded. Serum sialic acid levels were estimated using the resorcinol periodate method. Statistical analysis was performed using SPSS version 27.0 and GraphPad Prism version 5. Continuous variables were expressed as mean ± standard deviation, and a p-value of <0.05 was considered statistically significant.
Results: The majority of CAD patients belonged to the 51–60 years age group, with male predominance. Mean BMI and waist circumference were significantly higher in CAD patients compared to controls (p=0.001). Serum sialic acid levels were markedly elevated in CAD cases (78.6 ± 11.4 mg/dL) compared to controls (54.2 ± 8.7 mg/dL), which was statistically significant (p=0.001). Positive correlations were observed between serum sialic acid and BMI (r=0.61, p=0.002) as well as waist circumference (r=0.69, p=0.001).
Conclusion: Elevated serum sialic acid levels are significantly associated with coronary artery disease, obesity, and central adiposity. Serum sialic acid may serve as a useful inflammatory biomarker for cardiovascular risk assessment.

Keywords: Coronary Artery Disease, Serum Sialic Acid, Body Mass Index, Waist Circumference, Obesity, Inflammation, Atherosclerosis.

INTRODUCTION

Coronary artery disease (CAD) remains one of the leading causes of morbidity and mortality worldwide and poses a major public health burden, particularly in developing countries like India. CAD results primarily from atherosclerosis, a chronic inflammatory process involving lipid deposition, endothelial dysfunction, vascular inflammation, and plaque formation within coronary arteries. Conventional risk factors such as hypertension, diabetes mellitus, smoking, dyslipidemia, obesity, and sedentary lifestyle play a significant role in the development and progression of CAD.[1,2] In recent years, increasing attention has been focused on inflammatory and biochemical markers that may help in the early detection and risk assessment of coronary artery disease. Among these biomarkers, sialic acid has emerged as a potentially important indicator of vascular inflammation and atherosclerotic activity.[3]

Sialic acid is a family of acetylated derivatives of neuraminic acid present at the terminal portions of glycoproteins and glycolipids on cell membranes. It is considered an acute-phase reactant and plays an important role in cellular communication, immune response, and membrane stability.[4] Elevated serum sialic acid levels have been associated with various inflammatory and metabolic disorders including diabetes mellitus, obesity, metabolic syndrome, and cardiovascular diseases.[5] Several epidemiological studies have demonstrated that increased serum sialic acid concentration correlates with the severity of atherosclerosis and may predict future cardiovascular events independently of traditional risk factors.[3,6]
Obesity is another well-established risk factor for CAD and is closely linked with insulin resistance, dyslipidemia, systemic inflammation, and endothelial dysfunction.[7] Body mass index (BMI) and waist circumference are commonly used anthropometric parameters for assessing

general and central obesity respectively. While BMI reflects overall adiposity, waist circumference is a better indicator of visceral fat accumulation, which is metabolically more active and strongly associated with cardiovascular complications.[8] Central obesity contributes to the release of inflammatory cytokines and acute-phase proteins, thereby promoting a pro-inflammatory state that accelerates atherosclerosis and coronary artery disease.[9]
Recent studies suggest that serum sialic acid levels may increase in obese individuals due to chronic low-grade inflammation associated with excess adipose tissue. Increased adiposity, particularly abdominal obesity, leads to enhanced secretion of inflammatory mediators such as interleukin-6 and tumor necrosis factor-alpha, which stimulate hepatic synthesis of acute-phase glycoproteins rich in sialic acid.[5,10] Therefore, assessment of the association between serum sialic acid levels and anthropometric measures such as BMI and waist circumference may provide additional insight into the inflammatory and metabolic mechanisms underlying CAD.
Understanding the relationship between serum sialic acid, BMI, and waist circumference in patients with coronary artery disease may help identify individuals at higher cardiovascular risk and improve strategies for early diagnosis and prevention. Hence, the present study was undertaken to evaluate the association of serum sialic acid with BMI and waist circumference in patients with coronary artery disease.
The present study was undertaken to evaluate serum sialic acid levels in patients with coronary artery disease and compare them with healthy controls. It also aimed to assess the association of serum sialic acid with body mass index (BMI) and waist circumference, in order to understand their relationship with cardiovascular risk and obesity-related inflammation.

MATERIALS AND METHODS

Study Design: Hospital-based case-control study.

