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Relationship between triglyceride levels and different snoring states: a systematic review and meta-analysis

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Abstract

Objective High triglyceride (TG) levels are important risk factors for cardiovascular disease (CVD). Some recent studies have shown that snoring is also closely related to elevated TG levels. The specific pathogenesis of elevated TG levels in snoring patients is still unclear. Therefore, we performed this meta-analysis to evaluate the relationship between snoring and elevated TG levels.

Materials and methods A systematic search was conducted in four online electronic databases as of Jul 1, 2024. The standardized mean difference (SMD) and corresponding 95% confidence interval (CI) for TG levels in each study were pooled. Moreover, we performed subgroup analysis according to snoring status and body mass index (BMI). All the data were pooled and analysed with Review Manager 5.3.

Results The meta-analysis included five studies with 39,102 participants. Our results revealed that snoring was associated with elevated TG levels, with a pooled SMD of 0.23 (95% CI 0.14 to0.32; $P<0.00001$). We found that occasional snoring and habitual snoring were associated with high TG levels, with pooled SMD of 0.26 (95% CI 0.04to0.49; $P=0.002$) and 0.29 (95% CI 0.16to0.43; $P<0.0001$), respectively. According to the subgroup analysis of BMI, BMI < 25 kg/m^2 and BMI ≥ 25 kg/m^2 were associated with increased TG levels, with pooled SMD of 0.13 (95% CI 0.04 to 0.22; $P=0.004$) and 0.24 (95% CI 0.10 to 0.39; $P=0.0007$), respectively.

Conclusions Our meta-analysis revealed that both occasional and habitual snoring were associated with elevated TG levels. More importantly, our findings also revealed that the relationship between snoring-induced elevated TG levels and BMI was fragile.

Keywords Snoring, Body mass index, Triglyceride levels, Systematic review, Meta-analysis

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Introduction

Snoring is a ubiquitous sleep phenomenon. During sleep, airflow from the upper respiratory tract impacts the edges of the pharyngeal mucosa and secretions on the mucosal surface, causing vibrations to produce snoring. It is an important clinical manifestation of obstructive sleep apnea (OSA) syndrome. The common clinical types of snoring include the obstructive type and central type [1]. Obstructive patients often have poor respiratory airflow due to pharyngeal tissue relaxation, pharyngeal stenosis, and tonsil hypertrophy, whereas central patients have an abnormal nervous systems and poor breathing due to insufficient central respiratory power. There are still 20% of female snorers and 40% of male snorers without OSA [1]. Studies [2–4] in recent years have shown that snoring can increase the risk of cardiovascular disease (CVD). The main physiological changes associated with snoring are intermittent hypoxia and changes in pleural pressure. Intermittent hypoxia can cause oxygen desaturation in the blood. When desaturation becomes severe, it triggers a cycle of recurrent hypoxia and reoxygenation, akin to ischemia–reperfusion injury. This process stimulates the generation of reactive oxygen species (ROS), leading to a systemic inflammatory response and endothelial dysfunction. It also increases plasma levels of the vasoconstrictor endothelin, induces insulin resistance, enhances gluconeogenesis, and elevates triglyceride (TG) and glucose levels. These changes disrupt the balance of blood glucose and lipids, increasing the risk of insulin resistance and thereby accelerating the progression towards diabetes and hypertriglyceridaemia. Furthermore, snoring, a potential health risk, linked to hormonal imbalances and metabolic issues. Recent studies [5–7] suggested that frequent snoring can lead to increased testosterone levels in men, which in turn can elevate triglycerides, contributing to conditions like coronary heart disease, diabetes, and metabolic syndrome. The relationship between snoring and testosterone is complex, with sleep-disordered breathing potentially disrupting the hypothalamic-pituitary–gonadal axis and affecting hormone production. This hormonal shift can lead to metabolic dysregulation, increasing the risk of cardiovascular and metabolic diseases. Understanding this link is crucial for developing strategies to mitigate the health risks associated with snoring.

The relationship between snoring and metabolic health has become a topic of increasing interest in the fields of sleep medicine and public health. While early studies have suggested a correlation between the frequency of snoring and elevated TG levels [8, 9], the precise nature of this association—whether it is coincidental or causal—has not been fully explored. Our study is designed to investigate this relationship more deeply, with the aim of understanding not only the co-occurrence of these conditions but also the potential mechanisms that might link snoring to higher TG levels. By doing so, we hope to contribute to a more nuanced understanding of the health implications of snoring and to inform potential therapeutic strategies. Furthermore, previous meta-analyses have evaluated other cardiometabolic markers, such as composite lipid indices and the triglyceride–glucose index (TyG), in patients with apnea [9, 10]. To date, no meta-analysis has investigated whether snoring is associated with elevated TG levels. Therefore, to further evaluate the relationship between snoring and elevated TG levels, we conducted a meta-analysis of the literature on this topic to strengthen the reliability of the evidence.

Material and methods

We conducted a meta-analysis in accordance with the Preferred Reporting Items for Systematic Review and Meta-analyses Protocol (PRISMA-P) guidelines [11].

