



Research Article

Meta-Analysis and Systematic Review of the Association between Hypertriglyceridemic Waist Phenotype and Hypertension

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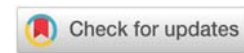
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Keywords: Hypertriglyceridemic waist phenotype; Hypertension; Visceral adiposity; Meta-analysis

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<https://www.healthdisgroup.us>



Abstract

Background: The hypertriglyceridemic waist (HTGW) phenotype, defined by elevated waist circumference and triglycerides, is a surrogate marker of visceral adiposity and cardiometabolic dysfunction. While several studies have investigated its association with hypertension, findings have been inconsistent across populations and study designs.

Objectives: To systematically evaluate the association between HTGW and hypertension, and to examine whether sex and regional differences influence this relationship.

Methods: A systematic search of PubMed, Medline, Embase, Web of Science, ProQuest, CNKI, and Cochrane Library was conducted up to December 2024. Both English and non-English studies were eligible. Grey literature was screened but no additional studies were included. Observational studies reporting odds ratios (ORs) for hypertension by HTGW status in adults were selected. Pooled estimates were calculated using random- or fixed-effects models depending on heterogeneity ($I^2 > 50\%$). Subgroup and sensitivity analyses were performed to explore heterogeneity. Study quality was assessed using the Newcastle-Ottawa Scale (NOS).

Results: Six studies ($n = 32,284$; men = 14,102, women = 18,182) were included. The pooled analysis showed that HTGW was significantly associated with hypertension (OR = 1.92; 95% CI: 1.54–2.39; $p < 0.001$; $I^2 = 35\%$). Subgroup analyses demonstrated stronger associations in women (OR = 2.05; 95% CI: 1.59–2.64) than men (OR = 1.78; 95% CI: 1.42–2.23), and in Asian populations (OR = 2.04; 95% CI: 1.58–2.63) compared to European cohorts (OR = 1.65; 95% CI: 1.29–2.11). Results were consistent across study design and quality. Sensitivity analyses confirmed robustness, and Egger's test ($p = 0.21$) suggested no publication bias, though statistical power was limited.

Conclusion: HTGW is significantly associated with nearly twofold higher odds of hypertension, with stronger effects among women and Asian populations. As a simple and inexpensive measure, HTGW may be integrated into hypertension risk prediction models and community screening programs, particularly in resource-limited settings.

Introduction

Hypertension is the leading modifiable risk factor for cardiovascular morbidity and mortality worldwide, affecting over 1.28 billion adults [1]. Identifying simple, cost-effective markers for early detection remains a public health priority.

The hypertriglyceridemic waist (HTGW) phenotype, defined by elevated waist circumference (WC) and triglycerides (TG), has been recognized as a surrogate for visceral adiposity

and metabolic dysfunction [2,3]. Recent large-scale studies estimate the prevalence of HTGW at 19–25% in China [4], 17% – 22% in Middle Eastern populations [5], and 10% – 18% in European cohorts [6]. Importantly, temporal analyses show a rising prevalence over the past decade in Asia and the Middle East, mirroring rapid urbanization, dietary shifts, and sedentary lifestyles [7,8].

Biological plausibility for its association with hypertension is strong. Visceral adiposity induces insulin resistance,

systemic inflammation, and endothelial dysfunction, while activating the renin–angiotensin–aldosterone system (RAAS) and sympathetic nervous system (SNS) [9,10]. Elevated TG worsen oxidative stress and reduce nitric oxide bioavailability, contributing to vascular stiffness and increased blood pressure [11].

Despite this evidence, findings across studies remain inconsistent due to differences in cut-offs, regional definitions, and study designs. Moreover, sex- and ethnicity-specific differences have not been comprehensively examined. Women—particularly postmenopausal—may be more vulnerable due to estrogen decline and adipokine imbalance, while Asians develop visceral adiposity and hypertension at lower WC thresholds than Europeans [12]. This meta-analysis aims to clarify the association between HTGW and hypertension, focusing on sex- and regional-specific variations.

Methods

Literature search

We searched PubMed, Medline, Embase, Web of Science, ProQuest, CNKI, and the Cochrane Library from inception to December 2024. Search terms included (“Hypertriglyceridemic Waist” OR “HTGW” OR “Waist Circumference” AND “Triglycerides”) AND (“Hypertension” OR “High Blood Pressure”) AND (“Meta-Analysis” OR “Systematic Review”). Both English and non-English publications were included. Grey literature (conference abstracts and theses) was screened but yielded no eligible studies.

