



Research Article

## Mechanisms of Autonomic Dysfunction in Hypothyroidism and Associated Cardiovascular Outcomes

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### ABSTRACT

Hypothyroidism is strongly linked with alterations in autonomic nervous system (ANS) control of the cardiovascular system, reflected in changes in heart rate variability (HRV), baroreflex sensitivity, vascular tone and electrophysiological stability. These autonomic changes contribute to an increased risk of hypertension, atherosclerosis, heart failure and arrhythmias, even in subclinical disease. Thyroid hormones act at multiple levels of the central and peripheral autonomic network, including the central autonomic nuclei, baroreflex pathways, vascular endothelium, myocardium and metabolic-inflammatory milieu. In overt hypothyroidism, the typical pattern is reduced sympathetic and parasympathetic cardiac modulation with impaired baroreflex function and increased systemic vascular resistance. Subclinical hypothyroidism shows similar but milder disturbances. Growing evidence indicates that a portion of the excess cardiovascular risk in hypothyroidism is mediated through autonomic dysregulation. This narrative review summarises current knowledge on the mechanisms linking thyroid hormone deficiency to autonomic dysfunction and synthesises clinical evidence relating these mechanisms to cardiovascular outcomes. It also highlights the reversibility of some autonomic abnormalities with levothyroxine therapy and proposes directions for future research, including standardized autonomic testing protocols and the use of HRV and baroreflex indices as prognostic tools in hypothyroid populations.

**Keywords:** hypothyroidism, autonomic nervous system, heart rate variability, baroreflex, endothelial dysfunction, cardiovascular disease.

### INTRODUCTION

Thyroid hormones play a key role in regulating systemic metabolism, cardiovascular function and autonomic balance. The heart and vascular system express a high density of thyroid hormone receptors, and thyroid status modulates heart rate, cardiac output, systemic vascular resistance and blood pressure(1). Both excess and deficiency of thyroid hormone are associated with cardiovascular disease (CVD), but the pathways by which hypothyroidism contributes to CVD are multifactorial and incompletely understood.(2)

Overt hypothyroidism classically produces sinus bradycardia, reduced cardiac output, increased peripheral vascular resistance, diastolic hypertension and characteristic electrocardiographic changes such as QTc prolongation (1). Subclinical hypothyroidism, defined by elevated TSH with normal free thyroid hormone levels, has fewer overt hemodynamic manifestations but has been linked to hypertension, dyslipidemia, increased carotid intima-media thickness and higher CVD events and mortality (3).

Autonomic dysfunction is increasingly recognized as a key intermediate between thyroid hormone deficiency and adverse cardiovascular outcomes. Multiple studies have demonstrated altered HRV, impaired baroreflex sensitivity and abnormal cardiovascular reflexes in hypothyroid patients, with partial normalization after levothyroxine replacement (4). Low HRV and impaired autonomic regulation are themselves established predictors of arrhythmia, sudden death and heart failure in other populations, suggesting a plausible mechanistic link (5).

