

Prevalence and Pattern of Thyrocardiac Disease among Patients with Hyperthyroidism in Ethiopia: A Systematic Review and Meta-Analysis

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ABSTRACT

Background: Thyrocardiac disease encompasses the spectrum of cardiovascular abnormalities that arise as complications of hyperthyroidism. Despite being clinically significant and potentially life-threatening, its burden in Ethiopia remains poorly defined.

Objective: To determine the pooled prevalence and pattern of thyrocardiac disease among hyperthyroid patients in Ethiopia.

Methods: A systematic review and meta-analysis was conducted in accordance with PRISMA 2020 guidelines. Comprehensive searches were carried out in PubMed, Google Scholar, AJOL, Hinari, Europe PMC, Cochrane library, and institutional repositories. Observational studies reporting cardiac outcomes in adults with hyperthyroidism in Ethiopia were included. Analysis was done using STATA version 17. Prevalence data were pooled using a random-effects model, and heterogeneity was assessed using the Cochrane Q and I² statistic.

Results: Seven studies with a total of 1,160 participants were included in the review. Sinus tachycardia (39.32%; 95% CI: 23.34%–55.31%), Heart failure (21.65%; 95% CI: 13.84–29.46%), and Pulmonary hypertension (19.43%; 95% CI: 6.78–32.09%) were the commonest presentations, while Dilated cardiomyopathy (12.35%; 95% CI: 6.16–18.53%) and Atrial fibrillation (16.27%; 95% CI: 12.17–20.38%) were the least common. Toxic multinodular goiter was the most common cause of hyperthyroidism among these patients accounting for 64.8% (95% CI: 53.2–75.3%).

Conclusion: Thyrocardiac disease is a frequent complication among hyperthyroid patients in Ethiopia, with sinus tachycardia and heart failure being the most common presentations. These findings highlight the importance of integrating routine cardiac evaluation into the clinical management of hyperthyroidism.

KEYWORDS: Atrial fibrillation, Heart failure, meta-analysis, pulmonary hypertension, Thyrocardiac, Hyperthyroidism, Thyrotoxicosis, Ethiopia.

INTRODUCTION

Hyperthyroidism is a condition in which there is excess circulating thyroid hormones, leading to increased basal metabolic rate and heightened sympathetic activity [1, 2]. Globally, hyperthyroidism affects approximately 0.3–3.4% of the population, with higher prevalence among women and older adults [3-6]. In low- and middle-income countries (LMICs) like Ethiopia, the burden of hyperthyroidism may be underestimated due to limited access to diagnostic services, under-reporting, and overlapping clinical features with other endemic diseases [3, 6]. The cardiovascular system is one of the primary targets of thyroid hormones, and even



subtle hormonal imbalances can result in significant cardiac effects [7]. Thyrocardiac disease refers to the spectrum of cardiovascular manifestations resulting from abnormal thyroid hormone levels, most notably in the setting of hyperthyroidism [8]. These include arrhythmias (atrial fibrillation and flutters), systemic hypertension, tachycardia, cardiomyopathy, and, in severe cases, heart failure [1, 7, 8]. Cardiac complications associated with hyperthyroidism, contribute significantly to morbidity and mortality and it can complicate disease management and prognosis if not identified and treated early [9].

In Ethiopia, several hospital-based studies have reported varying rates of thyrocardiac complications. However, these findings have been inconsistent, and there is a lack of comprehensive national data on the prevalence and clinical pattern of thyrocardiac disease. The absence of pooled national-level data presents a critical gap in understanding the burden of thyrocardiac disease among hyperthyroid patients in Ethiopia. Given the clinical significance of these complications and their impact on patient outcomes, a systematic review and meta-analysis is warranted. Therefore, this study aims to estimate the pooled prevalence and characterize the pattern of thyrocardiac disease among patients with hyperthyroidism in Ethiopia through a systematic review and meta-analysis of existing literature.

METHODS

Study Design and Reporting

This systematic review and meta-analysis was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines. The review is registered on Prospero (CRD420251055321).

Eligibility Criteria

Observational studies (cross-sectional, cohort, and case-control) conducted in Ethiopia that reported on prevalence and/or types of cardiac manifestations (atrial fibrillation, cardiomyopathy, heart failure, and pulmonary hypertension) among adult patients with hyperthyroidism or thyrotoxicosis were eligible. Both published and grey articles studies published in English were considered. Studies with insufficient data to calculate prevalence or extract relevant outcomes, Case reports, editorials, conference abstracts, and narrative reviews were excluded. In addition, studies involving patients with mixed thyroid dysfunction where hyperthyroidism specific data were not separated were excluded.

