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ELEVATED LDL-C IS ASSOCIATED WITH INCREASED HS-CRP LEVELS IN PATIENTS WITH CARDIOVASCULAR DISEASE: A CROSS-SECTIONAL STUDY

Meryem Mehmood[1], Dr. Gulzar Alam[2]*, Khunsha Anosh Ali[3], Ammara Bashir[4], Muhammad Imran[5]

[1]Riphah International University, Islamabad, Pakistan, meryemmehmood8@gmail.com,
[2]Riphah International University, Islamabad, Pakistan, Corresponding Author, gulzar.alam@riphah.edu.pk,
[3]Riphah International University, Islamabad, Pakistan, khunsha.anosh12@gmail.com,
[4]Riphah International University, Islamabad, Pakistan, ammarabashir150@gmail.com,
[5]Sarhad University of Science and Information Technology, Peshawar, Pakistan, imranafd812@gmail.com
*Corresponding Author: Dr. Gulzar Alam, E-mail: Gulzar.alam@riphah.edu.pk

ABSTRACT
Background: The mortality rate of cardiovascular disease (CVD) is increasing gradually. It is now known that chronic low-grade inflammation, along with dyslipidemia, causes the formation and progression of atherosclerosis. Low density lipoprotein cholesterol (LDL-C) and high-sensitivity C-reactive protein (hs-CRP) are known dyslipidemia and inflammation cardiometabolic risk factors (CVD) and their biomarkers. The main aim of this study is to assess the levels of serum LDL-C and hs-CRP among CVD patients and correlate the relationship between these two markers.
Methods: A cross-sectional analytical study was conducted at tertiary care hospital. Using convenience sampling, 341 patients with clinically diagnosed cardiovascular disease aged 30-80 years were included in the study. Data was collected using demographic/clinical questionnaires and laboratory data from medical records. Laboratory methods were used to assess fasting blood samples for lows in LDL-C and hs-CRP. Data was analyzed using SPSS, with a $p<0.05$.
Results: In this group of 341 people, 59.8% were found to have elevated levels of LDL-C (≥130 mg/dL) while hs-CRP levels were elevated in 66.9% (hs-CRP >3 mg/L). The mean LDL-C level was 139.2 ± 32.8 mg/dL, while the mean hs-CRP level was 4.7 ± 1.9 mg/L. Patients with raised levels of LDL-C and patients with normal levels of LDL-C had significantly different levels of hs-CRP concentration (5.1 ± 1.7 vs. 3.9 ± 1.5 mg/L, $p < 0.01$). This shows a positive clinically significant relationship between the two conditions (dyslipidemia and systemic inflammation).
Conclusion: Most patients with cardiovascular disease had high LDL-C and hs-CRP levels. The strong association between these two biomarkers supports the idea of a link between dyslipidemia and inflammation as mechanisms of cardiovascular disease. Evaluation of LDL-C and hs-CRP together may improve cardiovascular risk prediction and may give more clinically useful information in addition to standard lipid testing. More and larger prospective studies are needed to evaluate their risk prediction of future adverse cardiovascular events.

KEYWORDS: Cardiovascular disease; High sensitivity C-reactive protein; hs-CRP; LDL cholesterol; Dyslipidemia.

1. INTRODUCTION

Cardiovascular diseases (CVDs), recognized as one of the most significant public health issues in the 21st century, lead to the highest illnesses and deaths. The World Health Organization states that almost 18 million deceases from CVDs, and it is the cause for almost one-third of all deaths globally (1). Other atherosclerotic cardiovascular diseases contribute to early deaths and loss of ability as well as high national health costs, in addition to coronary artery disease and every other cerebrovascular condition (2,3). There has been an epidemic of major cardiovascular risk factors such as poor diet, smoking, sedentary lifestyle, high levels of obesity, diabetes, hypertension, and more recently, an explosion of all these factors particularly in low and middle-income countries (4). Although major advancements in diagnostic methods, treatment intervention, and cardiac interventional procedures have developed, cardiovascular disease is still a major global health concern; thus, producing new and improving existing biomarkers is essential to make early diagnosis of CD, assess risks of CD more precisely, and structure therapy to fit individual patient needs.
Atherosclerosis is responsible for at least some aspect of nearly all cardiovascular diseases. It is now known as a disorder with many factors, involving complicated relationships between the metabolism of lipids, dysfunction of the endothelium, oxidative stress, and persistent inflammation (5,6). Increased low-density lipoprotein cholesterol (LDL-

