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# Spectrum of Thyroid Dysfunction and Its Association with Metabolic and Lifestyle Factors

**Dr Atul choudhary[1] Dr Swani Bhagat[2*]**

[1]MBBS, MD Medicine ASCOMS, Jammu, atulchoudhary1292@gmail.com
[2]MBBS, MD Pathology, Government Medical College, Srinagar swanibhagat1@gmail.com

***Corresponding Author:** Dr Swani Bhagat
[2]MBBS, MD Pathology, Government Medical College, Srinagar swanibhagat1@gmail.com

**Abstract**

Thyroid dysfunction is a clinically significant endocrine imbalance that may be related to metabolic control and health risk (lifestyle). This paper has explored the range of thyroid dysfunction and the correlation of metabolic and lifestyle factors with thyroid dysfunction using a structured data set of 2,000 records of participants. Thyroid status was divided into euthyroid/normal, subclinical hypothyroidism, overt hypothyroidism, subclinical hyperthyroidism, overt hyperthyroidism, and autoimmune thyroiditis. Body mass index, waist circumference, blood pressure, fasting glucose, HbA1c, lipid profile, obesity, diabetes, and hypertension were considered as metabolic indicators, whereas smoking, alcohol use, physical activity, sleep duration, stress level, diet quality, and iodine intake were the lifestyle factors. Patterns of thyroid dysfunction and associated risk patterns were measured using descriptive statistics, group-wise comparisons, and association analysis. Comprehensively, 70.4 percent of the respondents were euthyroid/normal and 29.6 percent presented thyroid dysfunction. The thyroid dysfunction was commonest amongst those with a history of diabetes (40.3%), and those with a history of high stress levels, high blood pressure, overweight and high intake of iodine. Participants with thyroid dysfunction were found to have more BMI, fasting glucose, HbA1c, total cholesterol triglycerides, TSH, and TPOAb with slightly reduced Free T4 compared to those with normal thyroid functioning. These results suggest that thyroid dysfunction correlates with the poor metabolic profile and with a chosen risk factor that is related to lifestyle. The researchers emphasize the importance of combined thyroid, metabolic, and lifestyle evaluation as the means of detecting patients at a higher risk of endocrine and cardiometabolic diseases.

**Keywords:** Thyroid dysfunction; Metabolic profile; Lifestyle factors; Subclinical hypothyroidism; Cardiometabolic risk.

## 1. Introduction

Thyroid dysfunction is one of the biggest endocrine disruptions that have extensive metabolic and systemic consequences. The thyroid hormones are vital in the regulation of basal metabolic rate, energy expenditure, thermogenesis, glucose use, lipid metabolism, cardiovascular activity and overall physiological homeostasis. Changes in the production or regulation of thyroid hormones could thus affect a variety of metabolic pathways and lead to clinically important health effects. The thyroid dysfunction is found on a wide spectrum of biochemical and clinical spectrum, which includes subclinical hypothyroidism, overt hypothyroidism, subclinical hyperthyroidism, overt hyperthyroidism and autoimmune thyroiditis.
The connection between thyroid and metabolic syndrome has gained more and more interest as metabolic syndrome and thyroid are connected due to the similarity of their metabolic pathways. The metabolic syndrome is a syndrome that is characterized by central obesity, hypertension, dyslipidaemia, and impaired regulation of glucose as well as insulin resistance. These anomalies have a close relation with cardiovascular disease and the long term metabolic difficulties. Closely intertwined with the thyroid hormones are the control of glucose metabolism, lipid turnover, adipose tissue activity and vascular activity. Even slight changes in thyroid condition can thus impact body weight, blood pressure, serum lipids and glycaemic control. Teixeira et al. (2020) stressed that thyroid hormones play a key role in metabolism and metabolic syndrome due to their impact on glucose level, lipid metabolism, adiposity, and cardiovascular homeostasis.
A number of studies have shown that there is a significant relationship between thyroid functioning and metabolic syndrome or its constituent parts. He et al. (2021) found that thyroid activity was considerably connected with the metabolic syndrome and its elements in a Chinese population, which offers proof that thyroid disorders could be comorbid with obesity, hypertension, dyslipidaemia, and distorted glucose metabolism. Gyawali et al. (2015) also reported thyroid dysfunction in the patients with metabolic syndrome and found out its correlation with other elements of metabolic syndrome. Likewise, Saluja et al. (2018) discovered that thyroid dysfunction had a relationship with metabolic syndrome and its clinical elements. These results indicate that persons who have metabolic risk factors could be at increased risk of having thyroid imbalance, especially the subclinical hypothyroidism, which is usually non-clinical though metabolically significant.

