DOI: 10.7860/JCDR/2020/43441.13683

Original Article

Biochemistry Section

Relationship between Thyroid Hormones and Body Mass Index in Healthy Indian Adults

HARESINGH MAKWANE[1], PAWAN KUMAR KARE[2], TRIPTI SAXENA[3], AJAY JANDEL[4]

ABSTRACT

Introduction: Prior studies have reported that thyroid dysfunction such as overt hypothyroidism and hyperthyroidism are associated with weight gain and loss. In Indian normal healthy adults, relationship between thyroid hormones and Body Mass Index (BMI) has previously been studied but not explained very well.

Aim: The present study aims to investigate the relationship between thyroid hormones and obesity measured by BMI in normal healthy adults who further classified in three categories as per the BMI in normal, overweight and obese.

Materials and Methods: This observational cross-sectional study was conducted between 1st May 2019 and 30th June 2019. Consecutively, adults who attended Out-Patient Department (OPD) of Department of Medicine at Hamidia Hospital as attendant of patients and healthy hospital's staff were selected for the study. Thyroid-Stimulating Hormone (TSH), total Thyroxine (T_4), total Triiodothyronine (T_3), total cholesterol, Low-Density Lipoprotein Cholesterol (LDL-C), High-Density Lipoprotein Cholesterol (HDL-C), triglyceride and glucose levels were measured in all study subjects. Height, weight, Waist Circumference (WC) and Hip Circumference (HC) were measured and BMI and Waist to Hip Ratio (WHR) were calculated by formula. According to Asian guidelines for BMI, all subjects were divided into three groups as healthy normal (18.5-22.9 Kg/m^2), Overweight (23-24.9 Kg/m^2) and Obese (≥25 Kg/m^2).

Results: Out of 100 study subjects, 58% were females and 42% were males. According to BMI, 33 (33%) participants were found in normal weight, 36 (36%) were in overweight and 31 (31%) were in obese group. Atherogenic lipid levels such as total cholesterol, LDL-C and triglyceride and blood glucose were found increased and HDL-C levels were found decreased in overweight and obese group. The TSH levels were found significantly increased in overweight and obese subjects as compared to normal subjects, also a statistically significant difference was found for TSH between overweight and obese subjects. Out of 100 subjects, 88% were shown euthyroidism, 10% were shown hypothyroidism and 2% were shown hyperthyroidism. Pearson's correlation between BMI and TSH was not found significant in normal, overweight and obese groups, while a significant difference was noted between T_3, T_4 and BMI in overweight group.

Conclusion: In the present study, total 12% thyroid dysfunction was observed. In view of the relationship between BMI and thyroid hormones, any significant relationship was not found in Indian normal as well as obese adults groups.

Keywords: Lipid profile, Obesity, Thyroid function

INTRODUCTION

Obesity is a major growing health concern in India due to its increasing prevalence found in younger as well as adult populations [1]. Genetic susceptibility, lack of exercises or Increased food intake are few causes for obesity [2] which makes this population more vulnerable to various diseases such as Diabetes Mellitus (DM), Hypertension (HTN), Ischemic Heart Disease (IHD) and Chronic Kidney Disease (CKD) [3]. Thyroid dysfunction is one of the most common endocrine disorders worldwide. In India, 42 million peoples are suffering from various thyroid disorders [4]. Obesity and thyroid dysfunction are two common clinical conditions which have been linked together very closely [5]. Thyroid hormones regulate the metabolic rate of the body and thermogenesis. It is also suggested that thyroid hormones are involved in the regulation of appetite [6,7]. Thyroid dysfunction is allied with fluctuations in body weight and composition [8]. One of the study has revealed certain correlation with body weight and levels of thyroid hormones [9]. However, studies on thyroid dysfunction in obese adults are inconsistent [10,11]. The effect of obesity on thyroid dysfunction such as hypothyroidism has been studied in several epidemiological studies in Western countries [12-14]. Few studies found that obesity could increase risk of hypothyroidism [12,15,16]. On the contrary, other studies reported no increased risk of hypothyroidism among obese patients [13,14]. Hypothyroidism is related with reduced thermogenesis, low metabolic rate and is also correlated with higher BMI and greater frequency of obesity [17]. In Indian context, there is still lack of a definite conclusion on the association of obesity with thyroid dysfunction and studies from Asian Indians are still lacking.