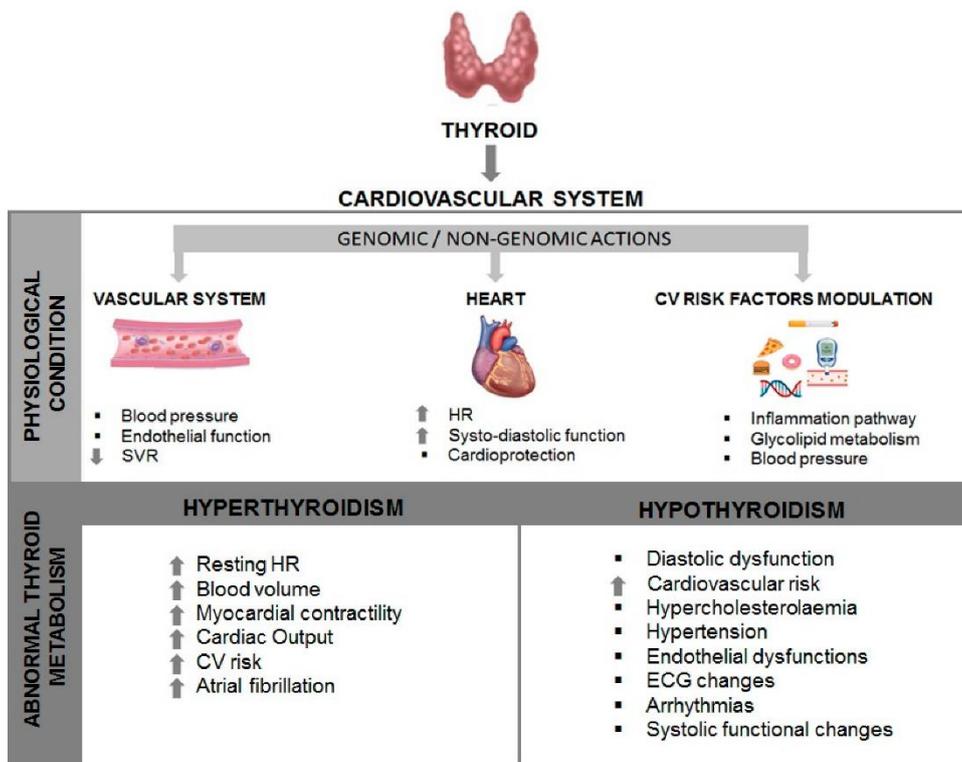
**This review focuses on:**

1. The physiological basis of thyroid–autonomic interactions.
2. Mechanisms by which hypothyroidism disrupts autonomic control.
3. Evidence for autonomic dysfunction in hypothyroid patients.
4. The contribution of these disturbances to cardiovascular outcomes.

**2. Thyroid Physiology and Autonomic Regulation**

Thyroid hormones (T3 and T4) influence cardiovascular and autonomic function through genomic and non-genomic actions. In the heart, they regulate expression of ion channels,  $\beta$ -adrenergic receptors, calcium-handling proteins and myosin heavy-chain isoforms, thereby modulating contractility, relaxation and chronotropy (1). At the vascular level, thyroid hormones promote nitric oxide (NO) synthesis, reduce systemic vascular resistance and improve endothelial-dependent vasodilation (6). The autonomic nervous system (ANS) integrates central and peripheral inputs to maintain cardiovascular homeostasis through sympathetic and parasympathetic efferents. HRV and baroreflex sensitivity (BRS) are widely used non-invasive markers of autonomic modulation. High HRV and preserved BRS reflect a flexible and adaptive ANS, whereas low HRV and blunted BRS indicate impaired autonomic control and increased cardiovascular risk (7).

Thyroid status modulates the balance of sympathetic and parasympathetic influences on the heart and vasculature. Experimental work shows that hypothyroidism enhances the contribution of autonomic input to resting arterial pressure and heart rate and alters baroreflex gain (8). In humans, both hyperthyroidism and hypothyroidism are associated with reduced HRV, suggesting an overall loss of autonomic flexibility irrespective of the direction of hormonal imbalance (4). The broad cardiovascular effects of thyroid hormones, mediated through genomic and non-genomic mechanisms, are summarized in Figure 1.



**Figure 1. Cardiovascular effects of thyroid hormones in normal and abnormal thyroid states(1).**

Thyroid hormones influence the cardiovascular system through genomic and non-genomic mechanisms affecting the heart, vascular system, and cardiovascular risk factor modulation. Hyperthyroidism is characterized by increased heart rate, cardiac output, myocardial contractility, and risk of atrial fibrillation, whereas hypothyroidism is associated with diastolic dysfunction, endothelial dysfunction, hypertension, dyslipidemia, electrophysiological changes, and increased cardiovascular risk.

**3. Pathophysiological Mechanisms of Autonomic Dysfunction in Hypothyroidism**

**3.1 Central autonomic network**

Thyroid hormone receptors are widely expressed in the hypothalamus, brainstem and limbic structures that form the central autonomic network. Alterations in thyroid status can change neurotransmitter systems, including noradrenergic, cholinergic and serotonergic pathways, and modify neuronal excitability(1). In hypothyroidism, reduced T3 availability may blunt central sympathetic drive in some circuits, while chronic hemodynamic load and metabolic stress can secondarily activate compensatory sympathetic outflow. The net result is often a paradoxical pattern of low resting heart rate with signs of

sympathetic predominance in HRV indices (e.g., relatively increased low-frequency power and decreased high-frequency power) (9).