Study Population: The study included patients diagnosed with coronary artery disease (CAD) attending the cardiology outpatient department and healthy age- and sex-matched controls.
Sample Size:
- Total sample size: 80 subjects.
- Cases: 40 angiographically proven CAD patients.
- Controls: 40 healthy individuals.

Study Duration: Conducted over a period of 2011 to 2012
Study Place: Department of Cardiology and Central Laboratory, Hospital/Medical College.

Inclusion Criteria:
Cases:
- Patients with angiographically proven coronary artery disease.
- Both male and female patients.
- Patients willing to participate in the study.

Controls:
- Apparently healthy individuals without evidence of coronary artery disease.
- Age- and sex-matched healthy subjects.
- Individuals providing informed consent.

Exclusion Criteria:
- Patients with acute or chronic inflammatory diseases.
- History of diabetes mellitus, renal disease, hepatic disease, or malignancy.
- Patients with infectious disorders or autoimmune diseases.
- Individuals on steroid or anti-inflammatory therapy.
- Pregnant women.
- Subjects unwilling to participate.

Methodology
- Detailed clinical history and anthropometric measurements including body mass index (BMI) and waist circumference were recorded.
- Venous blood samples were collected under aseptic precautions.
- Serum sialic acid levels were estimated using the resorcinol periodate method.
- The obtained data were statistically analyzed and compared between cases and controls.

The Svennerholm resorcinol method for the quantitative determination of sialic acid was modified by introducing a periodate oxidation step prior to heating with the resorcinol reagent. Sialic acid glycosides could be determined without acid hydrolysis. The glycosides gave chromogens stable to periodate oxidation at 37°C, whereas free sialic acid gave chromogens that were destroyed at this temperature but remained stable at 0°C. Using these properties, the periodate-resorcinol method was applied for the determination of total, free, and bound sialic acid. The periodate-resorcinol method was substantially more

sensitive than the conventional resorcinol procedure and was not affected by lipids, amino acids, or sugars. It could therefore be used for the detection of free or glycosidically bound sialic acids on paper chromatograms.
This technique involves conversion of total sialic acid, including free and glycosidically bound forms, into chromogenic substances by treatment with acid, followed by reaction of the chromogens with the reagent resorcinol. Periodate oxidation of glycosidically bound sialic acids produced a chromogen that reacted strongly positively with the Svennerholm resorcinol reagent.

Principle
Sialic acid, when subjected to oxidation by resorcinol, is converted into chromogenic substances. β-formylpyruvic acid reacts with resorcinol to produce an olive-green colored solution. Organic solvent tert-butyl alcohol is used for color enhancement. The intensity of the colored solution is directly proportional to the concentration of sialic acid. Absorbance was measured at 630 nm using a spectrophotometer.
Ethical clearance was obtained prior to initiation of the study. Written informed consent was obtained from both the cases and controls before recruiting them for the study. Sialic acid estimation was carried out using the periodate-resorcinol assay.

Determination of Sialic Acid by Resorcinol–Periodate Assay:
The reagents used for the quantitative assay were:
1. 0.04 M periodic acid
2. 0.6 g of resorcinol dissolved in a solution containing 60 mL of 28% HCl, 40 mL distilled water, and 25 mg of $CuSO_4$
3. 95% tert-butyl alcohol

The reagents were prepared fresh daily from stock 0.04 M periodic acid and 6% resorcinol solutions. The stock reagents were stable for several weeks at −18°C in the dark. All assay reagents were stored at 0°C except tert-butyl alcohol, which was maintained at room temperature.

The assay was performed as follows:
- A sample containing no more than 0.2 µmole of N-acetyl neuraminic acid (NANA) in a total volume of 0.5 mL was mixed with 0.1 mL of 0.04 M periodic acid solution.
- The solutions were thoroughly mixed and allowed to stand at room temperature for 20 minutes.
- Subsequently, 1.25 mL of the resorcinol reagent was added, and the solutions were mixed again. The tubes were then placed in an ice bath for 5 minutes, followed by heating in a boiling water bath for 15 minutes.
- After cooling, 7.5 mL of tert-butyl alcohol was added, and the mixture was shaken thoroughly to obtain a single-phase solution.
- The tubes were maintained at 37°C for 3 minutes to stabilize the color, cooled to room temperature, and the absorbance was measured at 630 nm using a spectrophotometer.

Quartz cuvettes with a light path length of 3 mm were used for absorbance measurements. The absorbance was directly proportional to the concentration of NANA within the range of 0.12–2.0 µmoles. The absorbance decreased by approximately 10–20% after standing at room temperature for 24 hours.