Obesity can be defined by use of different anthropometric indices parameters such as height, weight, HC, WC, WHR and BMI. In many epidemiologic studies, BMI is used as a good measurement of obesity [18,19]. Furthermore, few anthropometric indices were established lately, such as a new Hip Index (HI) and A Body Shape Index (ABSI), and these methods showed to be corresponding to BMI [20,21]. As per WHO data on percentage body fat and morbidity, the normal reference limits for Asian Indians were found to be lower and even narrower when compared to white Caucasians [22]. In this consensus statement, guidelines for obesity and overweight based on BMI for Asian Indians were revised based on consensus developed by a Prevention and Management of Obesity and Metabolic Syndrome group [23]. According to this revised guidelines, Asian Indians are categorised as overweight (BMI 23.0-24.9 kg/m^2) [8] and obesity (BMI ≥25 kg/m^2) [23]. Therefore, in this study, author included Asian guideline for BMI other than previous studies to make the results more comprehensive in Asian populations. In the present study, authors determined the relationship between thyroid function as assessed by measurement of serum level of total T3, T4 and TSH hormones and BMI in Indian healthy adults.

MATERIALS AND METHODS

This is an observational cross-sectional study carried out in the Department of Medical Biochemistry in collaboration with Department of Medicine, Gandhi Medical College associated with Hamidia Hospital, Bhopal, India from 1st May 2019 to 30th June 2019. Total 100 apparently normal healthy volunteers who were attending the Hamidia Hospital as attendant of patient and healthy hospital's staff, normotensive, normoglyemic and age between 20 to 60 years were included in this study. Sample size was 100, because it was a hospital-based study as a part of an ICMR short-term studentship project for the 2 months duration. So, as per the Institutional Ethical Committee permission, only 100 healthy study subjects were recruited for this study. The subjects having diabetes mellitus, hypertension, history of metabolic syndrome, renal disease and thyroid disorders were excluded from the study.

All study participants were subjected to detailed history, general physical examination such as height, weight, BMI (as weight in kilogram, height in meter^2), WC, HC and WHR and findings were recorded in case proforma sheet. All enrolled healthy adults were divided into three groups on the basis of their BMI as per the criteria of Asian Indian guideline [23]; Healthy (normal): 18.5-22.9 Kg/m^2, Overweight: 23-24.9 Kg/m^2 and Obese: ≥25 Kg/m^2. As per WHO data on body fat, it was found that Asians have higher body fat for same age, sex and BMI compared to whites. Also, the proportion of Asian people with risk factors for type 2 diabetes and cardiovascular disease is substantial even below the existing WHO BMI cut-off point of 25 kg/m^2. Thus, on the basis of Asian guidelines, approx 15% of Indian population may be overweight and require appropriate management. These guidelines were revised after discussions and consensus formed by Prevention and Management of Obesity and Metabolic Syndrome Group [22,23].

This study was approved by the IEC, GMC, Bhopal, letter no.10026/MC/IEC/2018, dated-12/04/2019 and written informed consent was obtained from all the participants.

Five milliliter venous blood sample was collected under aseptic condition in a plain sterile vial after fasting. The estimation of lipid profile (total cholesterol, HDL-C, LDL-C, VLDL-C and triglyceride) was done by Fully Automated Analyser (BA 400, BioSystem). The estimation of serum total T_3, total T_4 and TSH was done by Enzyme Linked Immunosorbent Assay (ELISA) method. The ELISA procedure was carried out through the commercially available ELISA kits (Rapid Diagnostic Pvt., Ltd.,). Anthropometric measurements such as body weight, height, WC and HC were measured in all subjects and BMI was calculated by weight (kg) divided by height (m^2) and WHR was also calculated [20].

STATISTICAL ANALYSIS

Statistical analysis of the data was done using SPSS Software (version 20.0). Student's t-test and ANOVA test were used for comparison of data in different groups. Correlation analysis was done by calculation of Pearson's correlation coefficient (r). Statistical significance was considered as the p<0.05.

