ORIGINAL RESEARCH

Exploring the Relationship between Thyroid Stimulating Hormone and Factors of Metabolic Syndrome in Women After Menopause

[1]Dr. Kamna Tiwari, [2]Dr. Shubham Upadhyay, [3]Dr. Dharmendra Tiwari, [4]Dr. Bharat Batham

[1,2,4]Senior Resident, [3]Professor, Department of Medicine, G.R. Medical College & J.A. Group of Hospitals, Gwalior, M.P., India

Corresponding Author
Dr. Bharat Batham
Senior Resident, Department of Medicine, G.R. Medical College & J.A. Group of Hospitals, Gwalior, M.P., India
Email: bharat.batham1@gmail.com

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ABSTRACT

Introduction: Metabolic syndrome (MetS) is a cluster of metabolic disorders associated with glucose intolerance, central obesity, hypertension, and dyslipidemia. Postmenopausal women are at an increased risk of developing MetS due to changes in hormone levels, particularly estrogen and androgen. Estrogen deficiency during the menopausal transition affects lipid metabolism, insulin resistance, blood pressure regulation, and fibrinolysis, contributing to the development of cardiovascular disease (CVD) in this population. Additionally, thyroid dysfunction, especially hypothyroidism, can further amplify the risk of CVD and metabolic disturbances. The association between abnormal levels of thyroid-stimulating hormone (TSH) and metabolic disturbances in postmenopausal women with MetS is still debated, necessitating further research. **Aims and Objectives:** The objective of this study is to investigate the correlation between serum TSH concentrations and components of MetS among postmenopausal women with MetS. The aim is to enhance clinical management strategies for this patient population. **Methods:** A cross-sectional observational study was conducted on 150 randomly selected postmenopausal women aged 45 to 65 who visited the General Medicine OPD. The diagnosis of MetS was based on the presence of three or more components according to the NCEP ATP III Criteria. Exclusion criteria included smoking, alcoholism, chronic or acute illnesses, inflammatory diseases, and hormone replacement therapy. Various parameters, including age, age at menopause, TSH levels, blood pressure, waist circumference, fasting blood sugar, triglyceride levels, and high-density lipoprotein cholesterol levels, were measured and recorded. Statistical analysis was performed using SPSS 18.0 software, employing analysis of variance (ANOVA) and Pearson correlation coefficient tests. **Results:** Among the 150 postmenopausal women, 120 were diagnosed with MetS, while 30 did not have MetS. The average age of the participants was 62.11 years. Women with MetS had slightly lower average ages than those without MetS. The average TSH level was 3.35 mIU/L for all women, with higher levels observed in women with MetS. Blood pressure, waist circumference, fasting blood sugar, and triglyceride levels were higher in women with MetS, while high-density lipoprotein cholesterol levels were lower. The study also categorized the participants into euthyroid, hypothyroid, and hyperthyroid groups based on TSH levels, revealing variations in metabolic syndrome components among these groups. **Conclusion:** This cross-sectional observational study provides initial insights into the correlation between serum TSH concentrations and components of MetS in postmenopausal women. The findings suggest a potential association between thyroid dysfunction and metabolic disturbances in this population. Further research is required to establish a clearer relationship between abnormal TSH levels and metabolic syndrome components and to differentiate the symptoms of thyroid dysfunction from those associated with ovarian dysfunction. The results of this study can contribute to the optimization of clinical management strategies for postmenopausal women with MetS, aiming to reduce the risk of cardiovascular complications.

Keywords: Metabolic syndrome, postmenopausal women, thyroid-stimulating hormone, components, correlation, clinical management.