Sources and search Strategy

A comprehensive literature search was conducted across the following electronic databases: PubMed, Google Scholar, African Journals Online (AJOL), Hinari, EuropePMC, Cochrane library, and repositories of Jimma University and Addis Ababa University Digital Library. The search was restricted to articles published in English, without restriction on the publication date. Search terms included combinations of Medical Subject Headings (MeSH) and keywords such as “hyperthyroidism”, “thyrotoxicosis”, “cardiac disease”, “pulmonary hypertension”, “atrial fibrillation”, “cardiomyopathy”, “thyrocardiac”, “heart failure” and “Ethiopia” using Boolean operators (AND, OR). The reference lists of eligible articles were also screened for additional eligible studies.

Study Selection Process

All search results were exported to Covidence for screening. Duplicates were removed automatically by the software. Subsequently, two independent groups of reviewers screened titles and abstracts, followed by full-text review to assess eligibility. Disagreements were resolved by consensus or consultation with a third reviewer.

Data Extraction

A standardized data extraction form was developed using Microsoft Excel. Extracted data included first author and year of publication, Study region and setting, Study design, sample size, Study population characteristics, types and prevalence of thyrocardiac manifestations with the corresponding confidence interval. Two groups of reviewers independently extracted data, and discrepancies were resolved through discussion.

Quality Assessment

Quality appraisal was done for included studies using the Joanna Briggs Institute (JBI) Critical Appraisal Checklist for Prevalence Studies. Each study was scored across 9 domains, and studies were classified as: High quality: $\geq 7/9$ criteria met, Moderate quality: 4–6 criteria met, Low quality: ≤ 3 criteria met [10].

Data Analysis

STATA version 16.0 was used to perform the statistical analysis. For studies with missing confidence interval, imputation was done. Pooled prevalence estimates across each presentations with the corresponding 95% confidence intervals were calculated using a random-effects model with DerSimonian and Laird method due to significant heterogeneity among studies. Heterogeneity was assessed using Cochran Q test and the I² statistic. Pooled prevalence was presented using forest plot. Publication bias was assessed using funnel plot and Egger’s test. For those with significant publication bias, trim and fill analysis was done.

RESULTS

Search results and study selection

Initial search yielded 412 studies and 59 studies were identified as duplicates. After title and abstract screening, 339 studies were excluded and 14 studies were considered for full article review. Of these, 3 studies were conducted on wrong population, 1 study reported wrong outcome, and 3 studies were duplicates published under different titles. Finally, 7 studies were included in the review (Figure 1).