Search strategy

To identify qualified original articles, two researchers independently searched four online electronic databases, including Embase, Web of Science, PubMed, and CNKI, up to July 1, 2024. The researchers used the following keywords: "snoring", "snorer" AND "hypertriglyceridaemia", "triglycerides", "TG". In addition, to identify potentially relevant articles, we manually searched previous reviews and the list of references included in the study. Any disagreements were resolved through discussions with a third researcher.

Inclusion and exclusion criteria

The original articles were carefully searched and examined. There are no national restrictions. The inclusion criteria were as follows: (1) all participants were at least 18 years old and tested for TG; (2) The snoring confirmed by the study was collected through questionnaires. Participants who responded with a "yes" or "no" option were categorized as snorers if they answered "yes," and as non-snorers otherwise. Subsequently, snorers were classified based on the frequency of snoring per week into never snoring, rare snoring, occasional snoring, and habitual snoring. (3) studies were limited to human beings, the publication language was not limited, and the original data were included; and (4) all participants excluded any drugs and diseases that might affect TG, such as atorvastatin, calcium tablets and fenofibrate. The exclusion criteria included (1) duplicate publications, abstracts, editorials, case reports and review articles and (2) insufficient information for data analysis or extraction.

Data extraction and quality assessment

Two researchers independently screened the titles and abstracts of the confirmed studies and then reviewed the full texts on the basis of the inclusion and exclusion criteria. The following key information was extracted from the included articles: the first author's name, publication year, snoring status, age, sex, body mass index (BMI), country, sample size, and study design. By reaching a consensus with the third author, the relevant differences in the extracted data were solved. The study quality was assessed by the Newcastle–Ottawa scale, which is an effective cohort study quality assessment technique. A study is considered high quality if it has an overall score of six stars or more; otherwise, it is considered low quality [12].

Statistical analysis

When the unit of TG level is mmol/L, it is converted into mg/dL. When the median and interquartile range (IQR) are provided, the standardized mean difference (SMD) is estimated via Xu's method [13]. For continuous variables, the SMD and corresponding 95% confidence interval (CI) of the TG levels in each study were pooled. The statistical heterogeneity among the included studies was assessed via the I^2 test. If $I^2 = 25\%–50\%$, there is low heterogeneity; if $I^2 = 51\%–75\%$, there is moderate heterogeneity; if $I^2 > 75\%$, there is high heterogeneity [14]. If there was significant heterogeneity ($P < 0.05$ or $I^2 > 50\%$), the random effects model(REM) was used. Otherwise, the fixed effects model(FEM) was applied. To determine the potential heterogeneity of this study, we used the leave-one-out method for sensitivity analysis, that is, deleting one study at a time and repeating the analysis. Moreover, we performed subgroup analysis according to snoring status and BMI. Publication bias was assessed via funnel plots [15]. A P value less than 0.05 was considered statistically significant. All the data was pooled and analysed with Review Manager 5.3.

Results

Literature search results

Using our search strategy, 345 related studies were identified from four online databases. After the exclusion of duplicate studies, 134 records remained, 117 of which were excluded because of irrelevant titles and abstracts. We carefully reviewed the full texts of the remaining 17 studies; 7 studies were excluded because of insufficient data, and 5 studies were excluded because they were review articles. Finally, 5 studies met the inclusion and exclusion criteria and were included in our meta-analysis. (Fig. 1**)**.

Characteristics of the studies

Five studies [16–20], with 39,102 participants, were included in the final quantitative synthesis. The characteristics of the included studies are shown in Table 1. Those studies, published in 2005 and 2019, came from different countries. Three studies were conducted in Korea[16–18] , one in the USA[19] , and one in China[20] . The proportion of males ranged from 36.9% to 73.1%. The average age of the patients varied between 45.7 and 63.7 years. The BMI of all participants ranged between 22.9 kg/m^2 and 29.8 kg/m^2. The frequency of snoring per week is divided into never snoring, rare snoring, occasional snoring, and habit snoring. Although each study has different criteria for snoring, it reflects the severity of snoring to a certain extent. The quality assessment of all included studies was 6 points or more, so those studies were of high quality (Table 2).

Main results

The forest plot for the correlation between snoring and elevated TG levels is shown in Fig. 2. Our results revealed that snoring was associated with elevated TG levels, with a pooled SMD of 0.23 (95% CI 0.14 to 0.32; $P < 0.00001$) (Fig. 2).

Subgroup analyses

According to the frequency of snoring per week, we found that occasional snoring and habitual snoring were associated with elevated TG levels, with pooled SMDs of 0.26 (95% CI 0.04 to 0.49; $P = 0.002$) and 0.29 (95% CI 0.16 to 0.43; $P < 0.0001$), respectively, as shown in Fig. 3. However, we found no significant difference between rare snoring and elevated TG levels, with a pooled SMD of 0.15 (95% CI −0.02 to 0.32; $P = 0.08$).