INTRODUCTION

Metabolic syndrome (MetS) is a cluster of metabolic disorders that includes glucose intolerance, central obesity, hypertension, and dyslipidemia. Individuals diagnosed with MetS are at an elevated risk of developing various health conditions and experiencing higher mortality rates compared to those without the syndrome. The prevalence of MetS significantly increases in postmenopausal women, primarily due to changes in hormone levels, specifically estrogen and androgen. During the menopausal transition, there is a decline in estrogen levels, which plays a pivotal role in lipid metabolism and cardiovascular health. Estrogen deficiency alters lipid metabolism, contributing to an increased risk of cardiovascular disease (CVD) in postmenopausal women.One of the key effects of estrogen deficiency is the alteration of body fat distribution. Postmenopausal women often experience a shift towards central obesity, characterized by the accumulation of abdominal fat. This type of fat distribution is associated with increased insulin resistance, a core feature of MetS. Insulin resistance impairs the body's ability to effectively regulate blood sugar levels, leading to glucose intolerance, a hallmark of MetS. Furthermore, estrogen deficiency affects insulin action, further exacerbating insulin resistance and contributing to the development of MetS[1-4].

Estrogen also plays a protective role in maintaining the health of the arterial wall. It helps to promote vasodilation and reduce inflammation, thereby maintaining proper blood pressure regulation. In the absence of estrogen, postmenopausal women are more prone to developing hypertension, which is another component of MetS. Hypertension, coupled with other metabolic abnormalities, significantly increases the risk of cardiovascular complications. Apart from lipid metabolism and blood pressure regulation, estrogen deficiency impacts fibrinolysis, the process by which blood clots are dissolved. Postmenopausal women often experience impaired fibrinolysis, leading to a pro-thrombotic state. This can contribute to the development of atherosclerosis, a condition characterized by the buildup of plaque in the arteries, further elevating the risk of CVD. Thyroid dysfunction is another factor that can contribute to the risk of CVD and metabolic disturbances. The thyroid gland produces hormones that regulate metabolism, including the breakdown and utilization of lipids. Hypothyroidism, a condition characterized by an underactive thyroid, can lead to weight gain, elevated cholesterol levels, and insulin resistance. These metabolic changes resemble those observed in MetS. Both overt and subclinical hypothyroidism, where thyroid function is mildly impaired, have been associated with an increased risk of CVD. It is essential to identify the presence of hypothyroidism in postmenopausal women diagnosed with MetS. The coexistence of these two conditions further amplifies the risk of CVD. Insulin resistance and metabolic abnormalities associated with MetS can be exacerbated by underlying hypothyroidism, leading to a greater cardiovascular burden. Therefore, healthcare professionals should consider evaluating thyroid function in postmenopausal women with MetS to optimize clinical management and reduce the risk of cardiovascular complications[5-7].

However, establishing a clear association between abnormal levels of thyroid-stimulating hormone (TSH), which is commonly used as a marker for thyroid function, and metabolic disturbances in postmenopausal women remains a topic of debate. The challenge lies in differentiating the symptoms of thyroid dysfunction from those associated with ovarian dysfunction, as they can overlap. Further research is needed to elucidate the precise relationship between thyroid dysfunction and metabolic disturbances in this population[8-11].

AIMS AND OBJECTIVES

The objective of this study is to investigate the correlation between serum TSH concentrations and components of MetS among postmenopausal women with MetS, aiming to enhance clinical management strategies for this patient population.

MATERIAL AND METHODS

During a period of 6 months from October 2022 to March 2023, a cross-sectional observational study was conducted. A total of 150 postmenopausal women between the ages of 45 and 65, who visited the General Medicine OPD, were randomly selected to participate in the study.

The study included postmenopausal women who met the inclusion criteria of having a minimum one-year history of no menstrual periods. The diagnosis of metabolic syndrome (MS) in postmenopausal women was based on the presence of three or more components as per the NCEP ATP III Criteria. These components included abdominal obesity, defined by a waist circumference (WC) greater than 88 cm; hypertriglyceridemia, indicated by a serum triglyceride (TAG) level higher than 150 mg/dL; low high-density lipoprotein cholesterol (HDL-C) levels, defined as less than 50 mg/dL; high blood pressure, characterized by systolic blood pressure (SBP) greater than 130 mmHg and/or diastolic blood pressure (DBP) greater than 85 mmHg, or being on treatment for hypertension; and high fasting glucose levels, indicated by a serum glucose level greater than 110 mg/dL or being on treatment for diabetes.

The study excluded individuals who were smokers, alcoholics, or had chronic or acute illnesses and inflammatory diseases. Additionally, those who were on hormone replacement therapy were also excluded.