### 3.2 Baroreflex dysfunction and arterial stiffness

The arterial baroreflex is critical for short-term blood pressure regulation. Animal studies show that hypothyroid states alter baroreflex gain and change the relative contributions of sympathetic and parasympathetic components to blood pressure and heart rate regulation (8). Increased arterial stiffness, a known feature of hypothyroidism, may further impair baroreceptor stretch and afferent signaling, leading to blunted baroreflex sensitivity (3). Reduced baroreflex sensitivity has been associated with ventricular arrhythmias, sudden cardiac death and poor outcomes after myocardial infarction in other populations (5). In hypothyroid patients, impaired BRS thus represents a plausible mechanistic link between hormonal deficiency, autonomic dysfunction and arrhythmic risk.

### 3.3 Vascular and endothelial mechanisms

Hypothyroidism increases systemic vascular resistance, elevates diastolic blood pressure and promotes endothelial dysfunction (6). Reduced NO bioavailability, increased oxidative stress, low-grade inflammation and changes in smooth muscle reactivity have all been proposed. Coronary endothelial dysfunction has been documented in hypothyroid individuals, even after adjustment for traditional risk factors (10). Endothelial dysfunction and increased arterial stiffness can modulate reflex control of vascular tone and interact with autonomic signaling, effectively “resetting” baroreflex curves and increasing sympathetic vasoconstrictor drive to maintain blood pressure. Over time, this contributes to structural vascular remodeling and raises afterload, further burdening the myocardium.

### 3.4 Myocardial and electrophysiological changes

In hypothyroidism, reduced expression of calcium-handling proteins and  $\beta$ -adrenergic receptors leads to impaired myocardial contractility and relaxation, while increased peripheral resistance reduces stroke volume and cardiac output (1). Electrocardiographic features include sinus bradycardia, low-voltage QRS complexes, T-wave changes and QTc prolongation, the latter predisposing to torsades de pointes in severe cases.(6) These intrinsic myocardial changes interact with autonomic modulation. A heart with reduced  $\beta$ -adrenergic responsiveness may show attenuated chronotropic response to sympathetic stimuli, but at the same time be more vulnerable to repolarization instability when sympathetic bursts occur on a substrate of prolonged QT. Thus, even if absolute sympathetic tone is not extremely high, the combination of low HRV, impaired BRS and prolonged repolarization may increase arrhythmia risk.

### 3.5 Metabolic, inflammatory and hormonal pathways

Hypothyroidism is associated with dyslipidemia, insulin resistance, weight gain, increased homocysteine and pro-inflammatory cytokines(11). These factors promote endothelial dysfunction and atherosclerosis and also affect autonomic regulation. Chronic low-grade inflammation and oxidative stress are known to depress HRV and shift autonomic balance toward sympathetic dominance (5). Renin–angiotensin–aldosterone system (RAAS) activity is often altered in hypothyroidism, with some studies suggesting reduced renin and aldosterone but increased vasopressin and catecholamine sensitivity (1). These hormonal changes can modify baroreflex set-points and vascular tone, reinforcing autonomic abnormalities.

### 3.6 Peripheral neuropathy and small-fiber involvement

Long-standing hypothyroidism is linked with peripheral neuropathy, including sensory, motor and autonomic fibers. Small-fiber neuropathy can affect sudomotor, vasomotor and cardiac autonomic function (12). Patients may present with reduced sweating, cold intolerance, orthostatic symptoms and abnormal cardiovascular reflex responses. Autonomic neuropathy of this type is likely to be less reversible with standard hormone replacement, especially in older patients or those with prolonged untreated disease.

The interaction between thyroid hormone deficiency, autonomic dysregulation, and cardiovascular pathology is multifactorial. The major autonomic alterations observed in hypothyroidism and their underlying mechanisms, along with associated cardiovascular consequences, are summarized in Table 1.

**Table 1. Autonomic Alterations and Cardiovascular Consequences in Hypothyroidism**

This table helps readers quickly connect mechanisms with outcomes. Reviewers usually like this.

Domain	Autonomic Change	Pathophysiological Mechanism	Cardiovascular Outcome
Heart rate control	Reduced HRV ( $\downarrow$ SDNN, $\downarrow$ HF)	Reduced parasympathetic modulation, altered $\beta$ -adrenergic responsiveness	Arrhythmias, sudden cardiac death
Baroreflex function	Blunted BRS	Arterial stiffness, impaired afferent signaling	BP variability, ventricular arrhythmias
Vascular tone	Sympathetic vasoconstrictor predominance	Endothelial dysfunction, $\downarrow$ nitric oxide	Diastolic hypertension

