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ORIGINAL ARTICLE *Volume 14 (Issue 4), 2025*

PAKISTAN JOURNAL OF MEDICINE & DENTISTRY

Evaluating the Effect of Hypothyroidism on Basal Metabolic Rate and Body Temperature Regulation

Wazeela Ahmad[1], Sabiya Kadeer[2], Fizza Tariq[3], Nargis Haider[4], Shazia Azhar[5], Ejaz Ahmed[6]

[1]Department of Pathology, Superior University, Lahore, [2]Department of Physiopathology, de'Montmorency college of Dentistry, Lahore, [3]Department of Physiology, Baqai Medical University, Karachi, [4]Department of Physiology Bolan Medical College, Quetta, [5]Department of Medical Technology, Baqai Institute of Medical Technology, Baqai Medical University, Karachi, Pakistan, [6]School of Pathology, International Max Planck Research Institute, Berlin, Germany.

ABSTRACT

Background: Hypothyroidism is a clinical condition resulting from inadequate production of thyroid hormone, which is an important regulator of basal metabolic rate (BMR) and thermoregulation. Slow metabolism and altered thermogenesis experienced by hypothyroid patients may result in significant physiological disruption. This study aimed to evaluate the impact of hypothyroidism on body temperature regulation and BMR in adults with primary hypothyroidism.

Methods: It was a cross-sectional analytical study, conducted with 200 adults aged 25-50 years were enrolled, consisting of 100 hypothyroid patients and 100 age- and sex-matched healthy controls. The indirect calorimetry was used to measure the BMR, and the core body temperature was measured by digital thermometry in a controlled ambient condition. The chemiluminescent immunoassay was used to measure thyroid function, including thyroid-stimulating hormone (TSH), triiodothyronine (T3), and thyroxine (T4). Independent t-test was used to measure continuous variables, and chi-square test for categorical variables through SPSS. $p < 0.05$ was considered statistically significant.

Results: The hypothyroid group demonstrated lower BMR compared to controls (1195.8 ± 105.4 kcal/day vs. 1362.7 ± 112.3 kcal/day; $p < 0.001$). A decrease in core body temperature was also observed ($p < 0.001$). There was a significant alteration in thyroid hormone levels with increased TSH (9.22 ± 2.1 IU/mL) and decreased free T3 (2.12 ± 0.5 pg/mL) and T4 (0.62 ± 0.2 ng/dL) in the hypothyroid group (all $p < 0.001$).

Conclusion: Hypothyroidism significantly diminishes metabolism rate and affects thermoregulation, highlighting that diagnosis and intervention are necessary.

Keywords: Hypothyroidism, Thyrotropin, Triiodothyronine, Thyroxine, Body Temperature.
***Corresponding Author:** Ejaz Ahmed,
Email: ejazahmedpatho@gmail.com

How to cite: Ahmad W, Kadeer S, Tariq F, Haider N, Azhar S, Ahmed E. Evaluating the Effect of Hypothyroidism on Basal Metabolic Rate and Body Temperature Regulation. Pak J Med Dent. 2025 September ;14(4): A-B. Doi: https://doi.org/10.36283/ziun-pjmd14-4/021.

Received: Wed, Aug 20, 2025 **Accepted:** Sun, September 28, 2025**. Published:** Mon, September 29, 2025

INTRODUCTION

Hypothyroidism is caused by insufficient production of thyroid hormones, including triiodothyronine (T3) and thyroxine (T4), which affect other metabolic functions such as basal metabolic rate (BMR) and thermoregulation [1]. It has been shown to represent one of the most prevalent endocrine disorders with an estimated prevalence of 4-10% worldwide, specifically among females and the older population [2]. Thyroid hormones are crucial in mitochondrial dynamics, thermogenesis, and energy homeostasis, and their insufficiency is commonly characterized by fatigue, weight gain, and cold intolerance [3]. Available evidence suggests that hypothyroidism is closely associated with obesity and abnormalities of lipid metabolism, which further exacerbate metabolic dysfunction [4]. Although hormonal correction is often a target of clinical management, some studies indicate that a large number of patients still experience impaired thermogenic and metabolic responses despite achieving normalized hormone levels [5].

Most human research examining resting energy expenditure does not measure thyroid hormone status, despite the evident physiological mechanisms by which thyroid activity influences BMR and body temperature [6]. Emerging data indicate that cold-induced thermogenesis is sensitive to thyroid hormone fluctuations even within the reference range [7]. Limited studies have directly assessed these parameters in recently diagnosed hypothyroid adults in controlled conditions [8]. A better comprehension of this connection may contribute to earlier clinical diagnosis and specific regulation of metabolic inadequacy related to thyroid involvement [9]. It may also manage chronic fatigue and weight gain that often remain unresolved after treatment [10].