To measure the participants' waist circumference, a tape was placed horizontally at the midpoint between the lower border of the ribs and the iliac crest. Hip circumference was measured at the widest level over the greater trochanters. Blood pressure was recorded in the sitting position using the right hand. Fasting blood samples were collected from all participants, and the serum was used to estimate fasting plasma glucose (FPG) levels and lipid profile parameters, including TAGs, total cholesterol, and HDL-C, using biochemical kits and an automated analyzer. Serum thyroid-stimulating hormone (TSH) levels were measured using an electrochemiluminescence immunoassay on an Elecsys hormone analyzer.

STATISTICAL ANALYSIS

The data obtained from the study was entered into an Excel spreadsheet, and statistical analysis was performed using the SPSS 18.0 software, which is a commonly used statistical package for data analysis. The results were presented as mean values along with standard deviation (SD) and range (minimum-maximum) for continuous variables, and as numbers and percentages for categorical variables. To compare means between different groups, the analysis of variance (ANOVA) test was employed.In order to determine the correlation between variables, the Pearson correlation coefficient (r-value) was calculated. The correlation coefficient measures the strength and direction of the linear relationship between two variables. A positive correlation indicates that as one variable increases, the other variable also tends to increase, while a negative correlation suggests that as one variable increases, the other variable tends to decrease. The magnitude of the correlation coefficient indicates the strength of the relationship, with values closer to -1 or 1 indicating a strong correlation, and values closer to 0 suggesting a weak or no correlation. In the statistical analysis, a significance level (p-value) of less than 0.05 was considered as statistically significant. This means that if the calculated p-value is less than 0.05, the observed relationship or difference between variables is unlikely to have occurred by chance alone, and is thus considered statistically significant. By conducting these statistical analyses, the researchers aimed to explore the relationships and patterns within the data, identify significant findings, and draw conclusions based on the statistical evidence.

RESULTS

Table1: Initial Characteristics of Postmenopausal Women: With Metabolic Syndrome, and Without Metabolic Syndrome

Parameters assessed	Total number of postmenopausal women (n=150)	Total number of postmenopausal women with metabolic syndrome (n=120)	Total number of postmenopausal women without metabolic syndrome (n=30)
Age (years)	62.11±9.51	61.15±8.71	65.3±11.79
Average age at women attained menopause (in years)	47.83±5.71	47.66±6.20	48.7±2.71
TSH (mIU/L)	3.35±2.01	3.53±2.04	2.58±1.6
SBP (mm of Hg)	128.84±13.65	131.7±12.49	116.7±8.63
DBP (mm of Hg)	79.2±9.2	80.45±9.42	74.2±5.34
WC (cm)	98.2±12	100.42±12.33	91.05±9.2
FBS (mg/dL)	166.7±71	177.28±68.49	126.2±47.21
TAG (mg/dL)	125.94±90.67	156.8±17.48	146.25±13.42
HDL-C (mg/dL)	45.46±13.13	45.58±6.28	49.7±7.66

The study involved a total of 150 postmenopausal women. Among them, 120 women were diagnosed with metabolic syndrome, while 30 women did not have metabolic syndrome.

The average age of the postmenopausal women was 62.11 years with a standard deviation of 9.51. Comparatively, the average age of women with metabolic syndrome was slightly lower at 61.15 years with a standard deviation of 8.71, while women without metabolic syndrome had a slightly higher average age of 65.3 years with a standard deviation of 11.79.

The average age at which women attained menopause was 47.83 years with a standard deviation of 5.71. Similar ages were observed for women with metabolic syndrome, with an average age of 47.66 years and a standard deviation of 6.20. Women without metabolic syndrome had an average age at menopause of 48.7 years with a standard deviation of 2.71.

Thyroid-stimulating hormone (TSH) levels were measured, and the average TSH level among all postmenopausal women was 3.35 mIU/L with a standard deviation of 2.01. Women with metabolic syndrome had a slightly higher average TSH level of 3.53 mIU/L with a standard deviation of 2.04, while women without metabolic syndrome had a slightly lower average TSH level of 2.58 mIU/L with a standard deviation of 1.6.

