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Original Research Article

Assessment of Vestibulo-Sympathetic Reflex Dysfunction in Patients with Thyroid Disorders Using Caloric Temperature Stimulation and Orthostatic Testing: A Hospital-Based Comparative Study

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Conflict of interest: Nil

Abstract

Background: Thyroid disorders are associated with autonomic nervous system dysfunction, resulting in altered cardiovascular regulation and postural hemodynamic responses. The vestibulo-sympathetic reflex (VSR) plays a crucial role in maintaining cardiovascular stability during postural changes; however, its involvement in thyroid disorders remains poorly understood. This study aimed to assess vestibulo-sympathetic reflex dysfunction in patients with thyroid disorders using caloric temperature stimulation and orthostatic cardiovascular testing.

Materials and Methods: A hospital-based comparative cross-sectional study was conducted over 12 months in the Departments of Physiology and Otorhinolaryngology. A total of 120 participants were enrolled into three groups: hypothyroidism (n=40), hyperthyroidism (n=40), and healthy euthyroid controls (n=40). Thyroid function was assessed using serum TSH, FT3, and FT4 levels. Vestibulo-sympathetic reflex function was evaluated by caloric temperature stimulation, while autonomic cardiovascular responses were assessed using orthostatic testing. Heart rate and blood pressure responses were compared among the three groups.

Results: Patients with hypothyroidism demonstrated reduced orthostatic heart rate responses and attenuated cardiovascular responses during caloric stimulation, whereas patients with hyperthyroidism exhibited enhanced sympathetic responses compared with healthy controls. Orthostatic cardiovascular parameters and caloric test responses differed significantly among the study groups ($p<0.05$). Serum TSH showed a significant negative correlation with orthostatic heart rate response, while FT3 and FT4 demonstrated positive correlations with vestibulo-autonomic parameters.

Conclusion: Assessment of the vestibulo-sympathetic reflex using caloric temperature stimulation and orthostatic testing appears to be a simple and non-invasive approach for detecting autonomic dysfunction in thyroid disorders. These findings suggest that vestibulo-autonomic assessment may complement routine clinical evaluation and facilitate early identification of autonomic impairment.

Keywords: Thyroid Disorders; Hypothyroidism; Hyperthyroidism; Vestibulo-Sympathetic Reflex; Caloric Test; Orthostatic Test; Autonomic Dysfunction.

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Introduction

Thyroid disorders are among the most common endocrine diseases worldwide and are an important public health problem. Both hypothyroidism and hyperthyroidism affect several body systems, including the cardiovascular, metabolic, and nervous systems. India has a high prevalence of thyroid disorders, particularly among women and older adults. If left untreated, these disorders may lead to cardiovascular complications, neurological symptoms, and reduced quality of life [1,2]. Thyroid hormones, triiodothyronine (T3) and thyroxine (T4), play an essential role in maintaining normal autonomic nervous system (ANS) function. They regulate heart rate, blood pressure, vascular tone, and cardiac contractility. Changes in thyroid hormone levels disturb the balance between sympathetic and parasympathetic activity, resulting in symptoms such as palpitations, dizziness, fatigue, postural hypotension, exercise intolerance, and syncope [3–5]. Hypothyroidism is generally associated with reduced sympathetic activity, decreased heart rate, and impaired baroreflex function, whereas hyperthyroidism is characterized by increased sympathetic activity, tachycardia, and exaggerated cardiovascular responses [4–7].

