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Hypertriglyceridemic waist phenotype and 10-year incidence of hypertension: Yazd healthy heart cohort study

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Abstract

BACKGROUND: The hypertriglyceridemic waist phenotype (HTGW), a surrogate indicator of visceral adiposity, has been proposed as a simple screening tool for cardiometabolic risk. Limited information is available on the influence of HTGW and its temporal variations on the development of hypertension. This study examined the association between HTGW and decade-long hypertension incidence in an urban population of Iranian adults.

METHODS: Data were obtained from the Yazd Healthy Heart Project (YHHP). In its initial phase (2005–2006), 2,000 participants aged 20–74 years were enrolled. At baseline, demographic characteristics, blood pressure, anthropometric data, and biochemical tests were evaluated and reassessed in 2015–2016. After excluding individuals with hypertension at baseline, 1,269 normotensive participants were followed for approximately 10 years to assess incident hypertension, using multivariable logistic regression analyses in SPSS.

RESULTS: In this study, after excluding participants lost to follow-up, 786 participants were selected for the final analysis. The cumulative incidence of hypertension was 40.3% (317 out of 786). After adjustment for potential confounders, the risk of HTN was significantly higher among participants with hypertriglyceridemia (OR=2.38, 95% CI: 1.21–4.67) and those with HTGW (OR=1.88, 95% CI: 1.12–3.13) compared to those with normal waist and normal triglycerides (NWNT) in the total population. In men, there was a significant positive association between hypertriglyceridemia (OR=2.71, 95% CI: 1.22–6.02) and HTGW (OR=2.35, 95% CI: 1.23–4.47) and the 10-year incidence of HTN after multivariate adjustment.

CONCLUSION: Our findings showed that hypertriglyceridemia and HTGW are independent predictors of 10-year hypertension incidence, particularly among men, in an Iranian urban adult population.

Keywords: Hypertension; Hypertriglyceridemic Waist; Incidence; Cohort Studies; Risk Factors

Introduction

Hypertension (HTN) is recognized as a leading driver of mortality and chronic illness worldwide and is associated with a high incidence of debilitating diseases[1]. The widespread use of antihypertensive medications has not prevented the global increase in the prevalence of hypertension[2-4]. The global prevalence of hypertension among adults aged 30–79 years is estimated at approximately one billion cases, with the highest burden concentrated in low- and middle-income country settings[5].

Lipid levels and obesity indices, particularly visceral obesity, are related to HTN and cardiovascular diseases[6,7]. The hypertriglyceridemic waist (HTGW) phenotype is characterized by a raised waist circumference alongside high levels of triglycerides (TGs)[8]. HTGW, as a simple indicator of high-risk features associated with excess visceral adiposity[9], could be a useful and inexpensive screening tool to identify people with excess visceral adipose tissue and high TG levels that lead to increased risk of coronary artery disease (CAD)[10].

Evidence linking HTGW to metabolic abnormalities is sparse, especially among Asian populations characterized by higher rates of central obesity[10]. Carolina Cunha et al. showed that HTGW is associated with metabolic alterations[11]. In a 7.5-year follow-up of low-risk, middle-aged men, Czernichow et al. demonstrated a significant association between HTGW and cardiovascular disease risk[12]. Another 10-year prospective study showed that participants with HTGW had higher blood pressure[13]. However, long-term prospective evidence on the association between the HTGW phenotype and incident hypertension, particularly within Middle Eastern populations characterized by distinct genetic and lifestyle determinants of cardiometabolic risk, remains limited.

This study therefore aimed to address this gap by investigating the association between the HTGW phenotype and the 10-year incidence of hypertension in a large urban Iranian adult cohort. Our study contributes to the literature by providing unique data from an understudied population, utilizing a long-term follow-up design, and specifically analyzing sex-specific associations to offer a greater comprehension of HTGW as a potential early marker for hypertension risk.

Materials and Methods

In this cohort study, a representative sample of 2,000 adults aged 20–74 years was selected using multistage random cluster sampling from urban Yazd, Iran, in the Yazd Healthy Heart Project (YHHP). During the first phase (2005–2006), 15 individuals were excluded due to refusal to participate. The prevalence of hypertensive subjects was calculated at 716 (36.1%), who were excluded. We followed non-hypertensive subjects (n=1,269) for about 10 years to determine HTN incidence. After repeated measurements during 2015–2016, 483 participants (38.1%) were lost to follow-up, and 786 participants (61.9%) were selected for final analysis to determine HTN incidence (Figure 1).