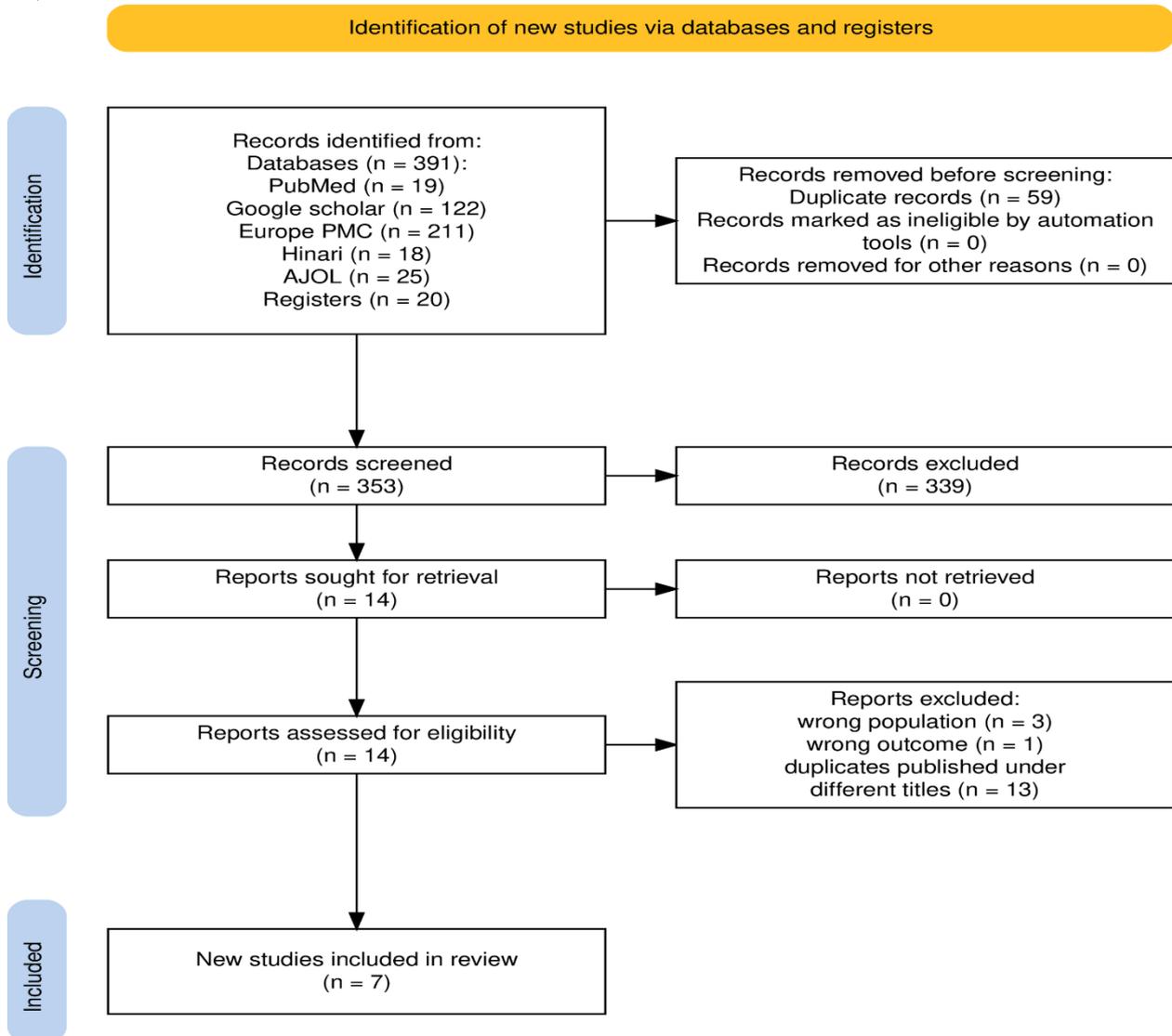


Figure 1: PRISMA study selection flow for prevalence and pattern of thyrocardiac disease among patients with hyperthyroidism in Ethiopia: a systematic review and meta-analysis



The included studies were conducted between 2019 and 2024 and involved a total of 1160 patients diagnosed with hyperthyroidism. All studies were done among adult patients aged 18 year and above. Furthermore, all studies employed a hospital based cross-sectional design in five parts of the country (Amhara[11], Oromia[12, 13], Tigray [14], Harari [15], and Addis Ababa[16, 17]). Criteria for hyperthyroidism and cardiac features diagnosis were largely consistent, relying on clinical evaluation along with thyroid function tests, electrocardiography (ECG), and echocardiographic assessments.

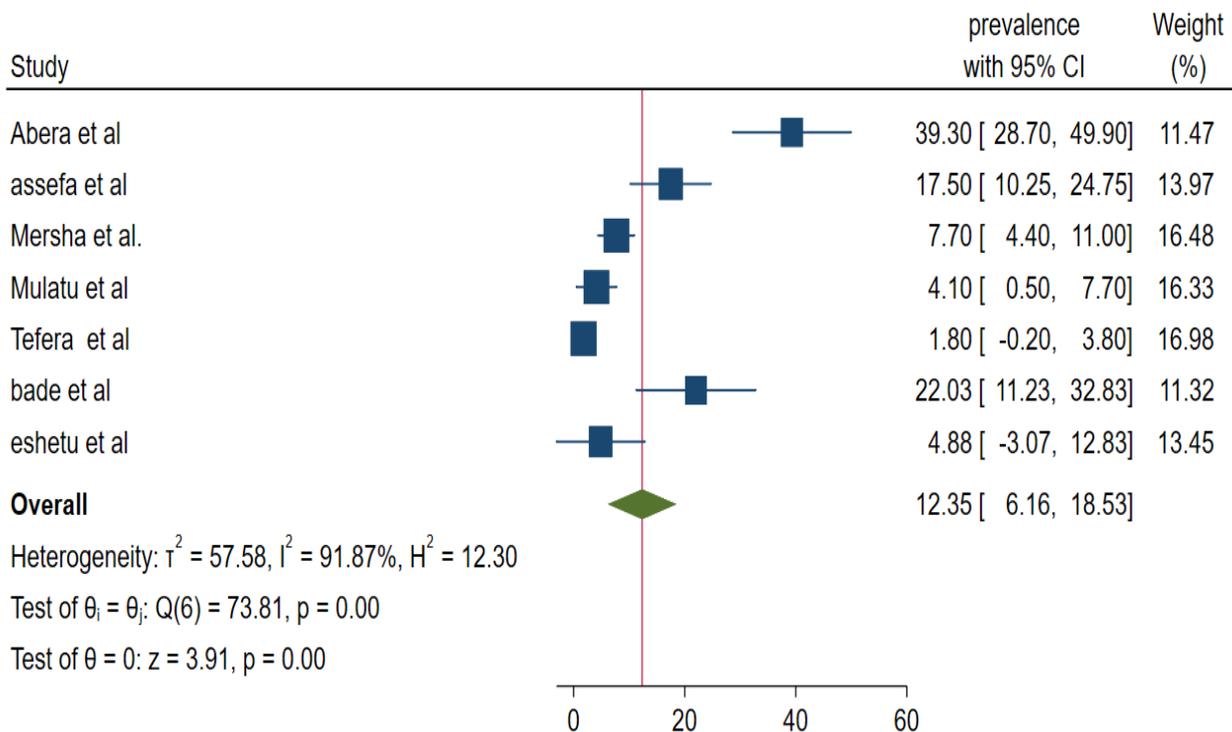
Quality Assessment

The quality of the included studies was assessed using the Joanna Briggs Institute (JBI) Critical Appraisal Checklist for Prevalence Studies. Based on the scoring system, 5 studies were rated as high quality[11, 14-17], 2 as moderate[12, 13], and none as low quality. Detailed quality appraisal results are presented in **Table 1**.