Statistical Analysis: We put the data into Microsoft Excel and then used SPSS software version 27.0 (SPSS Inc., Chicago, IL, USA) and GraphPad Prism version 5 to look at it. Mean ± standard deviation was used to show continuous variables, and frequencies and percentages were used to show categorical variables. The unpaired t-test was utilized to examine continuous variables between independent groups, whereas the paired t-test was employed for comparisons within the same group. The Chi-square test or Fisher's exact test was used to look at categorical variables, depending on which one was better. A p-value of less than 0.05 was seen to be statistically important.

RESULT

Table 1: Distribution of Age among Study Participants

Age Group (Years)	CAD Cases (N=40)	Controls (N=40)	P-Value
<40	4 (10%)	9 (22.5%)	0.041
41–50	10 (25%)	13 (32.5%)	
51–60	15 (37.5%)	11 (27.5%)	
61–70	8 (20%)	5 (12.5%)	

>70	3 (7.5%)	2 (5%)	
Total	40 (100%)	40 (100%)	

Table 2: Gender Distribution among Study Participants

Gender	CAD Cases (N=40)	Controls (N=40)	P-Value
Male	28 (70%)	24 (60%)	0.344
Female	12 (30%)	16 (40%)	
Total	40 (100%)	40 (100%)	

Table 3: Comparison of BMI between CAD Cases and Controls

BMI Category (Kg/M²)	CAD Cases (N=40)	Controls (N=40)	P-Value
Normal (<25)	9 (22.5%)	21 (52.5%)	0.018
Overweight (25–29.9)	19 (47.5%)	14 (35%)	
Obese (≥30)	12 (30%)	5 (12.5%)	
Mean BMI (kg/m²)	29.1 ± 3.8	24.8 ± 2.9	0.001

Table 4: Comparison of Waist Circumference between CAD Cases and Controls

Waist Circumference	Cad Cases (N=40)	Controls (N=40)	P-Value
Normal	11 (27.5%)	25 (62.5%)	0.006
Increased	29 (72.5%)	15 (37.5%)	
Mean Waist Circumference (cm)	101.4 ± 9.2	89.7 ± 7.5	0.001

Table 5: Comparison of Serum Sialic Acid Levels between CAD Cases and Controls

Parameter	CAD Cases (N=40)	Controls (N=40)	P-Value
Serum Sialic Acid (mg/dL)	78.6 ± 11.4	54.2 ± 8.7	0.001

Table 6: Correlation of Serum Sialic Acid with BMI and Waist Circumference in CAD Cases

Variable	Correlation Coefficient (R)	P-Value
BMI vs Serum Sialic Acid	0.61	0.002
Waist Circumference vs Serum Sialic Acid	0.69	0.001

Figure: 1. Distribution of Body Mass Index (BMI) Categories among CAD Cases and Controls