Myocardial electrophysiology	QTc prolongation	Altered ion channel expression, autonomic instability	Ventricular arrhythmias
Orthostatic regulation	Impaired reflex responses	Autonomic neuropathy, low cardiac output	Dizziness, presyncope
Long-term regulation	Reduced autonomic flexibility	Chronic inflammation, metabolic stress	Heart failure, increased mortality

*Note:* The table summarizes autonomic changes and associated cardiovascular outcomes in hypothyroidism based on previously published experimental and clinical studies.<sup>1-7</sup>

#### 4. Evidence for Autonomic Dysfunction in Hypothyroidism

##### 4.1 Heart rate variability

HRV is a key tool for assessing cardiac autonomic modulation. Multiple cross-sectional studies have shown reduced HRV in overt hypothyroidism compared to healthy controls, characterized by lower time-domain indices (e.g., SDNN, RMSSD) and reduced high-frequency (HF) power, indicating decreased parasympathetic modulation (9). Some studies also report relatively increased low-frequency (LF)/HF ratio, consistent with sympathovagal imbalance. A 2019 study using both linear and nonlinear HRV analysis reported attenuated autonomic responses to postural change in hypothyroid subjects, suggesting impaired dynamic regulation rather than just a static shift in resting tone (13). More recent work confirms that both overt and subclinical thyroid dysfunction are associated with lower HRV, and that HRV correlates with TSH and free T4 levels(4). Low HRV is independently associated with higher risk of cardiovascular morbidity and mortality in the general population, making these findings clinically relevant (7).

##### 4.2 Baroreflex sensitivity and blood pressure variability

Baroreflex sensitivity is less frequently studied than HRV but provides complementary information. Experimental work has demonstrated reduced BRS in hypothyroid states, consistent with altered baroreceptor mechanics and central integration (8). Human data are more limited, but available studies show blunted heart rate responses to blood pressure changes during pharmacological or postural testing in hypothyroid patients, suggesting impaired baroreflex control (4). Increased blood pressure variability, a marker of autonomic and vascular dysfunction, has been reported in patients with thyroid dysfunction and is associated with higher cardiovascular risk (12).

##### 4.3 Orthostatic intolerance and cardiovascular reflex tests

Classical autonomic function tests (deep breathing, Valsalva maneuver, sustained handgrip and active standing) reveal abnormalities in a proportion of hypothyroid patients. Studies report reduced heart rate response to deep breathing and standing, and in some cases, delayed or exaggerated blood pressure changes during postural challenge, reflecting mixed parasympathetic and sympathetic dysfunction(14). Clinically, some patients complain of fatigue, exercise intolerance, dizziness or presyncope on standing, which may be partly attributable to autonomic dysregulation superimposed on low cardiac output and increased vascular resistance (15).

##### 4.4 Subclinical versus overt hypothyroidism

Subclinical hypothyroidism (SCH) has milder biochemical and clinical abnormalities but is common in the general population. Several studies suggest that SCH is also associated with reduced HRV and subtle autonomic dysfunction, although effect sizes are smaller than in overt disease (4). SCH is linked with higher prevalence of hypertension, metabolic syndrome and subclinical atherosclerosis(3). A large cohort analysis found that CVD events mediated the relationship between SCH and all-cause mortality, emphasizing the importance of cardiovascular pathways in this population (16). Autonomic dysfunction may be one of the mechanisms through which SCH increases cardiovascular risk, although direct causal evidence is still limited.

##### 4.5 Reversibility with levothyroxine therapy

Several studies have evaluated the effect of levothyroxine therapy on autonomic indices. Early work showed that HRV improves after restoration of euthyroidism, with increases in time-domain and HF indices and partial normalization of LF/HF ratio (17). More recent data confirm that both HRV and some reflex responses improve after adequate thyroid hormone replacement, particularly in younger individuals and those with shorter disease duration (4). However, not all abnormalities fully reverse, especially in long-standing disease or where structural cardiovascular changes have occurred. This suggests a window of opportunity for early diagnosis and treatment to prevent irreversible autonomic and vascular damage.

#### 5. Cardiovascular Outcomes Associated with Autonomic Dysfunction

##### 5.1 Hypertension and diastolic dysfunction

Increased systemic vascular resistance in hypothyroidism contributes to diastolic hypertension and concentric left ventricular remodeling (1). Autonomic mechanisms are involved: impaired baroreflex buffering and heightened sympathetic vasoconstrictor drive can sustain elevated blood pressure and increase short-term variability, both of which are associated with target organ damage (8).