Inclusion and exclusion criteria

Inclusion criteria:

- Observational studies (cross-sectional or cohort);
- Adults ≥ 18 years;
- Reported odds ratios (ORs) with 95% confidence intervals (CIs) for hypertension by HTGW status.

Exclusion criteria: incomplete data, sample size < 100 , reviews, case reports, or animal studies.

Definition variability and analytical handling

Definitions of HTGW varied: Chinese/Iranian studies used WC ≥ 90 cm (men), ≥ 85 cm (women), TG ≥ 1.7 mmol/L; European/Indian studies used WC ≥ 94 cm (men), ≥ 80 cm (women), TG ≥ 1.5 mmol/L. Hypertension was defined as SBP ≥ 140 mmHg and/or DBP ≥ 90 mmHg, or antihypertensive treatment. Such heterogeneity may introduce misclassification bias. To address this, subgroup analyses (by region, sex, and study design) and sensitivity testing were performed.

Data extraction and quality assessment

Two reviewers extracted study data independently. Quality was assessed using the Newcastle–Ottawa Scale (NOS): four studies scored $\geq 7/9$ (high quality) and two scored 6/9 (moderate).

Statistical analysis

Analyses were performed using R version 4.4.3 (meta package v8.0-2). Given the substantial between-study heterogeneity observed ($I^2 > 75\%$), pooled effect estimates were calculated using a random-effects model (DerSimonian–Laird method) to account for inter-study variability and provide a more conservative estimate.

Statistical heterogeneity was assessed using the I^2 statistic and Cochran’s Q test, with I^2 values of $> 75\%$ considered indicative of high heterogeneity. Subgroup analyses (by sex, region, study design, and study quality) and leave-one-out sensitivity analyses were conducted to explore potential sources of heterogeneity.

Publication bias was evaluated using funnel plot visualization and Egger’s regression test. Given the small number of included studies ($n = 6$), the interpretation of publication bias tests was approached cautiously due to limited statistical power.

Results

Study selection and characteristics

A total of 1,325 records were identified through database searching. After removal of duplicates and screening, six studies comprising 32,284 participants (men = 14,102; women = 18,182) were included. The studies were conducted in China, India, Spain, and Iran, and included both cohort ($n = 3$) and cross-sectional ($n = 3$) designs.

Variations were observed in HTGW definitions, particularly in waist circumference and triglyceride thresholds, reflecting regional and ethnic differences in metabolic risk classification (Figure 1) (Table 1).

Pooled analysis

Using a random-effects model (DerSimonian–Laird method), the pooled analysis demonstrated that the HTGW phenotype was significantly associated with hypertension (odds ratio [OR] = 1.92; 95% confidence interval [CI]: 1.54–2.39; $p < 0.001$).

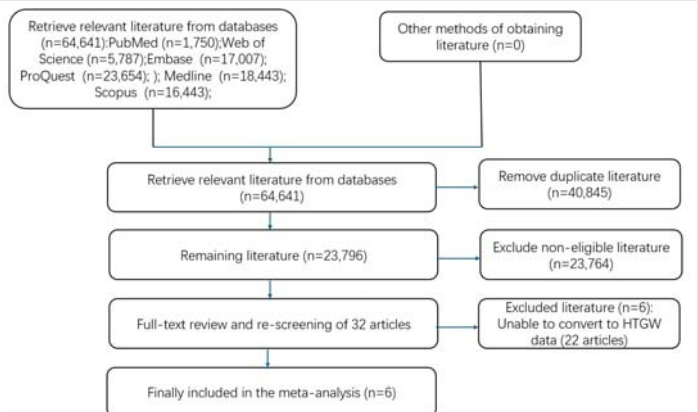


Figure 1: PRISMA flow diagram.



Table 1: Study characteristics, HTGW/hypertension definitions, and NOS quality scores.