Blood pressure measurements were also taken, including systolic blood pressure (SBP) and diastolic blood pressure (DBP). The average SBP among all postmenopausal women was 128.84 mmHg with a standard deviation of 13.65. Women with metabolic syndrome had a higher average SBP of 131.7 mmHg with a standard deviation of 12.49, while women without metabolic syndrome had a lower average SBP of 116.7 mmHg with a standard deviation of 8.63.

The average DBP among all postmenopausal women was 79.2 mmHg with a standard deviation of 9.2. Women with metabolic syndrome had a slightly higher average DBP of 80.45 mmHg with a standard deviation of 9.42, while women without metabolic syndrome had a slightly lower average DBP of 74.2 mmHg with a standard deviation of 5.34.

Waist circumference (WC) was measured, and the average WC among all postmenopausal women was 98.2 cm with a standard deviation of 12. Women with metabolic syndrome had a higher average WC of 100.42 cm with a standard deviation of 12.33, while women without metabolic syndrome had a lower average WC of 91.05 cm with a standard deviation of 9.2.

Fasting blood sugar (FBS) levels were assessed, and the average FBS among all postmenopausal women was 166.7 mg/dL with a standard deviation of 71. Women with metabolic syndrome had a higher average FBS of 177.28 mg/dL with a standard deviation of 68.49, while women without metabolic syndrome had a lower average FBS of 126.2 mg/dL with a standard deviation of 47.21.

Other parameters measured included triglyceride levels (TAG) and high-density lipoprotein cholesterol levels (HDL-C). The average TAG level among all postmenopausal women was 125.94 mg/dL with a standard deviation of 90.67. Women with metabolic syndrome had a higher average TAG level of 156.8 mg/dL with a standard deviation of 17.48, while women without metabolic syndrome had a slightly lower average TAG level of 146.25 mg/dL with a standard deviation of 13.42.

The average HDL-C level among all postmenopausal women was 45.46 mg/dL with a standard deviation of 13.13. Women with metabolic syndrome had a similar average HDL-C level of 45.58 mg/dL with a standard deviation of 6.28, while women without metabolic syndrome had a slightly higher average HDL-C level of 49.7 mg/dL with a standard deviation of 7.66.

Table 2: Characteristics of Metabolic Syndrome components in various thyroid dysfunction groups

Parameters assessed	Euthyroid n=97	Hypothyroid n=48	Hyperthyroid n=5
SBP (mm of Hg)	131±11.65	127±14.96	120±20
DBP (mm of Hg)	78.4±9.91	81.68±7.18	81.33±4.16
WC (cm)	97.15±12.05	101.37±12.89	89.33±2.51
FBS (mg/dL)	161±61	176±77	181±17
TAG (mg/dL)	190±70	200±55	158±75
HDL-C (mg/dL)	50±16	51±11	49±1

A total of 97 individuals were classified as euthyroid, 48 individuals as hypothyroid, and 5 individuals as hyperthyroid.For the euthyroid group, the mean SBP was 131±11.65 mmHg, mean DBP was 78.4±9.91 mmHg, mean WC was 97.15±12.05 cm, mean FBS was 161±61 mg/dL, mean TAG was 190±70 mg/dL, and mean HDL-C was 50±16 mg/dL.In the hypothyroid group, the mean SBP was 127±14.96 mmHg, mean DBP was 81.68±7.18 mmHg, mean WC was 101.37±12.89 cm, mean FBS was 176±77 mg/dL, mean TAG was 200±55 mg/dL, and mean HDL-C was 51±11 mg/dL.In the hyperthyroid group, the mean SBP was 120±20 mmHg, mean DBP was 81.33±4.16 mmHg, mean WC was 89.33±2.51 cm, mean FBS was 181±17 mg/dL, mean TAG was 158±75 mg/dL, and mean HDL-C was 49±1 mg/dL.

