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Association between triglyceride levels and rheumatoid arthritis prevalence in women: a cross-sectional study of NHANES (1999–2018)

Chang-Mei Zeng[1*], Jun He[1], Deng-Chao Wang[2] and Hong Xie[3]

Abstract

Background Rheumatoid arthritis (RA) is a chronic autoimmune disease with a higher prevalence in women. Triglycerides, key indicators of lipid metabolism, are linked to inflammation and metabolic disorders, both contributing to RA pathogenesis. However, the association between triglyceride levels and RA prevalence in women remains unclear. This study analyzes this association using NHANES (1999–2018) data to provide evidence for prevention and personalized intervention strategies.

Methods This study utilized data from the National Health and Nutrition Examination Survey (NHANES) spanning 1999 to 2018. It included 10,728 female participants, of whom 639 were diagnosed with RA. Triglyceride levels were categorized into four quartiles (Q1 to Q4), and multivariable logistic regression models were used to analyze the association between triglyceride levels and RA prevalence in women. Restricted cubic spline (RCS) analyses were performed to evaluate the potential nonlinear association between triglyceride levels and RA prevalence. Subgroup and interaction analyses were conducted to further investigate the association across different populations.

Results Among the 639 RA patients, higher triglyceride levels were significantly positively associated with RA prevalence in women. In the unadjusted model, elevated triglyceride levels were significantly associated with an increased RA prevalence (OR: 1.30, 95% CI: 1.04–1.61, $P = 0.019$). This association remained significant in the adjusted model, with the highest quartile showing a substantially higher risk compared to the lowest quartile (OR: 2.46, 95% CI: 1.22–4.95, P for trend = 0.04). RCS analyses indicated a linear association between triglyceride levels and RA prevalence (P for nonlinearity = 0.19). Subgroup analyses revealed consistent trends across various subgroups, with no significant interactions observed (all interaction P-values > 0.05).

Conclusion This study demonstrates a significant positive association between elevated triglyceride levels and RA prevalence in women, with a linear trend observed in this association. Future research should further investigate the role of triglyceride levels in the pathogenesis of RA and explore potential intervention pathways.

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Keywords Rheumatoid arthritis, Triglycerides, Women, NHANES, Logistic regression, Nonlinear association, Eepidemiology

Introduction

Role of rheumatoid arthritis in women

Rheumatoid arthritis (RA) is a chronic, systemic autoimmune disease characterized by joint inflammation, pain, and swelling, which can lead to joint deformities and functional disabilities in severe cases [1, 2]. The prevalence of RA is significantly higher in women than in men, suggesting that sex may be an important factor influencing disease onset. The disease course in female RA patients is often more complex, potentially involving hormonal fluctuations, immune response differences, and metabolic dysregulation [3–6]. This highlights the importance of understanding sex-specific risk factors to improve disease management and prevention strategies.

Impact of lipid metabolism on RA

Dyslipidemia, particularly elevated triglyceride levels, is closely associated with systemic inflammation and metabolic syndrome. These factors are key contributors to the pathogenesis of RA [7–9]. Studies have shown that elevated triglyceride levels influence immune responses by promoting the release of pro-inflammatory cytokines, such as tumor necrosis factor-α (TNF-α) and interleukin-6 (IL-6). These cytokines play crucial roles in RA-associated joint inflammation and systemic immune dysregulation [10, 11]. Additionally, dyslipidemia can disrupt lipid transport and oxidation, leading to the accumulation of triglyceride-rich lipoproteins. This may further exacerbate oxidative stress and endothelial dysfunction [12, 13], mechanisms that are closely linked to the progression of autoimmune diseases [14, 15].

Challenges in current research on women and RA

Nevertheless, existing studies primarily focus on cohorts from the general population. They often overlook the unique metabolic and hormonal characteristics of women, who represent a high-risk group for RA [16]. Women face unique metabolic challenges due to hormonal fluctuations, particularly during menopause [17–19]. Estrogen plays a crucial role in regulating lipid metabolism, influencing the production and clearance of triglycerides. The decline in estrogen levels during menopause may lead to increased fat accumulation and altered lipid metabolism, which can amplify the effects of triglycerides on immune regulation and inflammation [20–22]. Investigating female-specific risk factors is therefore critical to understanding RA pathogenesis. Existing studies on the relationship between triglyceride levels and RA are largely limited by small sample sizes and lack of representative data. Additionally, many studies have not comprehensively explored the interactions of these factors in RA, especially across different populations. Furthermore, research specifically focusing on women is particularly lacking, with a significant gap in large-scale studies exploring the relationship between triglyceride levels and RA in female populations. Addressing these gaps is essential to advancing research into the metabolic mechanisms of RA and identifying modifiable risk factors. Such efforts could improve prevention and intervention strategies for RA.

Study objectives and approach

To address these research gaps, this study analyzed the association between triglyceride levels and the prevalence of RA in women using data from the 1999–2018 National Health and Nutrition Examination Survey (NHANES). By focusing on a female-specific population and leveraging a nationally representative and robust dataset, this study aims to provide new insights into the metabolic mechanisms underlying RA pathogenesis. It also seeks to inform the development of targeted prevention and intervention strategies. Unlike previous studies, this research comprehensively examines triglycerides as a potential modifiable risk factor for RA, contributing to a deeper understanding of sex-specific disease mechanisms.