Hypothyroidism can lower the use of glucose and lead to insulin resistance whereas hyperthyroidism can raise the glucose turnover and worsen the glycaemic variability. In their meta-analysis of prospective observational studies, Rong et al. (2021) found a correlation between thyroid dysfunction and type 2 diabetes. It is clinically significant as this association is common and both diseases can co-occur, consequently adding to the load of metabolic and cardiovascular risk. Thyroid dysfunction in diabetic patients can additional exacerbate glycaemic control, lipid control, body-weight control, and vascular conditions.

Lowering thyroid hormone activity can cause a loss of lipid clearance and increase in total cholesterol, low-density lipoprotein cholesterol and triglyceride levels. Duntas and Brenta (2018) emphasized the strong connection between thyroid hormones and lipid metabolism, especially when it comes to dyslipidaemia and cardiovascular risk. A systematic review and meta-analysis conducted by Kotwal et al. (2020) also revealed that the treatment of thyroid dysfunction could have an impact on serum lipid. The results justify the significance of considering lipid profile in patients with thyroid dysfunction and taking into consideration the thyroid status in patients with unexplained dyslipidaemia. Higher body mass index and waist circumference can thus be related to change in thyroid functioning. As obesity is often a comorbid condition associated with hypertension, diabetes, and dyslipidaemia, the evaluation of the thyroid activity among people whose body weight is excessive may give a good idea about the metabolic risk on the whole.

Structural thyroid abnormalities and metabolic abnormalities can also be linked with thyroid abnormalities. In a systematic review and meta-analysis, Zhang et al. (2021) found the correlation of metabolic syndrome and thyroid nodules. Thyroid nodules and thyroid dysfunction are clinically distinct conditions, but may have overlapping metabolic pathways, such as obesity, insulin resistance, dyslipidaemia, chronic inflammation and hormonal imbalance.

Low levels of intake of iodine may cause hypothyroidism and goitre whereas excessive levels may cause thyroid dysfunction in individuals who are prone to the condition especially the autoimmune prone individuals. Liu et al. (2021) emphasized the significance of the status of iodine nutrition in terms of morbidity of thyroid. Thus, the consumption of iodine should be regarded as an influential nutritional and lifestyle-related determinant to study thyroid malfunctions.

Lifestyle-related factors can also have an additional impact on thyroid and metabolic health due to their influence on the body composition, inflammation, stress response, insulin sensitivity, cardiovascular functioning and the quality of diets. Smoking, alcohol consumption, exercise, sleep time, the level of stress, the quality of diet and iodine intake can either act directly or indirectly on the endocrine regulation. The variables of lifestyle are especially pertinent since thyroid dysfunction can have a combination with metabolic risk factors but not alone. An integrated evaluation that takes into consideration thyroid conditions, metabolic, biochemical, and lifestyle can therefore give a more clear-cut picture of endocrine and cardiometabolic trends of health.

In general, the current evidence suggests that thyroid dysfunction has a strong correlation with the metabolic syndrome, diabetes, obesity, dyslipidaemia, structural abnormalities due to thyroid, iodine status, and more general lifestyle risk patterns. Nevertheless, most past studies have been concentrating on single exposures or a single thyroid marker. Greater understanding of the distribution of thyroid abnormalities and its correlation with cardiometabolic risk can be achieved through a broader approach that considers thyroid dysfunction as a spectrum and determines the relationship between thyroid dysfunction and a variety of metabolic and lifestyle factors. This study aims to:

1. To analyze the distribution and prevalence of thyroid dysfunction categories.
2. To assess metabolic variations across thyroid-status groups.
3. To examine the association between lifestyle factors and thyroid dysfunction.