On the basis of the subgroup analysis of BMI, our results revealed that BMI < 25 kg/m^2 and BMI ≥ 25 kg/m^2 increased the risk of elevated TG levels, with pooled SMDs of 0.13 (95% CI 0.04 to 0.22; $P = 0.004$) and 0.24 (95% CI 0.10 to 0.39; $P = 0.0007$), respectively, as shown in Fig. 4.

Sensitivity analysis and publication bias

Our study showed great heterogeneity ($I^2 = 95\%$). When the Xia et al. study [20] was eliminated, the results affected the pooled outcomes (I^2 decreased from 95 to 92%). The results of the sensitivity analysis revealed that the range of the SMD was 0.21 (95% CI 0.13 to 0.28) to 0.25 (95% CI 0.16 to 0.34). The results of the sensitivity analysis were robust, and its significance was not affected after omitting any single study or after REM was converted to FEM in the meta-analysis. We obtained a symmetrical inverted funnel shape (Fig. 5) and found no significant evidence of publication bias in the meta-analysis.

Discussion

Our meta-analysis revealed a significant relationship between snoring and elevated TG levels. The elevated TG levels of snoring patients were highwer than those of non-snoring patients. However, the value of $I^2 = 95\%$ ($I^2 > 50$, $P < 0.01$) revealed high heterogeneity within the studies. High heterogeneity may stem from differences in patient demographics and study methodologies, as well as variations in intervention protocols and outcome

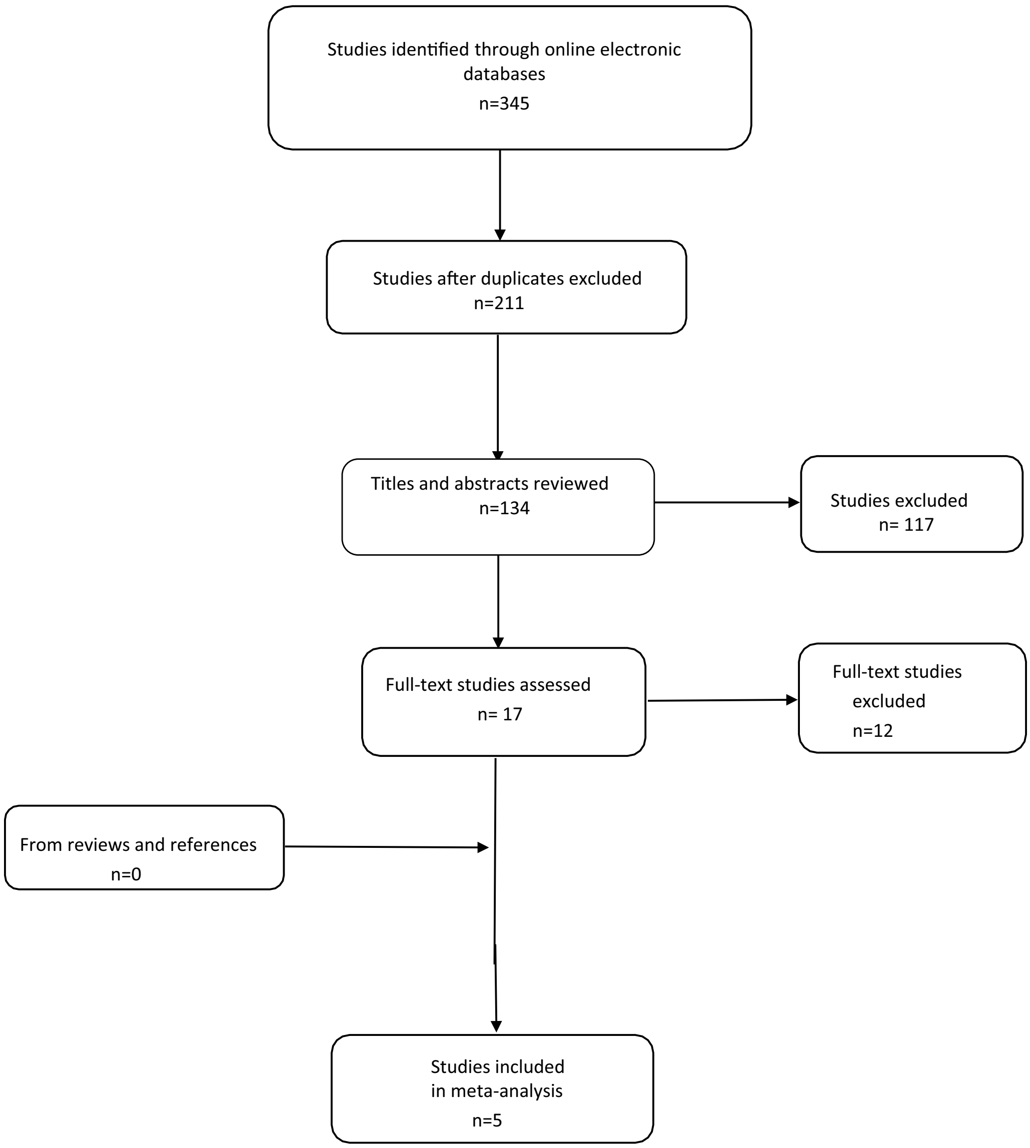

Fig. 1 Selection process for studies included in the meta-analysis

measurements across studies. Furthermore, potential biases and the inclusion of diverse study qualities can also contribute to this heterogeneity. Sensitivity analysis revealed that the total results remained valid when any single study was excluded or when REM was converted to FEM. Therefore, we are confident in the data obtained in our study, which revealed a strong association between snoring and elevated TG levels.

