MULTIDISCIPLINARY SCIENCE JOURNAL

RESEARCH ARTICLE
Published Online: March 26, 2026
https://doi.org/10.31893/multiscience.2026517

Association of cardiometabolic risk factors with remnant cholesterol in female law enforcement officers

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Abstract Compared to men, female law enforcement officers (LEOs) represent a special population who have higher cardiovascular risk factors and significant levels of professional stress. The conventional lipid profile has been utilized extensively in clinical practice over the past few decades as a target for pharmacological treatments and as a foundation for preventing cardiovascular disease in the population. Lately, other unconventional lipids have surfaced as potential substitute indicators of cardiometabolic risk. However, there is currently limited research exploring female LEOs and unconventional lipids as a predictor of cardiovascular risk. A population of female LEOs was subjected to a health screening exam at the East Java Regional Police headquarters between January and June 2024. A total of 381 female LEOs participated. Clinical and laboratory indicators were measured. Remnant cholesterol was used as a landmark to analyze the results of conventional risk factors, lipid profiles, and the values of the combined lipid indices. Due to abnormal parametric variables distribution, the descriptive data were presented as median and interquartile range. The median age of this population was 51 [33–70]. Among participants, 84.3% had high LDL levels, 69.4% were obese and overweight, 52.4% had hypertension, 50.5% had high remnant cholesterol, 32.7% had hypertriglyceridemia, and 20.4% had high blood glucose. There were significant correlations between remnant cholesterol and Castelli Risk Index I (CRI I), Castelli Risk Index II (CRI II), triglycerides, LDL, total cholesterol, IAP, AI, and TyG. This study identified strong relationships between numerous clinical and laboratory markers, including residual cholesterol. New parameters included in this study should be considered as predictors of cardiovascular risk and diseases.

Keywords: female law enforcement, cardiometabolic risk, remnant cholesterol, lipid indices

1. Introduction

Cardiovascular disease (CVD) continues to be a major contributor to illness and death among women, particularly in high-stress occupations such as law enforcement. Female law enforcement officers (LEOs) face unique challenges that could lead to a higher likelihood of cardiometabolic disorders, including obesity, hypertension, and dyslipidemia. Studies in recent years have brought attention to remnant cholesterol as a major cardiovascular risk factor, particularly in women, where traditional lipid profiles may not fully capture the risk (Yang et al., 2022).

Research indicates that female LEOs are more likely to have cardiometabolic risk factors than their male counterparts and civilian populations, with stress being a major contributor to this disparity (Gendron et al., 2019; Yang et al., 2022). Unconventional lipids, such as remnant cholesterol, have surfaced as promising and potential substitute indicators of cardiometabolic risk, compared to other conventional lipids (Quispe et al., 2021); however, there is currently limited research exploring female police officers and unconventional lipids as predictors of cardiovascular risk. Furthermore, in overweight or obese individuals, remnant cholesterol and triglycerides (TG) exhibited a more significant association with cardiovascular events than low-density lipoprotein cholesterol (LDL-C), regardless of lifestyle and other contributing factors (Yang et al., 2022).

New studies have uncovered biomarkers such as the triglyceride-glucose index (TyG), which may aid in the early identification of individuals who are at risk for cardiovascular events and fatal outcomes (Chen et al., 2023; Hong et al., 2020; Liu et al., 2020; Qu et al., 2022). Understanding the association between cardiometabolic risk factors, remnant cholesterol, and other novel biomarkers such as TyG in this population is essential for developing targeted interventions aimed at reducing CVD risk among female LEOs.

 Received: October 10, 2025 | Accepted: December 12, 2025

This study aims to investigate how various cardiometabolic risk factors correlate with remnant cholesterol levels in female police officers, contributing to the growing body of literature on gender-specific health risks in law enforcement. By identifying these associations, we can better inform health promotion strategies and improve the overall well-being of female LEOs.

2. Materials and Methods

2.1. Study population and eligibility criteria

This cross-sectional observational study aimed to assess the relationship between new and established cardiovascular risk factors in female LEOs in East Java. The study conducted between January and April 2024 involved female LEOs from the East Java Regional Police Headquarters. A total of 381 officers were selected due to the completion of all factors and data.