Demographic and relevant data were obtained through a researcher-developed checklist. Economic status was assessed using a composite index based on questions about household income and occupation, which were recorded during the initial phase by a trained interviewer. Participants were categorized into low, middle, or high groups for economic status according to established cut-off points from the assessment tools. Education levels were divided into three groups: primary, high school, and academic.

Physical activity was evaluated using the validated short form of the International Physical Activity Questionnaire (IPAQ). Based on physical activity level cut-offs, participants were divided into low (<600 kcal/week), moderate (600–1200 kcal/week), and high (>1200 kcal/week). Further, fasting blood sugar (FBS), triglycerides, and serum HDL-cholesterol were measured using standard methods and calibrated devices[14] during 2005–2006. To evaluate biochemical parameters in both phases, 5 cc of venous blood was collected after an overnight fasting period of 9–12 hours. The blood samples were then centrifuged to separate the serum. FBS and triglyceride levels were measured using Pars

Azmoon Kits (Tehran, Iran). HDL cholesterol was analyzed using Bionic kits (Tehran, Iran). All analyses were performed with a biochemical auto-analyzer (BT 3000, Italy).

Height was measured barefoot with a stadiometer, and weight was obtained using an electronic scale (Omron BF511), corrected to the nearest 0.1 cm and 0.1 kg, respectively. A non-stretchable measuring tape was used to measure waist circumference (WC). Blood pressure was assessed twice using an automatic digital monitor (Omron M6 Comfort) after participants had rested for 5 minutes in a seated position. The average of these two readings was used for all subsequent analyses[14].

Diagnosis of HTGW

HTGW is defined as WC of at least 91.5 cm in men or at least 85.5 cm in women together with a TG level of at least 150 mg/dL. Participants were classified into four groups based on these cut-offs[15,16]: normal waist normal triglyceride (NWNT, WC <91.5 cm for men and <85.5 cm for women; serum TG concentration <150 mg/dL), hypertriglyceridemia (HTG, WC <91.5 cm for men and <85.5 cm for women; serum TG concentration ≥150 mg/dL), enlarged waist (EW, WC ≥91.5 cm for men and ≥85.5 cm for women; serum TG concentration <150 mg/dL), and HTGW (hypertriglyceridemic waist, WC ≥91.5 cm for men and ≥85.5 cm for women; serum TG concentration ≥150 mg/dL). The definition for HTN according to the ESC/ESH guidelines is systolic blood pressure (SBP) ≥140 and/or diastolic blood pressure (DBP) ≥90 mmHg, or use of antihypertensive medication.

Statistical Analysis

Analyses were performed using SPSS v19 (IBM Corp., NY, USA). Independent t-tests compared quantitative variables between HTGW and non-HTGW groups. Associations between categorical variables were assessed using the chi-square test. Differences in mean values across more than two groups were evaluated by analysis of variance (ANOVA). Multivariable logistic regression assessed the association between HTGW phenotype and 10-year hypertension risk: crude, adjusted for age and sex (Model I), and further adjusted for smoking, physical activity, and education (Model II). A P <0.05 was considered to indicate statistical significance.

Results

In the cohort study, the prevalence and incidence of HTN were 36.1% and 40.3%, respectively. The 10-year incidence of HTN in men and women was 39.5% and 41.1% (Figure 1). A summary