Diastolic dysfunction, related to delayed myocardial relaxation and increased afterload, is frequently observed on echocardiography in overt and subclinical hypothyroidism (1). Autonomic imbalance (reduced parasympathetic and altered sympathetic tone) may worsen diastolic function by limiting heart rate adaptation and impairing coronary perfusion, particularly during exertion.

### **5.2 coronary artery disease and atherosclerosis**

Hypothyroidism and SCH are associated with increased LDL-cholesterol, lipoprotein(a), and pro-atherogenic inflammatory markers, contributing to coronary artery disease (CAD).(3). Impaired coronary endothelial function has been demonstrated in hypothyroid patients and is associated with reduced flow-mediated dilation and abnormal coronary vasomotion (10). Autonomic dysfunction may contribute to CAD progression and instability. Low HRV and impaired BRS are linked with plaque vulnerability, coronary vasospasm and adverse outcomes after myocardial infarction (10). In hypothyroidism, these autonomic abnormalities co-exist with metabolic and endothelial risk factors, creating a “high-risk phenotype” that may not be fully captured by traditional markers.

### **5.3 Arrhythmias and sudden cardiac death**

Although hyperthyroidism is more classically associated with atrial fibrillation, hypothyroidism is not electrophysiologically benign. QTc prolongation, low HRV and impaired BRS all increase susceptibility to ventricular arrhythmias and sudden cardiac death in other contexts (6). Population data suggest that both overt and subclinical hypothyroidism are associated with increased risk of major adverse cardiovascular events and mortality, with some studies implicating arrhythmic mechanisms (16). HRV-based studies in hypothyroid patients consistently show patterns associated with higher arrhythmic risk (low SDNN, reduced HF power), although direct linkage with clinical arrhythmia endpoints remains under-studied(4).

### **5.4 Heart failure and long-term mortality**

Hypothyroidism reduces cardiac output, impairs myocardial relaxation and increases systemic vascular resistance, all of which can precipitate or worsen heart failure in susceptible individuals(1). Observational studies indicate that low thyroid function is associated with higher incidence of heart failure and worse prognosis among patients with established CVD (2). Autonomic dysfunction is a recognized driver of disease progression and mortality in heart failure. Low HRV and impaired BRS predict hospitalization and death, and interventions that improve autonomic balance (e.g., exercise training, certain pharmacotherapies) improve outcomes (5). In hypothyroid patients, autonomic abnormalities may therefore be a key pathway through which thyroid dysfunction worsens heart failure and increases mortality risk.

## **6. Clinical Implications and Future Directions**

1. Routine consideration of autonomic involvement: Clinicians managing hypothyroid patients, particularly those with cardiovascular comorbidities, should be aware that symptoms such as fatigue, exercise intolerance, dizziness and palpitations may reflect autonomic involvement, not only “slow metabolism.” Simple bedside tests (orthostatic blood pressure and heart rate, deep breathing HR response) can provide preliminary information on autonomic function (14).
2. Potential role of HRV and BRS as risk markers: HRV analysis is non-invasive and increasingly accessible. Given its association with thyroid status and cardiovascular risk, HRV could serve as a useful adjunct to traditional risk stratification in hypothyroid patients, especially those with established CVD or heart failure (4). Baroreflex assessment remains more specialized but may be valuable in research and high-risk cases.
3. Importance of optimal thyroid hormone replacement: Data suggest that restoring and maintaining euthyroidism improves HRV, vascular function and some structural cardiac parameters(17). Both undertreatment and overtreatment appear harmful, with increased cardiovascular events when TSH is persistently high or suppressed (18). This underscores the need for individualized levothyroxine dosing and regular biochemical and clinical follow-up.
4. Integrating lifestyle and cardioprotective therapies: Because autonomic dysfunction is influenced by physical inactivity, obesity, sleep disturbance and psychological stress, lifestyle interventions that improve cardiorespiratory fitness and reduce stress can enhance HRV and possibly mitigate cardiovascular risk.[MDPI+1](#) In patients with significant CVD, standard cardioprotective strategies (statins, blood pressure control, RAAS blockade,  $\beta$ -blockers where appropriate) remain essential and may indirectly improve autonomic balance.