The objective of this study was to compare BMR and core body temperature in newly diagnosed adult hypothyroid patients and corresponding healthy controls. It also assessed that thyroid hormone deficiency leads to quantifiable impairments in energy balance and thermoregulation, supporting early clinical intervention.

METHODS

The effect of hypothyroidism on BMR and core body temperature regulation was determined using a cross-sectional study design, conducted at the Endocrinology Department in a tertiary care hospital, faculty of AHS, SU and SZH Lahore from January and April 2024 (Ref: RS-4111). The participants in the inpatient endocrine unit were recruited by consecutive non-probability sampling. Participants were enrolled by receiving written informed consent during the usual thyroid assessment. The sample size of 200 participants was determined using OpenEpi version 3.0.0 (released 2013, Atlanta, GA, USA) based on the effect size (0.5), alpha (0.05), and power (80%) [11].

The inclusion criteria were patients aged 25-50 years, diagnosed with untreated primary hypothyroidism, selected with elevated thyroid-stimulating hormone (TSH) and low free T3/T4. Exclusion criteria were pregnancy, lactation, diabetes mellitus, cardiovascular disease, psychiatric illness, infections, fever, and BMI > 35 kg/m^2, or concurrent use of medications that influenced thyroid activity or metabolism. Participants were divided into two groups: Group A (n = 100) and Group B (n = 100), comprising age and sex-matched healthy controls with normal thyroid parameters. No interventions were used; natural clinical exposure was investigated. All participants were asked to starve and rest before measurements. BMR was calculated using indirect calorimetry in control conditions. After 15 minutes of rest, a calibrated digital oral thermometer was used to measure core body temperature. TSH, free T3, and T4 hormones were determined by a chemiluminescence immunoassay.

The data were analyzed using SPSS version 26.0 (released 2019, IBM Corp., Armonk, NY). Continuous variables were analyzed through independent samples t-tests, and chi-square tests were applied to the categorical variables. The p-value < 0.05 was considered statistically significant.

RESULTS

This study examined the effect of hypothyroidism on BMR and core body temperature in 200 adults. The findings revealed that hypothyroid patients exhibited a significant decrease in BMR and body temperature compared to controls. A significant change in thyroid hormone levels was observed in the hypothyroid group, indicating that hypothyroidism impairs both metabolism and thermoregulation. Baseline demographic and clinical characteristics of study participants are indicated in **Table 1**.

Table 1: Baseline Demographic and Clinical Characteristics

Variable	Hypothyroid Group (n = 100)	Control Group (n = 100)	Test Value	p-value
Age (years)	38.7 ± 6.1	37.9 ± 6.4	t = 0.94	0.347
Sex (Male/Female)	35 (35%) / 65 (65%)	37 (37%) / 63 (63%)	χ^2 = 0.10	0.751
BMI (kg/m²)	26.8 ± 3.2	25.9 ± 2.9	t = 2.01	0.046*
Smoking Status (Yes/No)	18 (18%) / 82 (82%)	15 (15%) / 85 (85%)	χ^2 = 0.34	0.559

*n = Number of Participants, BMI = Basal Metabolic Index, SD = Standard Deviation, % = Percentage, * = Significance at p<0.05*

BMI was significantly higher in the hypothyroid group (26.8 ± 3.2) compared to the controls (25.9 ± 2.9; p = 0.046). There were no significant variations in age (p = 0.347), sex (p = 0.751), and smoking status (p = 0.559). It signifies similar baseline profiles except for BMI, which could be relevant to metabolic outcomes. **Table 2** illustrates the Thyroid functions and clinical parameters in both groups.

Table 2: Thyroid Functions and Clinical Parameters

Parameter	Hypothyroid Group	Control Group	Test Value	p- value
TSH (µIU/mL)	9.2 ± 2.1	2.4 ± 0.8	t = 26.73	<0.001*
Free T3 (pg/mL)	2.1 ± 0.5	3.4 ± 0.6	t = -17.39	<0.001*
Free T4 (ng/dL)	0.6 ± 0.2	1.3 ± 0.3	t = -20.76	<0.001*
Resting Heart Rate (bpm)	62.5 ± 7.3	72.1 ± 6.9	t = -9.12	<0.001*
Blood Pressure (mmHg)	118.2 ± 11.5 / 76.4 ± 8.1	121.5 ± 10.9 / 78.6 ± 7.4	t = -2.07	0.040*

** = Significance at p<0.05*

TSH was high, whereas T3 and T4 were considerably low in the hypothyroid group (p < 0.001), Hypothyroid patients also had a lower resting heart rate (62.5 ± 7.3 bpm vs. 72.1 ± 6.9 bpm; p < 0.001). There was a slight reduction in systolic blood pressure and diastolic blood pressure (p = 0.040). These results indicate systemic outcomes of low thyroid hormone levels. Table 3 presents the comparison of BMR and core body temperature between the two groups