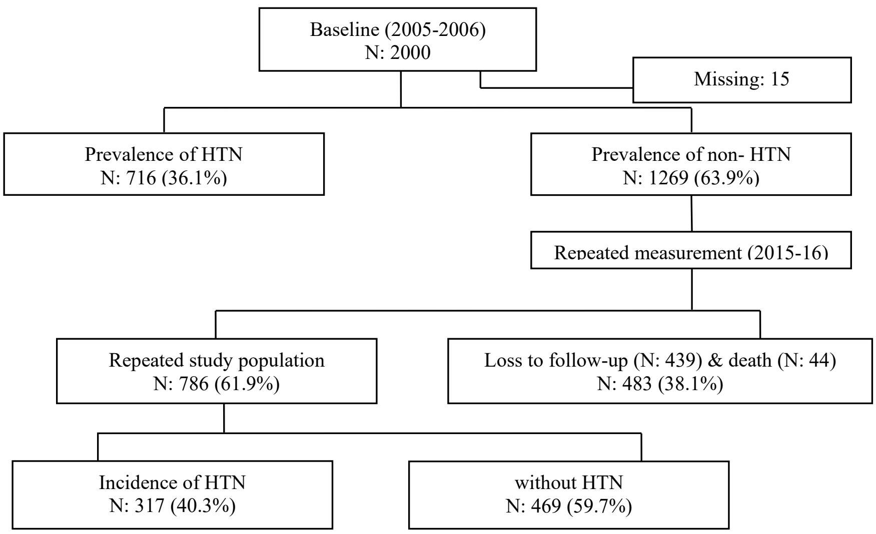

Figure 1. Flow diagram showing the incidence of HTN in total population in urban population of Yazd, Iran after 10-year follow-up during 2006-2016

of the baseline characteristics is provided in Table 1. Significant differences were observed in age, weight, BMI, WC, SBP, DBP, FBS, TG, total cholesterol, HDL-cholesterol, LDL-cholesterol, sex, physical activity, and educational levels between participants with and without HTGW (P <0.05), whereas smoking status and economic level did not differ significantly (P >0.05).

The baseline characteristics and laboratory data of the study population, stratified by the four phenotype groups, are presented in Tables 2 and 3 for the total population and by sex. Participants with HTGW were older, heavier, and exhibited higher BMI, BP, fasting blood glucose, and dyslipidemia compared with the other groups across men, women, and the total population.

Table 4 presents the associations between the HTGW phenotype and the 10-year risk of hypertension, analyzed using multivariable logistic regression models for the total population and stratified by sex. After adjustment for potential confounders, the risk of HTN was significantly higher among participants with hypertriglyceridemia (OR = 2.38, 95% CI: 1.21–4.67) and those with HTGW (OR = 1.88, 95% CI: 1.12–3.13) compared to those with NWNT in the total population. In men, there was a significant positive association between hypertriglyceridemia (OR = 2.71, 95% CI: 1.22–6.02) and HTGW (OR = 2.35, 95% CI: 1.23–4.47) and the 10-year incidence of HTN after multivariate adjustment.

Table 1. Baseline characteristics of participants between who developed HTGW and subjects without HTGW as well as the total participants.

Variables	HTGW (n: 779)	Non- HTGW (n: 1206)	Total (n: 1985)	P value
Age (years)	51.9 ± 13	46.5 ± 16.1	48.7 ± 15.2	0.001
Weight (Kg)	76.2 ± 12	67.2 ± 12.3	70.8 ± 12.9	0.001
BMI (Kg/m^2)	28.2 ± 3.8	24.7 ± 4.3	26.1 ± 4.5	0.001
SBP (mmHg)	131.9 ± 15.6	125.6 ± 15.2	128.2 ± 15.7	0.001
DBP (mmHg)	84.2 ± 8.7	81.3 ± 8.7	82.5 ± 8.9	0.001
FBS (mg/dL)	116.3 ± 57	94 ± 33.6	102.8 ± 45.6	0.001
TG (mg/dL)	249.7 ± 105.7	126.7 ± 73.4	175 ± 106.2	0.001
Total cholesterol (mg/dL)	217.2 ± 44.2	187.2 ± 64.8	199.1 ± 59.4	0.001
HDL-cholesterol(mg/dL)	51.5 ± 13	55.4 ± 13.8	53.9 ± 13.7	0.001
LDL-cholesterol(mg/dL)	115.8 ± 38.1	104 ± 34.6	108.5 ± 36.4	0.001
Waist circumference (cm)	101.1 ± 8.1	88.5 ± 11.9	93.5 ± 12.2	0.001
Sex (n, %)				
Male	354(45.4)	635(52.7)	989(49.8)	0.002
Female	425(54.6)	571(47.3)	996(50.2)	
Smoking status (n, %)				
Smokers	121(15.5)	226(18.7)	347(17.5)	0.051
Non-smokers	657(84.3)	980(81.3)	1637(82.5)	
Economic Status (n, %)				
Low	117(15)	156(12.9)	273(31)	0.21
Middle	126(16.2)	225(18.7)	351(39.8)	
High	101(13)	156(12.9)	257(29.2)	
Physical activity (n, %)				
Low	404(51.9)	526(43.6)	930(68.5)	0.001
Moderate	117(15)	247(20.5)	364(26.8)	
High	24(3.1)	39(3.2)	63(4.6)	
Educational level (n, %)				
Primary	527(67.7)	650(53.9)	1177(60.8)	0.001
High School	192(24.6)	390(32.3)	582(30)	
Academic	51(6.5)	127(10.5)	178(9.2)	

BMI: Body Mass Index; SBP: Systolic Blood Pressure; DBP: Diastolic Blood Pressure; FBS: Fasting Blood Sugar; TG: Triglyceride. Results are expressed as percentage for categorical variables and mean ±standard deviation for continuous variables. Comparisons performed between-group using chi-square for categorical variables and T-test for continuous variables.