Materials and methods

Data source

This study utilized data from the 1999–2018 NHANES. Conducted by the Centers for Disease Control and Prevention (CDC), NHANES is a nationwide, representative cross-sectional survey designed to collect health and nutritional status data from the U.S. population through interviews, physical examinations, and laboratory tests. The NHANES data were obtained using a stratified, multistage sampling design to ensure national representativeness. Data from all eligible female participants in the NHANES database were used to analyze the association between triglyceride levels and the prevalence of RA. NHANES adheres to strict ethical guidelines, with approval from the Institutional Review Board of the National Institutes of Health (NIH) and the CDC, and informed consent was obtained from all participants. This study involved secondary analysis of publicly available anonymized data, thus requiring no additional ethical approval or informed consent procedures [23, 24].

Study population

This study utilized data from NHANES (1999–2018) to investigate the association between triglyceride levels and the prevalence of RA in women. Participants were selected based on the following criteria: (1) only individuals aged 20 years or older were considered, excluding 46,235 participants under the age of 20; (2) since the study focused exclusively on women, 26,473 male participants were excluded; (3) participants with missing key data were excluded, including 14,403 individuals without triglyceride measurements and 3,477 individuals without RA data. After applying these criteria, a total of 10,728 eligible female participants were included in the final analysis. Figure 1 illustrates the study population screening process.

Measurement of triglycerides

Triglyceride levels were measured based on NHANES laboratory data. Serum samples were collected, frozen, and transported to the University of Minnesota for analysis. All testing procedures strictly adhered to the quality control standards outlined in the 1988 Clinical Laboratory Improvement Amendments (CLIA), covering every stage from sample handling to testing. Data analysis included only participants who had fasted for at least 8.5 h. Triglyceride values were converted to grams per liter (g/L) units to ensure data accuracy and representativeness.

Definition of RA

In this study, RA was defined based on self-reported data from participants in the health questionnaire. Participants were first asked whether a healthcare professional had ever diagnosed them with arthritis. They were then asked to specify the type of arthritis. The questionnaire provided various options, including RA, osteoarthritis, psoriatic arthritis, other types, or responses such as "refused to answer" or "do not know." Previous research has indicated that the concordance rate between self-reported arthritis and clinical diagnoses can be as high as 85%. This method facilitates the identification and classification of RA, enabling a more precise analysis of its association with triglyceride levels [25].

Covariates

In this study, a series of covariates were included to more comprehensively assess the association between triglyceride levels and RA prevalence in women. These covariates included age; race (Mexican American, other Hispanic, non-Hispanic White, non-Hispanic Black, and other races); education level (less than high school, high school or equivalent, and college or above); marital status (married, widowed, divorced, separated, never married, and living with partner); poverty-income ratio (PIR); body mass index (BMI); daily alcohol intake; daily moisture intake; daily energy intake; daily protein intake; daily carbohydrate intake; daily total fat intake; hypertension status (yes/no); hemoglobin A1c level; presence of renal failure (determined based on self-reported responses to the question, "Has a doctor or other health professional ever told you that you had weak or failing kidneys?"); smoking status (never smoker, former smoker, and current smoker) [26]; cholesterol levels; and C-reactive protein (CRP) levels. The inclusion of these covariates aimed to control for potential confounders, thereby enhancing the accuracy and reliability of the results.

Statistical analyses

In this study, triglyceride levels were categorized into four quartiles: Q1, Q2, Q3, and Q4. Categorical variables were presented as percentages and compared between groups using weighted chi-square tests. For continuous variables with a normal distribution, data were expressed as mean ± standard deviation (SD) and differences were analyzed using one-way ANOVA. For continuous variables with a non-normal distribution, results were described as medians and interquartile ranges (IQR) and analyzed using Kruskal-Wallis test. To explore the association between triglyceride levels and the prevalence of RA in women, three multivariable logistic regression models were constructed. Model 1 included no adjustments; Model 2 was adjusted for age, race, education level, marital status, and PIR; and Model 3 further adjusted for BMI, daily alcohol intake, daily moisture intake, daily energy intake, daily protein intake, daily carbohydrate intake, daily total fat intake, hypertension status, hemoglobin A1c level, presence of renal failure, smoking status, cholesterol levels, and CRP levels. The association between triglyceride levels and the prevalence of RA in women was evaluated in each model using odds ratios (ORs), which measure the relative odds of an event occurring in one group compared to another. OR values greater than 1 indicate a higher probability of the event occurring in the group, while values less than 1 indicate a lower probability. Additionally, 95% confidence intervals (CIs) were used to represent the range within which the true value is expected to fall with 95% confidence. A trend test was conducted by treating triglyceride quartiles as a continuous variable in logistic regression models to evaluate the linear trend across quartiles. Additionally, restricted cubic spline (RCS) analysis was used to evaluate the potential nonlinear relationship between triglyceride levels and the prevalence of RA in women. Subgroup analyses were conducted to further investigate the association between triglyceride levels and RA prevalence across different populations. To assess the potential impact of various covariates on the association, interaction analyses were performed to examine the interaction between