C) has been a main contributor to atherogenesis among lipid-related risk factors. An excess of LDL particles seep into the walls of arteries and create an oxidative modification that sets off a chain reaction of inflammatory activities that call for macrophage formation and foam cells and plaque formation (7). Higher correlative values in cases of higher LDL-C values and an increased incidence of CAD and ischemic stroke were found in large studies such as the Framingham study and the INTERHEART study (8,9). As a result, LDL-C is the main focus for treatment in the primary and secondary prevention of cardiovascular morbidity, and how it has been shown that statins in particular, lipid lowering therapy, has significantly reduced cardiovascular morbidity and mortality (10).

There is accumulating evidence suggesting that inflammation is important for the development, progression and destabilization of atherosclerotic plaques; although dyslipidemia is an important component of most cardiovascular risk evaluations, it is clear that inflammation is of equal importance (11). High-sensitivity C-reactive protein (hs-CRP) is a biomarker of low-grade systemic inflammation. As an acute-phase reactant, it is produced predominantly in the liver in response to pro-inflammatory cytokines (12). The hs-CRP testing, unlike most other CRP tests, can detect much lower concentrations of CRP that are most often associated with chronic inflammation concerning cardiovascular diseases. When hs-CRP is elevated, the risk of myocardial infarction, stroke, peripheral arterial disease and cardiovascular death is higher, and hs-CRP should be considered (13). Apart from being a biomarker, CRP has been associated with Plaque instability, Thrombogenesis, Endothelial dysfunction, and Complement Activation implying that CRP takes part directly in the Pathophysiology of atherosclerosis (14).

Recent research in cardiology emphasizes the interaction of lipid disorders and inflammatory mechanisms. Oxidized LDL particles trigger pro-inflammatory cytokine release and activate numerous inflammatory signaling cascades in the vascular endothelium. Chronic inflammation also results in lipid oxidation, damage to the endothelium, and plaque progression, thereby creating a self-perpetuating cycle that worsens atherothrombotic disease (15). This has generated interest in simultaneous evaluations of lipid and inflammatory biomarkers. The JUPITER study was the first to show that patients with normal LDL-C and elevated hs-CRP have a residual inflammatory risk in CVD. After statin treatment, patients had a significant reduction of CVD events (16). Studies show that patients who lower both LDL-C and hs-CRP have a lower rate of repeated cardiovascular events. This is compared with patients who still have inflammatory activity, even after lipid control, is achieved. (17, 18).

Despite substantial evidence supporting the independent prognostic value of LDL-C and hs-CRP, data regarding their combined assessment among patients with established cardiovascular disease remain limited. Therefore, the present study was undertaken to determine serum levels of LDL-C and hs-CRP and to evaluate the association between these biomarkers in cardiovascular patients. The findings may contribute to improved cardiovascular risk stratification and support the incorporation of combined biomarker assessment into routine clinical practice for the prevention and management of cardiovascular disease.

2. MATERIALS AND METHODS

2.1. Study Design and Setting

This cross-sectional analytical study was conducted at Allama Iqbal Teaching Hospital, Dera Ghazi Khan, Pakistan, a tertiary care teaching hospital providing specialized cardiovascular services. The study was conducted over a one-year period. It aimed to assess serum low-density lipoprotein cholesterol (LDL-C) and high-sensitivity C-reactive protein (hs-CRP) levels among patients with established cardiovascular disease (CVD) and to evaluate the association between these two biomarkers.

2.2. Study Population and Sample Size

The sample included 341 clinically diagnosed cases of patients with CVD. Using Cochran's formula with a 95% confidence level and a 5% confidence interval, a statistically adequate sample was ensured. The convenience sampling technique was used to enroll participants who were patients of the cardiology outpatient department and those who occupied the cardiovascular inpatient units during the study period.