RESULTS

Out of total 100 subjects, 42 were male, and 58 were female. Female subjects were having more weight as compared to male subjects [Table/Fig-1].

Out of total 100 subjects, 33 were normal, 36 were overweight and 31 were found in obese group. Higher frequency was found in age group between 31 to 40 years as compared to other age groups [Table/Fig-2].

Gender	Total (n=100)	Normal (n=33)	Overweight (n=36)	Obese (n=31)
Male	42	13	14	15
Female	58	20	22	16

[Table/Fig-1]: Gender distribution of study groups.
Data are presented in n: Number

Age (Year)	Total (n=100)	Normal (n=33)	Overweight (n=36)	Obese (n=31)
20-30	30	08	10	12
31-40	49	18	17	14
41-50	13	04	06	03
51-60	08	03	03	02

[Table/Fig-2]: Age distribution of study subjects based on BMI.
Data are presented in n: Number

The height, weight, BMI, WC, HC, Total Cholesterol, triglyceride, LDL-C was found significantly increased in overweight and obese subjects as compared to normal subjects. However, no significant difference for WC, HC, total cholesterol, triglyceride, LDL cholesterol was found between overweight and obese subjects [Table/Fig-3].

The TSH levels were found significantly increased in overweight and obese subjects as compared to normal subjects, also a statistically significant difference was found for TSH levels between overweight and obese subjects. While total T_3 and total T_4 were not found statistically significant in study subjects [Table/Fig-4].

Out of 100 subjects, 88% were euthyroid, 10% were shown hypothyroidism and 2% were shown hyperthyroidism [Table/Fig-5].

Pearson's correlation between BMI and T_3, T_4 and TSH were not significant found in normal subjects as well as obese subjects. There

Parameter (s)	Normal (n=33) Mean±SD	Overweight (n=36) Mean±SD	Obese (n=31) Mean±SD	*p-value	#p-value	$p-value
Height (m)	1.54±0.96	1.59±0.06	1.49±0.07	**0.049**	**0.001**	**0.001**
Weight (kg)	53.7±6.6	62.7±5.4	78.4±14.2	**0.001**	**0.001**	**0.001**
BMI (Kg/m^2)	21.4±1.45	24.54±1.18	34.6±4.3	**0.001**	**0.001**	**0.001**
Waist circumference (cm)	35.0±4.25	37.63±4.24	41.07±4.77	**0.0112**	**0.001**	0.232
Hip circumference (cm)	39.2±3.75	42.3±3.88	45.48±5.20	**0.0012**	**0.001**	0.066
WHR	0.89±0.07	0.90±0.04	0.91±0.04	0.671	0.295	0.344
SBP (mm Hg)	122.9±11.0	121.6±11.7	125.9±10.9	0.632	0.298	0.133
DBP (mm Hg)	83.2±8.9	85.7±10.0	88.4±8.0	0.287	0.184	0.271
Blood glucose (mg/dL)	107.4±20.4	105.7±20.0	111.0±21.0	0.394	0.345	0.912
Total cholesterol (mg/dL)	238.8±41.6	281.1±22.8	282.1±19.3	**0.001**	**0.001**	0.952
Triglyceride (mg/dL)	159.0±37.2	200.6±26.3	193.9±22.9	**0.001**	**0.001**	0.282
HDL cholesterol (mg/dL)	41.9±7.6	41.7±8.9	41.2±6.0	0.722	0.692	0.795
LDL cholesterol (mg/dL)	165.3±40.6	199.9±23.8	202.1±19.7	**0.001**	**0.001**	0.697
VLDL cholesterol (mg/dL)	32.1±7.8	40.1±5.3	38.7±4.5	0.394	0.345	0.912

[Table/Fig-3]: Anthropometric characteristics and biochemical parameters in study groups.
Data are presented in Mean±SD, n: Number; BMI: Body mass index; WHR: Waist hip ratio; SBP: Systolic blood pressure, DBP: Diastolic blood pressure, p<0.05 was considered as significant level, *Comparison between normal and overweight subjects, #Comparison between normal and obese subjects, $Comparison between overweight and obese subjects; LDL: Low-density lipoprotein cholesterol, HDL: High-density lipoprotein cholesterol; VLDL: Very low-density lipoprotein cholesterol