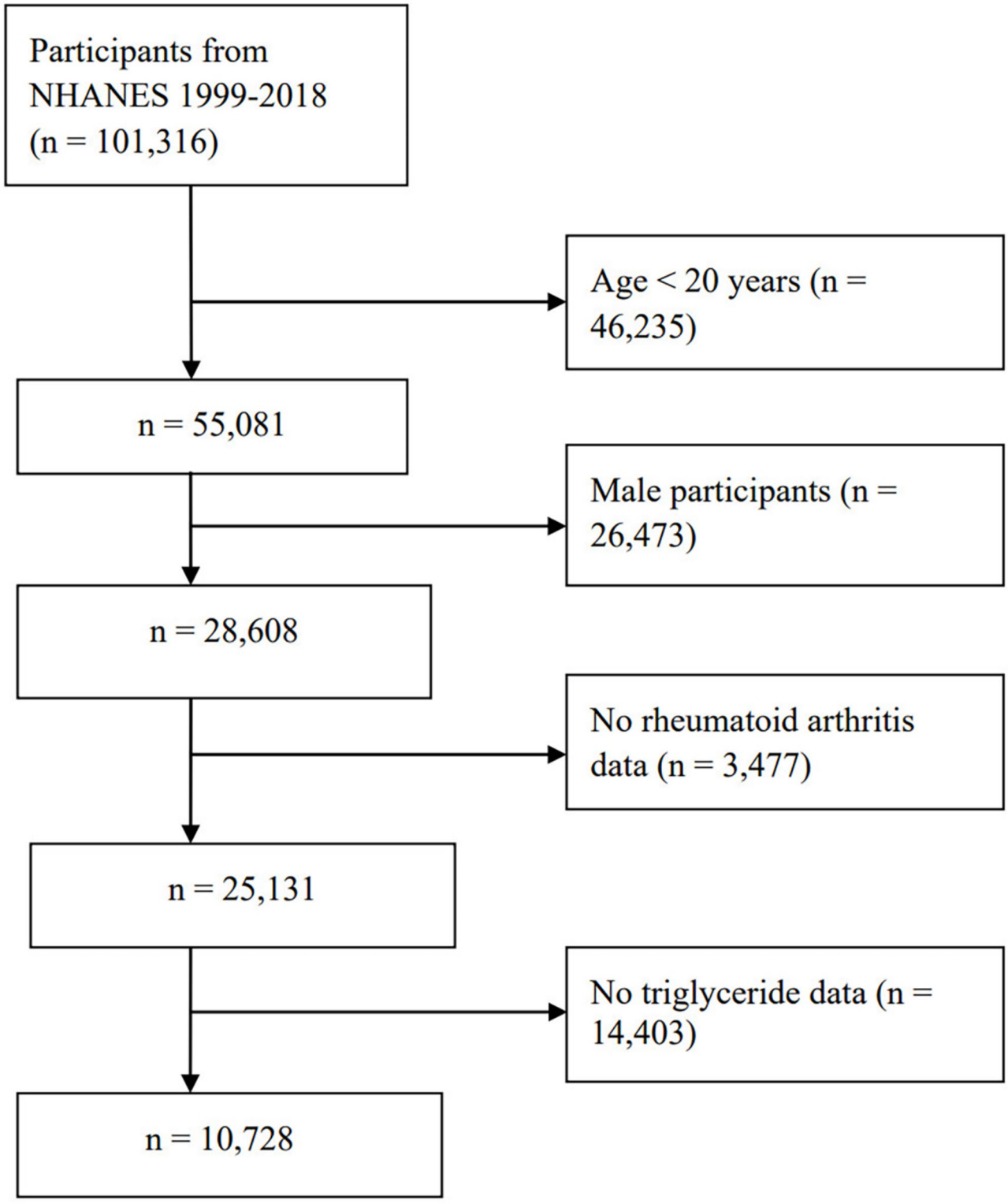

Fig. 1 Flow diagram of the study design

triglyceride levels and key covariates. All statistical analyses were conducted using R software (version 4.2.2) and Free Statistics software (version 1.9). Two-sided p-values less than 0.05 were considered statistically significant, with Bonferroni correction applied to control for increased Type I error in multiple comparisons [27].

Results

Participants and demographic characteristics

This study analyzed NHANES data from 1999 to 2018, including a total of 10,728 eligible participants, of whom 639 were diagnosed with RA. Triglyceride levels were divided into four groups: Q1 (0.10–0.70 g/L) with 2,671 participants, where the RA prevalence was 104/2,671 (3.9%); Q2 (0.71–1.01 g/L) with 2,625 participants, in which the RA prevalence was 154/2,625 (5.9%); Q3 (1.02–1.50 g/L) with 2,734 participants, where the RA prevalence was 189/2,734 (6.9%); and Q4 (1.51–42.33 g/L) with 2,698 participants, where the RA prevalence was 192/2,698 (7.1%). Participants in the Q4 group were more likely to have RA, be older, identify as Mexican American, have less than a high school education, be widowed, have a lower PIR, a higher BMI, lower daily alcohol intake, higher daily energy intake, higher daily protein and carbohydrate intake, lower daily total fat intake, have a history of hypertension, higher glycohemoglobin levels, renal failure, current smoking status, and higher cholesterol and CRP levels (Table 1).