Table 2. Baseline characteristics of study population and laboratory data based on the four phenotype groups in total population

Variables	NWNT (n: 450)	HTG (n: 240)	EW (n: 515)	HTGW (n: 780)	P value
Age (years)	40.5 ± 16.3	50.3 ± 15.3	50.1 ± 14.8	51.9 ± 13	0.001
Weight (Kg)	61 ± 9.5	63.9 ± 10.4	74.3 ± 11.7	76.21 ± 12	0.001
BMI (Kg/m^2)	21.9 ± 3.1	23.4 ± 2.6	27.8 ± 3.9	28.2 ± 3.9	0.001
SBP (mmHg)	120 ± 13.5	128.8 ± 15.3	129 ± 15	132 ± 15.6	0.001
DBP (mmHg)	78.8 ± 7.5	82.4 ± 9.3	83 ± 9	84.2 ± 8.7	0.001
FBS (mg/dL)	86.7 ± 25.5	100.6 ± 39.7	97.1 ± 35.4	116.4 ± 57	0.001
TG (mg/dL)	93.2 ± 29	231 ± 100.6	107 ± 27	249 ± 105.7	0.001
Total cholesterol (mg/dL)	172.9 ± 37.5	203.2 ± 42.2	192.3 ± 86.4	217.2 ± 44.2	0.001
HDL-cholesterol(mg/dL)	56.9 ± 13.2	51.4 ± 14.8	56 ± 13.7	51.6 ± 13	0.001
LDL-cholesterol(mg/dL)	95.9 ± 33	108.8 ± 38.3	109 ± 33	115.8 ± 38	0.001
Waist circumference (cm)	79 ± 7.5	83.8 ± 6.1	99.1 ± 8	101.1 ± 8.1	0.001

BMI: Body Mass Index; SBP: Systolic Blood Pressure; DBP: Diastolic Blood Pressure; FBS: Fasting Blood Sugar; TG: Triglyceride; NWNT: Normal Waist Normal Triglyceride; HTG: Hypertriglyceridemia; EW: Enlarged Waist Circumference; HTGW: Hypertriglyceridemic Waist. Results are expressed as mean ±standard deviation for continuous variables. Between-group comparisons performed using analysis of variance (ANOVA).

Table 3. Baseline characteristics of study population in laboratory data based on the four phenotype groups in men and women