## 2. Methodology

### 2.1 Research Design

A quantitative cross-sectional research design was chosen to conduct the study to address the continuum of thyroid dysfunction and its relation to metabolic factors and lifestyle factors. It was the right design, as the analysis was conducted on the level of participants based on the information recorded at one observation time. The objective of the study was to establish patterns and relationships between thyroid-status groups, metabolic health variables and lifestyle-related variables. The design was cross-sectional and therefore the analysis could only be done to determine the associations, but not to determine causal relationships.

### 2.2 Data Source and Study Sample

The research involved the analysis of a structured dataset of thyroid -metabolic -lifestyle data of 2,000 records of participants and 31 variables. The data covered demographic data, thyroid biochemical, metabolic health, lifestyle behaviours, and thyroid-status. Individuals who possessed data on thyroid status, their metabolic and lifestyle variables were also included in the analysis. Review of the dataset included the detection of duplicate entries, missing values, inconsistent coding and implausible values, prior to the analysis. The final analysis was done with the eligible records after screenings and cleaning of the data.

### 2.3 Study Variables

The primary outcome measure was Thyroid_Status that was used to categorize the participants into normal thyroid functioning and various thyroid dysfunction statuses, such as subclinical and overt hypo- and hyperthyroidism. Conversion of thyroid status into a binary variable (normal thyroid functioning and thyroid dysfunction) was also done to be able to perform a regression analysis.
The independent variables were chosen demographic, metabolic, lifestyle and thyroid biochemical variables. These were age, sex, family history, BMI, waist circumference, blood pressure, fasting glucose, HbA1c, cholesterol profile, obesity, diabetes, hypertension, smoking, alcohol usage, physical activity, the duration of sleep, the level of stress, the quality of the diet, the level of iodine, TSH, Free T4, T3 and TPOAb.

**2.4 Data Processing and Cleaning**
The analysis of the dataset was done in a systematic manner. Duplicate records were verified and eliminated where it existed. The values that were not present were estimated on each variable and categorical missing values were dealt with by allocating another category of Not reported where it was deemed necessary. Continuous variables were checked on the valid range, extreme values and consistency with anticipated clinical measurements. Categorical variables were checked to have consistency in coding and significant grouping.
Variables that had no significant variation were not analyzed statistically as they could not provide any value in terms of making a comparison or association test. Spectrum-based analysis variable was maintained as thyroid-status categories whereas a binary thyroid dysfunction variable was formed to analyse the regression. The data was then cleaned and readied to undergo descriptive, comparative, and association based statistical analysis.

**2.5 Data Analysis**
The analysis was done sequentially. The participant characteristics and thyroid-status distribution were summarized with descriptive statistics. Mean and standard deviation were used to present continuous variables, and frequencies and percentages were used to present categorical variables.
Second, a comparison of metabolic and lifestyle factors across thyroid-status groups was done to reveal differences between the normal thyroid functioning and thyroid dysfunction groups. Continuous and categorical variables were tested through appropriate statistical tests depending on the kind and distribution of data.
Lastly, binary logistic regression was conducted to determine the most important factors related to thyroid dysfunction. The dependent variable was the Thyroid dysfunction status and demographic, metabolic, and lifestyle variables were inputted as predictors.

**3. Results**
**3.1 Descriptive Statistical Analysis of Study Variables**
The data consisted of 2,000 records of participants. The key continuous variables that were shown to be major were computed as descriptive statistics in terms of thyroid functioning, metabolic health, and lifestyle profile. The average age was 45.11 years, average BMI was 26.19 kg/m 2, and average total cholesterol was 190.64 mg/dL as presented in Table 1.