Pooled prevalence of cardiac manifestations

Pooled prevalence of Dilated Cardiomyopathy

Dilated cardiomyopathy (DCM) was reported in 7 studies involving 948 patients. The reported prevalence ranged from 39.3% [14] to 1.8% [11]. The pooled prevalence of DCM among hyperthyroid patients was 12.35% (95% CI: 6.16–18.53%) ($I^2 = 91.87%$) (**Figure 2**). Egger’s test showed significant publication bias ($p < 0.001$). However, non-parametric trim and fill analysis did not change the estimate and result was assumed to arise from the high heterogeneity.



Random-effects DerSimonian-Laird model

Figure 2: Pooled prevalence of Dilated Cardiomyopathy among patients with hyperthyroidism in Ethiopia: a systematic review and meta-analysis

Pooled prevalence of Heart Failure

Heart failure was reported in 3 studies involving 627 participants. The reported prevalence ranged from 17% [16] to 30.6% [13]. The pooled prevalence was 21.65% (95% CI: 13.84–29.46%) ($I^2 = 80.33%$) (**Figure 3**).

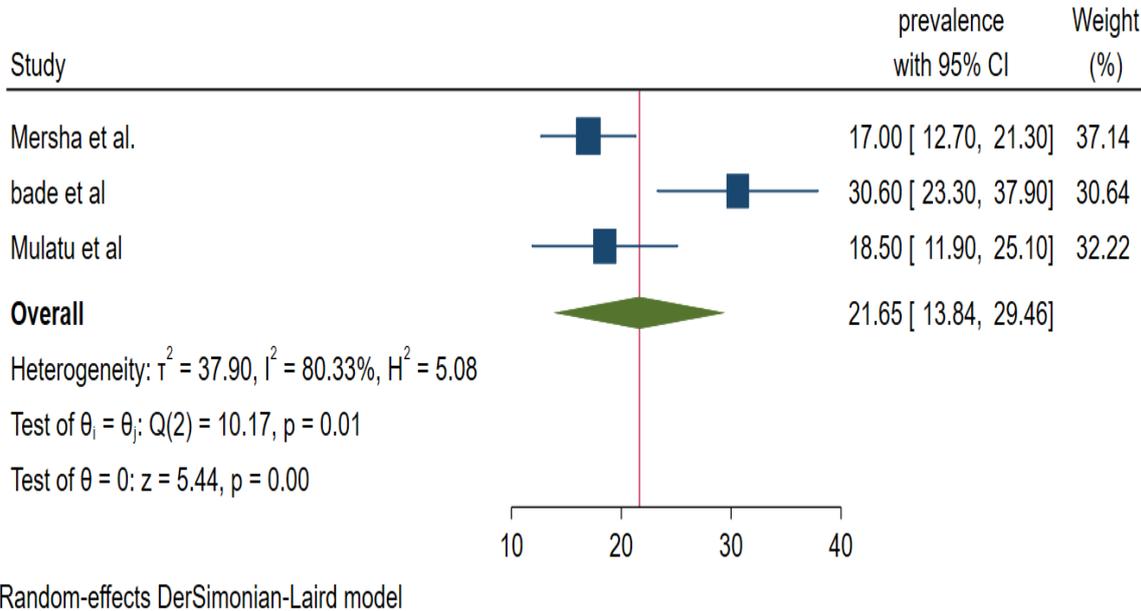


Figure 3: Pooled prevalence of Heart Failure among patients with hyperthyroidism in Ethiopia: a systematic review and meta-analysis

Prevalence of Pulmonary Hypertension

Five studies with 828 study participants reported data on pulmonary hypertension. The reported prevalence ranged from 4.1% [16] to 65% [12]. The pooled prevalence was estimated at 19.43% (95% CI: 6.78–32.09), $I^2 = 97.76\%$ (Figure 4). Assefa et al [12] was an extreme outlier and its exclusion dropped the pooled prevalence to 6.3% (95% CI: 6.8–9.6%) and heterogeneity became moderate ($I^2 = 47\%$).