The vestibulo-sympathetic reflex (VSR) is an important physiological mechanism that helps maintain blood pressure during changes in posture. The vestibular system of the inner ear detects head movement and body position and communicates with autonomic centres in the brainstem. This interaction increases sympathetic activity during standing, thereby maintaining cerebral blood flow and preventing orthostatic hypotension [8–10]. Impairment of the VSR may result in dizziness, postural instability, and orthostatic intolerance [9–12]. Caloric temperature stimulation is a well-established vestibular function test that activates the horizontal semicircular canal by irrigation of the external auditory canal with warm or cold water. Besides producing nystagmus, caloric stimulation also induces measurable changes in heart rate and blood pressure through vestibulo-autonomic pathways [10,13]. Similarly, orthostatic testing is a simple bedside method used to evaluate autonomic cardiovascular function by recording heart rate and blood pressure responses after standing [11,14]. The combined use of these two tests provides a practical method for assessing vestibulo-sympathetic reflex function.

Several Indian studies have reported autonomic dysfunction in patients with hypothyroidism and hyperthyroidism using conventional cardiovascular autonomic function tests such as heart rate variability, Valsalva manoeuvre, deep breathing test, sustained handgrip test, and orthostatic blood pressure measurement.

These studies have demonstrated significant alterations in sympathetic and parasympathetic function in thyroid disorders [5,15–18]. However, very few studies have specifically evaluated vestibulo-sympathetic reflex function in these patients, especially using both caloric temperature stimulation and orthostatic testing. Therefore, the present study was undertaken to assess vestibulo-sympathetic reflex dysfunction in patients with hypothyroidism and hyperthyroidism using caloric temperature stimulation and orthostatic cardiovascular testing. The study also aimed to compare these responses with healthy euthyroid individuals and to determine the relationship between thyroid hormone levels and vestibulo-autonomic function.

Materials and Methods

Study Design and Participants: This hospital-based comparative cross-sectional study was conducted jointly in the Department of Physiology and the Department of Otorhinolaryngology (ENT) at a tertiary care teaching hospital over a period of 12 months after obtaining approval from the Institutional Ethics Committee. Written informed consent was obtained from all participants before enrolment, and the study was carried out in accordance with the Declaration of Helsinki [19,20]. A total of 120 participants aged 18–60 years were included in the study and divided into three groups: Group A comprised patients with newly diagnosed overt hypothyroidism (n=40), Group B included patients with newly diagnosed overt hyperthyroidism (n=40), and Group C consisted of age- and sex-matched healthy euthyroid controls (n=40). The diagnosis of thyroid disorders was established on the basis of clinical evaluation and thyroid function tests (serum TSH, FT3, and FT4) according to the American Thyroid Association guidelines [21].

Sample Size: The sample size was calculated assuming a 95% confidence level, 80% study power, and 5% level of significance. A minimum of 36 participants was required in each group. Considering possible dropouts, 40 participants were enrolled in each group, giving a total sample size of 120 subjects [22].

Inclusion Criteria: Patients aged 18–60 years with newly diagnosed overt hypothyroidism or hyperthyroidism who had not received thyroid-specific treatment were included. Healthy euthyroid volunteers of the same age group served as controls.

Exclusion Criteria: Patients with diabetes mellitus, hypertension on treatment, coronary artery disease, heart failure, cardiac arrhythmias, chronic kidney disease, cerebrovascular disease, peripheral neuropathy, vestibular disorders, previous ear surgery, tympanic membrane perforation, acute or chronic otitis media, pregnancy, lactation, or those receiving medications known to affect autonomic function (β-blockers, calcium channel blockers, antidepressants, or sedatives) were excluded. Individuals unwilling to participate were also excluded.

Study Procedure: After enrolment, demographic and clinical details including age, sex, body mass index (BMI), pulse rate, blood pressure, duration of symptoms, and relevant medical history were recorded using a structured case record form. Following an overnight fast, venous blood samples were collected for estimation of serum TSH, free T3 (FT3), and free T4 (FT4) using a chemiluminescent immunoassay (CLIA) method in the central biochemistry laboratory.

Orthostatic Cardiovascular Testing: Orthostatic testing was performed in a quiet laboratory maintained at 24–26°C. Participants were advised to avoid caffeine, alcohol, smoking, and vigorous physical activity for at least 12 hours before testing.