2.3. Inclusion and Exclusion Criteria

Eligible participants were between 30-80 and had cardiovascular disease. They were recruited after chemical marker screening of routine lipid samples and inflammatory markers.

chronic inflammatory diseases such as systemic lupus erythematosus or rheumatoid arthritis, neoplasia, chronic active liver diseases, chronic renal disease and regularly scheduled dialysis, recent surgery or trauma, long-term immunosuppressive therapy, pregnancy, and lactation are exclusion criteria. These were used in this study, focusing on hs-CRP concentrations and avoiding confounding variables.

2.4. Data Collection

After documented authorized agreement, we gathered data via a standardized survey and examined health documents. These methods provided age, sex, height and weight, smoking. Height and weight were used to calculate body mass

index which was then classified as per the World Health Organization standards as either normal weight, between the kg/m² range of 18.5 and 24.9, higher weight, between the kg/m² range of 25.0 and 29.9, and cellular mass obesity, greater than or equal to 30 kg/m².

2.5. Laboratory Analysis

After an overnight 8-12 hour fast, about 5-7 mL of venous blood was drawn from each participant and handled with aseptic procedures. The blood was centrifuged and analyzed per the Standard Operating Procedure and the Quality Control Protocols of the Clinical Laboratory, which is licensed by the Ministry of Health.

Clinical Laboratory Services used enzymatic colorimetric assays to evaluate lipid profiles. LDL-C levels were measured using a homogeneous assay. In the case of the unavailability of a direct measurement of LDL-C, it was calculated using the Friedewald equation, applicable to samples with triglycerides levels < 400 mg/dL.

Serum levels of hs-CRP were measured using an assay of high-sensitivity, immunoturbidimetry. As per the established risk assessment criteria for cardiovascular diseases, assessment of LDL-C levels that were ≥130 mg/dL was regarded to be of concern and of hs-CRP levels that were >3.0 mg/L were considered to be of concern.

2.6. Statistical Analysis

Data was processed in the IBM SPSS Statistics version 25 (IBM SPSS, Armonk, NY, USA). Continuous variables were analyzed. Group comparisons were done using an independent samples t-test or chi-square, as applicable to study the association between LDL-C and hs-CRP levels. A p-value of 0.05 or less (two-tailed) was considered statistically significant.

2.7. Ethical Considerations

Approval for the study protocol was obtained from the Institutional Ethics Review Committee of Allama Iqbal Teaching Hospital, Dera Ghazi Khan (Approval No. 001101). The study followed the guidelines of the Declaration of Helsinki. Informed consents were taken from all the participants. Maintained the confidentiality of patient information during the study.

3. RESULTS

Gender Distribution of Participants

A total of 341 CVD patients were included in the study. Of these, 214 (62.8%) were males and 127 (37.2%) were females (Table 3.1, Figure 1).

Table 3.1. Gender-wise Distribution of Cardiovascular Patients (n = 341)