## **5. Research priorities.**

Future work should address several gaps:

- Prospective studies linking quantified autonomic indices (HRV, BRS, BP variability) with hard cardiovascular outcomes in overt and subclinical hypothyroidism.
- Randomized trials assessing whether treatment decisions guided partly by autonomic markers improve prognosis compared with biochemical monitoring alone.
- Mechanistic studies dissecting central vs peripheral contributions to autonomic changes, including neuroimaging and advanced autonomic testing.
- Exploration of adjunct therapies (e.g., supervised exercise, vagal stimulation, breathing interventions) aimed at directly improving autonomic tone in high-risk hypothyroid populations.

## CONCLUSION

Hypothyroidism affects the cardiovascular system not only through hemodynamic and metabolic changes but also by disrupting autonomic regulation. Evidence from HRV, baroreflex and reflex testing demonstrates a pattern of reduced overall autonomic flexibility, impaired parasympathetic modulation and altered sympathetic control in both overt and subclinical disease. These abnormalities are closely linked to hypertension, endothelial dysfunction, arrhythmias, heart failure and increased cardiovascular events and mortality. Some autonomic disturbances improve with timely and adequate levothyroxine therapy, highlighting the importance of early diagnosis and optimal management of thyroid dysfunction. However, residual autonomic and structural cardiovascular abnormalities may persist in long-standing or poorly controlled disease. Incorporating autonomic assessment into clinical and research practice offers an opportunity to refine cardiovascular risk stratification and potentially guide targeted interventions in patients with hypothyroidism.

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## CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this manuscript.

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## STATEMENT OF INFORMED CONSENT

This article is a narrative review based on previously published studies. No new studies involving human participants or animals were performed by the authors. Therefore, informed consent was not required.

## ETHICS APPROVAL STATEMENT

Ethical approval was not required for this study as it is a narrative review of previously published literature and does not involve direct experimentation on human or animal subjects.

## REFERENCE

1. Razvi S, Jabbar A, Pingitore A, Danzi S, Biondi B, Klein I, et al. Thyroid Hormones and Cardiovascular Function and Diseases. *J Am Coll Cardiol* [Internet]. 2018 Apr 24 [cited 2025 Dec 1];71(16):1781–96. Available from: /doi/pdf/10.1016/j.jacc.2018.02.045?download=true
2. Cappola AR, Desai AS, Medici M, Cooper LS, Egan D, Sopko G, et al. Thyroid and Cardiovascular Disease: Research Agenda for Enhancing Knowledge, Prevention, and Treatment. *Circulation* [Internet]. 2019 Jun 18 [cited 2025 Dec 1];139(25):2892–909. Available from: /doi/pdf/10.1161/CIRCULATIONAHA.118.036859?download=true
3. Suh S, Kim DK. Subclinical Hypothyroidism and Cardiovascular Disease. *Endocrinology and Metabolism* [Internet]. 2015 [cited 2025 Dec 1];30(3):246–51. Available from: [http://www.e-enm.org/journal/view.php?number=1664&utm\\_source=chatgpt.com](http://www.e-enm.org/journal/view.php?number=1664&utm_source=chatgpt.com)
4. Bogdan C, Ivan VM, Apostol A, Sandu OE, Maralescu FM, Lighezan DF. Hypothyroidism and Heart Rate Variability: Implications for Cardiac Autonomic Regulation. *Diagnostics* [Internet]. 2024 Jun 1 [cited 2025 Dec 1];14(12):1261. Available from: <https://pmc.ncbi.nlm.nih.gov/articles/PMC11202468/>
5. Sgoifo A, Carnevali L, Pico Alfonso MDLA, Amore M. Autonomic dysfunction and heart rate variability in depression. *Stress* [Internet]. 2015 May 4 [cited 2025 Dec 1];18(3):343–52. Available from: <https://www.tandfonline.com/doi/pdf/10.3109/10253890.2015.1045868>
6. Khan R, Sikanderkhel S, Gui J, Adeniyi AR, O'Dell K, Erickson M, et al. Thyroid and Cardiovascular Disease: A Focused Review on the Impact of Hyperthyroidism in Heart Failure. *Cardiol Res* [Internet]. 2020 [cited 2025 Dec 1];11(2):68. Available from: <https://pmc.ncbi.nlm.nih.gov/articles/PMC7092768/>
7. Brusseau V, Tauveron I, Bagheri R, Ugbolue UC, Magnon V, Bouillon-Minois JB, et al. Heart Rate Variability in Hyperthyroidism: A Systematic Review and Meta-Analysis. *Int J Environ Res Public Health* [Internet]. 2022 Mar 1 [cited 2025 Dec 1];19(6):3606. Available from: <https://www.mdpi.com/1660-4601/19/6/3606/htm>
8. Foley CM, McAllister RM, Hasser EM. Thyroid status influences baroreflex function and autonomic contributions to arterial pressure and heart rate. <https://doi.org/10.1152/ajpheart.2001.280.5.H2061> [Internet]. 2001 [cited 2025 Dec 1];280(5 49-5):2061–8. Available from: /doi/pdf/10.1152/ajpheart.2001.280.5.H2061?download=true
9. Ahmed M, Begum N, Ferdousi S, Begum S, Ali T. Power Spectral Analysis of Heart Rate Variability In Hypothyroidism. *Journal of Bangladesh Society of Physiologist* [Internet]. 2010 Jan 1 [cited 2025 Dec 1];5(2):53–9. Available from: <https://www.banglajol.info/index.php/JBSP/article/view/6777>
10. Sara JD, Zhang M, Gharib H, Lerman LO, Lerman A. Hypothyroidism Is Associated With Coronary Endothelial Dysfunction in Women. *J Am Heart Assoc* [Internet]. 2015 Jul 29 [cited 2025 Dec 1];4(8):e002225. Available from: /doi/pdf/10.1161/JAHA.115.002225?download=true