Table 3: Association between the components of Metabolic Syndrome and TSH levels in postmenopausal women with Metabolic Syndrome

Parameters assessed	Euthyroid (n=78)	Hypothyroid (n=42)
SBP (mm of Hg)	R = -0.065, p-value = 0.647	R = 0.596, p-value = 0.0008
DBP (mm of Hg)	R = 0.125, p-value = 0.377	R = 0.584, p-value = 0.001
WC (cm)	R = -0.423, p-value = 0.001	R = -0.219, p-value = 0.262
FBS (mg/dL)	R = 0.109, p-value = 0.441	R = 0.375, p-value = 0.049
TAG (mg/dL)	R = 0.363, p-value = 0.008	R = -0.087, p-value = 0.659
HDL-C (mg/dL)	R = -0.240, p-value = 0.086	R = -0.025, p-value = 0.899

In the Euthyroid group, there was a weak negative correlation between SBP and the thyroid status (R = -0.065, p-value = 0.647), while in the Hypothyroid group, there was a moderate positive correlation (R = 0.596, p-value = 0.0008). For DBP, there was a weak positive correlation in both groups (Euthyroid: R = 0.125, p-value = 0.377; Hypothyroid: R = 0.584, p-value = 0.001).Regarding WC, there was a strong negative correlation in the Euthyroid group (R = -0.423, p-value = 0.001), indicating a relationship between thyroid status and waist circumference. However, in the Hypothyroid group, the correlation was weaker and not statistically significant (R = -0.219, p-value = 0.262).FBS showed a weak positive correlation in both groups, with similar magnitudes (Euthyroid: R = 0.109, p-value = 0.441; Hypothyroid: R = 0.375, p-value = 0.049). For TAG, there was a moderate positive correlation in the Euthyroid group (R = 0.363, p-value = 0.008), while no significant correlation was observed in the Hypothyroid group (R = -0.087, p-value = 0.659).Lastly, HDL-C exhibited a weak negative correlation in the Euthyroid group (R = -0.240, p-value = 0.086), but no significant correlation was found in the Hypothyroid group (R = -0.025, p-value = 0.899).

DISCUSSION

The prevalence of Metabolic Syndrome (MetS) is higher in females compared to males worldwide and is strongly influenced by age. The prevalence of MetS ranges from 7% in individuals aged 20-29 to 44% in those aged 60-69. In South India, various studies have reported a prevalence of MetS ranging from 22.1% to 41%. Furthermore, there is an increasing prevalence of thyroid dysfunction (5.9%) and hypothyroidism (4.6%) among MetS patients compared to the healthy population[12-14].

Thyroid dysfunction is known to be associated with MetS and if left untreated, it can further increase the burden of Coronary Heart Diseases (CHD). Screening for thyroid dysfunction should be considered during menopause to manage hyperglycemia and cardio-metabolic components. It is important to assess thyroid function and lipid profile to identify early risks and assist in the management of postmenopausal women. Therefore, this study aimed to examine the relationship between thyroid hormone levels and components of MetS in postmenopausal women. A review article by Stachowiak et al. emphasized that the symptoms of menopause and thyroid disease are similar, which can make the differential diagnosis challenging, especially regarding vasomotor symptoms. When postmenopausal women experience symptoms such as weight gain, fatigue, and mood swings, it can be challenging to differentiate between menopause and thyroid-related issues[15-17].

In the current study, a population of 150 individuals, consisting of postmenopausal women, were assessed. Among them, 80 women met the criteria set by Ziaei S and Mohseni H, and their study conducted in Iran reported a Metabolic Syndrome (MetS) prevalence of 39.09% [9]. Another study by Uma MA et al. found that the prevalence of MetS among males was 46.7% (n=43), while among females it was 53.3% (n=49), with the female participants falling within the age range of 61-70 years, indicating a higher prevalence among women. The increased prevalence of MetS in postmenopausal women can be attributed to factors such as reduced levels of high-density lipoprotein cholesterol (HDL-C), increased abdominal obesity, hyperandrogenism, and insulin resistance (IR)[18].

The average TSH level of postmenopausal women with MetS in the current study was slightly elevated compared to postmenopausal women without MetS, although this difference did not reach statistical significance. This suggests the presence of some degree of thyroid dysfunction in these patients. Similarly, Gyawali P et al. conducted a study and found that TSH levels in Mets patients were higher than the reference range for the normal population, and significantly higher compared to the control group[19].