The study's inclusion criteria were active-duty status and willingness to participate. The Ethical Review Board of the Faculty of Medicine at Universitas Airlangga in Indonesia approved this study, which adhered to the ethical principles specified in the Declaration of Helsinki (as revised in 2013). Each participant gave their informed consent after being fully briefed on the study’s objectives, methods, and the voluntary aspect of their involvement. All participants were made aware that, at any point, they were free to withdraw from the study without facing any consequences.

2.2. Data collection

Data were gathered using structured interviews, physical examinations, and laboratory tests. Physical examinations and blood sample collection were carried out by trained medical experts. The interviews were intended to collect demographic information and personal health histories. Several clinical parameters were measured using defined techniques to ensure accuracy and consistency. Body mass index (BMI) was computed using the participants’ weights, measured in kilograms on a digital scale, and heights, measured in centimeters on a stadiometer. To measure waist circumference (WC), a non-stretch tape was placed at the midpoint between the upper edge of the iliac crest and the lower boundary of the last palpable rib. Abnormal WC was defined as more than 102 cm. After the subject had rested for at least five minutes in a seated position, their blood pressure (BP) was measured using an automated sphygmomanometer, with two readings taken and the average used for analysis. In this study, uncontrolled hypertension was considered when systolic BP ≥140 and diastolic BP ≥90. Because the participants' medical history was not taken into account, normal blood pressure was classified as either controlled hypertension or non-hypertension.

The RC cut-off of ≥30 mg/dL was selected based on prior epidemiological evidence identifying this threshold as the point at which the risk of major adverse cardiovascular events increases significantly (Varbo et al., 2014; Zhang et al., 2022). The TyG index does not have a universally accepted cut-off; however, values above 8.5 have been associated with increased insulin resistance and CVD risk in Asian populations (Moon et al., 2023).

Blood samples were collected after the subjects fasted for at least eight hours overnight, and their fasting blood glucose levels were measured using the hexokinase method, which is widely regarded as the gold standard for glucose measurement due to its accuracy. Blood parameters were measured and calculated (total platelet, the lymphocyte-to-platelet ratio, platelet-to-lymphocyte ratio, and the neutrophil-to-lymphocyte ratio). Lipid profiles, including total cholesterol, LDL, HDL, and TG, were measured in the laboratory with enzymatic colorimetric methods. These methods were chosen for their reliability and precision in clinical settings.

Remnant cholesterol was measured using the following formula:

$$Remnant\ Cholesterol = Total\ Cholesterol - LDL\text{-}C - HDL\text{-}C \quad (1)$$

The TyG (Triglyceride-Glucose) index was calculated using the following formula:

$$TyG = ln\,(triglycerides\ [mg/dL] \times fasting\ glucose\ [mg/dL]\ /\ 2) \quad (2)$$

Combined lipid indices calculated in this study were AI, LCI, Castelli risk index-I (CRI-I), and Castelli risk index-II (CRI-II).

Atherogenic Index (AI), expressed in mmol/L, was calculated by the following formula:

$$AI = non - HDL - C\ /\ HDL - C \quad (3)$$

Lipoprotein Combined Index (LCI) was calculated by the following formula:

$$(Total\ Cholesterol \times Triglycerides \times LDL - C)\ /\ HDL - C \quad (4)$$

Castelli risk index-I (CRI-I) was calculated using the following formula:

$$Castelli\ Risk\ Index - I = Total\ Cholesterol\ /\ HDL - C \quad (5)$$

Castelli risk index-II (CRI-II) was calculated using the following formula:

$$Castelli\ Risk\ Index - II = LDL - C\ /\ HDL - C \quad (6)$$

2.3. Statistical Analysis

The data for this investigation were coded, cleaned, and exported using Microsoft Excel, and then analyzed using the Statistical Package for Social Sciences (SPSS) version 26.0. The participants' attributes were described using descriptive statistics. Continuous data were reported as mean ± SD, whereas categorical variables were presented as frequencies and percentages. The normality of the distribution of continuous variables was determined using the Kolmogorov-Smirnov test.

The relationships between traditional cardiovascular risk factors (age, waist circumference, Body Mass Index, fasting glucose, LDL, HDL, TG), remnant cholesterol, combined lipid indices (AI, LCI, CRI-I, and CRI-II), and TyG index were analyzed using Spearman's correlation coefficient. Statistical significance was determined at $p < 0.05$.