Previous studies [21–23] have shown that snoring is related to hypertriglyceridaemia, which is consistent with our conclusion. The mechanism of the relationship between snoring and elevated TG levels has not been elucidated. The possible mechanism by which snoring increases hypertriglyceridaemia may be that chronic intermittent hypoxia caused by snoring stimulates oxidative stress, causes insulin resistance and increases gluconeogenesis, thus increasing TG levels. Furthermore, chronic intermittent hypoxia has been shown to upregulate sterol regulatory element-binding protein 1 (SREBP-1), a crucial transcription factor that governs the expression of enzymes necessary for the synthesis of endogenous cholesterol, fatty acids, TG, and phospholipids, thereby increasing TG synthesis [24, 25].

Although each study has different criteria for snoring, it reflects the severity of snoring to a certain extent. This conclusion is consistent with that of Xia et al. [20].

Table 1 Description of included studies

First author	Year	Snoring status	Age (years)	Male [n(%)]	BMI (kg/m^2)	Country	Samply size	Quality score
Lee[16]	2018	NS (0 day/week)	50.7 ± 8.7	864(41%)	23.6 ± 2.9	Korean	10,030	8
		OS(< 4 day/week)	50.3 ± 8.2	1,089(49.8)	24.5 ± 2.9			
		HS(≥ 4 day/week)	52.3 ± 8.3	385(58.4)	25.5 ± 3.1			
Shin[17]	2005	HS(≥ 4 day/week)	50.9 ± 8.1	NG	23.7 ± 2.2	Korean	2,719	7
		NH(< 4 day/week)	50.9 ± 8.8	NG	23.0 ± 2.3			
Shin[18]	2013	NS(0 day/week)	62.4 ± 10.3	1,417(38.3)	23.5 ± 3.0	Korean	7,048	7
		RS(< 1 day/week)	58.9 ± 9.5	388 (36.9)	24.6 ± 3.1			
		OS(< 3 day/week)	60.0 ± 9.2	477 (44.7)	25.0 ± 3.1			
		HS(≥ 4 day/week)	60.7 ± 8.8	544 (44.2)	25.5 ± 3.2			
Yeboah[19]	2011	NS(0 day/week)	63.7 ± 10.2	842(58)	27.8 ± 5.8	USA	5,130	8
		HS(≥ 3 day/week)	61.4 ± 9.4	1,664(45.2)	29.8 ± 5.8			
Xia[20]	2019	NS(0 day/week)	45.7 ± 7.1	3,260(38.4)	22.9 ± 3.2	China	14,175	7
		RS(≤ 2 day/week)	47.6 ± 6.9	1,763(55.6)	24.2 ± 3.4			
		OS(< 6 day/week)	48.9 ± 6.8	942 (63.5)	25.0 ± 3.7			
		HS(≥ 6 day/week)	49.1 ± 6.8	757 (73.1)	25.3 ± 3.9			

Snorers were classified based on the frequency of snoring per week into never snoring, rare snoring, occasional snoring, and habitual snoring. Abbreviations: BMI: body mass index; NS: Never Snoring; RS: Rare Snoring; OS: Occasional Snoring; HS: Habitual Snoring; NG, not given; USA, United States of America.

Table 2 Quality assessment of the included studies by the Newcastle–Ottawa scale

References	Selection				Comparability	Outcome			Total
	Exposed cohort	Nonexposed cohort	Ascertainment of exposure	Outcome of interest		Assessment of outcome	Length of follow-up	Adequacy of follow-up	
Lee 2018[16]	*	*	*	*	*	*	*	*	8
Shin 2005[17]	*	*	*	*	*	*	*		7
Shin 2014[18]	*	*	*	*	*	*	*		7
Yeboah 2011[19]	*	*	*	*	*	*	*	*	8
Xia 2019[20]	*	*	*	*	*	*	*		7

Our results revealed that occasional snoring and habitual snoring are associated with elevated TG levels. This may be related to the severity of hypoxia caused by occasional snoring and habitual snoring compared with never snoring. However, contrary to the conclusion of Xia et al. [20], our study revealed that rare snoring was not associated with elevated TG levels. This may be related to the lesser degree of hypoxia caused by snoring and the smaller number of studies included. Because BMI has an effect on snoring and TG levels, we performed a subgroup analysis on the basis of BMI. Zhang et al. [26] reported that snoring in patients with a BMI ≥ 25 kg/m^2 was associated with dyslipidemia but not in participants with a BMI < 25 kg/m^2. Our results revealed that BMI < 25 kg/