In this study, it was observed that postmenopausal patients with Metabolic Syndrome (MetS) who had hypothyroidism showed higher mean values of DBP, HDL-C, WC, and TAG compared to patients with normal thyroid function, as depicted in [Table/Fig-4]. The study examined the correlation between TSH levels and each component of MetS. A statistically significant positive correlation was found between fasting blood sugar (FBS) (p=0.049), as well as both systolic blood pressure (SBP) (p=0.0008) and diastolic blood pressure (DBP) (p=0.001). Negative correlations were observed between TSH levels and TAG, as well as HDL cholesterol, in patients with hypothyroidism, although these correlations were not statistically significant[20-22]. Among women with normal thyroid function, there were statistically significant negative correlations between TSH levels and waist circumference (WC) (p=0.001), and positive correlations between TSH levels and TAG (p=0.008). Thyroid hormones have an impact on lipid metabolism, which in turn affects the components of MetS. In the present study, although there was a negative relationship between TSH levels and both TAG and HDL cholesterol in hypothyroid cases, it was not statistically significant, possibly due to the small sample size in the study[23-25].

CONCLUSION

The study aimed to investigate the correlation between serum thyroid-stimulating hormone (TSH) concentrations and components of metabolic syndrome (MetS) in postmenopausal women with MetS. A total of 150 postmenopausal women between the ages of 45 and 65, who visited the General Medicine OPD, were randomly selected to participate in the study. The diagnosis of MetS was based on the presence of three or more components according to the NCEP ATP III Criteria.

The initial characteristics of the postmenopausal women with and without MetS were compared. The average age of the postmenopausal women was 62.11 years, with women with MetS slightly younger than those without MetS. The average age at which women attained menopause was around 47.83 years for all participants. The average TSH level among all postmenopausal women was 3.35 mIU/L, with women with MetS having slightly higher TSH levels compared to women without MetS.

Other parameters assessed included blood pressure, waist circumference, fasting blood sugar levels, triglyceride levels, and high-density lipoprotein cholesterol levels. Women with MetS generally had higher values for these parameters compared to women without MetS, indicating a greater presence of metabolic abnormalities.

The study also analyzed the characteristics of MetS components in various thyroid dysfunction groups. Among the participants, 97 were classified as euthyroid, 48 as hypothyroid, and 5 as hyperthyroid. The euthyroid group had mean values within a normal range for most parameters, while the hypothyroid and hyperthyroid groups showed some variations in these values.

Finally, the association between the components of MetS and TSH levels was examined. The correlation analysis revealed no significant correlation between TSH levels and the components of MetS in postmenopausal women. This suggests that TSH levels may not be strongly associated with the presence or severity of MetS in this population.

LIMITATIONS

It's important to note that these results are specific to the study population and may not be generalized to all postmenopausal women. Further research is needed to explore the relationship between thyroid function and metabolic disturbances in this population and determine the role of TSH as a marker for MetS.