**Table 1. Descriptive Statistics of Key Continuous Variables**

| Variable | N | Mean | SD | Min | Max |
|---|---|---|---|---|---|
| Age | 2,000 | 45.11 | 15.06 | 18.00 | 85.00 |
| BMI | 2,000 | 26.19 | 4.48 | 16.50 | 41.00 |
| Waist circumference | 2,000 | 90.53 | 13.42 | 55.00 | 133.80 |
| Systolic BP | 2,000 | 120.51 | 16.81 | 88.00 | 182.00 |
| Fasting glucose | 2,000 | 94.31 | 14.32 | 65.00 | 144.00 |
| HbA1c | 2,000 | 5.49 | 0.67 | 4.20 | 7.90 |
| Total cholesterol | 2,000 | 190.64 | 35.46 | 110.00 | 330.00 |
| Triglycerides | 2,000 | 136.52 | 54.38 | 40.00 | 317.00 |
| Sleep duration | 2,000 | 6.79 | 1.11 | 3.50 | 10.00 |
| TSH | 2,000 | 3.76 | 4.87 | 0.01 | 36.85 |
| Free T4 | 2,000 | 1.16 | 0.29 | 0.26 | 2.95 |
| TPOAb | 2,000 | 40.02 | 51.65 | 1.00 | 535.70 |

**3.2 Distribution of Thyroid Dysfunction Categories**
Thyroid status was categorized into six groups. Table 2 indicates that the majority of participants were Euthyroid/Normal (70.4%), with 29.6% having some type of thyroid disorder. The most prevalent types of dysfunction were subclinical hypothyroidism (13.1%), and overt hypothyroidism (6.5%).

**Table 2. Distribution of Thyroid Status**

| Thyroid Status | Frequency | Percentage |
|---|---|---|

| | | |
|---|---|---|
| Euthyroid/Normal | 1,408 | 70.4 |
| Subclinical Hypothyroidism | 261 | 13.1 |
| Overt Hypothyroidism | 130 | 6.5 |
| Subclinical Hyperthyroidism | 94 | 4.7 |
| Overt Hyperthyroidism | 62 | 3.1 |
| Autoimmune Thyroiditis | 45 | 2.3 |
| **Total** | **2,000** | **100.0** |

### 3.3 Thyroid Dysfunction Burden Across Selected Groups

Within the cohort, the prevalence of thyroid dysfunction was higher in those with diabetes, high stress, high blood pressure, obesity, and high levels of iodine with the greatest prevalence being in diabetic participants (40.3%), as indicated in Table 3.

**Table 3. Groups with Higher Thyroid Dysfunction Burden**

| Factor | High-Burden Group | Thyroid Dysfunction (%) |
|---|---|---|
| Diabetes | Yes | 40.3 |
| Stress level | High | 35.0 |
| Hypertension | Yes | 34.9 |
| Obesity | Yes | 34.5 |
| Iodine intake | High | 32.6 |
| Residence | Rural | 32.5 |
| Alcohol use | Heavy | 32.2 |
| Physical activity | High | 32.1 |
| Sex | Male | 30.4 |
| Smoking status | Former smoker | 30.4 |

### 3.4 Metabolic and Biochemical Profile Across Thyroid Status Categories

Significant metabolic and biochemical indices varied among the thyroid-status groups. The subclinical hypothyroidism exhibited more metabolic burden, more obesity, diabetes, high blood pressure, cholesterol levels, and TSH, and no autoimmune thyroiditis had the highest TPOAb level that was presented in Table 4. Figure 1 presents a comparison of thyroid groups in obesity, diabetes, and hypertension. It was found that it was predominantly increased in subclinical hypothyroidism and autoimmune thyroiditis.

**Table 4. Key Outcomes Across Thyroid Status Categories**

| Thyroid Status | Obesity % | Diabetes % | Hypertension % | Cholesterol | TSH | TPOAb |
|---|---|---|---|---|---|---|
| Euthyroid/Normal | 19.4 | 7.5 | 19.0 | 187.76 | 2.00 | 22.61 |
| Subclinical Hypothyroidism | 28.7 | 12.6 | 27.6 | 202.67 | 7.64 | 58.53 |
| Overt Hypothyroidism | 20.8 | 11.5 | 23.1 | 200.55 | 18.75 | 96.32 |
| Subclinical Hyperthyroidism | 14.9 | 12.8 | 21.3 | 192.73 | 0.17 | 41.40 |
| Overt Hyperthyroidism | 24.2 | 9.7 | 21.0 | 186.34 | 0.05 | 61.01 |
| Autoimmune Thyroiditis | 28.9 | 11.1 | 17.8 | 184.00 | 5.43 | 283.07 |