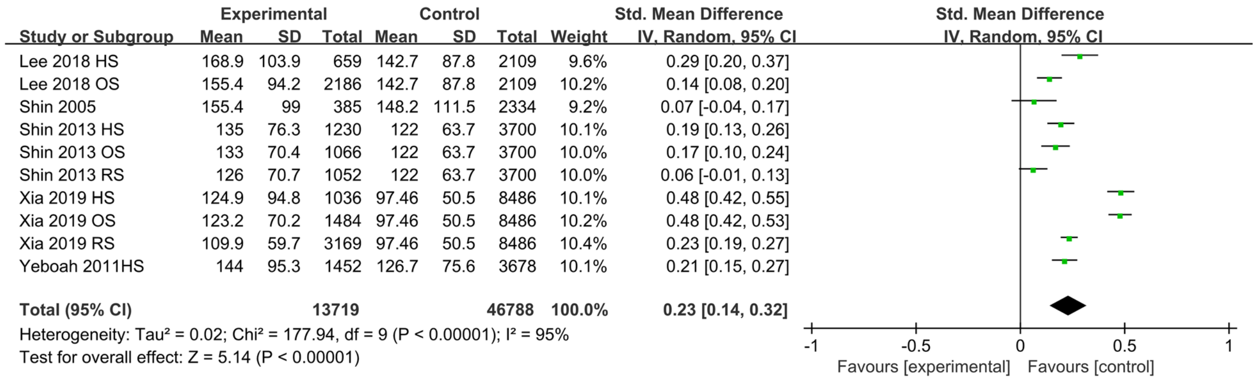

Fig. 2 Forest plot for the relationship between snoring and TG risk. The forest plot analysed five studies that each included different snoring states, and the results indicated that snoring was significantly associated with TG risk 0.23 (95% CI 0.14 to 0.32; P < 0.00001). RS: rare snoring; OS: occasional snoring; HS: habitual snoring; TG: triglyceride; IV: inverse variance; SD: standard deviation; CI: confidence interval

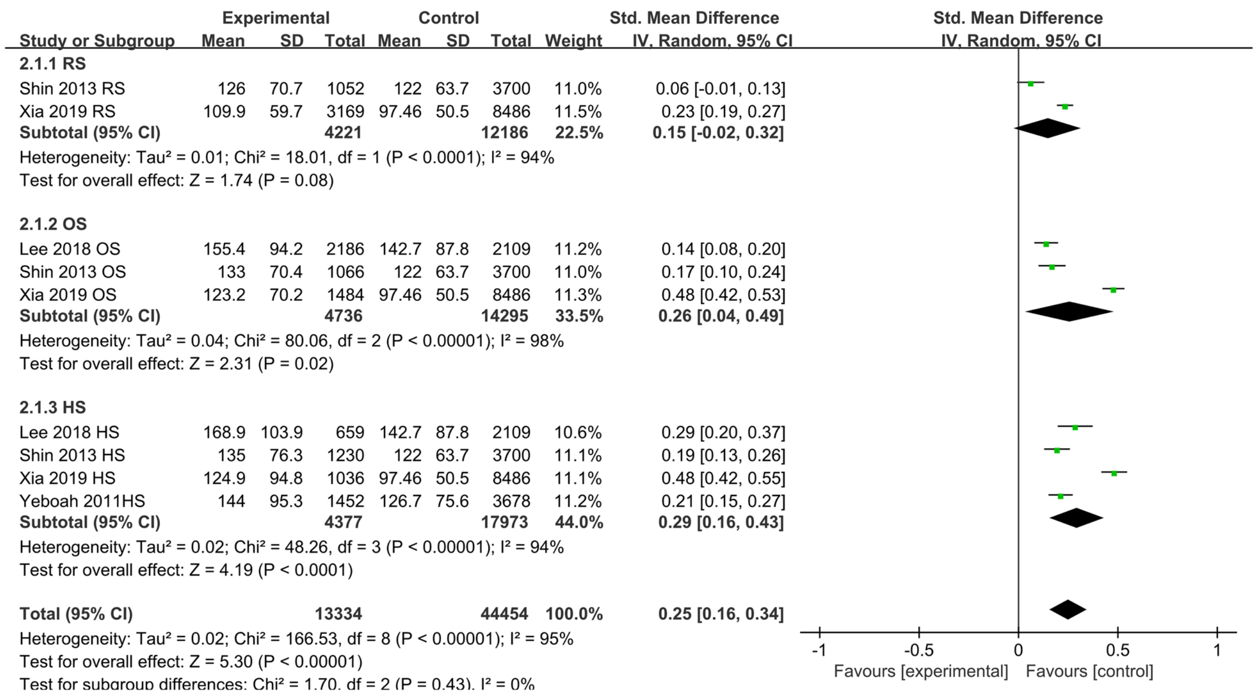

Fig. 3 Forest plot for the relationship between snoring status and TG risk. The subgroup analyses included 2 studies for the RS group, 3 for the OS group, and 4 for the HS group. The pooled analysis revealed that the RS group was not associated with TG risk, with a pooled SMD of 0.15 (95% CI −0.02 to 0.32; P = 0.008), whereas the OS and HS groups were significantly associated with TG risk, with pooled SMDs of 0.26 (95% CI 0.04 to 0.49; P = 0.002) and 0.29 (95% CI 0.16 to 0.43; P < 0.0001), respectively.RS: rare snoring; OS: occasional snoring; HS: habitual snoring; TG: triglyceride; IV: inverse variance; SD: standard deviation; CI: confidence interval