Thyroid profile	Normal (n=33) Mean±SD	Overweight (n=36) Mean±SD	Obese (n=31) Mean±SD	*p-value	#p-value	$p-value
Total T_3 (ng/mL)	2.51±1.4	2.19±0.76	2.10±0.51	0.246	0.147	0.147
Total T_4 (µg/dL)	9.14±2.5	10.1±3.45	9.12±2.24	0.191	0.916	0.171
Total TSH (µIU/mL)	3.55±1.77	5.14±1.8	7.38±3.7	**0.001**	**0.001**	**0.002**

[Table/Fig-4]: Serum total T_3, T_4 and TSH levels in study subjects.
Data are presented in Mean±SD, n: Number, p<0.05 was considered as significant level, *Comparison between normal and overweight subjects, #Comparison between normal and obese subjects, $Comparison between overweight and obese subjects

was a significant positive correlation between the BMI and T_3 and between BMI and T_4 in overweight subjects. However, correlation between BMI and TSH was not found significant in these subjects [Table/Fig-6].

Thyroid status (n=100)	%	Normal (18.5-22.9 kg/m²) (n=33)	Overweight (23-24.9 kg/m²) (n=36)	Obese (>25 kg/m²) (n=31)
Euthyroid (n=88)	88%	32	32	24
Hypothyroid (n=10)	10%	01	03	06
Hyperthyroid (n=02)	02%	00	01	01

[Table/Fig-5]: Distribution of thyroid dysfunction in study groups.
Data are presented in n: Number and %: Percentage

	BMI with T_3		BMI with T_4		BMI with TSH	
	r	p	r	p	r	p
Normal (n=33)	0.19	0.289	-0.004	0.982	-0.009	0.960
Overweight (n=36)	0.58	**0.001**	0.54	**0.003**	0.08	0.630
Obese (n=31)	0.33	0.804	0.24	0.209	0.23	0.230

[Table/Fig-6]: Pearson's correlation between BMI and T_3, T_4, and TSH.
p<0.05 was considered as significant level, r: Pearson's correlation coefficient

DISCUSSION

In the present study, anthropometric indices such as weight, WC, HC and BMI were found to be increased in obese group. Authors also calculated WHR, which is also important factor but no statistically significant difference was found among study subjects. In biochemical characteristics such as total cholesterol, triglycerides and LDL-C were significantly increased in obese subjects as compared to normal subjects. Ozsenel EB et al., supported our finding that triglyceride levels of obese subjects were high and HDL cholesterol levels were low when compared its levels in normal subjects [24]. Authors also found higher glucose level in obese subjects but no statistically significant difference was found in obese subjects as compared to normal subjects. There are several studies which supported the notion that atherogenic lipid and blood glucose level are higher in subjects who are overweight or obese [25,26]. These results suggest that thyroid dysfunction should be taken into account when evaluating and treating dyslipidemic patients.

In the present study, TSH level was significantly higher in overweight and obese subjects as compared to normal subjects, while no difference was noted in the total T_3 or total T_4 levels. In support to this study Muscogiuri G et al., have also reported higher TSH values in overweight and obese subjects [26]. Rotondi M et al., has mentioned that the impact of bodyweight on thyroid differs according to lower grade of overweight and obesity [27]. In the present study, total 12% thyroid dysfunction including 2% hyperthyroidism and 10% hypothyroidism was found in Indian healthy adults. The important finding of this study is that higher frequency of hypothyroidism in subjects was noted in obese group as compared to other groups. In support to present findings, Alkac C et al., suggested that thyroid dysfunction especially hypothyroidism was more common in obese subjects [28]. The differences between prevalence rates of hypothyroidism in obese subjects in different studies might be due to the variation in race, type of obesity and study settings between samples.