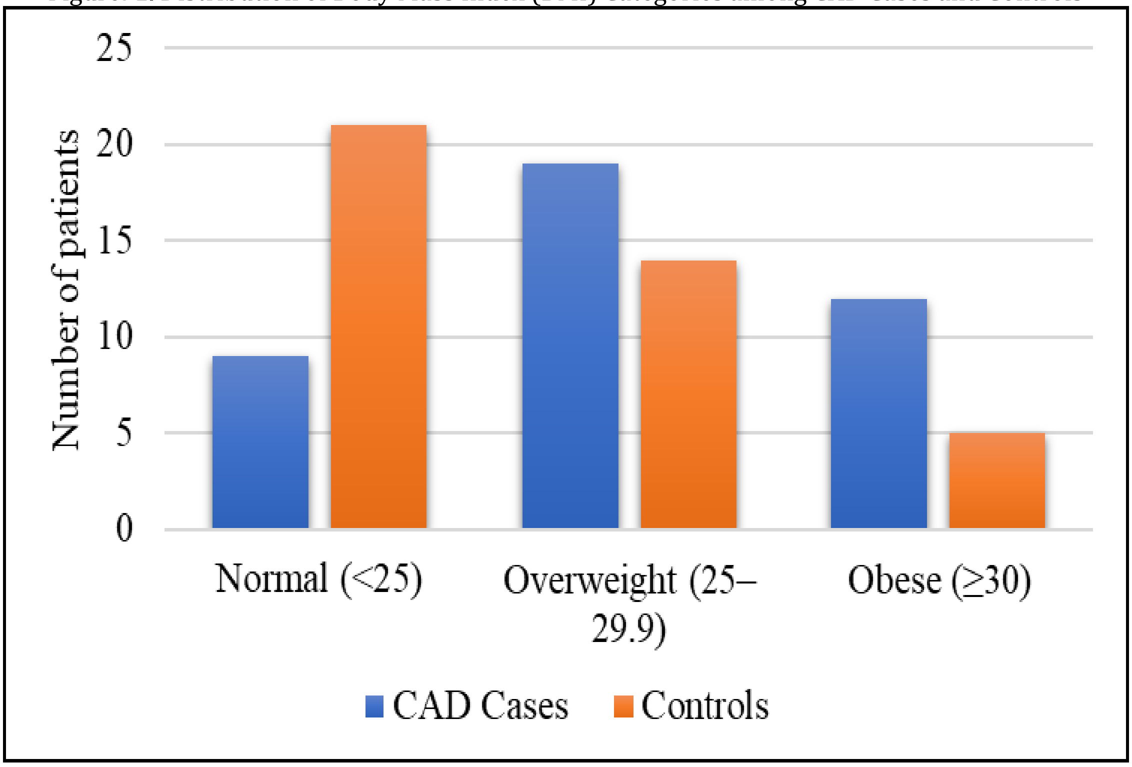

Figure: 2. Distribution of Sialic Acid Levels among CAD Cases and Controls

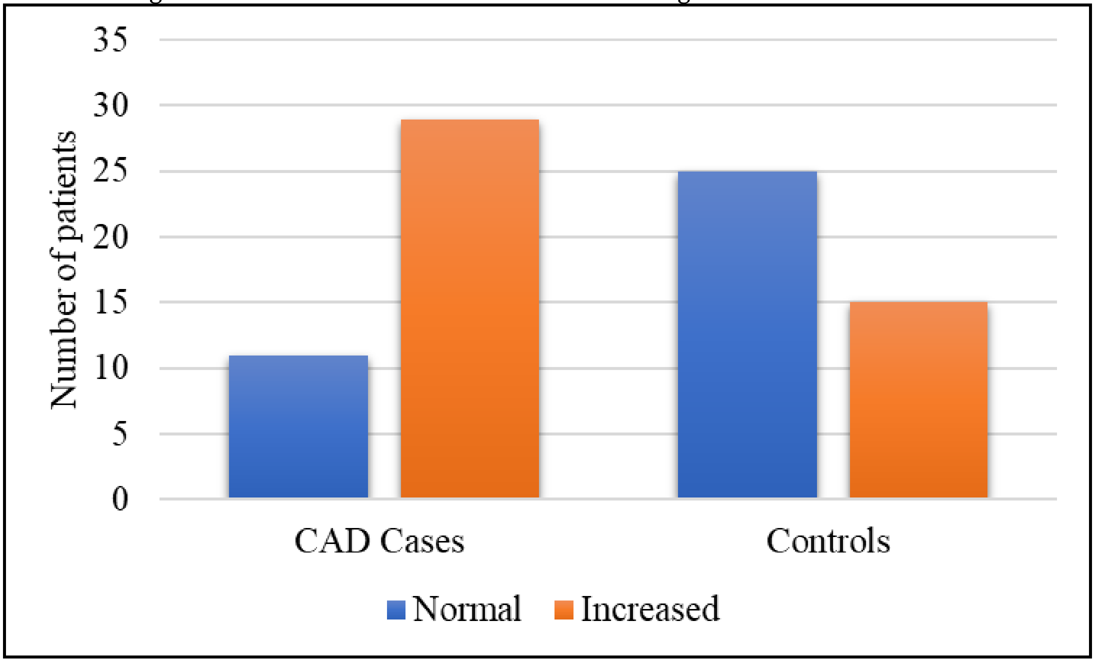

Table 1: Distribution of Age among Study Participants

The age-wise distribution of the study participants showed that the majority of CAD patients belonged to the 51–60 years age group, accounting for 15 cases (37.5%), followed by 41–50 years with 10 cases (25%). Patients aged 61–70 years constituted 8 cases (20%), while 4 patients (10%) were below 40 years of age and 3 patients (7.5%) were above 70 years. In the control group, the majority of participants were in the 41–50 years age group comprising 13 individuals (32.5%), followed by 51–60 years with 11 individuals (27.5%). The difference in age distribution between cases and controls was found to be statistically significant (p=0.041), indicating a higher prevalence of CAD in the middle and older age groups.