Table 3: Comparison of BMR and Core Body Temperature

Parameter	Hypothyroid Group (n= 100)	Control Group (n = 100)	Test Value	p- value
BMR (kcal/day)	1195.8 ± 105.4	1362.7 ± 112.3	t = -10.27	<0.001*
Core Body Temperature (°C)	36.1 ± 0.3	36.7 ± 0.4	t = -10.08	<0.001*
Fatigue Severity Score	5.6 ± 0.9	2.4 ± 0.7	t = 26.11	<0.001*

** = Significance at p<0.05*

BMR was lower in the hypothyroid group (1195.8 ± 105.4 kcal/day) compared to controls (1362.7 ± 112.3, $p < 0.001$). Core temperature was also decreased (36.1 ± 0.3°C vs. 36.7 ± 0.4°C; $p < 0.001$). Higher fatigue scores were found in the hypothyroid group ($p < 0.001$). These findings support that hypothyroidism disrupts thermoregulation and energy homeostasis.

DISCUSSION

The aim of the study was to determine the impact of primary hypothyroidism in maintenance of body temperature and BMR in adults. These results confirm that thyroid hormone deficiency has a considerable adverse impact on the metabolic efficiency and thermoregulation. The outcome of thyroid hormone profiling indicated that subjects in the hypothyroid group had an extremely high level of TSH but with low levels of free T3 and T4. These results are consistent with earlier literature that has determined the critical importance of thyroid hormones in the maintenance of cellular metabolism and systemic thermogenesis [12]. A different study revealed that the hormonal alterations prevent mitochondrial functioning and oxidative phosphorylation thus leading to low metabolism output [13]. Metabolic data showed a reduction in BMR that was significantly reduced in the subjects that were hypothyroid. This aligns with information on animal models, whereby hypothyroidism resulted in a gotting down of energy turnover and thermogenic gene expression in skeletal muscle [14]. Further, the literature of resting energy expenditure studies has continuously indicated that hypothyroid conditions impair the use of ATP and thermogenesis capacity [15]. Reduced activity of Na + /K + ATPase pumps in hypothyroid patients also indicated slowed metabolism in another study [16].

Hypothyroid individuals also demonstrated lower core body temperature and higher fatigue scores. This is in line with clinical observations that thyroid hormones stimulate hypothalamic thermoregulatory pathways [17]. Human imaging studies indicated that impairment of TRα1 receptor signaling can inhibit hypothalamic thermogenic output [18]. Additional evidence revealed that circadian control of core temperature is diminished in hypothyroid states, altering normal body heat rhythms [19]. Some other studies vary, exhibiting normalized temperature in patients with treated hypothyroidism that could be due to differences in disease severity or length of therapy [20]. Similar problems have been observed in mild subclinical hypothyroidism, undergoing inconsistent effects in BMR, perhaps representing a compensatory process [21].

However, most evidence points towards a close association between hypothyroidism and defective thermoregulation [22]. There is a practical implication of these findings. The early identification of thyroid dysfunction can help manage thermal homeostasis and prevent metabolic dysregulation [23].

Healthcare professionals should consider both biochemical and functional parameters in diagnosis and monitoring [24]. Individualized dosing regimens are more effective in reinstituting BMR in athyreotic patients [25,26].

Limitations include the cross-sectional design of the study, which may affect causality. Other potential confounding factors, including physical activity, diet, and environmental temperature, were not controlled strictly. Future research must include longitudinal studies to assess the impact of hormonal therapy on BMR and thermoregulation and broaden sampling into subclinical groups and varied climates.

CONCLUSION

This study discovered that core body temperatures and BMR were significantly reduced in hypothyroidism patients compared to healthy individuals. It was observed that thyroid hormone deficiency disrupts energy homeostasis and thermoregulation. These findings support that metabolic and thermal defects are major functional outcomes of hypothyroidism.

These observations emphasize the importance of clinicians evaluating both the biochemical and physiological variables in hypothyroid treatment. Early diagnosis and personalized therapy may help restore metabolic homeostasis and prevent chronic disturbance.

LIST OF ABBREVIATIONS

BMR Basal Metabolic Rate

BMI Basal Metabolic Index

TSH Thyroid-Stimulating Hormone

T3 Triiodothyronine

T4 Thyroxine

TRα1 Thyroid Hormone Receptor Alpha 1

ACKNOWLEDGEMENT

None

FUNDING

None

CONFLICT OF INTEREST

None

ETHICAL APPROVAL

Ethical approval was obtained from the Institution Research Board (IRB) of Department of Pathology, The Superior University and Shaikh Zayed Hospital, Lahore (Ref: IRB /FAHS/Allied-HS/02/24/MS/RS-4111).

AUTHORS' CONTRIBUTION

All authors contributed equally as per ICMJE.

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