After resting in the supine position for 10 minutes, baseline heart rate, systolic blood pressure, and diastolic blood pressure were recorded using an automated digital sphygmomanometer. Participants were then asked to stand actively, and heart rate and blood pressure were measured immediately after standing and again at 1 minute and 3 minutes. Changes in heart rate (ΔHR), systolic blood pressure (ΔSBP), and diastolic blood pressure (ΔDBP) were calculated. Orthostatic hypotension was diagnosed according to standard clinical criteria [23].

Caloric Temperature Stimulation: Vestibulo-sympathetic reflex function was assessed in the ENT vestibular laboratory using the standard bithermal caloric test. After otoscopic examination to exclude external and middle ear pathology, each external auditory canal was irrigated sequentially with warm water (44°C) and cold water (30°C) for approximately 30–40 seconds, with adequate intervals between irrigations. During caloric stimulation, the presence and duration of nystagmus, subjective vertigo, heart rate, systolic blood pressure, and diastolic blood pressure were recorded before and immediately after stimulation. Cardiovascular responses elicited during caloric testing were considered indirect measures of vestibulo-sympathetic reflex function.

Statistical Analysis: Data were entered into Microsoft Excel and analysed using IBM SPSS Statistics version 26.0. Continuous variables were expressed as mean ±standard deviation (SD), while categorical variables were expressed as frequencies and percentages. Data normality was assessed using the Shapiro–Wilk test. Comparisons among the three groups were performed using one-way ANOVA followed by Tukey's post hoc test for normally distributed variables, whereas the Kruskal–Wallis test was used for non-normally distributed data. Categorical variables were analysed using the Chi-square test or Fisher's exact test. Correlation between thyroid hormone levels and vestibulo-autonomic parameters was evaluated using Pearson's or Spearman's correlation coefficient, as appropriate.

A p-value <0.05 was considered statistically significant [24].

Results

A total of 120 participants were included in the study, comprising 40 patients with hypothyroidism (Group A), 40 patients with hyperthyroidism (Group B), and 40 healthy euthyroid controls (Group C). All participants completed caloric temperature stimulation and orthostatic cardiovascular testing.

Baseline Characteristics: The three groups were comparable with respect to age and sex distribution (p > 0.05). Patients with hyperthyroidism had a significantly higher resting pulse rate than controls, whereas hypothyroid patients had a lower resting pulse rate.

Table 1: Baseline demographic and clinical characteristics

Variable	Hypothyroidism (n=40)	Hyperthyroidism (n=40)	Controls (n=40)	p-value
Age (years)	39.8 ±10.2	37.9 ±9.4	38.6 ±9.8	0.71
Male/Female	12/28	11/29	13/27	0.93
BMI (kg/m²)	26.3 ±3.4	22.4 ±2.9	24.1 ±3.1	<0.001
Resting HR (beats/min)	67.4 ±8.1	96.8 ±10.4	75.6 ±7.2	<0.001
SBP (mmHg)	118.6 ±10.8	126.7 ±11.6	120.4 ±9.7	0.004
DBP (mmHg)	76.8 ±7.2	78.6 ±6.9	75.5 ±6.4	0.18