The association between triglyceride levels and the prevalence of RA in women

Table 2 presents the association between triglyceride levels and the prevalence of RA in women, based on multivariable logistic regression models. When triglyceride levels were analyzed as a continuous variable, Model 1, without adjustment for covariates, indicated a significant positive association between triglyceride levels and the prevalence of RA in women (OR: 1.30, 95% CI: 1.04–1.61; $P = 0.019$). This association remained significant in Models 2 and 3 after adjusting for covariates. As triglyceride levels increased, the association became stronger. In Model 3, the OR for the fourth quartile was significantly higher than that for the first quartile (OR: 2.46, 95% CI: 1.22–4.95). Trend tests demonstrated a significant positive association between triglyceride levels and the prevalence of RA in women (P for trend = 0.04). After accounting for all potential confounding factors, RCS analysis showed that the association between triglyceride levels and RA prevalence in women remained significant, with no evidence of nonlinearity (P for nonlinearity = 0.19) (Fig. 2).

Subgroup analyses and interaction

This study conducted stratified and interaction analyses based on variables such as age, race, education level, marital status, PIR, BMI, daily alcohol intake, smoking status, hemoglobin A1c levels, and presence of renal failure. The results indicated consistent trends across all subgroups, with no significant interactions observed (all interaction P-values > 0.05). Detailed results are presented in Fig. 3.

Discussion

In this study, we analyzed the relationship between triglyceride levels and the prevalence of RA in women based on NHANES data from 1999 to 2018. The results indicated a strong positive association between elevated triglyceride levels and the prevalence of RA in women. Multivariable logistic regression analyses showed that this association remained significant even after adjusting for various potential confounders. Women in the highest triglyceride quartile (Q4) had a significantly higher prevalence of RA compared to those in the lowest quartile (Q1). Additionally, RCS analyses confirmed that this positive association was linear, with no significant nonlinear characteristics. Subgroup analyses revealed consistent trends across all subgroups, with no significant interactions detected. This suggests that elevated triglyceride levels may be an important risk factor for RA in women.

Existing studies have shown that dyslipidemia is closely associated with RA. A study by Rodríguez-Carrio et al. involving 113 RA patients analyzed triglyceride levels. It found that elevated triglyceride levels were connected to systemic inflammation. The study also suggested that triglycerides may play a key role in inflammation and dyslipidemia, and affect the response to anti-TNFα therapy in RA patients [28]. In addition, a study by van Halm et al. included 79 blood donors who were ultimately diagnosed with RA and compared their blood samples with those of 1,071 healthy controls. Retrospective analysis of lipid level changes revealed that these patients had significantly elevated triglyceride levels. This occurred at least 10 years before the onset of symptoms. These findings suggest that triglycerides may be involved in the early pathogenesis of the disease [29]. Further, a case study by Yagi et al. indicated that a sudden increase in triglyceride levels may be associated with the fragility of coronary plaques in RA patients, highlighting its potential role in cardiovascular complications [30]. These studies collectively suggest that elevated triglyceride levels may influence RA progression and metabolic disturbances through multiple mechanisms.

Compared to existing studies, our research has several advantages. First, we utilized nationwide data from the 1999–2018 NHANES, which provided a large and representative sample covering women from diverse age groups, races, and socioeconomic backgrounds. This