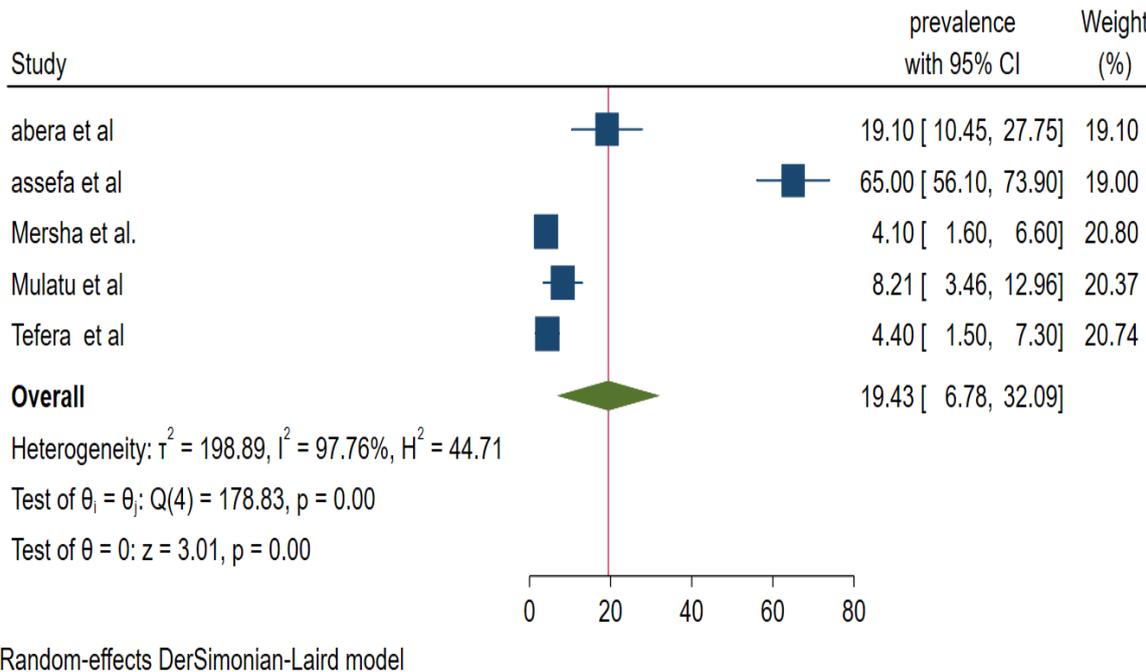


Figure 4: Pooled prevalence of Pulmonary Hypertension among patients with hyperthyroidism in Ethiopia: a systematic review and meta-analysis

Prevalence of Atrial Fibrillation

Atrial fibrillation (AF) was reported in 7 studies with 1160 participants. Prevalence ranged from 11% [17] to 28.9% [14]. The pooled prevalence was 16.27% (95% CI: 12.17-20.38%); ($I^2 = 74.09\%$) (Figure 5). Egger’s test showed a publication bias ($P= 0.1197$) but trim and fill analysis showed no change in the final prevalence.

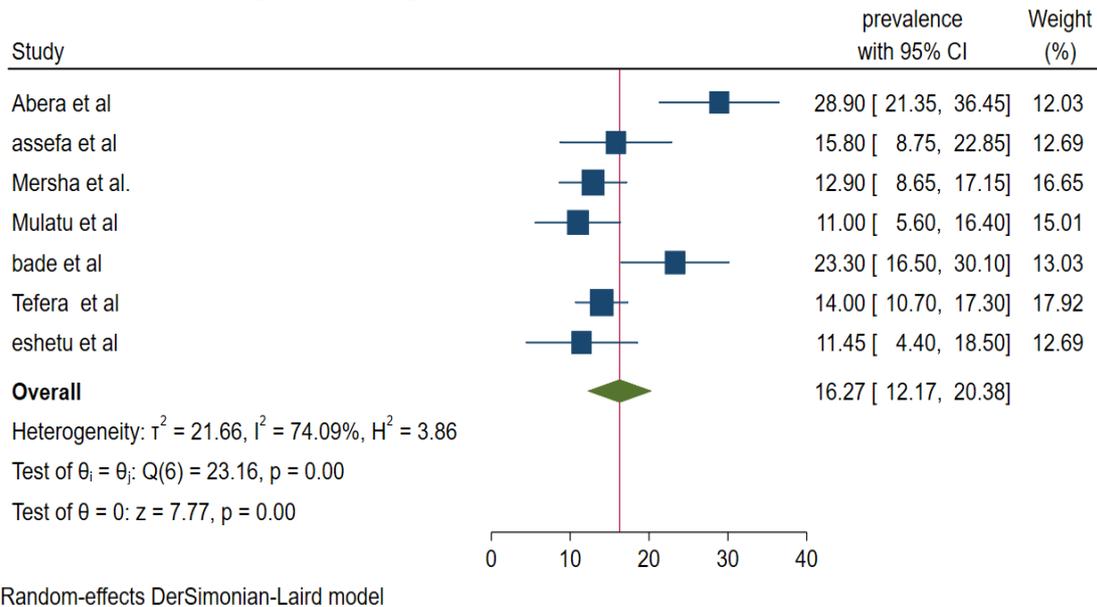


Figure 5: Pooled prevalence of Atrial Fibrillation among patients with hyperthyroidism in Ethiopia: a systematic review and meta-analysis