11. Patrizio A, Ferrari SM, Elia G, Ragusa F, Balestri E, Botrini C, et al. Hypothyroidism and metabolic cardiovascular disease. *Front Endocrinol (Lausanne)*. 2024 Jun 3;15:1408684.
12. Ahmadi N, Ahmadi F, Sadiqi M, Ziennicka K, Minczykowski A. Thyroid gland dysfunction and its effect on the cardiovascular system: A comprehensive review of the literature. Vol. 71, *Endokrynologia Polska*. Via Medica; 2020. p. 466–78.
13. Hoshi RA, Andreão R V., Santos IS, Dantas EM, Mill JG, Lotufo PA, et al. Linear and nonlinear analyses of heart rate variability following orthostatism in subclinical hypothyroidism. *Medicine (United States)* [Internet]. 2019 Jan 1 [cited 2025 Dec 1];98(4). Available from: [https://journals.lww.com/md-journal/fulltext/2019/01250/linear\\_and\\_nonlinear\\_analyses\\_of\\_heart\\_rate.27.aspx](https://journals.lww.com/md-journal/fulltext/2019/01250/linear_and_nonlinear_analyses_of_heart_rate.27.aspx)
14. Pervin S, Mostafizur Rahman M, Mostana Nazma Begum M, Abdul Quddus M, Rahman F, Professor A. Evaluation of Autonomic Nervous System Dysfunction in Hypothyroid Children. *International Journal of Medical Science in Clinical Research and Review Online* [Internet]. Available from: <https://doi.org/10.5281/zenodo.16729193>
15. Udovicic M, Pena RH, Patham B, Tabatabai L, Kansara A. Hypothyroidism and the Heart. *Methodist Debaquey Cardiovasc J*. 2017 Apr 1;13(2):55–9.
16. Inoue K, Ritz B, Brent GA, Ebrahimi R, Rhee CM, Leung AM. Association of Subclinical Hypothyroidism and Cardiovascular Disease With Mortality. *JAMA Netw Open* [Internet]. 2020 Feb 5 [cited 2025 Dec 1];3(2):e1920745–e1920745. Available from: <https://jamanetwork.com/journals/jamanetworkopen/fullarticle/2760440>
17. Huili ZING, Ying SHEN, Hanbei CHEN, Yichen WNG, Weifen SHEN. Heart Rate variability and its response to thyroxine replacement therapy in patients with hypothyroidism. *Mednexus- Chinese Medical Journal* [Internet]. 2025 [cited 2025 Dec 1];114(9):906–8. Available from: <https://mednexus.org/doi/pdf/10.3760/cma.j.issn.0366-6999.2001.09.103>
18. Lillevang-Johansen M, Abrahamsen B, Jørgensen HL, Brix TH, Hegedüs L. Duration of over- And under-treatment of hypothyroidism is associated with increased cardiovascular risk. *Eur J Endocrinol* [Internet]. 2019 Jun 1 [cited 2025 Dec 1];180(6):407–16. Available from: <https://www.thyroid.org/patient-thyroid-information/ct-for-patients/february-2020/vol-13-issue-2-p-3-4/>