ROC curve analysis was performed to evaluate the discriminatory performance of individual cardiometabolic variables in identifying elevated remnant cholesterol. The area under the ROC curve (AUC) with 95% confidence intervals was calculated using the non-parametric method. Sensitivity and specificity values across all possible thresholds were generated, and the optimal cutoff point for each marker was determined using the Youden Index (sensitivity + specificity – 1). Variables with AUC values significantly greater than 0.5 were considered to have meaningful discriminatory ability. All analyses were conducted using IBM SPSS Statistics (version 23).

3. Results

3.1. Demographic Data

Participants with RC levels ≥30 mg/dL (n = 192) demonstrated a higher proportion of uncontrolled hypertension (58.9%) compared with participants with RC <30 mg/dL (n = 188; 45.7%). Despite the comparable mean ages and waist circumferences observed between the two groups (mean age: 50 [19] vs. 52 [19] years; waist circumference: 90.00 [13.00] and 90.50 [15.00] cm, respectively), the results indicated significant differences in the lipid profile and blood pressure status between the two groups. In the RC <30 mg/dL group, obesity was more prevalent (37.8% vs. 29.7%), and hypertriglyceridemia was more common (37.2% vs. 28.1%).

Notably, a significantly higher proportion of individuals with RC <30 mg/dL exhibited elevated LDL levels, at 96.8%, compared with the 72.9% observed in the ≥30 mg/dL group. Furthermore, mean triglyceride levels were marginally elevated in the RC <30 mg/dL group (119 [89] mg/dL vs. 107 [70] mg/dL). The inflammatory and platelet-related indices, including the neutrophil-lymphocyte ratio, lymphocyte-platelet ratio, and platelet-lymphocyte ratio, were found to be consistent across the study groups. Furthermore, subjects with RC levels below 30 mg/dL exhibited lower total cholesterol levels (188.5 [37] mg/dL vs. 228.0 [44] mg/dL), CRI-I (4.01 [0.93] vs 4.85 [1.45]), and AI (3.01 [0.94] vs 3.86 [1.45]), but higher CRI-II (3.00 [1.15] vs 2.44 [0.87]) and LCI (67,192.26 [71,698.87] vs 62,876.85 [46,434.57]). The participants' demographic data are displayed in Table 1.

3.2. Correlation between RC and lipid parameters

Pearson correlation analysis was conducted to investigate how RC correlates with various lipid parameters, as the data were not normally distributed (Table 2). The results indicated that RC was notably correlated with TG ($p = 0.003$), LDL ($p < 0.001$), TyG ($p = 0.002$), total cholesterol ($p < 0.001$), IAP ($p = 0.009$), CRI-I ($p < 0.001$), CRI-II ($p < 0.001$), and AI ($p < 0.001$). No significant correlation was observed between RC and age ($p = 0.422$), GDA ($p = 0.187$), HDL ($p = 0.754$), or LCI ($p = 0.082$). As demonstrated in Figure 1, scatter plots are presented, demonstrating the varied relationships between RC and lipid parameters.

3.3. Multivariat regression

A multivariate logistic regression analysis was performed including age, TYG, AI, and CRI-I as independent variables. The overall model was statistically significant ($\chi^2 = 120.824$, $p < 0.001$) and demonstrated good calibration based on the Hosmer–Lemeshow test ($p = 0.218$). The model explained 36.3% of the variance (Nagelkerke $R^2 = 0.363$) and correctly classified 73.9% of cases.

In the adjusted model, TYG and CRI-I were independently associated with the outcome. Higher TYG levels significantly increased the odds of the event (OR = 1.97, 95% CI: 1.31–2.97, $p = 0.001$). Conversely, a higher CRI-I ratio was associated with lower odds (OR = 0.193, 95% CI: 0.092–0.402, $p < 0.001$). Meanwhile, AI and age were not significant predictors in the multivariate model ($p > 0.05$).

3.4. ROC Curve

The discriminatory performance of each cardiometabolic marker for predicting elevated remnant cholesterol was evaluated using receiver operating characteristic (ROC) analysis. Among the tested indices, CRI-I demonstrated the highest predictive ability, with an AUC of 0.792 (95% CI: 0.748–0.837; $p < 0.001$), indicating good discriminatory power. This was followed by AI, which also showed strong performance with an AUC of 0.778 (95% CI: 0.732–0.824; $p < 0.001$).