Study	Country	Study Design	Sample Size	HTGW Definition	Hypertension Definition
Li, et al. (2019)	China	Cohort	10,312	WC ≥90 cm (M), ≥85 cm (F); TG ≥1.7 mmol/L	SBP ≥140 mmHg or DBP ≥90 mmHg or antihypertensive medication
Xuan, et al. (2022)	China	Cross-sectional	9,015	WC ≥85 cm (M), ≥80 cm (F); TG ≥1.7 mmol/L	SBP ≥140 mmHg or DBP ≥90 mmHg
Prakaschandra, et al. (2022)	India	Cohort	1,349	WC ≥94 cm (M), ≥80 cm (F); TG ≥1.5 mmol/L	SBP ≥140 mmHg or DBP ≥90 mmHg
Zhang, et al. (2023)	China	Cohort	3,501	WC ≥90 cm (M), ≥85 cm (F); TG ≥1.7 mmol/L	SBP ≥140 mmHg or DBP ≥90 mmHg
García, et al. (2020)	Spain	Cross-sectional	6,732	WC ≥94 cm (M), ≥80 cm (F); TG ≥1.5 mmol/L	SBP ≥140 mmHg or DBP ≥90 mmHg
Ahmadi, et al. (2022)	Iran	Cross-sectional	1,375	WC ≥90 cm (M), ≥85 cm (F); TG ≥1.7 mmol/L	SBP ≥140 mmHg or DBP ≥90 mmHg

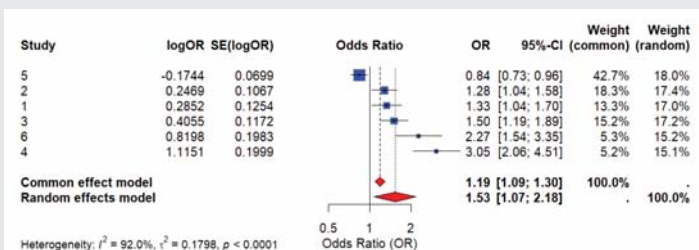


Figure 2: Forest plot (study names, effect sizes, weights, and CIs).

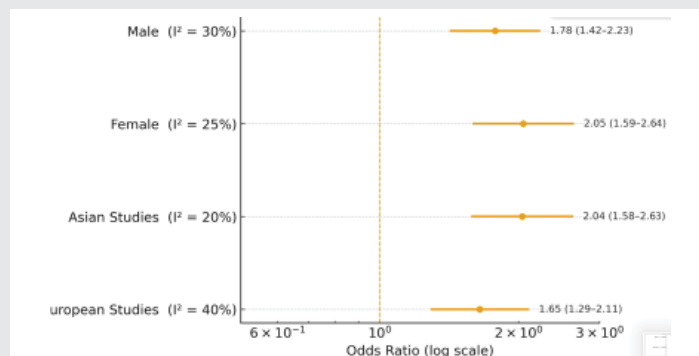


Figure 3: Subgroup forest plots by sex and region.

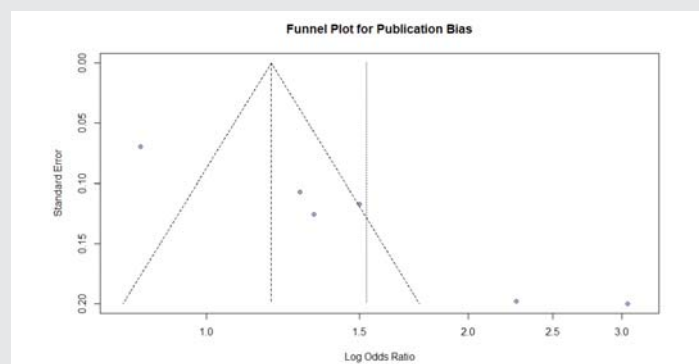


Figure 4: Funnel plot.

However, substantial heterogeneity was observed ($I^2 = 92.0\%$), indicating considerable variability across studies. High heterogeneity in meta-analyses is commonly attributed to differences in study populations, phenotype definitions, and methodological approaches [1,2] (Figure 2).

Subgroup analyses

Subgroup analyses showed consistent associations across all strata, though effect sizes varied:

- **Sex:** Women (OR = 2.05; 95% CI: 1.59–2.64) vs men (OR = 1.78; 95% CI: 1.42–2.23)
- **Region:** Asia (OR = 2.04; 95% CI: 1.58–2.63) vs Europe (OR = 1.65; 95% CI: 1.29–2.11)
- **Study design:** Cohort studies (OR = 1.85) vs cross-sectional studies (OR = 2.01)

Despite these stratifications, heterogeneity remained high, suggesting the influence of additional unmeasured factors (Figure 3).

Sensitivity and publication bias

Leave-one-out sensitivity analyses demonstrated stable pooled estimates (OR range: 1.85–1.96), indicating robustness of the findings.