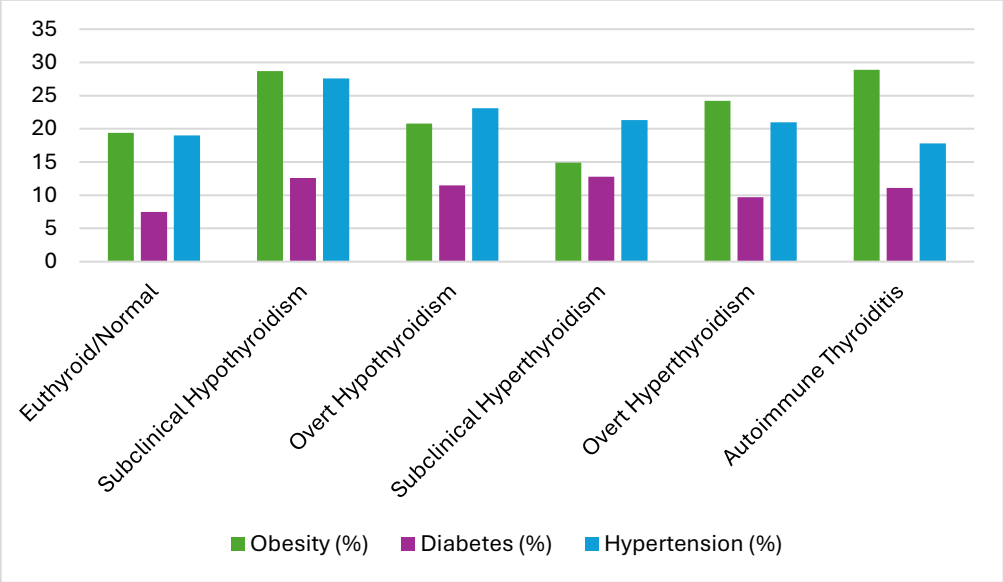


**Figure 1. Metabolic outcomes across thyroid-status categories**

### 3.5 Comparative Deviations Between Normal Thyroid Function and Thyroid Dysfunction

Table 5 indicates that the participants who had thyroid dysfunction had higher obesity, diabetes, hypertension, high stress, cholesterol, triglycerides, TSH, and TPOAb levels than those with normal thyroid functioning and Free T4 was also slightly lower. Figure 2 indicates that the thyroid dysfunction group experienced greater metabolic load, especially diabetes, hypertension, cholesterol, triglycerides, TSH and TPOAb.

**Table 5. Normal Thyroid Function vs Thyroid Dysfunction**

| Indicator | Normal | Dysfunction | Difference |
|---|---|---|---|
| Obesity (%) | 19.4 | 24.3 | ↑ 4.9 |
| Diabetes (%) | 7.5 | 12.0 | ↑ 4.5 |
| Hypertension (%) | 19.0 | 24.2 | ↑ 5.2 |
| High stress (%) | 21.7 | 27.9 | ↑ 6.2 |
| BMI | 26.04 | 26.54 | ↑ 0.50 |
| Fasting glucose | 93.77 | 95.60 | ↑ 1.83 |
| Total cholesterol | 187.76 | 197.49 | ↑ 9.73 |
| Triglycerides | 134.49 | 141.35 | ↑ 6.86 |
| TSH | 2.00 | 7.93 | ↑ 5.93 |
| Free T4 | 1.18 | 1.11 | ↓ 0.07 |
| TPOAb | 22.61 | 81.44 | ↑ 58.83 |