Gender	Frequency (n)	Percentage (%)
Male	214	62.8
Female	127	37.2
Total	341	100

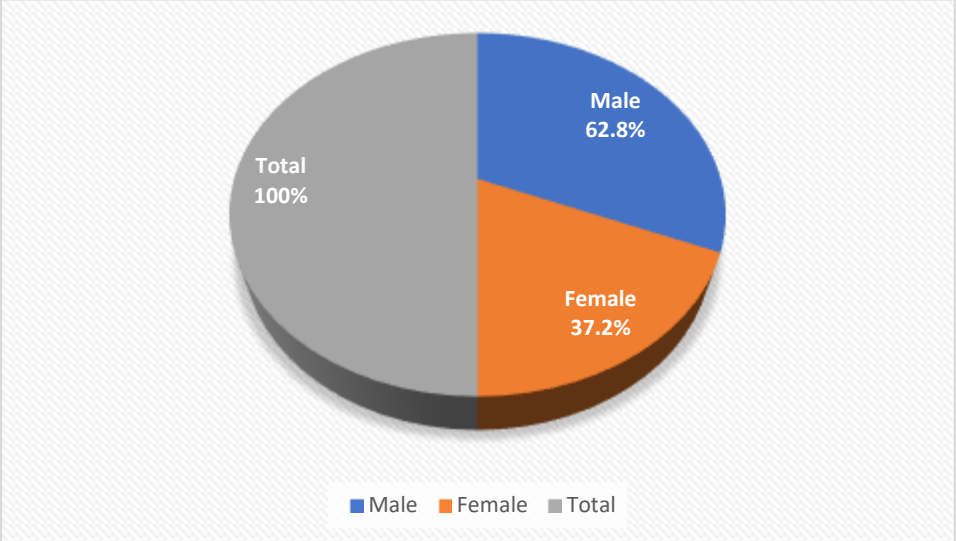

Figure 1. Gender-wise Distribution of Cardiovascular Patients (n = 341)

Age Distribution of Participants

Most of the participants belonged to the 51–70 years age group (n = 198, 58.1%), followed by the 30–50 years age group (n = 84, 24.6%) and the 71–80 years age group (n = 59, 17.3%) (Table 3.2).

Table 3.2. Age-wise Distribution of Cardiovascular Patients (n = 341)

Age Group (Years)	Frequency (n)	Percentage (%)
30–50	84	24.6
51–70	198	58.1
71–80	59	17.3
Total	341	100

Distribution According to BMI and Smoking Status

Among the study participants, 76 (22.3%) had normal BMI, 169 (49.6%) were overweight, and 96 (28.1%) were obese. Regarding smoking status, 119 (34.9%) participants were smokers, whereas 222 (65.1%) were non-smokers (Table 3.3, Figure 2).

Table 3.3. Distribution of Cardiovascular Patients by BMI and Smoking Status (n = 341)

Variable	Category	Frequency (n)	Percentage (%)
BMI (kg/m²)	Normal (18.5–24.9)	76	22.3
	Overweight (25–29.9)	169	49.6
	Obese (≥30)	96	28.1
Smoking Status	Smoker	119	34.9
	Non-smoker	222	65.1

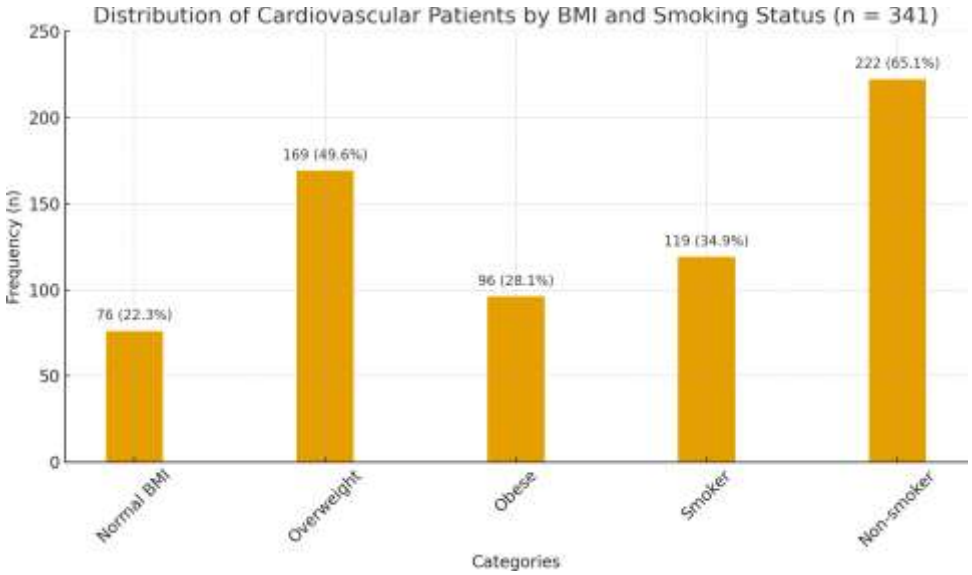

Figure 2. Distribution of Cardiovascular Patients by BMI and Smoking Status (n=341)

LDL-C and hs-CRP Levels among Cardiovascular Patients

The mean LDL-C level was 139.2 ± 32.8 mg/dL, and elevated LDL-C (≥130 mg/dL) was observed in 204 (59.8%) participants. The mean hs-CRP level was 4.7 ± 1.9 mg/L, and elevated hs-CRP (>3 mg/L) was observed in 228 (66.9%) participants (Table 3.4, Figure 3).