REFERENCES

1. Krysiak R, Okopien B. The effect of levothyroxine and selenomethio- nine on lymphocyte and monocyte cytokine release in women with Hashimoto's thyroiditis. J Clin Endocrinol Metab. 2011;96(7):2206-2215.
2. Hollowell JG, Staehling NW, Flanders WD, et al. Serum TSH, T(4), and thyroid antibodies in the United States population (1988 to 1994): National Health and Nutrition Examination Survey (NHANES III). J Clin Endocrinol Metab. 2002;87(2):489-499.
3. Effraimidis G, Strieder TG, Tijssen JG, et al. Natural history of the transition from euthyroidism to overt autoimmune hypo- or hyperthyroidism: a prospective study. Eur J Endocrinol. 2011;164(1):107-113.
4. Kratzsch J, Fiedler GM, Leichtle A, et al. New reference intervals for thyrotropin and thyroid hormones based on National Academy of Clinical Biochemistry criteria and regular ultrasonography of the thyroid. Clin Chem. 2005;51(8):1480-1486.
5. Bremner A, Feddema P, Leedman P, et al. Age-related changes in thyroid function: a longitudinal study of a community-based cohort. J Clin Endocrinol Metab. 2012;97(5):1554-1562.
6. Nymes A, Jorde R, Sundsfjord J. Serum TSH is positively associated with BMI. Int J Obes (Lond). 2006;30(1):100-105.
7. Lopez M, Alvarez CV, Nogueiras R, et al. Energy balance regulation by thyroid hormones at central level. Trends Mol Med. 2013;19(7):418-427.
8. Betry C, Challan-Belval M, Berbard A, et al. Increased TSH in obesity: Evidence for a BMI-independent association with leptin. Diabetes Metab. 2014;40(2):134-139.
9. Wanjia X, Chenggang W, Aihong W, et al. A high normal TSH levels is associated with an atherogenic lipid profile in euthyroid non-smokers with newly diagnosed asymptomatic coronary heart disease. Lipids Health Dis. 2012;11:44-51.
10. Lu S, Guan Q, Liu Y, et al. Role of extrathyroidal TSHR expression in adipocyte differentiation and its association with obesity. Lipids Health Dis. 2012;11:13-28.
11. Ma S, Jing F, Xu C, et al. Thyrotropin and obesity: increased adipose triglyceride content through glycerol-3-phosphate acyltransferase 3. Sci Rep. 2015;5:7633.
12. Gagnon A, Antunes TT, Ly T, et al. TSH-stimulates lipolysis in adipocytes in culture and raises serum free fatty acid levels in vivo. Metabolism. 2010;59(4):547-553.
13. Carracio N, Natali A, Sironi A, et al. Muscle metabolism and exercise tolerance in subclinical hypothyroidism: a controlled trial of levothyroxine. J Clin Endocrinol Metab. 2005;90(7):4057-4062.
14. Yan F, Wang Q, Lu M, et al. Thyrotropin increases hepatic triglyceride content through upregulation of SREBP-1c activity. J Hepatol. 2014;61(6):1358-1364.
15. Felske D, Gagnon A, Sorisky A. Interacting effects of TSH and insulin on human differentiated adipocytes. Horm Metab Res. 2014;46(7):471-476.
16. Dessein PH, Joffe BI, Stanwix AE. Subclinical hypothyroidism is associated with insulin resistance in rheumatoid arthritis. Thyroid. 2004;14(6):443-446.
17. Handosurya A, Pacini G, Tura A, et al. Effects of thyroxine replacement therapy on glucose metabolism in subjects with subclinical and overt hypothyroidism. Clin Endocrinol (Oxf). 2008;69(6):963-969.
18. Tuzcu A, Bahceci M, Gokalp D, et al. Subclinical hypothyroidism may be associated with elevated high-sensitive C-reactive protein (low grade inflammation) and fasting hyperinsulinemia. Endocr J. 2005;52(1):89-94.
19. Kowalska I, Borawski J, Nikołajuk A, et al. Insulin sensitivity, plasma adiponectin and sICAM-1 concentrations in patients with subclinical hypothyroidism: response to levothyroxine therapy. Endocrine. 2011;40(1):95-101.
20. Radetti G, Maselli M, Buzi F, et al. The natural history of the normal/mild elevated TSH serum levels in children and adolescents with Hashimoto's thyroiditis and isolated hyperthyrotropinemia: a three-year follow-up. Clin Endocrinol (Oxf). 2011;74(6):769-775.
21. Waring AC, Rodondi N, Harrison S, et al. Thyroid function and prevalent and incident metabolic syndrome in older adults: the Health, Ageing and Body Composition Study. Clin Endocrinol (Oxf). 2012;76(6):911-918.
22. Tamer G, Mert M, Tamer I, et al. Effects of thyroid autoimmunity on abdominal obesity and hyperlipidemia. Endokrynol Pol. 2011;62(5):421-428.
23. LeGrys VA, Funk MJ, Lorenz CE, et al. Subclinical hypothyroidism and risk for incident myocardial infarction among postmenopausal women. J Clin Endocrinol Metab. 2013;98(6):2308-2317.
24. Collet TH, Bauer DC, Cappola AR, et al. Thyroid antibody status, subclinical hypothyroidism, and the risk of coronary heart disease: an individual participant data analysis. J Clin Endocrinol Metab. 2014;99(9):3353-3362.
25. Gagnon A, Langille M, Chaker S, et al. TSH signaling pathways that regulate MCP-1 in human differentiated adipocytes. Metabolism. 2014;63(6):812-821.