Table 1 Baseline characteristics of the study participants

		Triglyceride levels (g/L)				
		Q1 (0.10 ~ 0.70)	Q2(0.71 ~ 1.01)	Q3(1.02 ~ 1.50)	Q4(1.51 ~ 42.33)	
Variables	**Total (*n* = 10,728)**	**(*n* = 2,671)**	**(*n* = 2,625)**	**(*n* = 2,734)**	**(*n* = 2,698)**	**P-value**
Weighted sample size	45,081,940	11,965,548	11,505,066	11,263,960	10,347,365	
RA, n (%)						< 0.001
Yes	639 (6.0)	104 (3.9)	154 (5.9)	189 (6.9)	192 (7.1)	
No	10,089 (94.0)	2,567 (96.1)	2,471 (94.1)	2,545 (93.1)	2,506 (92.9)	
Age (years), Mean ± SD	47.7 ± 18.0	41.5 ± 16.2	47.4 ± 17.7	50.9 ± 18.3	50.9 ± 18.0	< 0.001
Race, n (%)						< 0.001
Mexican American	1,972 (18.4)	303 (11.3)	416 (15.8)	571 (20.9)	682 (25.3)	
Other Hispanic	936 (8.7)	205 (7.7)	239 (9.1)	262 (9.6)	230 (8.5)	
Non-Hispanic White	4,641 (43.3)	989 (37)	1,098 (41.8)	1,228 (44.9)	1,326 (49.1)	
Non-Hispanic Black	2,160 (20.1)	854 (32)	629 (24)	431 (15.8)	246 (9.1)	
Other Race	1,019 (9.5)	320 (12)	243 (9.3)	242 (8.9)	214 (7.9)	
Education, n (%)						< 0.001
Less than high school	2,645 (24.7)	435 (16.3)	583 (22.2)	766 (28)	861 (32)	
High school or equivalent	2,354 (22.0)	505 (18.9)	561 (21.4)	634 (23.2)	654 (24.3)	
College or above	5,714 (53.3)	1,726 (64.7)	1,478 (56.4)	1,332 (48.8)	1,178 (43.7)	
Marital status, n (%)						< 0.001
Married	5,253 (49.5)	1,245 (46.8)	1,232 (47.4)	1,344 (49.5)	1,432 (54.2)	
Widowed	1,148 (10.8)	145 (5.5)	275 (10.6)	367 (13.5)	361 (13.7)	
Divorced	1,180 (11.1)	259 (9.7)	320 (12.3)	302 (11.1)	299 (11.3)	
Separated	424 (4.0)	101 (3.8)	105 (4)	121 (4.5)	97 (3.7)	
Never married	1,802 (17.0)	678 (25.5)	461 (17.7)	397 (14.6)	266 (10.1)	
Living with partner	807 (7.6)	230 (8.7)	208 (8)	182 (6.7)	187 (7.1)	
PIR, Median (IQR)	2.1 (1.1, 4.0)	2.4 (1.2, 4.3)	2.1 (1.1, 4.2)	2.0 (1.1, 3.8)	1.9 (1.1, 3.6)	< 0.001
BMI (kg/m^2), Mean ± SD	29.1 ± 7.3	27.1 ± 7.2	28.5 ± 7.4	30.0 ± 7.3	30.9 ± 6.7	< 0.001
Daily alcohol intake (g), Median (IQR)	0.0 (0.0, 0.0)	0.0 (0.0, 0.5)	0.0 (0.0, 0.0)	0.0 (0.0, 0.0)	0.0 (0.0, 0.0)	< 0.001
Daily moisture intake (g), Median (IQR)	2,366.3 ± 1,109.5	2,405.3 ± 1,092.3	2,359.1 ± 1129.8	2,362.7 ± 1111.5	2,336.9 ± 1,104.4	0.208
Daily energy intake (kcal), Mean ± SD	1,785.2 ± 692.3	1,842.2 ± 716.5	1,768.4 ± 702.6	1,748.6 ± 661.8	1,782.8 ± 685.5	< 0.001
Daily protein intake (g), Median (IQR)	68.9 ± 29.2	71.9 ± 30.9	67.9 ± 28.8	67.3 ± 27.8	68.6 ± 29.1	< 0.001
Daily carbohydrate intake (g), Mean ± SD	223.8 ± 94.3	223.0 ± 95.2	221.5 ± 93.7	221.3 ± 91.2	229.4 ± 96.7	0.006
Daily total fat intake (g), Mean ± SD	67.8 ± 33.1	72.2 ± 34.8	67.2 ± 33.1	65.7 ± 31.8	66.1 ± 32.3	< 0.001
Hypertension, n (%)						< 0.001
Yes	3,481 (32.5)	554 (20.8)	801 (30.6)	1036 (38)	1090 (40.6)	
No	7,217 (67.5)	2,113 (79.2)	1,816 (69.4)	1,692 (62)	1,596 (59.4)	
Glycohemoglobin (%), Mean ± SD	5.6 ± 1.0	5.4 ± 0.6	5.6 ± 0.9	5.7 ± 1.1	5.9 ± 1.3	< 0.001
Presence of renal failure, n (%)						< 0.001
Yes	322 (3.0)	51 (1.9)	65 (2.5)	84 (3.1)	122 (4.5)	
No	10,386 (97.0)	2,617 (98.1)	2,557 (97.5)	2642 (96.9)	2,570 (95.5)	
Smoking, n (%)						< 0.001
Never	6,902 (64.4)	1,931 (72.3)	1,688 (64.4)	1,721 (63)	1,562 (58)	
Former	2,018 (18.8)	404 (15.1)	481 (18.3)	529 (19.4)	604 (22.4)	
Now	1,799 (16.8)	335 (12.5)	453 (17.3)	482 (17.6)	529 (19.6)	
Cholesterol (mg/dL), Mean ± SD	198.3 ± 43.0	176.0 ± 34.1	192.3 ± 37.3	202.3 ± 38.8	222.0 ± 47.1	< 0.001
CRP (mg/dL), Median (IQR)	0.3 (0.1, 0.7)	0.1 (0.0, 0.3)	0.2 (0.1, 0.5)	0.3 (0.1, 0.7)	0.4 (0.2, 0.8)	< 0.001

ensures a more comprehensive reflection of the association between triglyceride levels and the prevalence of RA in women. Second, our study employed multivariable logistic regression models and RCS analyses, systematically adjusting for multiple confounding factors such as age, BMI, and daily dietary intake, thereby enhancing the precision and robustness of our findings. The results of the RCS analysis indicated a linear association between triglyceride levels and the prevalence of RA. In practical terms, this means that as triglyceride levels increase, the prevalence of RA in women also increases in a consistent and proportional manner. However, it is worth noting that although our findings support a linear relationship, the possibility of nonlinear associations cannot