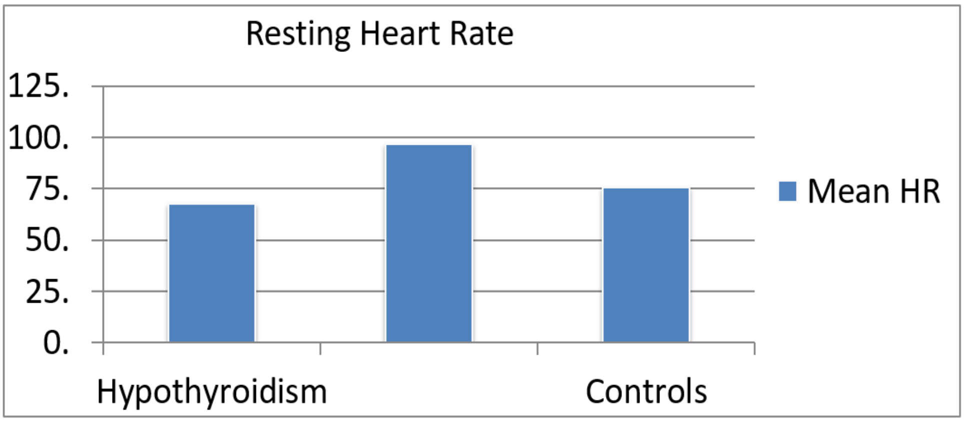

Figure 1: Resting Heart Rate among the Three Study Groups

Thyroid Hormone Profile: As expected, thyroid hormone parameters differed significantly among the three groups.

Table 2: Thyroid function profile

Parameter	Hypothyroidism	Hyperthyroidism	Controls	p-value
TSH (µIU/mL)	18.9 ±6.5	0.08 ±0.05	2.41 ±0.96	<0.001
FT3 (pg/mL)	2.01 ±0.46	6.94 ±1.52	3.42 ±0.51	<0.001
FT4 (ng/dL)	0.61 ±0.18	2.63 ±0.54	1.29 ±0.22	<0.001

Orthostatic Cardiovascular Responses: Hypothetical orthostatic responses differed among the groups.

Table 3: Orthostatic cardiovascular parameters

Parameter	Hypothyroidism	Hyperthyroidism	Controls	p-value
Δ Heart rate (beats/min)	8.6 ±3.1	20.5 ±5.2	13.4 ±3.8	<0.001
Δ SBP (mmHg)	−12.4 ±6.2	−4.1 ±4.3	−6.5 ±3.9	<0.001
Δ DBP (mmHg)	+1.8 ±2.6	+6.1 ±3.2	+3.7 ±2.5	<0.001

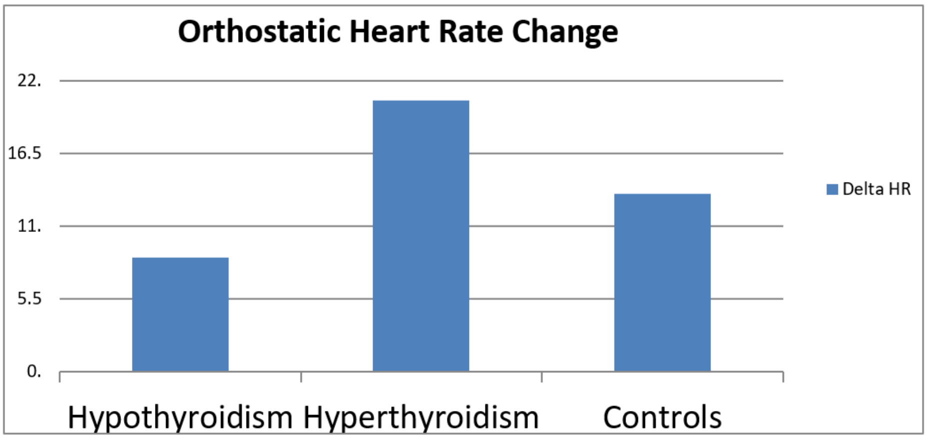

Figure 2: Comparison of Orthostatic Heart Rate Change (ΔHR) among the Three Groups

Caloric Temperature Test Responses: Illustrative vestibulo-autonomic responses are shown below.