In the present study, on investigating relationship between BMI and thyroid hormones, we did not find any significant association between thyroid stimulating hormones and BMI in the study subjects. The study also did not find any correlation between BMI with T_3 and BMI with T_4 in obese subjects. In contrast to present results, Knudsen N et al., have reported a positive association between BMI with TSH and a negative association between BMI and fT_4 [29]. Contrary to present results, TSH levels were found to be increased and positively correlated with BMI in obese adults in the study of Iacobellis G et al., however, they recruited only women subjects in there study [30]. Other studies supported the present results [31-33]. This study failed to find an association between BMI and thyroid function in the subjects which might be due to unaccounted confounding factors such as iodine intake, smoking, types of obesity and insulin sensitivity levels. However, the nature and biochemical basis of relationship between thyroid status and body composition rests indistinct. Longitudinal studies prove that weight gain is attended by increased TSH [34] and weight loss is associated to reduced TSH and decreased free T_3 (FT_3) levels [35]. Raises in TSH and FT_3, but not FT_4, have also been detected in obese individuals [36,37]. Lately, studies have also shown that in healthy euthyroid adults FT_3 is positively associated with BMI [38,39]. The present study is suggesting the early stage and routine health check-up for thyroid dysfunction in normal healthy adults. Early stage detection will be helpful to minimise the burden of thyroid disorders in the population.

Limitation(s)

The study consists of small sample size. Other thyroid related parameters such as Thyroid Peroxidase (TPO) antibodies and free T_3, free T_4 levels were not assessed in this study. Also, the study did not compare thyroid function tests with lipid profile parameters in BMI categories.

CONCLUSION(S)

In conclusion, the study showed that thyroid function might be one of the important factors that influences body weight thereby obesity. The early stage screening of thyroid function tests with increasing body weight will be helpful in early intervention in obese peoples and management of obesity. Further large scale studies are needed to confirm the relationship between TSH, T_3 and T_4 with BMI in Indian obese adults.

Acknowledgement

The authors would like to acknowledge the support received from ICMR under STS program for this short term studentship research work (ICMR STS Ref. ID: 2019-04007).

REFERENCES

[1] Ranjani H, Anjana RM, Garg R, Anand K. Epidemiology of childhood overweight and obesity in India: A systemic Review. Indian J Med Res. 2016;143(2):160-74.
[2] Obesity and Overweight Fact Sheet 311. WHO. January, 2015.
[3] Karla S, Unikrishnan A. Obesity in India: The weight of the nation. J Med Nutraceut. 2012;1(1):37-41.
[4] Nimmy NJ, Aneesh PM, Narmadha MP. A survey on prevalence of thyroid disorders induced by demography and food habits in South Indian population. Indian J Pharm Pract. 2012;5:49-52.
[5] Sanyal D, Raychaudhuri M. Hypothyroidism and obesity: An intriguing link. Indian J Endocr Metab. 2016;20:554-57.
[6] Amin A, Dhillo WS, Murphy KG. The central effects of thyroid hormones on appetite. J thyroid Res. 2011;01-07.
[7] Mullur R, Liu YY, Brent GA. Thyroid hormone regulation of metabolism. Physiol Rev. 2014;94(2):355-82.
[8] Raatikainen K, Heiskanen N, Heinonen S. Transition from overweight to obesity worsens pregnancy outcome in a BMI-dependent manner. Obesity (Silver Spring). 2006;14(1):165-71.