Table 2 The associations between triglycerides and the prevalence of RA in women

	Model 1		Model 2		Model 3	
Exposure	**OR (95%CI)**	**P-value**	**OR (95%CI)**	**P-value**	**OR (95%CI)**	**P-value**
Continuous	1.30 (1.04, 1.61)	0.019	1.08 (1.07, 1.10)	< 0.001	1.19 (1.04, 1.37)	0.014
Quartile						
Q1	Reference		Reference		Reference	
Q2	2.65 (1.41, 4.99)	0.003	1.08 (0.74, 1.56)	0.689	1.79 (0.93, 3.44)	0.080
Q3	3.12 (1.69, 5.78)	< 0.001	1.18 (0.81, 1.72)	0.377	1.73 (0.92, 3.25)	0.085
Q4	5.01 (2.79, 9.00)	< 0.001	1.44 (0.96, 2.14)	0.065	2.46 (1.22, 4.95)	0.013
P for trend		< 0.001		0.050		0.040

Model 1: No covariates were adjusted

Model 2: Based on Model 1, adjustments were made for age, race, education, marital status, and PIR

Model 3: Building on Model 2, additional adjustments were made for BMI, daily alcohol intake, daily moisture intake, daily energy intake, daily protein intake, daily carbohydrate intake, daily total fat intake, hypertension, glycohemoglobin, presence of renal failure, smoking, cholesterol, c-reactive protein

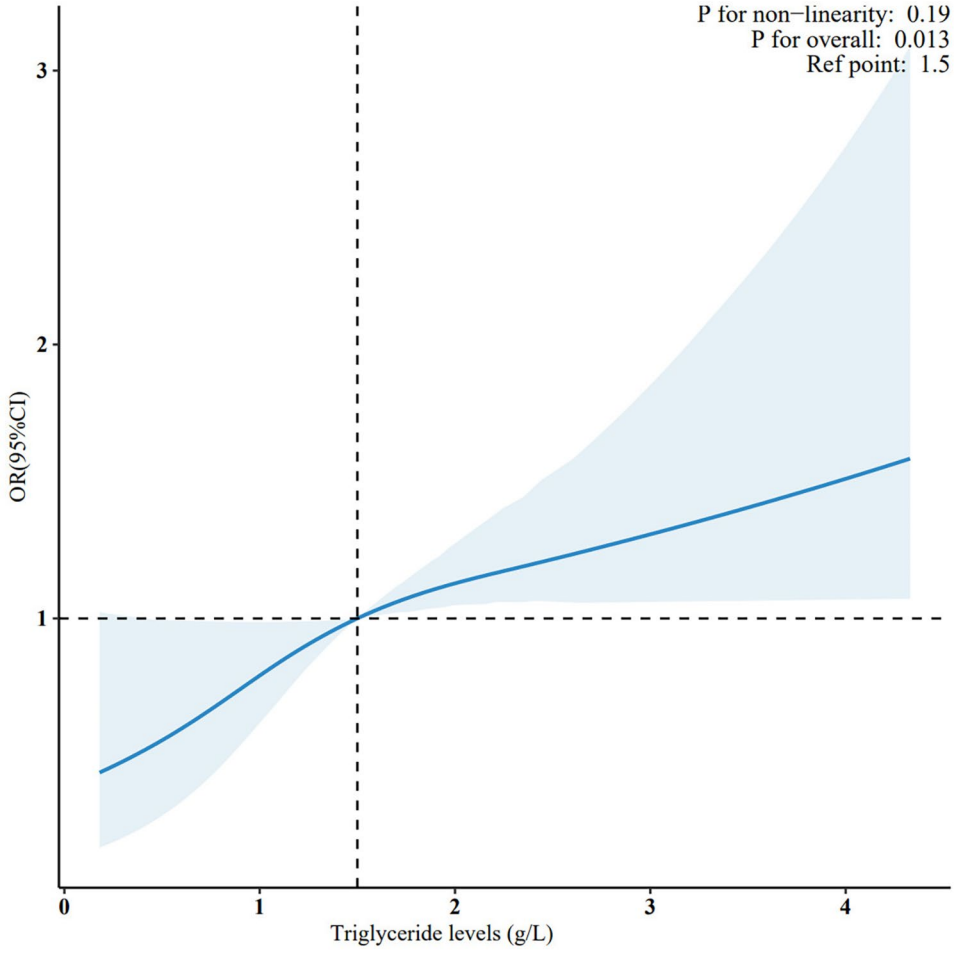

Fig. 2 RCS with multivariate-adjusted associations between triglycerides and the prevalence of RA in women

be entirely ruled out, particularly in populations with extreme triglyceride levels or other metabolic abnormalities. Furthermore, our research not only focused on the linear association between triglyceride levels and RA but also conducted subgroup analyses to reveal complex interactions that are rarely examined in existing literature. These advantages enable our research to provide new insights into the association between triglyceride levels and the prevalence of RA in women, advancing the understanding of potential metabolic risk factors for RA. By addressing gaps in existing studies and offering robust and high-quality evidence, our research makes a significant contribution to the field and paves the way for