Table 4: Caloric stimulation responses

Parameter	Hypothyroidism	Hyperthyroidism	Controls	p-value
Nystagmus duration (seconds)	88.6 ±14.3	118.5 ±18.7	101.4 ±15.8	<0.001
Heart rate change (beats/min)	4.1 ±2.0	11.2 ±3.4	7.2 ±2.5	<0.001
SBP change (mmHg)	2.4 ±3.1	8.6 ±4.2	5.1 ±3.5	<0.001

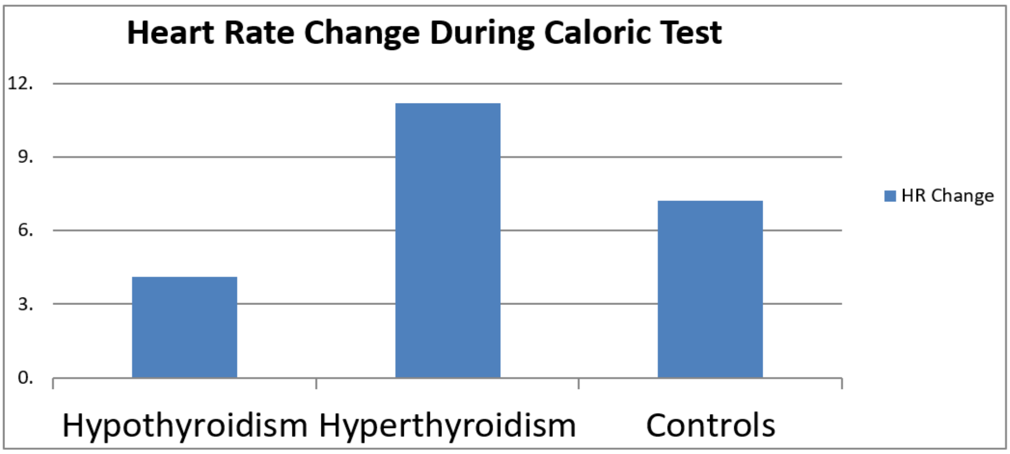

Figure 3: Comparison of Heart Rate Response during Caloric Temperature Stimulation

Correlation Analysis

Table 5: Illustrative correlation between thyroid hormones and autonomic parameters

Variable	r	p-value
TSH vs Δ Heart rate	-0.48	<0.001
TSH vs Δ SBP	-0.41	0.002
FT3 vs Caloric HR response	0.52	<0.001
FT4 vs Caloric HR response	0.46	<0.001

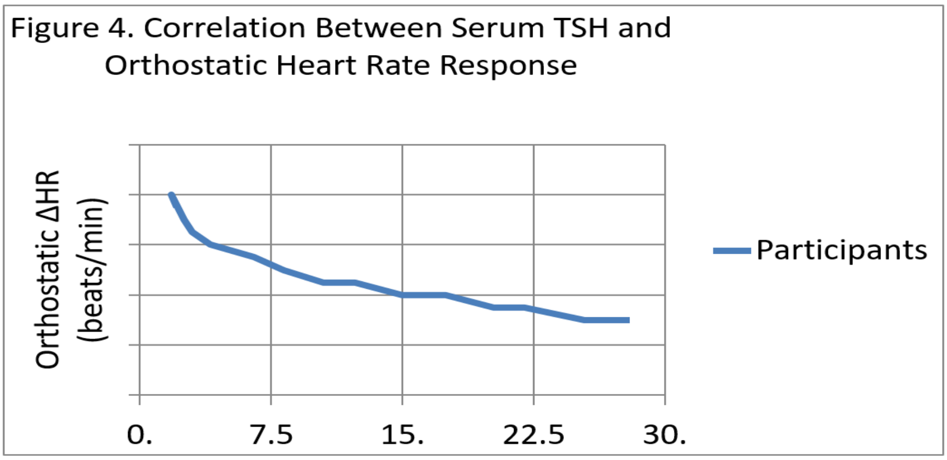

Figure 4. Scatter Plot Showing Correlation between Serum TSH and Orthostatic Heart Rate Response (ΔHR)

Discussion

The present study evaluated vestibulo-sympathetic reflex (VSR) function in patients with hypothyroidism and hyperthyroidism using caloric temperature stimulation and orthostatic cardiovascular testing.