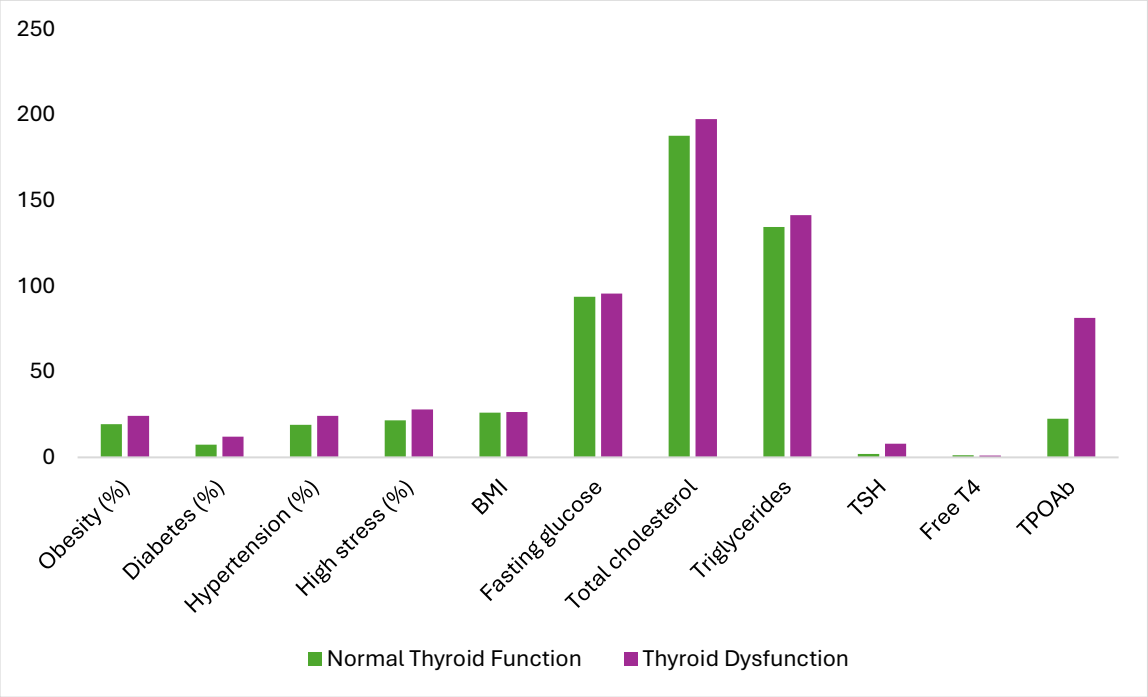


**Figure 2. Comparison between normal thyroid function and thyroid dysfunction**

## 4. Discussion

The results of the research show that there was a significant percentage of thyroid dysfunction in the population of subjects and was linked to both metabolic and lifestyle-related risk factors. Out of 2,000 participants, 70.4% were euthyroid or had normal thyroid functioning with 29.6 having some kind of thyroid dysfunction. This indicates that the abnormalities of the thyroid were rather prevalent in the study population. Subclinical hypothyroidism was the most common dysfunction with 13.1 percent of the participants with subclinical hypothyroidism and overt hypothyroidism, subclinical hyperthyroidism, overt hyperthyroidism and autoimmune thyroiditis. The clinical significance of subclinical hypothyroidism preeminence is that it might be not detected in the usual clinical practice yet could be a contributing factor to metabolic imbalance and cardiometabolic risk.

The research indicated that thyroid dysfunction was prevalent amongst the participants with diabetes with 40.3% of diabetic participants experiencing thyroid dysfunction. This burden was the greatest among the chosen groups, which showed that thyroid dysfunction was strongly correlated with impaired metabolism of glucose. This observation aligns with that of Biondi et al. (2019), who defined thyroid dysfunction and diabetes mellitus as the two disorders that are closely related. Thyroid hormones have an impact on the production of hepatic glucose, intestinal glucose uptake, insulin secretion, and peripheral insulin responsiveness.

Stress also proved to be another significant factor (lifestyle) in relation to thyroid dysfunction. Thyroid dysfunction was common in high stress participants with the prevalence of thyroid dysfunction being 35.0% and high stress being more prevalent in the thyroid dysfunction group compared to the normal group. This observation indicates that stresses related to psychosocial factors can be considered in the health patterns of thyroid. Neuroendocrine mechanisms such as alteration of the hypothalamic-pituitary-thyroid axis might contribute to the action of stress on thyroid functioning. Wu et al. (2021) indicated that thyroid functioning was linked to lifestyle factors in subclinical hypothyroidism and Huang et al. (2019) indicated that lifestyle was linked with thyroid dysfunction in an epidemiological context. These studies contribute to the understanding that, besides biological and biochemical factors, lifestyle and behavioural exposures can have a role in thyroid dysfunction.