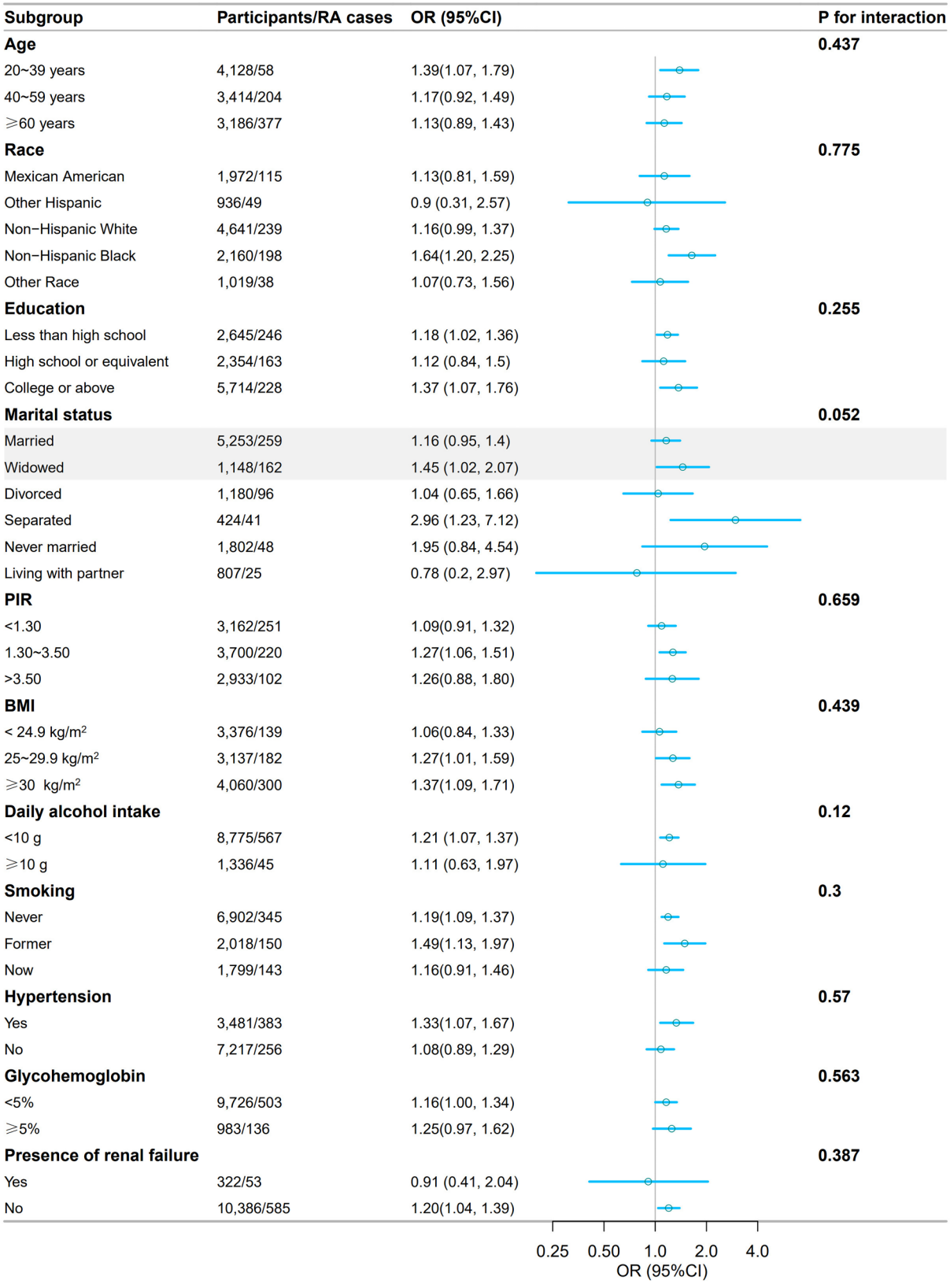

Fig. 3 Subgroup analysis of the association between triglycerides and the prevalence of RA in women

future investigations into the impact of metabolic factors on RA.