Prevalence of Sinus Tachycardia

Sinus tachycardia was reported in 4 studies with 737 participants. Prevalence ranged from 19.79% [15] to 57.4% [11]. The pooled prevalence was found to be 39.32% (95% CI: 23.34%–55.31%); ($I^2 = 95.04\%$) (Figure 6). There was no publication bias noted ($P=0.758$)

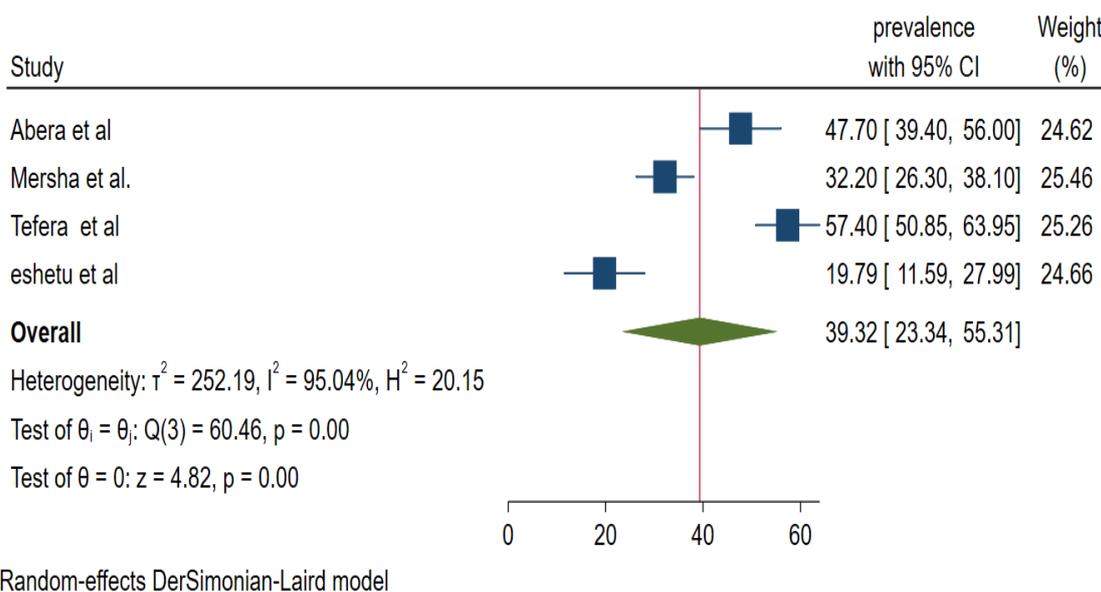


Figure 6: Pooled prevalence of Sinus tachycardia among patients with hyperthyroidism in Ethiopia: a systematic review and meta-analysis



Primary Diagnosis of Hyperthyroidism

The most commonly reported cause of hyperthyroidism was toxic multinodular goiter, followed by Graves' disease and toxic adenoma. Pooled analysis of primary diagnosis types revealed that: Toxic multinodular goiter accounted for 64.8% (95% CI: 53.2-75.3%), Graves' disease for 18.7% (95% CI: 8.6-32.1%) and Toxic adenoma for 4.5% (95% CI: 2.0-7.9%). Thyroid cancer and thyroiditis were reported in two studies with pooled prevalence of 1.6% (95% CI: 0.4-3.9%) and (95% CI: 0.5-2.5%) respectively.

DISCUSSION

This systematic review and meta-analysis provides a comprehensive synthesis of the magnitude and pattern of cardiac complications among patients with hyperthyroidism in Ethiopia. The pooled data show nearly one-third of hyperthyroid patients develop at least one form of cardiovascular involvement.

Among the reported manifestations, sinus tachycardia emerged as the most prevalent, affecting nearly half of participants. This aligns with the known chronotropic effects of excess thyroid hormone, which increases β -adrenergic receptor sensitivity and basal metabolic rate [1, 7]. While often considered benign, persistent tachycardia may lead to left ventricular dysfunction if unrecognized or untreated [18].

Furthermore, atrial fibrillation (AF), an arrhythmic complication, was present in 17% of patients. This finding is comparable to findings from similar studies done in India (17.9%) [19] but higher than reported in meta-analysis conducted in Africa (9%) [6]. The prevalence of AF is higher among patients with toxic multinodular goiter [20], and this could explain the higher prevalence seen in our study. AF in thyrotoxicosis is associated with significant risk of thromboembolism, particularly in older patients or those with structural heart disease, and this warrants careful monitoring and control of AF [21]. Furthermore, it can also contribute to the high output heart failure seen among hyperthyroid patients [22].