Conversely, CRI-II showed poor discriminatory ability with an AUC of 0.295 (95% CI: 0.244–0.347; p < 0.001), suggesting an inverse or non-useful classification performance. Other parameters, including TyG (AUC = 0.423; p = 0.009), IAP (AUC = 0.443; p = 0.054), age (AUC = 0.459; p = 0.162), and LCI (AUC = 0.449; p = 0.082), showed AUC values close to 0.5, indicating limited or no discriminatory value for identifying elevated remnant cholesterol in this population.

Table 1 Characteristics of participants.

Variable	RC	
	>30 mg/dL (n = 192)	<30 mg/dL (n = 188)
Age (years)	50 (19)	52 (19)
Hypertension		
Uncontrolled hypertension, n (%)	113 (58.9)	86 (45.7)
Non-hypertension/controlled hypertension, n (%)	79 (41.1)	102 (54.3)
Waist circumference (cm)	90.00 (13.00)	90.50 (15.00)
BMI		
Obesity, n (%)	57 (29.7)	71 (37.8)
Overweight, n (%)	69 (35.9)	67 (35.6)
Normal, n (%)	66 (34.4)	50 (26.6)
Fasting glucose (mg/dL)	86 (13)	87 (13)
High blood glucose, n (%)	38 (19.8)	39 (20.7)
Normal blood glucose, n (%)	154 (80.2)	149 (79.3)
Neutrophil	62.0 (8.5)	61.0 (8.0)
Lymphocyte	32.6 (8.0)	33.0 (7.9)
Platelet	274 (83)	272 (68)
Neutrophil lymphocyte ratio	1.90 (0.73)	1.82 (0.70)
Lymphocyte platelet ratio	0.12 (0.05)	0.12 (0.05)
Platelet lymphocyte ratio	8.12 (3.41)	8.18 (3.25)
Triglycerides (mg/dL)	107 (70)	119 (89)
Hypertriglyceridemia, n (%)	54 (28.1)	70 (37.2)
Normal, n (%)	138 (71.9)	118 (62.8)
LDL (mg/dL)	115.00 (36)	140.50 (31)
High LDL, n (%)	140 (72.9)	182 (96.8)
Normal, n (%)	52 (27.1)	6 (3.2)
HDL (mg/dL)	46.50 (12)	47.00 (13)
Cholesterol (mg/dL)	228.00 (44)	188.50 (37)
TyG	8.49 (0.72)	8.57 (0.68)
IAP	0.38 (0.28)	0.39 (0.31)
CRI-1	4.85 (1.45)	4.01 (0.93)
CRI-II	2.44 (0.87)	3.00 (1.15)
AI	3.86 (1.45)	3.01 (0.94)
LCI	62,876.85 (46,434.57)	67,192.26 (71,698.87)

Data are expressed as n (%) or median [IQR] as appropriate.

Abbreviations: RC, remnant cholesterol; BMI, body mass index; LDL, low-density lipoprotein; HDL, high-density lipoprotein; TyG, triglyceride-glucose index; IAP, atherogenic plasma index; CRI-I, Castelli Risk Index I; CRI-II, Castelli Risk Index II; AI, atherogenic index; LCI, lipoprotein combine index; NLR, neutrophil-to-lymphocyte ratio; LPR, lymphocyte-to-platelet ratio; PLR, platelet-to-lymphocyte ratio.

Table 2 Correlation between RC and age and lipid parameters.

Variabel	*P*
Age	0.422
Fasting Glucose	0.187
TG	0.003*
LDL	<.001*
HDL	0.754
Total Cholesterol	<.001*
TyG	0.002*
IAP	0.009*
CRI-I	<.001*
CRI-II	<.001*
AI	<.001*
LCI	0.082

Note: Statistically significant (p < 0.05).

Abbreviations: TG, triglycerides; LDL, low-density lipoprotein; HDL, high-density lipoprotein; TyG, triglyceride-glucose index; IAP, atherogenic plasma index; CRI-I, Castelli Risk Index I; CRI-II, Castelli Risk Index II; AI, atherogenic index; LCI, lipoprotein combined index.