Table 3.4. Biochemical Parameters among Cardiovascular Patients (n = 341)

Parameter	Mean ± SD	Reference Range	Elevated Cases n (%)
LDL-C (mg/dL)	139.2 ± 32.8	<130 mg/dL	204 (59.8)
hs-CRP (mg/L)	4.7 ± 1.9	<3.0 mg/L	228 (66.9)

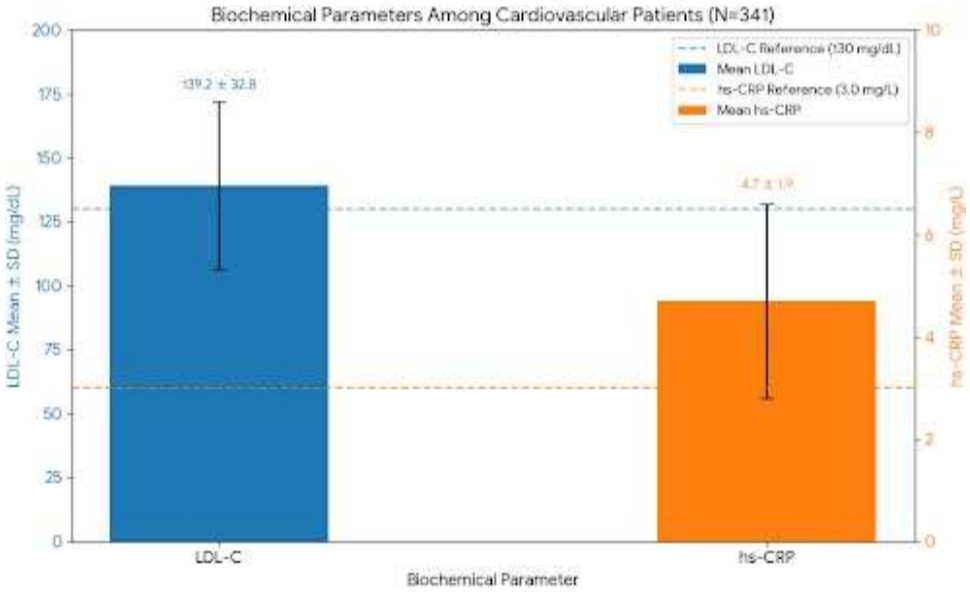

Figure 3. Biochemical Parameters among Cardiovascular Patients (n = 341)

Relationship Between LDL-C and hs-CRP Levels

Participants with elevated LDL-C levels (≥130 mg/dL) demonstrated significantly higher hs-CRP concentrations compared with those having normal LDL-C levels (<130 mg/dL). The mean hs-CRP level was 5.1 ± 1.7 mg/L among participants with elevated LDL-C, compared with 3.9 ± 1.5 mg/L among those with normal LDL-C levels. This difference was statistically significant ($p < 0.01$) (Table 3.5, Figure 4).

Table 3.5. Relationship Between LDL-C and hs-CRP Levels

LDL-C Category	N	Mean hs-CRP (mg/L) ± SD	p-value
Normal (<130 mg/dL)	137	3.9 ± 1.5	
Elevated (≥130 mg/dL)	204	5.1 ± 1.7	<0.01