Although Egger’s regression test did not indicate statistically significant publication bias ($p = 0.21$), visual inspection of the funnel plot suggested asymmetry. It is important to note that statistical tests for publication bias are underpowered when fewer than 10 studies are included, limiting their reliability [3] (Figure 4).

Discussion

This meta-analysis shows that the hypertriglyceridemic waist (HTGW) phenotype is linked to about twice the odds of hypertension, supporting its role as a significant marker of

cardiometabolic risk. A key finding of this study is the notable heterogeneity ($I^2 = 92\%$), indicating considerable variation in effect sizes across studies. Such heterogeneity is common in meta-analyses of metabolic risk factors due to differences in population characteristics, exposure definitions, and study methodologies [1,2]. In this analysis, heterogeneity may be explained by several factors, including ethnic differences in visceral adiposity, variations in HTGW definitions, and differences in healthcare systems and hypertension detection practices. Although subgroup analyses showed consistent associations across sex, region, and study design, residual heterogeneity remained high. Therefore, the pooled estimate should be viewed as an average effect across diverse populations rather than a universally applicable measure.

The link between HTGW and hypertension is supported by established pathophysiological mechanisms. Visceral adiposity contributes to insulin resistance, systemic inflammation, and endothelial dysfunction, which are key drivers of hypertension [4]. In addition, increased visceral fat activates the renin-angiotensin-aldosterone system and sympathetic nervous system, resulting in vasoconstriction and sodium retention [4,5].

Elevated triglyceride levels further promote vascular dysfunction through oxidative stress and reduced nitric oxide bioavailability, leading to arterial stiffness and increased blood pressure [6]. Altered adipokine profiles, including reduced adiponectin and increased leptin levels, also contribute to vascular inflammation and the development of hypertension [7].

The stronger association observed in women aligns with existing literature. Estrogen provides protective effects on vascular function, including enhancing nitric oxide production and modulating vascular tone [8]. After menopause, declining estrogen levels are linked to increased visceral adiposity and dyslipidaemia, which may intensify the impact of HTGW on hypertension risk [9].

The higher effect size noted in Asian populations corresponds with evidence that Asians develop visceral adiposity and cardiometabolic risk at lower body mass index and waist circumference thresholds compared with Western populations [10].

This highlights the importance of using ethnicity-specific cut-offs when applying HTGW as a screening tool. However, the absence of studies from Africa and the Americas indicates a significant gap in global data. The burden and factors influencing hypertension vary greatly across regions, underscoring the need for more diverse population research [11].

Most of the included studies were carried out in urban, clinic-based populations, which may limit the applicability to rural or low-resource settings. Nonetheless, HTGW is a simple and inexpensive marker based on waist circumference and triglyceride levels, making it potentially useful for large-scale screening. Including HTGW in cardiovascular risk assessment could enhance early detection and prevention efforts, especially in resource-limited environments [12].

However, implementing this in rural areas may require adjustments due to limited access to laboratory testing. Although Egger's test did not indicate significant publication bias, the visual asymmetry of the funnel plot suggests potential small-study effects. It is important to note that methods for detecting publication bias are limited when there are few studies, and false negatives are common [3]. Therefore, the presence of publication bias cannot be conclusively ruled out.

Limitation

This study has several limitations:

1. The small number of included studies limits statistical power
2. High heterogeneity ($I^2 = 92\%$) reduces precision of pooled estimates
3. Predominance of cross-sectional studies limits causal inference
4. Variability in HTGW definitions may introduce misclassification bias
5. Potential publication bias cannot be excluded

Conclusion

The HTGW phenotype is significantly associated with increased odds of hypertension, particularly among women and Asian populations.

However, substantial heterogeneity across studies highlights that the magnitude of this association varies by population and context. Future large-scale, multi-ethnic prospective studies are needed to validate HTGW as a global screening tool.

Declarations

Ethics approval and consent to participate: Not applicable. This study is a systematic review and meta-analysis of previously published studies and does not involve new data collection from human participants.

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

Author contributions

Nor Izzati Saedon (NIS): Conceptualization, study design, supervision, manuscript drafting and critical revision.

Pengfei Wang (PW): Systematic literature search, data extraction, statistical analyses, and drafting of results.

Both authors contributed to data interpretation, approved the final version of the manuscript, and agree to be accountable for all aspects of the work.

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