From a mechanistic perspective, triglycerides may play a significant role in the onset and progression of RA through multiple pathways. First, elevated triglyceride levels may exacerbate systemic inflammatory responses in RA patients [31]. It activates Toll-like receptor 2 (TLR2) through its apolipoprotein C-III (ApoC-III), thereby activating the nuclear factor kappa B (NF-κB) signaling pathway, initiating the inflammatory response [32]. Studies have demonstrated that high triglyceride levels are linked to increased levels of pro-inflammatory cytokines. These include TNF-α and monocyte chemoattractant protein-1, which play critical roles in the inflammatory progression and joint destruction seen in RA [33–35]. Our study also identified a significant upward trend in CRP levels with increasing triglyceride levels ($P < 0.001$), even though CRP values remained within the normal range. This finding suggests that elevated triglyceride levels may contribute to low-grade systemic inflammation, consistent with prior research linking dyslipidemia and chronic inflammation. Second, RA is often accompanied by features of metabolic syndrome, such as dyslipidemia characterized by elevated triglyceride levels, insulin resistance, and hypertension [36]. These factors collectively increase the cardiovascular disease risk in RA patients [37–39]. A state of heightened inflammation can significantly impact lipid metabolism, leading to increased triglyceride levels. These elevated levels are associated with inflammation-induced lipoprotein metabolic abnormalities, such as reduced low-density lipoprotein particle size and increased triglyceride-rich lipoproteins [40, 41]. While reducing inflammation may partially improve these metabolic abnormalities, it often does not fully normalize elevated triglyceride levels [42, 43]. Furthermore, elevated triglyceride levels are significantly associated with an increased risk of cardiovascular complications. They may accelerate atherosclerosis through mechanisms such as increased plaque vulnerability and impaired endothelial function [44–47]. These mechanisms suggest that triglycerides may exert complex effects in the pathophysiological processes of RA through pathways involving inflammation, metabolic disturbances, and increased cardiovascular risk. Clinically, our findings suggest that monitoring and managing triglyceride levels in women could be an important step in identifying those at higher risk for developing RA, particularly in populations with existing metabolic disturbances. Early intervention to regulate triglycerides may help mitigate the inflammatory processes contributing to RA development, providing a potential strategy for RA prevention or early management.

Although this study revealed a significant association between triglyceride levels and the prevalence of RA in women, it has several limitations. (1) First, the study was based on cross-sectional data, which does not allow for the establishment of causal relationships and only describes associations. Future longitudinal studies are needed to explore the direction of causality. (2) Second, triglyceride levels were measured at a single time point, which may not fully capture fluctuations in long-term lipid metabolism. Triglycerides are a single indicator, and in most direct clinical tests, they can be affected by various factors. Future studies could consider combining other indicators to form a ratio to explore the relationship with rheumatoid arthritis, such as the triglyceride to high-density lipoprotein cholesterol ratio. (3) Additionally, although we adjusted for a wide range of confounding factors, there may still be uncontrolled confounders, such as genetic background and other potential influences, that could affect the results. (4) Finally, the diagnosis of RA in this study relied on self-reported data from NHANES, which may introduce information bias. Additionally, NHANES does not include key clinical indicators for diagnosing RA, such as rheumatoid factor (RF) and anti-cyclic citrullinated peptide antibody (anti-CCP). The lack of these biomarkers limits the ability to confirm RA diagnoses based on clinical standards, which may impact the accuracy of the findings. Despite these limitations, our study provides important preliminary evidence suggesting that triglyceride levels may be related to the pathological progression of RA in women.

Conclusion

This study demonstrates a significant positive association between elevated triglyceride levels and the prevalence of RA in women, and this association remains significant even after adjusting for multiple confounding factors. Our findings suggest that monitoring triglyceride levels in women with RA could be valuable. Elevated triglycerides may serve as a modifiable risk factor for the disease. Targeting triglyceride levels through lifestyle changes or pharmacological treatments may help reduce inflammation and improve patient outcomes. Based on this finding, future research should further explore the biological mechanisms through which triglycerides contribute to the development of RA. It should also explore intervention strategies, such as lifestyle changes or pharmacological treatments targeting lipid metabolism. These efforts could enhance prevention and management strategies for RA in women.

Abbreviations

BMI	Body Mass Index
CDC	Centers for Disease Control and Prevention
CI	Confidence Interval
CRP	C-Reactive Protein
IQR	Interquartile Ranges
NHANES	National Health and Nutrition Examination Survey
OR	Odds Ratio

PIR	Poverty Income Ratio
RA	Rheumatoid Arthritis
RCS	Restricted Cubic Spline
SD	Standard Deviation
TNF-α	Tumor Necrosis Factor Alpha

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None.

Author contributions
All authors contributed significantly to this study. Chang-Mei Zeng (CZ) was responsible for study conceptualization, overseeing data collection, and drafting the initial manuscript. Jun He (JH) contributed to study methodology development, conducted statistical analyses, and assisted in manuscript preparation. Deng-Chao Wang (DW) supported data curation, performed literature review, and contributed to manuscript revisions. Hong Xie (HX) participated in data validation, reproduced figures, guided manuscript revisions, and performed grammar checks in addition to general contributions.

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Data availability
The NHANES dataset used in this study is publicly available and can be accessed at: https://wwwn.cdc.gov/nchs/nhanes.

Declarations

Ethics approval and consent to participate
The study was approved by the Institutional Review Board of the CDC's National Center for Health Statistics, and all participants provided written informed consent. The research adhered to the ethical standards set forth in the Helsinki Declaration. As this analysis was based on publicly available NHANES secondary data, no additional ethical approval was necessary.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

Clinical trial number
Not applicable.

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