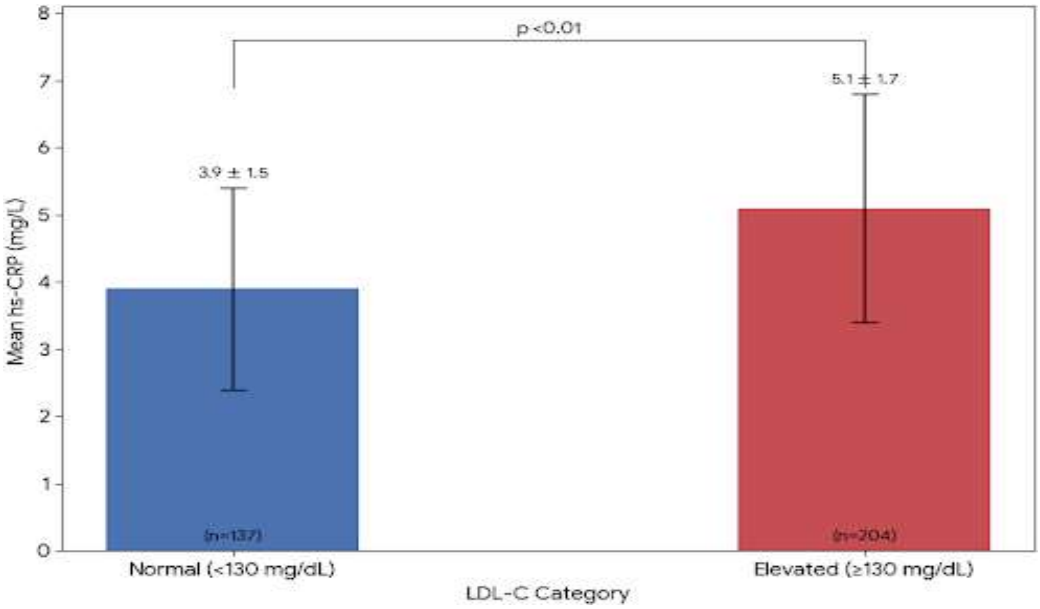

Figure 4. Relationship Between hs-CRP and LDL-C Levels

4. DISCUSSION

The present study investigated serum LDL-C and hs-CRP levels among patients with established cardiovascular disease and examined the relationship between these biomarkers. The findings demonstrated a high prevalence of both

elevated LDL-C and elevated hs-CRP levels, indicating that dyslipidemia and systemic inflammation frequently coexist in cardiovascular patients.

Elevated levels of hs-CRP were associated with elevated levels of blood LDL-C. Lipid and blood inflammatory levels disrupt cellular function in cardiovascular disease progression.

In this study, the mean LDL-C level was found to be 139.2 ± 32.8 mg/dL, surpassing the target threshold set for high-risk CV patients. This level indicates that there are still residual lipid-related risks present in this population. On the other hand, the mean hs-CRP level was 4.7 ± 1.9 mg/L which was also above the level considered to be low-risk for CV, indicating there is still some degree of low-level systemic inflammation. In turn, this system of inflammation is present is also evidence of the inflammation that develops due to condition of atherosclerosis, which is not simply a condition of the accumulation of lipids, but also has chronic inflammation and various interstitial functions of lipids and vascular endothelial gaps and inflammation (19,20).

The current study's finding of elevated LDL-C and hs-CRP levels occurring together is very much in line with more recent studies on the correlation between dyslipidemia and inflammation with respect to cardiovascular disease. Previous study reported that subjects with LDL-C and hs-CRP levels that were both persistently elevated had even higher levels of recurrent adverse cardiovascular events after undergoing percutaneous coronary intervention. This emphasizes that predicting risk should include the concurrent assessment of both lipid and inflammatory components (22). Another study showed that LDL-C and hs-CRP both advance plaque and both contribute to and progress atheromatous lesions (23).

The present study found a strong correlation between higher hs-CRP concentrations and higher levels of LDL-C. Patients with LDL-C ≥ 130 mg/dL had higher hs-CRP concentrations when compared to patients with LDL-C < 130 mg/dL ($p < 0.01$). Elevated LDL-C and hs-CRP levels point toward a combined state of dyslipidemia and chronic inflammation. Endothelial cells can be activated by oxidized LDL. This leads to the production of cytokines and to further inflammation and the development of atherosclerotic plaques (24). Chronic inflammation in turn causes a cycle of endothelial dysfunction, oxidative stress, and plaque instability. This cycle further progresses cardiovascular disease.