m^2 and BMI ≥ 25 kg/m^2 increased the risk of dyslipidemia. More importantly, those with a BMI ≥ 25 kg/m^2 had higher TG levels than those with a BMI < 25 kg/m^2. The possible reason is that obese patients can have high TG levels [27].

Snoring is increasingly recognized as a potential harbinger of hormonal imbalances and metabolic disorders, which can precipitate serious health conditions such as coronary heart disease, diabetes, and metabolic syndrome.[7] Research has indicated that snoring is associated with an increase in serum testosterone levels, which can lead to elevated triglyceride levels and metabolic syndrome. This hormonal imbalance can have significant implications for men's health, potentially contributing to conditions like erectile dysfunction, as suggested by a cross-sectional study[6]. Furthermore, a systematic

Study or Subgroup	Experimental Mean	Experimental SD	Experimental Total	Control Mean	Control SD	Control Total	Weight	Std. Mean Difference IV, Random, 95% CI
3.1.1 BMI<25kg/m^2								
Shin 2013 RS	126	70.7	1052	122	63.7	3700	11.4%	0.06 [-0.01, 0.13]
Shin 2005	155.4	99	385	148.2	111.5	2334	10.3%	0.07 [-0.04, 0.17]
Lee 2018 OS	155.4	94.2	2186	142.7	87.8	2109	11.5%	0.14 [0.08, 0.20]
Xia 2019 RS	109.9	59.7	3169	97.46	50.5	8486	11.9%	0.23 [0.19, 0.27]
Subtotal (95% CI)			**6792**			**16629**	**45.1%**	**0.13 [0.04, 0.22]**
Heterogeneity: Tau² = 0.01; Chi² = 23.68, df = 3 (P < 0.0001); I² = 87%								
Test for overall effect: Z = 2.86 (P = 0.004)								
3.1.2 BMI≥25kg/m^2								
Shin 2013 RS	126	70.7	1052	122	63.7	270	9.6%	0.06 [-0.08, 0.19]
Shin 2013 OS	133	70.4	1066	122	63.7	2700	11.3%	0.17 [0.10, 0.24]
Yeboah 2011HS	144	95.3	1452	126.7	75.6	3678	11.5%	0.21 [0.15, 0.27]
Lee 2018 HS	168.9	103.9	659	142.7	87.8	2109	10.9%	0.29 [0.20, 0.37]
Xia 2019 OS	123.2	70.2	1484	97.46	50.5	8486	11.6%	0.48 [0.42, 0.53]
Subtotal (95% CI)			**5713**			**17243**	**54.9%**	**0.24 [0.10, 0.39]**
Heterogeneity: Tau² = 0.02; Chi² = 73.19, df = 4 (P < 0.00001); I² = 95%								
Test for overall effect: Z = 3.37 (P = 0.0007)								
Total (95% CI)			**12505**			**33872**	**100.0%**	**0.19 [0.10, 0.28]**
Heterogeneity: Tau² = 0.02; Chi² = 128.36, df = 8 (P < 0.00001); I² = 94%								
Test for overall effect: Z = 4.21 (P < 0.0001)								
Test for subgroup differences: Chi² = 1.77, df = 1 (P = 0.18), I² = 43.4%								

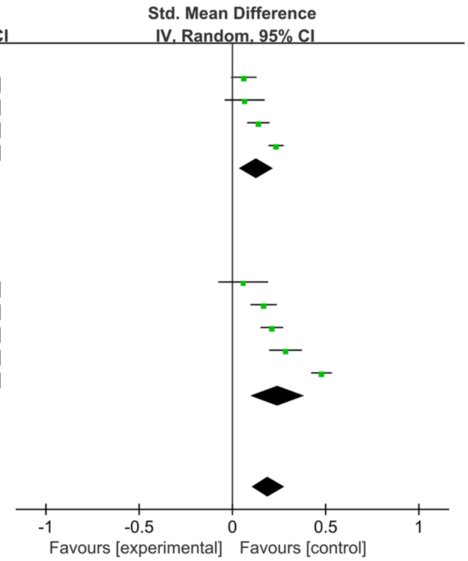

Figure 4 Forest plot for the association between snoring and TG risk stratified by BMI subgroup. The subgroup analyses included 4 patients in the BMI < 25 kg/m^2 group and 5 patients in the BMI > 25 kg/m^2 group. Pooled analysis revealed that BMI < 25 kg/m2 and BMI > 25 kg/m2 were significantly associated with TG risk with pooled SMDs of 0.13 (95% CI 0.04 to 0.22; *P* = 0.004) and 0.24 (95% CI 0.10 to 0.39; *P* = 0.0007). RS: rare snoring; OS: occasional snoring; HS: habitual snoring; TG: triglyceride; IV: inverse variance; SD: standard deviation; CI: confidence interval.