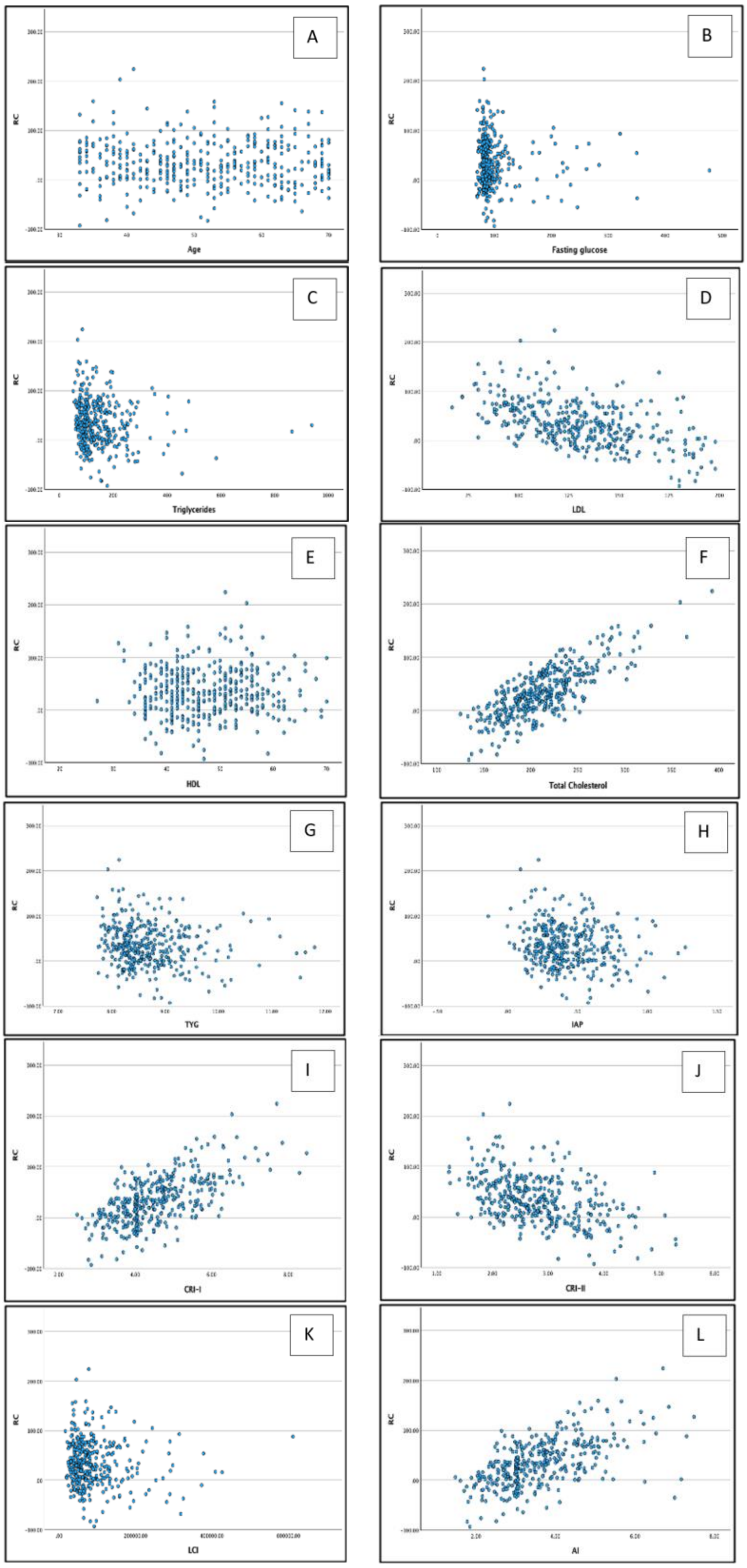

Figure 1 Correlation between remnant cholesterol (RC) and various metabolic variables.

Note: A, Age; B, Fasting glucose; C, Triglycerides (TG); D, Low-density lipoprotein (LDL); E, High-density lipoprotein (HDL); F, Total cholesterol; G, Triglyceride-glucose index (TyG); H, Atherogenic plasma index (IAP); I, Castelli Risk Index I (CRI-I); J, Castelli Risk Index II (CRI-II); K, Lipoprotein Combine Index (LCI); L, Atherogenic index (AI). RC was significantly associated with C, D, F, G, H, I, J, and L, but not with A, B, E, or K.

Abbreviations: RC, remnant cholesterol; TG, triglycerides; LDL, low-density lipoprotein; HDL, high-density lipoprotein; TyG, triglyceride-glucose index; IAP, atherogenic plasma index; CRI-I, Castelli risk index I; CRI-II, Castelli risk index II; LCI, lipoprotein combine index; AI, atherogenic index.