Moreover, dilated cardiomyopathy (DCM) and heart failure, both markers of advanced or prolonged hyperthyroid states, were seen in 14% and 22% of patients respectively. These findings are consistent with previous studies indicating that prolonged exposure to excess thyroid hormone can lead to myocyte degeneration, volume overload, and impaired systolic function [7, 9]. However, this prevalence of HF is higher than reported in a global meta-analysis conducted in 2023 (8%) [22] and a 2022 meta-analysis from Africa (12%) [6]. This could be related to late presentation seen among patients from LMIC countries [6]. Clinical guidelines should consider early cardiac imaging for patients with chronic or poorly managed hyperthyroidism to detect early signs and for prompt management.

Pulmonary hypertension showed wide variability in prevalence between studies (4% to 65%) with a pooled prevalence of 19%. Upon exclusion of an outlier study, the estimate and its heterogeneity decreased significantly, indicating the influence of study-level factors such as bias in diagnosis. This findings relatively lower than previous studies that reported 35% [23] to 65% [24] prevalence. Pulmonary hypertension is more commonly seen among patients with Graves' disease than other subtypes [20] and the lower prevalence in our study could be related the lower proportion of patients with Grave's.

In terms of etiology, toxic multinodular goiter was the predominant cause of hyperthyroidism, accounting for nearly two-thirds of cases. This is consistent with prior research in iodine-deficient regions, where nodular thyroid disease is more common than autoimmune etiologies like Graves' disease [6]. Furthermore, studies have shown serious cardiac complications of hyperthyroidism are more prevalent among TMNG patients and this could explain the relatively higher prevalence in our study [20].

STRENGTHS AND LIMITATIONS

This is the first systematic review and meta-analysis to quantify the burden and pattern of thyrocardiac disease among hyperthyroid patients in Ethiopia. The study included a diverse range of hospital-based studies from multiple regions, improving the generalizability of findings. In addition, the analysis addressed a wide spectrum of cardiac complications, providing a comprehensive overview of the clinical spectrum of hyperthyroidism-related cardiovascular disease. However, there were some limitations for this study. First, majority of included studies were cross-sectional, limiting causal inference between hyperthyroidism and cardiac outcomes. Some important outcomes, such as heart failure were reported in only a few studies, reducing the power and precision of pooled estimates. Finally, most studies were conducted in tertiary referral centers, which may over-represent severe cases and limit applicability to the general population.



CONCLUSION

Thyrocardiac disease is a prevalent and clinically significant complication among hyperthyroid patients in Ethiopia. Sinus tachycardia and Heart failure were the most common manifestations, but substantial proportion also had other serious conditions such as AF, dilated cardiomyopathy, and pulmonary hypertension. These findings highlight the need for routine cardiovascular screening in hyperthyroid patients, particularly those with longstanding or poorly controlled disease. Timely diagnosis and management of cardiac complications are essential for reversal of morbidity and reduction of risk of long-term morbidity and mortality. Thus, we recommend all patients diagnosed with hyperthyroidism to undergo baseline ECG and echocardiographic evaluation. Clinicians should also have a high index of suspicion for arrhythmias and heart failure. We also recommend prospective studies to be conducted in the future to establish causation and identify predictors.

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Ethical approval-not required.

Conflicts of Interest: The authors declare no conflict of interest.