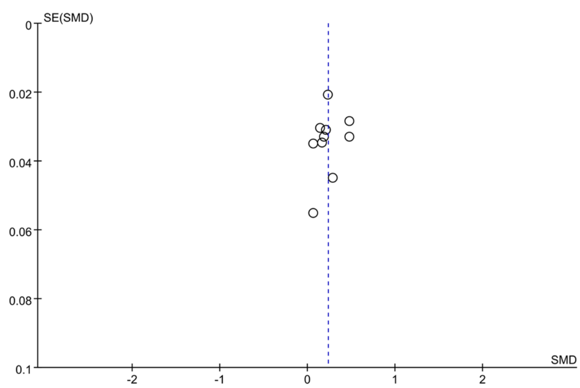

Figure 5 Funnel plots of studies evaluating the association of snoring with TG risk

review and meta-analysis[5] has confirmed the association between self-reported snoring and metabolic syndrome, emphasizing the importance of recognizing snoring as a potential indicator of metabolic health issues that can lead to broader cardiovascular and metabolic complications if left unchecked. These findings underscore the need for further investigation into the relationship between snoring and metabolic health, as well as the development of interventions to mitigate the associated risks.

The clinical utility of our findings is multifaceted. First, by establishing a link between snoring and elevated triglyceride levels, we provide a basis for clinicians to screen for hypertriglyceridaemia in habitual snorers, potentially leading to earlier interventions to manage lipid profiles and reduce cardiovascular risk. Second, our study results highlight that the relationship between snoring and triglyceride levels is not strongly influenced by BMI, indicating that attention should not only be given to obese patients but also that thin individuals should not be overlooked. Finally, our meta-analysis offers insights into the differential impact of snoring frequency on triglyceride levels, which could guide personalized clinical approaches to assess and treat snoring patients more effectively.

To date, there has been no consensus on the relationship between snoring and elevated TG levels, and we used a meta-analysis for the first time to demonstrate the mechanism involved. At the same time, some limitations of our study must be discussed. First, each study had different snoring criteria, which could affect the accuracy of the results. Second, our study explored sources of heterogeneity by frequency of snoring and BMI, but we could not find other heterogeneities due to the limited availability of other clinical data. Third, due to the limited number of included studies and insufficient sample size, which may affect the accuracy of the results, multicenter studies with increased sample sizes are needed to confirm our conclusions. Fourth, different methods of measuring plasma or serum may affect the results. In addition, because meta-analyses are often subject to publication bias, some negative studies are overlooked and need attention. Finally, we were unable to determine reliable cut-off points for TG in patients with different snoring states because we did not have raw data for plotting receiver operating characteristic (ROC) curves. Therefore, more and larger studies should be encouraged to avoid these shortcomings.

Conclusions

Our meta-analysis revealed that occasional and habitual snoring associated with elevated TG levels. More importantly, our results also revealed that the relationship between TG caused by snoring and BMI was fragile.

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Not applicable.

Author contributions
FF, BBW and LNY designed and analyzed the study; YC, QW, YC and QW wrote and revised the manuscript; all authors collected the data, and approved the manuscript.

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Availability of data and materials
No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate
Not applicable.

Consent for publication
Not applicable.

Human ethics and consent to participate declarations
Not applicable.

Human participants
Not applicable.

Competing interests
The authors declare no competing interests.