Overall, CRI-I and AI were the only markers demonstrating clinically meaningful predictive accuracy, as also visualized in the ROC curve, where both curves were clearly separated above the reference line compared to other variables.

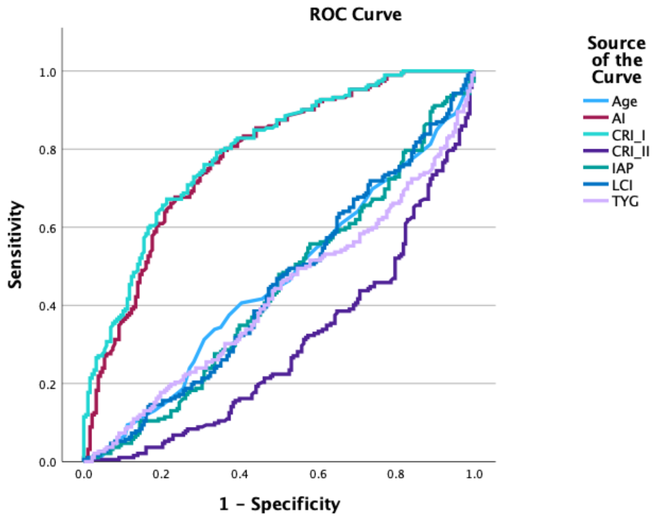

Figure 2 ROC Curve.

4. Discussion

This study presents crucial findings regarding the cardiovascular risk profile of female LEOs in East Java, Indonesia. The findings reveal a high prevalence of obesity, hypertension, dyslipidemia, and elevated levels of remnant cholesterol (RC). These findings highlight a notable association between RC and a range of atherogenic lipid indices, which highlights the potential role of RC as an emerging biomarker for cardiovascular risk assessment in this population.

4.1. Elevated Cardiometabolic Risk Factor

The study population exhibited alarming levels of obesity (69.4%), hypertension (52.4%), and dyslipidemia (84.3% with high LDL), which are consistent with previous studies indicating that female LEOs face a high risk of CVD in 56.7% of the population based on the 2013 American College of Sports Medicine guidelines (Medicine, 2013). Furthermore, female LEOs demonstrate a higher prevalence of CVD risk factors than the general female population (Yoo & Franke, 2011). These risk factors are likely prevalent due to the unique stressors associated with working in law enforcement, including shift work, psychological stress, and limited opportunities for physical activity (Ma et al., 2015). Law enforcement work is an occupation that is characterized by extended working hours, elevated levels of stress, irregular eating and sleeping patterns, and sudden surges of adrenaline. These factors contribute to the prevalence of hypertension, dyslipidemia, and obesity, which are well-established risk factors for heart disease (Saffari et al., 2020; Yoo & Franke, 2011). A study revealed that female LEOs exhibited elevated stress levels in comparison to their male LEOs (Yoo & Franke, 2011). In line with this, another investigation involving a similar group revealed that police officers exhibited considerably higher CVD risk profiles and Atherogenic Index of Plasma (AIP) compared to the civilian population, confirming the need for aggressive prevention strategies in this population group (Ardiana et al., 2022).

4.2. The Potential of Remnant Cholesterol as an Emerging Biomarker

Remnant cholesterol (RC) is gaining recognition as a key biomarker for CVD, providing predictive value that extends beyond conventional lipid measurements like LDL-C. RC may contribute directly to atherosclerosis by exacerbating endothelial dysfunction (ED), inflammation, and thrombosis (Chen & Li, 2023; Varbo et al., 2014). Increased RC levels have been associated with an increased risk of developing coronary artery calcium (CAC), regardless of conventional cardiovascular risk factors, despite having a normal LDL-C (Hao et al., 2022). Higher risk of cardiovascular death has been reported in patients with higher LDL-C (≥130 mg/dL), higher RC [≥25.7/23.7 mg/dL in males/females corresponding to the clinical cutoff point of LDL-C (130 mg/dL)] and abnormal HDL-C levels (<40/50 mg/dL in males/females) (Zhang et al., 2022).