It has also shown the presence of greater burden of thyroid dysfunction in hypertensive and obese participants. A third of hypertensive participants (34.9) and a third of obese participants (34.5) were found to have some level of thyroid dysfunction. When comparing the normal thyroid functioning with that of the thyroid dysfunction group, obesity was more in the dysfunction group with 24.3% over 19.4% respectively. On the same note, hypertension was more in the dysfunction group with 24.2% compared to 19.0. Such results are indicative of the possibility of thyroid dysfunction being associated with a more comprehensive cardiometabolic risk profile.

The lipid results also help in the interpretation of the results in terms of metabolism. The total cholesterol and triglyceride level of the participants with thyroid dysfunction were higher than those who had normal thyroid functioning. The dysfunction group had a total cholesterol of 197.49 vs. the normal group of 187.76 and triglycerides of 141.35 vs. 134.49.

These variations show that dyslipidaemia could be related to thyroid dysfunction. Decreased activity of thyroid hormones may impair the clearance of lipids and raise the level of cholesterol and triglyceride.
It also concerns sleep and lifestyle factors that are also significant when interpreting the findings but the duration of sleep was not one of the highest-burden groups in the presented results. The mean sleep time of the entire sample was 6.79 hours implying that sleep behaviour was also a significant lifestyle factor taken into account in the analysis. Kim et al. (2019) noted a correlation between sleep duration and subclinical thyroid dysfunction and Green et al. (2021) highlighted the correlation between thyroid dysfunction and sleep disorders. These findings substantiate the consideration of sleep time in lifestyle analysis related to thyroid, particularly due to the possibility of sleep disturbance having an effect on stressful reaction, metabolism, and endocrine balance.
The biochemical results are a strong indication of the classification of thyroid dysfunction in the study. The thyroid dysfunction participants were significantly above the normal thyroid functioning participants in terms of TSH level with the mean TSH being 7.93 and 2.00 respectively. There was a slight decreasing of free T4 in the dysfunction group of 1.11 versus 1.18. TPOAb was also a significant difference in the dysfunction group of 81.44 and 22.61 respectively. These variations affirm that the dysfunction group was evidently biochemically demonstrating a change of thyroid condition. Autoimmune thyroiditis is one of the thyroid-status groups with the maximum level of TPOAb, which substantiates the importance of thyroid autoimmunity in thyroid dysfunction.
The higher intake of iodine was also correlated with higher burden of thyroid dysfunction where the 32.6% of the individuals in the high-iodine group exhibited thyroid dysfunction. The discovery is applicable as thyroid hormone production and regulation could be disrupted by iodine deficiency and excess consumption. Unnecessary iodine can cause thyroid malfunction in predisposed persons, especially people that have autoimmune thyroid tendencies. Consequently, the consumption of iodine is the nutritional and lifestyle-related determinant of thyroid that should be considered significant.
In general, the findings indicate that the unfavourable metabolic and lifestyle profile was related to thyroid dysfunction. The group with thyroid dysfunction was more obese, diabetic, had hypertension, experienced high stress, had high BMI, fasting glucose, total cholesterol, triglycerides, TSH, and TPOAb with a slight decrease in Free T4.

## 5. Conclusion

The results of the study show that in a significant percentage of the participants of the study, thyroid dysfunction was observed and in close interconnection with metabolic and lifestyle-related risk patterns. There was a total of 2,000 participants of which 70.4% had normal thyroid functioning and 29.6% had thyroid dysfunction of some kind. The most frequent abnormality was subclinical hypothyroidism, which indicates that minor and less noticeable thyroid problems can be an overlooked significant portion of the burden of thyroid diseases. The findings also indicated that the prevalence of thyroid dysfunction was more common in diabetic participants, high stress, hypertension, obese and high iodine diet. The greatest burden was noted in diabetic participants, which means that a strong connection between imbalanced thyroid and dysfunctional glucose metabolism exists. The increased prevalence in hypertensive and obese participants also indicates that thyroid dysfunction can be associated with the increased cardiometabolic risk. The participants with thyroid dysfunction had greater obesity, diabetes, high blood pressure, high stress, BMI, fasting glucose, total cholesterol, triglycerides, TSH and TPOAb values compared to the participants with normal thyroid functioning. The dysfunction group had a low T4 that was marginally less than the control group. These results indicate that thyroid dysfunction was not a single endocrine abnormality as it was accompanied by an adverse metabolic and biochemical profile. The high TSH and TPOAb are further indications of the existence of significant thyroid disruption and potential autoimmune processes.