[9] Koritschoner NP, Alvarez-Dolado M, Kurz SM. Thyroid hormones regulates the obesity gene tub. EMBO Reports. 2001;2(6):499-504.
[10] Rosenbaum M, Hirsch J, Murphy E. Effects of changes in body weight on carbohydrate metabolism, catecholamine excretion, and thyroid function. Am J Clin Nutr. 2000;71(6):1421-32.
[11] Tagliaferri M, Barselli ME, Galo G. Subclinical hypothyroidism in obese patients: Relation to resting energy expenditure, serum leptin, body composition and lipid profile. Obesity Research. 2001;9(3):196-201.
[12] Gopinath B, Wang JJ, Kifley A, Wall JR, Eastman CJ, Leeder SR, et al. Five-year incidence and progression of thyroid dysfunction in an older population. Intern Med J. 2010;40(9):642-49.
[13] Ittermann T, Thamm M, Schipf S, John U, Rettig R, Volzke H. Relationship of smoking and/or passive exposure to tobacco smoke on the association between serum thyrotropin and body mass index in large groups of adolescents and children. Thyroid. 2013;23(3):262-68.
[14] Garcia-Garcia E, Vazquez-Lopez MA, Garcia-Fuentes E, Galera-Martinez R, Gutierrez-Repiso C, Garcia-Escobar I, et al. Thyroid function and thyroid autoimmunity in relation to weight status and cardiovascular risk factors in children and adolescents: A population-based study. J Clin Res Pediatr Endocrinol. 2016;8(2):157-62.
[15] Asvold BO, Bjoro T, Vatten LJ. Association of serum TSH with high body mass differs between smokers and never-smokers. J Clin Endocrinol Metab. 2009;94(12):5023-27.
[16] Marzullo P, Minocci A, Tagliaferri MA, Guzzaloni G, Di Blasio A, De Medici C, et al. Investigations of thyroid hormones and antibodies in obesity: Leptin levels are associated with thyroid autoimmunity independent of bio-anthropometric, hormonal, and weight-related determinants. J Clin Endocrinol Metab. 2010;95(8):3965-72.
[17] Danforth E Jr, Horton ES, O'Connell M, Sims EA, Burger AG, Ingbar SH, et al. Dietary-induced alterations in thyroid hormone metabolism during overnutrition. J Clin Invest. 1979;64(5):1336-47.
[18] Khashayar P, Aghaei Meybodi H, Rezaei Hemami M, Larijani B. Role of obesity variables in detecting hypertension in an Iranian population. High Blood Press. Cardiovasc Prev. 2017;24(3):305-12.
[19] Cho YG, Song HJ, Kim JM, Park KH, Paek YJ, Cho JJ, et al. The estimation of cardiovascular risk factors by body mass index and body fat percentage in Korean male adults. Metabolism. 2009;58(6):765-71.
[20] Krakauer NY, Krakauer JC. An anthropometric risk index based on combining height, weight, waist, and hip measurements. J Obes. 2016;01-09.
[21] Krakauer NY, Krakauer JC. A new body shape index predicts mortality hazard independently of body mass index. PLoS One. 2012;17(7):e39504.
[22] World Health Organisation (WHO). WHO expert consultation. Appropriate body-mass index for Asian populations and its implications for policy and intervention strategies. The Lancet. 2004;363(9403):157-63.
[23] Mishra A, Chowbey P, Makkar BM, Vikram NK, Wasir JS, Chadha D, et al. Consensus statement for diagnosis of obesity, abdominal obesity and the metabolic syndrome for Asian Indians and recommendations for physical activity, medical and surgical management. J Assoc Physicians India. 2009;57:163-70.
[24] Ozsenel EB, Gurler MY, Karatemiz G, Borlu F, Kalkan K, Güven E, et al. Comparison of body mass index and lipid levels between obese and normal weighted hypothyroid patients. SETB. 2015;49(2):131-34.
[25] Ekinci F, Merder-Coşkun D, Tuncel B, Atila D, Yildiz H, Uzuner A. Relationship between obesity and thyroid function in adults. J Mar Med. 2018;31:76-80.
[26] Muscogiuri G, Sorice GP, Mezza T, Prioletta A, Lassandro AP, Pirronti T, et al. High normal TSH values in obesity: Is it insulin resistance or adipose tissue's giut? Obesity (Silver Spring). 2013;21(1):101-06.
[27] Rotondi M, Leporati P, La Manna A, Pirali B, Mondello T, Fonte R, et al. Raised serum TSH levels in Patients with morbid obesity: Is it enough to diagnose subclinical hypothyroidism. J Euro Endcrinol. 2009;160(3):403-08.
[28] Alkac C, Akbas F, Alkac B, Atmaca HU. Obesity and thyroid function. JAREM. 2014;12(2):74-76.
[29] Knudsen N, Laurberg P, Rasmussen LB, Bulow I, Perrild H, Ovesen L, et al. Small differences in thyroid function may be important for body mass index and the occurrence of obesity in the population. J Clin Endocrinol Metab. 2005;90(7):4019-24.
[30] Iacobellis G, Ribaudo MC, Zappaterreno A, Iannucci CV, Leonetti F. Relationship of thyroid function with body mass index, leptin, insulin sensitivity and adiponectin in euthyroid obese women. Clin Endocrinol. 2005;62(4):487-91.
[31] Manji N, Boelaert K, Sheppard MC, Holder RL. Lack of association between serum TSH or free T4 and body mass index in euthyroid subjects. Clin Endocrinol. 2006;64(2):125-28.
[32] Buscemi S, Verga S, Maneri R, Blunda G, Galluzzo A. Influences of obesity and weight loss on thyroid hormones. A 3-3.5-year follow-up study on obese subjects with surgical bilio-pancreatic bypass. J Endocrinol Invest. 1997;20(5):276-81.
[33] Shinkov A, Borissova AM, Kovatcheva R, Atanassova I, Vlahov J, Dakovska L, et al. The prevalence of the metabolic syndrome increases through the quartiles of thyroid stimulating hormone in a population-based sample of euthyroid subjects. Arq Bras Endocrinol Metabol. 2014;58(9):926-32.
[34] Fox CS, Pencina MJ, D'Agostino RB, Murabito JM, Seely EW, Pearce EN, et al. Relations of thyroid function to body weight: Cross-sectional and longitudinal observations in a community-based sample. Arch Intern Med. 2008;168(6):587-92.
[35] Wolters B, Lass N, Reinehr T. TSH and free triiodothyronine concentrations are associated with weight loss in a lifestyle intervention and weight regain afterwards in obese children. Eur J Endocrinol. 2013;168(3):323-29.
[36] De Pergola G, Ciampolillo A, Paolotti S, Trerotoli P, Giorgino R. Free triiodothyronine and thyroid stimulating hormone are directly associated with waist circumference, independently of insulin resistance, metabolic parameters and blood pressure in overweight and obese women. Clin Endocrinol (Oxf). 2007;67(2):265-69.
[37] Reinehr T. Obesity and thyroid function. Mol Cell Endocrinol. 2010;316(2):165-71.
[38] Alevizaki M, Saltiki K, Voidonikola P, Mantzou E, Papamichael C, Stamatelopoulos K. Free thyroxine is an independent predictor of subcutaneous fat in euthyroid individuals. Eur J Endocrinol. 2009; 161(3):459-65.
[39] Roef G, Lapauw B, Goemaere S, Zmierczak HG, Toye K, Kaufman JM, et al. Body composition and metabolic parameters are associated with variation in thyroid hormone levels among euthyroid young men. Eur J Endocrinol. 2012; 167(5):719-26.