Table 2: Gender Distribution among Study Participants

Gender distribution revealed a male predominance in both groups. Among CAD cases, males constituted 28 participants (70%) whereas females accounted for 12 participants (30%). In the control group, 24 participants (60%) were males and 16 participants (40%) were females. Although males were more commonly affected with CAD compared to females, the difference in gender distribution between the two groups was statistically not significant (p=0.344).

Table 3: Comparison of BMI between CAD Cases and Controls

Comparison of body mass index (BMI) between CAD cases and controls demonstrated that overweight and obesity were more prevalent among CAD patients. In the CAD group, 19 participants (47.5%) were overweight and 12 participants (30%) were obese, while only 9 participants (22.5%) had normal BMI. In contrast, the control group showed a higher proportion of individuals with normal BMI, accounting for 21 participants (52.5%). Obesity was observed in only 5 controls (12.5%). The mean BMI among CAD cases was significantly higher (29.1 ± 3.8 kg/m²) compared to controls (24.8 ± 2.9 kg/m²), and this difference was statistically highly significant (p=0.001). These findings suggest a strong association between elevated BMI and coronary artery disease.

Table 4: Comparison of Waist Circumference between CAD Cases and Controls

Waist circumference analysis showed that central obesity was markedly higher among CAD patients. Increased waist circumference was observed in 29 CAD cases (72.5%) compared to 15 controls (37.5%). Only 11 CAD patients (27.5%) had normal waist circumference, whereas the majority of controls, 25 individuals (62.5%), had normal values. The mean waist circumference among CAD cases was 101.4 ± 9.2 cm, significantly higher than controls who had a mean waist circumference of 89.7 ± 7.5 cm. The difference was statistically significant (p=0.001). This finding highlights the important role of abdominal obesity as a cardiovascular risk factor in CAD patients.

Table 5: Comparison of Serum Sialic Acid Levels between CAD Cases and Controls

Serum sialic acid levels were found to be considerably elevated in CAD patients when compared to healthy controls. The mean serum sialic acid level among CAD cases was 78.6 ± 11.4 mg/dL, whereas controls had a significantly lower mean value of 54.2 ± 8.7 mg/dL. Statistical analysis revealed a highly significant difference between the two groups (p=0.001). The elevated serum sialic acid levels observed in CAD patients may reflect the underlying inflammatory and atherosclerotic processes associated with coronary artery disease.

Table 6: Correlation of Serum Sialic Acid with BMI and Waist Circumference in CAD Cases

Correlation analysis demonstrated a positive association between serum sialic acid levels and anthropometric indices among CAD patients. Serum sialic acid showed a significant positive correlation with BMI (r=0.61, p=0.002), indicating that higher BMI values were associated with elevated serum sialic acid levels. Similarly, waist circumference demonstrated a stronger positive correlation with serum sialic acid (r=0.69, p=0.001). These findings suggest that obesity, particularly central obesity, may contribute to increased inflammatory activity in CAD patients, as reflected by elevated serum sialic acid concentrations.

DISCUSSION

The present study evaluated the association of serum sialic acid with body mass index (BMI) and waist circumference in patients with coronary artery disease (CAD). The findings demonstrated significantly elevated serum sialic acid levels among CAD patients along with higher BMI and waist circumference values, suggesting a strong relationship between obesity, inflammation, and coronary atherosclerosis.

The present study demonstrated that the majority of coronary artery disease (CAD) patients belonged to the 51–60 years age group, followed by the 41–50 years age group, indicating that CAD is predominantly a disease of middle-aged and elderly individuals. Advancing age is associated with progressive endothelial dysfunction, arterial stiffness, oxidative stress, and cumulative exposure to cardiovascular risk factors, all of which contribute to the development of atherosclerosis and coronary artery disease. Similar findings were reported by Gupta et al., who observed a higher prevalence of CAD among individuals above 50 years of age due to age-related vascular and metabolic alterations.[11] Yusuf et al. also reported that increasing age significantly elevates the risk of myocardial infarction because of prolonged exposure to hypertension, diabetes mellitus, dyslipidemia, smoking, and obesity.[12] The findings of the present study are therefore consistent with previous epidemiological evidence demonstrating the strong association between advancing age and CAD.