The findings suggest that thyroid dysfunction is associated with significant alterations in autonomic cardiovascular regulation. Patients with hypothyroidism showed reduced orthostatic and vestibulo-autonomic responses, whereas patients with hyperthyroidism demonstrated exaggerated sympathetic responses compared with healthy controls. These findings indicate that thyroid hormones play an important role in maintaining vestibulo-autonomic function.

In the present study, the three groups were comparable in terms of age and sex, reducing the possibility of demographic bias. Similar age- and sex-matched study designs have been used in previous Indian studies evaluating autonomic dysfunction in thyroid disorders [15,16].

A lower resting heart rate observed in hypothyroid patients and a higher resting heart rate in hyperthyroid patients are consistent with the known physiological effects of thyroid hormones. Reduced sympathetic activity and decreased β-adrenergic responsiveness in hypothyroidism lead to bradycardia, whereas increased β-adrenergic sensitivity in hyperthyroidism results in tachycardia [4,6]. Similar observations have been reported by Mahajan et al. [3], Syamsunder et al. [4], and Paul et al. [6]. Orthostatic testing showed impaired cardiovascular adaptation in patients with hypothyroidism, reflected by a smaller increase in heart rate and a greater fall in systolic blood pressure after standing. In contrast, patients with hyperthyroidism showed greater heart rate responses during standing. These findings are comparable with those reported by Mahajan et al. [3] and Lakshmi et al. [19], who demonstrated significant autonomic dysfunction in thyroid disorders using conventional cardiovascular autonomic function tests.

Caloric temperature stimulation also demonstrated altered vestibulo-autonomic responses in patients with thyroid dysfunction. Hypothyroid patients exhibited reduced cardiovascular responses during vestibular stimulation, whereas hyperthyroid patients showed exaggerated responses. These observations support the role of the vestibulo-sympathetic reflex in cardiovascular regulation during postural stress and are in agreement with the physiological concepts described by Yates et al. [9] and Ray and Carter [10], who reported that vestibular stimulation activates sympathetic pathways involved in blood pressure regulation.

The present study also found a significant relationship between thyroid hormone levels and autonomic parameters. Higher serum TSH levels were associated with reduced orthostatic cardiovascular responses, while higher FT3 and FT4 levels showed positive associations with vestibulo-autonomic activity. Similar correlations between thyroid hormone status and autonomic function have been reported in previous studies evaluating heart rate variability and cardiovascular reflex tests [5,17]. The findings of the present study have important clinical implications. Patients with thyroid disorders frequently complain of dizziness, imbalance, and postural symptoms even in the absence of overt vestibular disease. Assessment of vestibulo-sympathetic reflex function using caloric stimulation and orthostatic testing may help identify early autonomic dysfunction and guide timely clinical management. Both tests are simple, non-invasive, inexpensive, and can be performed in routine clinical practice.

The major strength of this study is the combined assessment of vestibular and autonomic function using two simple physiological tests. However, the study was conducted at a single centre with a relatively small sample size. In addition, caloric testing evaluates mainly the horizontal semicircular canal and may not represent the function of the entire vestibular system. Larger multicentre studies using advanced autonomic and vestibular investigations are recommended to further validate these findings. Overall, the present study suggests that thyroid dysfunction is associated with impairment of vestibulo-sympathetic reflex function, with reduced autonomic responses in hypothyroidism and increased sympathetic activity in hyperthyroidism. These findings support the use of caloric temperature stimulation and orthostatic testing as useful physiological tools for evaluating autonomic dysfunction in patients with thyroid disorders.

Conclusion

The present study suggests that thyroid disorders are associated with changes in vestibulo-sympathetic reflex and autonomic function. Patients with hypothyroidism showed reduced autonomic responses, while patients with hyperthyroidism showed increased sympathetic activity during caloric stimulation and orthostatic testing. These tests are simple, non-invasive, and useful for the early detection of autonomic dysfunction in thyroid disorders. Further studies with larger sample sizes are needed to confirm these findings and establish their clinical significance.

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