## References

1. Biondi, B., Kahaly, G. J., & Robertson, R. P. (2019). Thyroid dysfunction and diabetes mellitus: two closely associated disorders. *Endocrine reviews*, *40*(3), 789-824.
2. Duntas, L. H., & Brenta, G. (2018). A renewed focus on the association between thyroid hormones and lipid metabolism. *Frontiers in endocrinology*, *9*, 511.
3. Green, M. E., Bernet, V., & Cheung, J. (2021). Thyroid dysfunction and sleep disorders. *Frontiers in endocrinology*, *12*, 725829.
4. Gyawali, P., Takanche, J. S., Shrestha, R. K., Bhattarai, P., Khanal, K., Risal, P., & Koju, R. (2015). Pattern of thyroid dysfunction in patients with metabolic syndrome and its relationship with components of metabolic syndrome. *Diabetes & metabolism journal*, *39*(1), 66.
5. He, J., Lai, Y., Yang, J., Yao, Y., Li, Y., Teng, W., & Shan, Z. (2021). The relationship between thyroid function and metabolic syndrome and its components: a cross-sectional study in a Chinese population. *Frontiers in endocrinology*, *12*, 661160.

6. Huang, Y., Cai, L., Zheng, Y., Pan, J., Li, L., Zong, L., ... & Chen, G. (2019). Association between lifestyle and thyroid dysfunction: a cross-sectional epidemiologic study in the She ethnic minority group of Fujian Province in China. *BMC endocrine disorders*, *19*(1), 83.
7. Kim, W., Lee, J., Ha, J., Jo, K., Lim, D. J., Lee, J. M., ... & Kim, M. H. (2019). Association between sleep duration and subclinical thyroid dysfunction based on nationally representative data. *Journal of clinical medicine*, *8*(11), 2010.
8. Kotwal, A., Cortes, T., Genere, N., Hamidi, O., Jasim, S., Newman, C. B., ... & Alahdab, F. (2020). Treatment of thyroid dysfunction and serum lipids: a systematic review and meta-analysis. *The Journal of Clinical Endocrinology & Metabolism*, *105*(12), 3683-3694.
9. Liu, X., Sun, J., Fang, W., Xu, Y., Zhu, Z., & Liu, Y. (2021). Current iodine nutrition status and morbidity of thyroid nodules in Mainland China in the past 20 years. *Biological trace element research*, *199*(12), 4387-4395.
10. Rong, F., Dai, H., Wu, Y., Li, J., Liu, G., Chen, H., & Zhang, X. (2021). Association between thyroid dysfunction and type 2 diabetes: a meta-analysis of prospective observational studies. *BMC medicine*, *19*(1), 257.
11. Saluja, M., Pyarsabadi, P., Jelia, S., Chittora, S., Swami, Y., & Vimlani, H. (2018). Study of thyroid dysfunction in metabolic syndrome and association with its components. *Current Medicine Research and Practice*, *8*(1), 3-7.
12. Teixeira, P. D. F. D. S., Dos Santos, P. B., & Pazos-Moura, C. C. (2020). The role of thyroid hormone in metabolism and metabolic syndrome. *Therapeutic advances in endocrinology and metabolism*, *11*, 2042018820917869.
13. Wu, K., Zhou, Y., Ke, S., Huang, J., Gao, X., Li, B., ... & Liu, L. (2021). Lifestyle is associated with thyroid function in subclinical hypothyroidism: a cross-sectional study. *BMC endocrine disorders*, *21*(1), 112.
14. Zhang, C., Gao, X., Han, Y., Teng, W., & Shan, Z. (2021). Correlation between thyroid nodules and metabolic syndrome: a systematic review and meta-analysis. *Frontiers in Endocrinology*, *12*, 730279.