REFERENCES

1. Klein I, Ojamaa K. Thyroid Hormone and the Cardiovascular System. *New England Journal of Medicine*. 2001;344(7):501-9.
2. Ertek S, Cicero AF. Hyperthyroidism and cardiovascular complications: a narrative review on the basis of pathophysiology. *Arch Med Sci*. 2013;9(5):944-52.
3. Kostopoulos G, Effraimidis G. Epidemiology, prognosis, and challenges in the management of hyperthyroidism-related atrial fibrillation. *European Thyroid Journal*. 2024;13(2):e230254.
4. Lee SY, Pearce EN. Hyperthyroidism: A Review. *JAMA*. 2023;330(15):1472-83.
5. Wiersinga WM, Poppe KG, Effraimidis G. Hyperthyroidism: aetiology, pathogenesis, diagnosis, management, complications, and prognosis. *The lancet Diabetes & endocrinology*. 2023;11(4):282-98.
6. Azeez TA, Adetunji TA, Adio M. Thyrotoxicosis in Africa: a systematic review and meta-analysis of the clinical presentation. *The Egyptian Journal of Internal Medicine*. 2022;34(1):57.
7. Navarro-Navajas A, Cruz JD, Ariza-Ordoñez N, Giral H, Palmezano J, Bolívar-Mejía A, et al. Cardiac manifestations in hyperthyroidism. *Rev Cardiovasc Med*. 2022;23(4):136.
8. Dahl P, Danzi S, Klein I. Thyrotoxic cardiac disease. *Curr Heart Fail Rep*. 2008;5(3):170-6.
9. Osuna PM, Udovicic M, Sharma MD. Hyperthyroidism and the Heart. *Methodist Debaquey Cardiovasc J*. 2017;13(2):60-3.
10. Sánchez-Rodríguez C, Capitán-Moyano L, Malih N, Yanez AM, Bannasar-Veny M, Velasco-Roldán O, et al. Prevalence of musculoskeletal disorders among hotel housekeepers and cleaners: A systematic review with meta-analysis. *Musculoskeletal Science and Practice*. 2024;69:102890.
11. Tefera EM, Tefera YM, Yimer M, Mulat Worku B, Ayele E, Zewdu Asmare B, et al. Atrial Fibrillation and Associated Factors Among Hyperthyroidism Patients Attending at University of Gondar Comprehensive Specialized Hospital, Northwest Ethiopia. *Clinical Medicine Insights: Endocrinology and Diabetes*. 2024;17:11795514241285347.
12. Asefa ET, Nasir MA, Abafogi MM, Tukeni KN. Patterns of Echocardiographic abnormalities in thyrotoxic patients on follow up at Jimma Medical Center, Ethiopia, A Hospital based observational study. 2023.
13. Bade A. ASSESSMENT OF ATRIAL FIBRILLATION AND ASSOCIATED CARDIOVASCULAR DISORDERS AMONG ADULT HYPERTHYROIDISM PATIENT AT JIMMA UNIVERSITY FOLLOW UP CLINICS FROM JUNE 2016- AUGUST 2021 G.C Jimma: Jimma University; 2021.
14. Abera BT, Abera MA, Berhe G, Abreha GF, Gebru HT, Abraha HE, et al. Presentation, Complication, Management, and Drug Adherence of Patients with Thyrotoxicosis in Developing Countries. 2021.
15. Eshetu L. Patterns, clinical presentations and treatment outcome of thyroid disorders among adult patients attending department of internal medicine and surgical referral clinic of Hiwot Fana Comprehensive Specialized Hospital, Harar, Eastern Ethiopia. Haromaya: Haromaya Univeristy; 2024.
16. Mersha BH, Abdissa SG, Alemneh TA, Kebede N, Tsega Y, Nigussie S, et al. Magnitude of cardiac abnormality and its associated factors among hyperthyroidism patients on follow-up at Tikur Anbessa Specialized Hospital, Addis Ababa, Ethiopia. *BMC Cardiovascular Disorders*. 2024;24(1):558.



17. Mulatu HA. Pattern and presentation of thyro-cardiac disease among patients with hyperthyroidism attending a tertiary hospital in Ethiopia: a cross sectional study. Ethiopian journal of health sciences. 2019;29(1).
18. Klein I, Danzi S. Thyroid Disease and the Heart. Circulation. 2007;116(15):1725-35.
19. Nijith L, Ranjan R. Cardiovascular Manifestations in Hyperthyroidism: A Cross-Sectional Study in a Tertiary Care Hospital in South India. Cureus. 2022;14(5):e25232.
20. Biondi B, Kahaly GJ. Cardiovascular involvement in patients with different causes of hyperthyroidism. Nat Rev Endocrinol. 2010;6(8):431-43.
21. Presti CF, Hart RG. Thyrotoxicosis, atrial fibrillation, and embolism, revisited. The American heart journal. 1989;117(4):976-7.
22. Fan SWD, Ong LT. Prevalence and Risk Factors of Heart Failure in Patients Diagnosed with Hyperthyroidism: A Systematic Review and Meta-analysis. touchREV Endocrinol. 2024;20(2):91-9.
23. Scicchitano P, Dentamaro I, Tunzi F, Ricci G, Carbonara S, Devito F, et al. Pulmonary hypertension in thyroid diseases. Endocrine. 2016;54:578-87.
24. Berta E, Lengyel I, Halmi S, Zrínyi M, Erdei A, Harangi M, et al. Hypertension in thyroid disorders. Frontiers in endocrinology. 2019;10:482.

Appendix

Table 1. Quality assessment of studies using the JBI critical appraisal tool for descriptive cross-sectional studies.

Author s	Was the sample frame appropriate to address the target population?	Were study participants sampled in an appropriate way?	Was the sample size adequate ?	Were the study subjects and the setting described in detail?	Was the data analysis conducted with sufficient coverage of the identified sample?	Were valid methods used for the identification of the condition?	Was the condition measured in a standard, reliable way for all participants?	Was there appropriate statistical analysis?	Was the response rate adequate, and if not, was the low response rate managed appropriately?	Score (Yes/9)
Abera et al	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	No	7
Assefa et al	Yes	Unclear	Yes	Yes	Unclear	Yes	Yes	Yes	No	6
Merasha et al.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Unclear	8
Mulatu et al	Yes	Yes	Yes	Yes	Unclear	Yes	Yes	Yes	No	7
bade et al	Yes	No	unclear	Yes	Yes	Yes	No	Yes	Yes	5
Tefera et al	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	9
Eshetu et al	Yes	Yes	Yes	Yes	Yes	Yes	Unclear	Yes	Unclear	7

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