Variable	NWNT	HTG	EW	HTGW	P value
Men	(n: 280)	(n: 159)	(n: 196)	(n: 354)	
Age (years)	42.8 ± 17.1	49.2 ± 15	53.3 ± 14.3	50.8 ± 12.7	0.001
Weight (Kg)	63.4 ± 8.5	67.8 ± 8.3	79.8 ± 10.3	81.6 ± 9.8	0.001
BMI (Kg/m^2)	21.4 ± 2.7	23.3 ± 2.3	26.7 ± 3	27.5 ± 3	0.001
SBP (mmHg)	123.1 ± 13.3	130 ± 14.7	132.2 ± 14.3	132.2 ± 14.9	0.001
DBP (mmHg)	80.3 ± 7.5	83.4 ± 9.3	84.6 ± 8.7	84.8 ± 8.8	0.001
FBS (mg/dL)	87.5 ± 25.4	97.6 ± 35.4	99.1 ± 35.6	114.5 ± 51.4	0.001
TG (mg/dL)	97.5 ± 28.5	235.2 ± 92.1	107.7 ± 27.8	254.2 ± 115	0.001
Total cholesterol (mg/dL)	172.4 ± 37.7	198.1 ± 41	183 ± 35.2	207.6 ± 41	0.001
HDL-cholesterol(mg/dL)	55.5 ± 12.4	50 ± 14.1	53.4 ± 12.3	48.4 ± 12	0.001
LDL-cholesterol(mg/dL)	95.9 ± 33.8	105.6 ± 39.3	106.7 ± 32	107.5 ± 35.6	0.001
Waist circumference (cm)	80.4 ± 7.8	59 ± 5.2	100.8 ± 7	101.8 ± 7.1	0.001
Women	(n: 170)	(n: 81)	(n: 319)	(n: 326)	
Age (years)	36.7 ± 14.1	52.4 ± 15.6	48.1 ± 14.7	52.8 ± 13	0.001
Weight (Kg)	57 ± 9.3	56.1 ± 9.8	70.9 ± 11.2	71.7 ± 11.7	0.001
BMI (Kg/m^2)	22.6 ± 3.5	23.4 ± 3.2	28.5 ± 4.1	28.8 ± 4.2	0.001
SBP (mmHg)	114.6 ±12	126.3 ± 16.2	127.7 ± 15.2	131.7 ± 16.1	0.001
DBP (mmHg)	76.3 ± 7	80.5 ± 9	82 ± 8.9	83.8 ± 8.6	0.001
FBS (mg/dL)	85.5 ± 25.6	106.5 ± 47.3	96 ± 35.3	118 ± 61	0.001
TG (mg/dL)	86.1 ± 28.1	222.7 ± 115.5	106.7 ± 26.5	246 ± 96.5	0.001
Total cholesterol (mg/dL)	173.2 ± 37.2	213.3 ± 43	198 ± 105.5	225.2 ± 44.9	0.001
HDL-cholesterol(mg/dL)	59.2 ± 14.1	54 ± 14.1	57.6 ± 14.2	54.1 ± 13.2	0.001
LDL-cholesterol(mg/dL)	95.9 ± 32.3	114.8 ± 35.7	110.3 ± 33.7	122.3 ± 38.6	0.001
Waist circumference (cm)	76.6 ± 6.1	79.7 ± 5.7	98 ± 8.4	100.5 ± 8.7	0.001

NWNT: Normal Waist Normal Triglyceride; HTG: Hypertriglyceridemia; EW: Enlarged Waist Circumference; HTGW: Hypertriglyceridemic Waist. Results are expressed as mean ±standard deviation for continuous variables. Between-group comparisons performed using analysis of variance (ANOVA).

Discussion

The present cohort study investigated the association between the HTGW phenotype and the 10-year incidence of hypertension in an Iranian urban adult population. Our key findings indicate that HTG alone, as well as the combined HTGW phenotype, were significantly associated with an increased risk of incident hypertension in the overall population and particularly in men, even after adjustment for several potential confounders.

Our results align with and extend previous

Table 4. The association between HTGW and the 10-year risk of HTN in the total population, men and women

Variables	Odds Ratio (95% Confidence Interval)			
	Cases/Participants	**Crude**	**Model I**	**Model II**
Total				
NWNT	49/221	1	1	1
HTG	48/96	3.51 (2.11-5.85)	2.53 (1.47-4.34)	2.38 (1.21-4.67)
EW	91/207	2.75 (1.81-4.19)	1.82 (1.15-2.87)	1.71 (0.98-2.99)
HTGW	129/262	3.40 (2.28-5.10)	2.27 (1.48-3.48)	1.88 (1.12-3.13)
Men				
NWNT	29/133	1	1	1
HTG	33/66	3.59 (1.90-6.76)	2.82 (1.44-5.51)	2.71 (1.22-6.02)
EW	33/77	2.69 (1.46-4.95)	1.63 (0.84-3.15)	1.55 (0.73-3.30)
HTGW	62/121	3.77 (2.19-6.50)	2.91 (1.64-5.15)	2.35 (1.23-4.47)
Women				
NWNT	20/88	1	1	1
HTG	15/30	3.40 (1.42-8.13)	2.04 (0.81-5.14)	1.86 (0.48-7.16)
EW	58/130	2.74 (1.49-5.02)	1.76 (0.92-3.38)	1.45 (0.60-3.52)
HTGW	67/141	3.08 (1.69-5.60)	1.66 (0.81-3.20)	1.19 (0.50-2.86)

NWNT: Normal Waist Normal Triglyceride; HTG: Hypertriglyceridemia; EW: Enlarged Waist Circumference; HTGW: Hypertriglyceridemic Waist. model I, adjusting for age and sex; model II, adjusting for age, sex, smoking, physical activity, and educational level. multivariable Logistic Regression used.

research. The finding is consistent with the study of Janghorbani et al.[17], which reported that the HTGW phenotype was a stronger predictor for HTN compared to other obesity indices in their population after a 7-year follow-up. In our cohort, the association for HTGW was attenuated after full adjustment, while HTG remained a significant predictor, especially among men. Notably, the point estimate for HTG was higher than for HTGW in our adjusted model, suggesting that elevated triglycerides may be a particularly strong component of the risk associated with this visceral adiposity phenotype.