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References

1. Ohayon MM, Guilleminault C, Priest RG, Caulet M. Snoring and breathing pauses during sleep: telephone interview survey of a United Kingdom population sample. BMJ. 1997;314(7084):860–3.
2. Niu Y, Sui X, He Y, Xi H, Zhu R, Xu H, et al. Association between self-reported snoring and hypertension: a systematic review and meta-analysis. Sleep Med. 2021;88:140–8.
3. Nagayoshi M, Tanigawa T, Yamagishi K, Sakurai S, Kitamura A. Self-reported snoring frequency and incidence of cardiovascular disease: the circulatory risk in communities study (CIRCS). J Epidemiol. 2012;22(4):295–301.
4. Yang C, Yan P, Wu X, Zhang W, Cui H, Zhang L, et al. Associations of sleep with cardiometabolic risk factors and cardiovascular diseases: an umbrella review of observational and mendelian randomization studies. Sleep Med Rev. 2024;77: 101965.
5. Dilixiati D, Kadier K, Laihaiti D, Lu JD, Rezhake R, Azhati B, Rexiati M. The relationship between sleep disorders, quality, and duration and sexual dysfunction: a systematic review and meta-analysis. J Sex Med. 2023.
6. Yilmaz M, Karaaslan M, Tonyali S, Celik M, Toprak T, Odabas O. Triglyceride-Glucose Index (TyG) is associated with erectile dysfunction: A cross-sectional study. Andrology. 2021;9(1):238–44.
7. Dilixiati D, Waili A, Tuerxunmaimaiti A, Tao L, Zebibula A, Rexiati M. Risk factors for erectile dysfunction in diabetes mellitus: a systematic review and meta-analysis. Front Endocrinol. 2024;4(15):1368079.
8. Kim CE, Shin S, Lee HW, Lim J, Lee JK, Kang D. Frequency of loud snoring and metabolic syndrome among korean adults: results from the health examinees (HEXA) study. Int J Environ Res Public Health. 2017;14(11):1294.
9. Behnoush AH, Bahiraie P, Shokri Varniab Z, Foroutani L, Khalaji A. Composite lipid indices in patients with obstructive sleep apnea: a systematic review and meta-analysis. Lipids Health Dis. 2023;22(1):84.
10. Behnoush AH, Khalaji A, Ghondaghsaz E, Masrour M, Shokri Varniab Z, Khalaji S, et al. Triglyceride-glucose index and obstructive sleep apnea: a systematic review and meta-analysis. Lipids Health Dis. 2024;23(1):4.
11. Moher D, Liberati A, Tetzlaff J, Altman DG, PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. PLoS Med. 2009;6(7):e1000097.
12. Stang A. Critical evaluation of the Newcastle-Ottawa scale for the assessment of the quality of nonrandomized studies in meta-analyses. Eur J Epidemiol. 2010;25(9):603–5.
13. Yang-Peng XU, Ya-Yu YU, Wun-Jie FU, Yuan T, Jun-Yi WU, Qian HE, et al. Introduction to missing standard deviation conversion and standardized mean difference estimation methods in meta-analysis. Chin J Evid-Based Cardiovasc Med. 2016;8:1412–5.
14. Higgins JP, Thompson SG. Quantifying heterogeneity in a meta-analysis. Stat Med. 2002;21(11):1539–58.
15. Egger M, Davey Smith G, Schneider M, Minder C. Bias in meta-analysis detected by a simple, graphical test. BMJ. 1997;315(7109):629–34.
16. Lee SK, Choi K, Chang YH, Kim J, Shin C. Increased risk for new-onset hypertension in midlife male snorers: the 14-year follow-up study. J Sleep Res. 2019;28(5): e12757.
17. Shin C, Kim J, Kim J, Lee S, Shim J, In K, et al. Association of habitual snoring with glucose and insulin metabolism in nonobese Korean adult men. Am J Respir Crit Care Med. 2005;171(3):287–91.
18. Shin MH, Kweon SS, Choi BY, Kim MK, Chun BY, et al. Self-reported snoring and metabolic syndrome: the Korean multi-rural communities cohort study. Sleep Breath. 2014;18(2):423–30.
19. Yeboah J, Redline S, Johnson C, Tracy R, Ouyang P, Blumenthal RS, et al. Association between sleep apnea, snoring, incident cardio- vascular events and all-cause mortality in an adult population: MESA. Atherosclerosis. 2011;219(2):963–8.
20. Xia Y, Zhou L, Li Y. Cross sectional study on the relationship between snoring and hypertriglyceridaemia. Chin J Circ. 2019;34:85–9.
21. Tian Y, Li D, Mu H, Wei S, Guo D. Positive correlation between snoring and dyslipidemia in adults: results from NHANES. Lipids Health Dis. 2023;22(1):73.
22. Zou J, Song F, Xu H, Fu Y, Xia Y, Qian Y, et al. The relationship between simple snoring and metabolic syndrome: a cross-sectional study. J Diabetes Res. 2019;2019:9578391.
23. Ma J, Zhang H, Wang H, Gao Q, Sun H, He S, et al. Association between self-reported snoring and metabolic syndrome: a systematic review and meta-analysis. Front Neurol. 2020;11:517120.
24. Drager LF, Jun J, Polotsky VY. Obstructive sleep apnea and dyslipidemia: implications for atherosclerosis. Curr Opin Endocrinol Diabetes Obes. 2010;17(2):161–5.
25. Olafiranye O, Adedayo AM. Obstructive sleep apnea and dyslipidemia: pathophysiological mechanisms. Sleep Breath. 2013;17(2):445.
26. Zhang N, Chen Y, Chen S, Jia P, Guo X, Sun G, et al. Self-reported snoring is associated with dyslipidemia, high total cholesterol, and high low-density lipoprotein cholesterol in obesity: a cross-sectional study from a rural area of China. Int J Environ Res Public Health. 2017;14(1):86.
27. Li Y, Gao Q, Li L, Shen Y, Lu Q, Huang J, et al. Additive interaction of snoring and body mass index on the prevalence of metabolic syndrome among Chinese coal mine employees: a cross-sectional study. BMC Endocr Disord. 2019;19(1):28.

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