The present study is made stronger by modern evidence supporting that inflammatory biomarkers are clinically important in cardiovascular disease. Some previous studies showed that elevated hs-CRP levels were linked with a greater degree of CAD along with greater changes in blood vessel structures, which reinforces the role of inflammation when it comes to the progression of atherosclerosis (25,26). Also, recent studies actually showed that residual inflammatory risk may persist after lipid-lowering therapy, which emphasize the limitations of conducting measurement of LDL-C solely in estimating cardiovascular risk (27).

In recent years, interest in dual-pathway cardiovascular risk evaluation has gone up. The seminal JUPITER research showed that statins lowered LDL-C and hs-CRP in addition to significantly lowering the rate of cardiovascular events for study subjects who started the trial with an acceptable baseline level of cholesterol (28). It has been seen that patients that have acceptable levels of LDL-C but have high levels of hs-CRP seem to have high levels of risk due to multiple cardiovascular events. Because of this, it is important to combine approaches both to lipids and inflammation (29). Thus, looking at LDL-C alongside hs-CRP may give a better understanding of cardiovascular risk than standard lipid tests, as it combines more factors.

The results of this study contribute to the existing literature outlining the complicated interplay between dyslipidemia and inflammation in the context of cardiovascular disease. The addition of both inflammation and lipid dysregulation markers into the risk assessment models for cardiovascular events should be strongly considered based on the high populations of hs-CRP and LDL-C levels.

4.1. Limitations of the Study

When considering this study, a few limitations should be noted. First, a cross-sectional method does not allow us to determine the cause of the observed relationships between LDL-C and hs-CRP. Second, since participants were recruited from one tertiary-care center using convenience sampling, the impact of this research is not more widely applicable. Third, we did not pursue long-term cardiovascular outcomes of recurrent myocardial infarction, stroke, and death. Lastly, we did not assess a number of potential confounding factors including diet, exercise, and medication and where research gaps may be seen, the assessment of socioeconomic factors.

5. CONCLUSION

In the present study, the relation between both markers was analyzed. We conclude that the patients who had elevated LDL-C had higher hs-CRP too both markers have strong association. These results indicate that measuring hs-CRP, along with standard lipid tests, provides a better assessment of cardiovascular risk. Normal inflammatory risk factors along with hs-CRP increase the risk assessment protocol for cardiovascular disease. This provides a basis for customizing a prevention and treatment protocol.

5.1. Recommendations

1. Incorporation of Combined Biomarker Assessment

Cardiovascular disease patients should include the joint evaluation of LDL-C and hs-CRP as a component of their CVD risk assessment. Inflammation-related and lipid-related CVD risk may be more fully characterized with this assessment.

2. Comprehensive Cardiovascular Risk Management

Dyslipidemia and other modifiable risk factors for cardiovascular diseases can be tackled through various clinical management strategies. Evidence based clinical management strategies offer a variety of pharmacological therapy options and lifestyle management interventions such as a healthy diet, physical activity, smoking cessation, and weight management.

3. Enhanced Patient Awareness and Education

Patients need education on controlling lipids and following the steps to bring down their risk factors for cardiovascular issues. They will need to take their prescribed medications and make the recommended lifestyle changes.

4. Future Research

More proximal, multicenter studies are needed to assess the risk of combining hs-CRP with LDL-C comparative to the risk of not combining these tests and to assess whether combining strategies for controlling inflammation as well as lipids will improve risk.

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8. Conflict of Interest

None

9. Authors' Contributions

- **Meryem Mehmood:** Conceptualization, data collection, investigation, data curation, manuscript drafting.
- **Dr. Gulzar Alam:** Study supervision, methodology development, critical review, manuscript editing, final approval.
- **Khunsha Anosh Ali:** Data analysis, interpretation of results, literature review, manuscript editing.
- **Ammara Bashir:** Laboratory work, data verification, quality assurance, manuscript review.
- **Muhammad Imran:** Statistical analysis, manuscript writing and editing, visualization, reference management, formatting, final proofreading.

All authors read and approved the final version of the manuscript and agree to be accountable for all aspects of the work.

10. Consent for Publication

Not applicable.

11. Availability of Data and Materials

The datasets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request.

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