The pronounced sex-specific disparity in our findings is critical and may be attributed to several interlinked factors. Firstly, men are predisposed to android fat distribution, leading to a greater burden of metabolically adverse visceral adipose tissue for a given waist circumference compared to premenopausal women, who typically store more fat in gluteofemoral depots[18]. Secondly, the cardiometabolic effects of central obesity may be partially modulated in premenopausal women by the vasoprotective and insulin-sensitizing effects of estrogen[19,20]. Thirdly, behavioral and healthcare utilization patterns may differ; evidence suggests women often exhibit greater health awareness and engagement in preventive lifestyle modifications, which could attenuate the hypertensive risk conveyed by the HTGW phenotype[21]. Finally, the possibility of residual confounding by unmeasured or imperfectly adjusted sex-specific factors (e.g., dietary sodium intake, psychosocial stress levels, or genetic influences) cannot be excluded[22].

In men, after adjusting for all potential confounding factors, the risk of HTN in participants with HTG was higher than participants with NWNT. In the study of Tohidi et al., HTG was independently associated with the risk of incident HTN after a 6.4-year follow-up in the women population[23]. Also, the HTG phenotype had a meaningful effect on the rise of new cases of hypertension in the total population compared with participants with NTNW after a 7-year follow-up of participants free of hypertension and diabetes at baseline[17]. Our findings align with the 8.5-year cohort study by Sánchez-Iñigo et al.[8], which reported that higher plasma triglycerides and TG-related lipid profiles, including the TG/HDL-C ratio, were independently associated with an increased risk of hypertension, particularly among men.

Our results substantiate the patho-physiological premise that visceral adiposity and its associated atherogenic dyslipidemia are central drivers of hypertension development. The HTGW phenotype serves as a practical, low-cost clinical surrogate for this high-risk metabolic profile characterized by excess visceral fat[24]. The observed association is biologically plausible, as visceral adipose tissue functions as an active endocrine organ, promoting a state of chronic low-grade inflammation, insulin resistance, and sympathetic nervous system overactivation—all established precursors to elevated blood pressure[25]. Concurrent hypertriglyceridemia further contributes to endothelial dysfunction and vascular remodeling, creating a synergistic pathway towards hypertension[26].

In the current study, strengths may include: (1) The survey was the first cohort in central Iran to investigate the association between HTGW phenotype and incidence of HTN, (2) Potential confounders (age, sex, smoking, physical activity, and education levels) were adjusted in the study, (3) Standardized measurement protocols for all clinical and biochemical variables, and (4) While the follow-up for this cohort concluded in 2015–2016, the extended observation period is a central strength that allows for the assessment of long-term hypertensive risk. The biological association between visceral adiposity, dyslipidemia, and hypertension, which is the basis for our investigation, is still valid. Therefore, these results confirm the lasting value of the HTGW phenotype for predicting long-term risk, establishing an important reference point for future research in comparable populations.

Limitations

We also acknowledge some limitations: (1) The loss to follow-up of approximately 38%, which is common in long-term cohort studies, (2) Due to the lack of data on some potential confounders (e.g., detailed dietary intake, family history, and alcohol consumption), these variables could not be adjusted for in the analysis, and (3) While this extended follow-up is essential for evaluating long-term risk, readers should consider the historical context of the data. Changes in lifestyle patterns, dietary habits, or environmental factors after 2016 are not captured.

Conclusion

The evidence of the study demonstrated a significant positive association between hypertriglyceridemia, HTGW, and the 10-year incidence of HTN in men and in the total population.

Further research is warranted to verify and expand upon these findings. In addition, lifestyle modifications focusing on weight management, triglyceride reduction, and increased physical activity are recommended to prevent HTGW that lead to HTN in adults' population.

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Conflict of interests

The authors declare no conflict of interest.

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Author's Contributions

Study Conception or Design:
Data Acquisition:
Data Analysis or Interpretation:
Manuscript Drafting:
Critical Manuscript Revision:
All authors have approved the final manuscript and are responsible for all aspects of the work.

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