Several lipid indices, including CRI-I and CRI-II, are commonly observed to increase in patients with coronary artery disease (CAD) confirmed through angiographic methods. By integrating the ratio of pro-atherogenic and anti-atherogenic lipoproteins, these indices deliver a more comprehensive evaluation of lipid-associated risks. These indices also correlate with coronary plaque formation and the CVD risk associated with metabolic syndrome (Raaj et al., 2024). This study's primary result was the strong relationship between RC and atherogenic lipid indices (CRI-I, CRI-II, AI). CRI-I reflects total cholesterol balance, whereas RC contributes to total cholesterol. CRI-II focuses on the LDL-C/HDL-C ratio; RC adds to the residual risk when LDL-C is controlled. In AI, non-HDL-C includes RC, so AI is inherently correlated with RC. Despite the validity of CRI-I and CRI-II for the assessment of traditional lipid imbalances, RC is emerging as a superior biomarker for residual CVD risk, particularly in metabolic syndrome and diabetes (Raaj et al., 2024).

In this study, CRI-I and AI emerged as the most informative lipid ratios for identifying high residual cholesterol among female law enforcement officers. The relatively high AUC values observed for CRI-I (0.792) and AI (0.778) indicate that these ratios capture most of the atherogenic lipid burden associated with residual particles. These findings are consistent with previous literature suggesting that non-HDL-based indices are strong markers for overall atherogenic lipoproteins, including VLDL remnant particles, which are not adequately reflected by isolated LDL-C measurements.

4.3. Role of Insulin Resistance and the TyG Index

Insulin resistance can be widely and easily predicted by measuring the TyG index. A plethora of studies have proven the TyG index's effectiveness in diagnosing CVD risk (Ibrahim et al., 2024; Moon et al., 2023). The present study showed a correlation between RC and the TyG index. This is predicated on the same underlying mechanism that facilitates the relationship between the two biomarkers and metabolic dysfunction, as well as atherosclerosis formation. Insulin resistance has been demonstrated to result in an increase in remnant lipoproteins, which, in turn, has been shown to increase RC levels and promote the development of atherosclerosis. The integration of the TyG index and RC measurement has been demonstrated to enhance cardiovascular risk stratification through the incorporation of metabolic and lipoprotein pathways associated with atherogenesis.

This research has several limitations. First, it is not possible to establish a causal connection between RC and CVD due to the cross-sectional nature of the study. Reliance on self-reported medical history may introduce memory bias, particularly with regard to hypertension and glucose control. Second, the study population consisted exclusively of female law enforcement officers (LEOs) from a single regional police headquarters, limiting the generalizability of these findings to male police officers, civilian populations, or other regions with different occupational stress factors. Furthermore, the limited geographical scope and specific occupational focus of this research hinder its broader generalizability. The cardiovascular system is subject to the influence of numerous factors; however, this study did not focus on measuring dietary habits, stress levels, and physical activity. Consequently, this study necessitates longitudinal follow-up research to evaluate and substantiate these findings.

The findings of this study have important implications for occupational health policy in the field of law enforcement. Given the strong association between RC and various cardiometabolic markers, integrating RC screening and the TyG index into routine health evaluations for female law enforcement officers (LEOs) could help identify high-risk individuals earlier. Implementing structured wellness programs focused on stress reduction, dietary modification, and shift scheduling optimization could further reduce long-term cardiovascular burden in this population. Policy makers in law enforcement agencies may consider adopting these biomarkers as part of periodic health monitoring to guide preventive interventions.

5. Conclusions

This study revealed a significant occurrence of cardiometabolic risk factors among female LEOs in East Java, with RC showing significant associations with TG, LDL-C, total cholesterol, TyG index, and several atherogenic indices. CRI-I and AI demonstrated superior ability in identifying high residual cholesterol among female law enforcement officers, outperforming LDL-based indices and insulin resistance. These findings highlight the value of simple lipid ratios routinely available as practical markers for early detection of cardiometabolic risk in this population. Integrating these indices into routine screening could improve risk stratification and facilitate earlier preventive interventions. Further research is needed to validate these results in larger and more diverse populations.

Acknowledgment

The authors would like to express their sincere gratitude to all individuals and institutions involved in data access and logistical support.

6. Declarations

6.1. Ethical considerations

All participants provided written informed consent prior to participation.

6.2. Use of artificial intelligence (AI)

The authors declare that no generative artificial intelligence (AI) tools were used in the preparation, analysis, or writing of this manuscript.

6.3. Conflict of Interest

The authors declare that they have no conflicts of interest that could have influenced the work reported in this manuscript.

6.4. Funding

This research did not receive any financial support.

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