A clear male predominance was observed among CAD patients in the current study, with males constituting the majority of cases. This finding is in agreement with earlier studies that identified male gender as an important non-modifiable risk factor for coronary artery disease. Sharma et al. reported that men are more susceptible to CAD due to greater exposure to smoking, alcohol consumption, psychosocial stress, sedentary lifestyle, and occupational strain.[13] In addition, the protective role of estrogen in premenopausal women contributes to delayed onset of cardiovascular disease among females. Similar observations were documented in the Framingham Heart Study conducted by Kannel et al., where men exhibited a higher prevalence and earlier onset of coronary artery disease compared to women.[14] The present findings therefore support previous studies emphasizing the increased burden of CAD among males.

The present study further revealed significantly higher body mass index (BMI) values among CAD patients compared to healthy controls, indicating a greater prevalence of overweight and obesity in affected individuals. Obesity contributes to the pathogenesis of coronary artery disease through multiple mechanisms including insulin resistance, dyslipidemia, endothelial dysfunction, oxidative stress, and chronic systemic inflammation. Similar observations were made by Després et al., who demonstrated that increased BMI is strongly associated with metabolic abnormalities that accelerate atherosclerotic plaque formation and vascular injury.[15] Hubert et al. also identified obesity as an independent predictor of cardiovascular morbidity and mortality in the

Framingham cohort study.[16] Excess adipose tissue acts as an endocrine organ that releases pro-inflammatory cytokines and adipokines, thereby promoting vascular inflammation and endothelial damage. The significantly elevated BMI observed among CAD patients in the present study reinforces the importance of obesity as a major modifiable cardiovascular risk factor.

Waist circumference was also significantly increased among CAD patients, suggesting a high prevalence of central obesity. Visceral adiposity is metabolically more active than peripheral fat and has been strongly associated with adverse cardiovascular outcomes. Janssen et al. reported that waist circumference is a better predictor of cardiovascular risk than BMI because it more accurately reflects abdominal fat accumulation and visceral obesity.[17] Similarly, Lean et al. demonstrated that increased waist circumference is associated with insulin resistance, dyslipidemia, elevated inflammatory markers, and increased risk of coronary artery disease.[18] Central obesity promotes the secretion of inflammatory mediators such as interleukin-6 and tumor necrosis factor-alpha, which contribute to endothelial dysfunction and progression of atherosclerosis. The present findings therefore highlight the significant contribution of abdominal obesity in the development of CAD.

The present study also demonstrated significantly elevated serum sialic acid levels among CAD patients compared to controls. Sialic acid is considered an acute phase reactant and a marker of systemic inflammation, endothelial injury, and vascular damage. Elevated serum sialic acid levels in CAD patients support the inflammatory basis of atherosclerosis. Similar findings were reported by Lindberg et al., who observed that increased serum sialic acid concentrations were associated with higher cardiovascular mortality and severity of atherosclerotic disease.[19] Rajappa and Sharma also documented significantly elevated serum sialic acid levels in patients with ischemic heart disease and suggested its potential utility as an inflammatory biomarker for cardiovascular risk assessment.[20] Increased serum sialic acid levels may reflect enhanced hepatic synthesis of acute phase glycoproteins secondary to chronic vascular inflammation and endothelial injury.

Furthermore, the present study identified a positive correlation between serum sialic acid levels and both BMI and waist circumference among CAD patients. This finding suggests that obesity-associated inflammation may play a key role in elevating serum sialic acid concentrations. Increased adipose tissue, particularly visceral fat, stimulates the production of inflammatory cytokines that enhance hepatic synthesis of acute phase reactants rich in sialic acid. The stronger association observed with waist circumference indicates that central obesity may exert a greater inflammatory effect compared to generalized obesity. Therefore, combined assessment of serum sialic acid, BMI, and waist circumference may serve as a useful approach for identifying individuals at increased risk of coronary artery disease and associated metabolic complications.

CONCLUSION

The present study demonstrated that serum sialic acid levels were significantly elevated in patients with coronary artery disease compared to healthy controls, indicating its role as an important inflammatory biomarker associated with atherosclerosis and vascular injury. CAD patients also showed significantly higher body mass index and waist circumference values, suggesting a strong association between obesity, particularly central obesity, and cardiovascular disease. Positive correlations observed between serum sialic acid levels, BMI, and waist circumference further support the concept that obesity-related chronic inflammation contributes to the pathogenesis and progression of coronary artery disease. Among the anthropometric parameters, waist circumference showed a stronger association with serum sialic acid, highlighting the importance of abdominal obesity in cardiovascular risk assessment. Therefore, combined evaluation of serum sialic acid along with BMI and waist circumference may serve as a useful and cost-effective approach for early identification of high-risk individuals and improved prevention strategies in coronary artery disease.

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