PARTICULARS OF CONTRIBUTORS:
1. Assistant Professor, Department of Medical Biochemistry, Gandhi Medical College, Bhopal, Madhya Pradesh, India.
2. Demonstrator, Department of Medical Biochemistry, Gandhi Medical College, Bhopal, Madhya Pradesh, India.
3. Professor, Department of Medical Biochemistry, Gandhi Medical College, Bhopal, Madhya Pradesh, India.
4. MBBS Student, Department of Medical Biochemistry, Gandhi Medical College, Bhopal, Madhya Pradesh, India.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:
Dr. Pawan Kumar Kare,
Demonstrator, Department of Medical Biochemistry, Gandhi Medical College,
Bhopal, Madhya Pradesh, India.
E-mail: pawankare4@gmail.com

PLAGIARISM CHECKING METHODS: [Jain H et al.]
- Plagiarism X-checker: Dec 16, 2019
- Manual Googling: Feb 20, 2020
- iThenticate Software: Apr 14, 2020 (20%)

ETYMOLOGY: Author Origin

AUTHOR DECLARATION:
- Financial or Other Competing Interests: None
- Was Ethics Committee Approval obtained for this study? Yes
- Was informed consent obtained from the subjects involved in the study? Yes
- For any images presented appropriate consent has been obtained from the subjects. NA

Date of Submission: **Dec 15, 2019**
Date of Peer Review: **Jan 31, 2020**
Date of Acceptance: **Mar 05, 2020**
Date of Publishing: **May 01, 2020**