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Correlation of T3, T4 and TSH with Lipid Indices In Obesity

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Abstract
Aim :- *To study the influence of Thyroid hormones on Lipid Indices in Obese individuals*
Background :- *Prevalence of obesity is increasing in India in all age groups irrespective of socioeconomic status in both urban and rural areas. Obesity poses certain health hazards like Diabetes Mellitus, Metabolic syndrome ,Hypertension and Cardiovascular disease. Several studies are underway to understand the cause and effects of obesity. Thyroid dysfunction is a common occurence in South India. Increased accumulation of fats is a common feature of Obesity and Hypothyroidism. An attempt was made to ascertain the relationship of Lipid indices with Thyroid hormones.*
Material and Methods:- *The study was undertaken at Government General Hospital , Guntur. 150 Obese individuals with BMI of >30 were recruited for the study after taking written informed consent. They are classified into 3 groups based on thyroid profile - Euthyroid(N=77), Hypothyroid (N=45)and Hyperthyroid (N=28). Their fasting venous blood samples were analysed for Thyroid profile, Lipid profile , FBS and Creatinine. Anthropometric data like Height, weight & abdominal circumference was recorded . Lipid indices like Atherogenic index of plasma(AIP), Castelli's Risk Index (CRI) 1& 2 , small dense LDL(sdLDL) and Atherogenic Coefficient(AC) were calculated.BMI was calculated(Wt in Kgs/Ht in Mts2)*
Results :- *All the 3 groups showed female preponderance. In all 3 groups TSH and T4 showed significant correlation with individual lipid parameters (ONEWAY ANOVA p value <0.0001) as well as with AIP,CRI 1&2, sdLDL and AC(ONEWAY ANOVA p value <0.00001)There was statistically significant correlation of TSH and T3 with TC, TG and LDL between hypothyroid , hyperthyroid and euthyroid individuals (p value <0.0001).Individually T3, T4 & TSH correlated positively with TG, TC, HDL & LDL in all 3 groups .(p < 0.00001). T3 , T4 & TSH correlated significantly with the Lipid Indices (AIP, CRI-1 & 2 , sdLDL and AC in all 3 groups (p <0.00001) . Spearman's Rho correlation analysis was done to study the correlations among parameters - showed negative correlation of AIP with TC in all 3 groups. Whereas TGs and LDL correlated positively with CRI 1 & 2 , sdLDL & AC (p <0.001) in all 3 groups.*
Conclusion:- *Along with other investigations assessment of thyroid function is mandatory in all obese individuals to predict complications especially cardiovascular disease .*
Key words*: Thyroid profile, Lipid indices ,Obesity*

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I. Introduction

Obesity is a growing health problem in India and worldwide. Changes in lifestyle, urbanization, stress were risk factors increasing the incidence and prevalence of Obesity. According to National Family Health Survey , India-5(2019-20) phase-1 in the state of Andhra Pradesh 36.3% females and 31.1% males were obese or overweight.[1] 44.4% females , 37.7% males urban population and 32.6% females , 28.0% males residents of rural areas have BMI of **≥25.0 kg/m^2.** BMI greater than 30 was considered obese. BMI was calculated using the formula weight in Kgs / height (Mt)^2. The National Cholesterol Education Programme (NCEP) defines dyslipidemia as follows.[2]

1. Hypercholesterolemia -Serum Total Cholesterol >200mgs/dl
2. Hypertriglyceridemia - Serum Triglycerides >150mgs/dl
3. Low HDL-C - Serum High Density Lipoproteins < 40mgs/dl
4. Elevated LDL-C - Serum Low Density Lipoproteins > 130mgs/dl

The Normal range of Thyroid Hormones is

T3 : 0.87-1.78mgs/ml **T4** : 4.82 - 15.65mgs/dl **TSH** : 0.4 - 5.6IU/ml

Thyroid dysfunction was associated with dyslipidemia . Lipid indices were being considered better predictors of risk of cardiovascular disease rather than individual lipid parameters. The Lipid indices were calculated using the following formulae.

Atherogenic Index of Plasma (AIP) = Log (TG/HDL-C)

Castelli's Risk Index - (CRI-1) = TC / HDL-C
Castelli's Risk Index - (CRI-2) = LDL/ HDL-C
Small dense LDL-C (sdLDL) = TG / HDL-C [3]
Atherogenic Coefficient (AC) = (TC-HDL-C) / HDL-C
The following are the abnormal values of lipid ratios for cardiovascular risk: AIP >0.1, CRI-1 >3.5 in males and >3.0 in females, CRI-2 >3.3, AC >3.0, and sdLDL > 4.0[4]

Inspite of the fact that LDL-C is the single atherogenic fraction with risk of CVD, residual and equally important risk factors to be kept in mind are Hypertriglyceridemia, reduced HDL-C and small dense LDL. Non-HDL-C (TC-HDL-C) fraction represents remnant Lipoproteins which increase inflammatory markers and atherosclerosis.[5] It is found that proinflammatory markers remain elevated despite statin therapy.

Thyroid hormones modulate carbohydrate, protein and lipid metabolism.Lipid metabolism is mainly regulated by thyroid hormones.[6] Cholesterol is synthesised in liver and other tissues and transported in circulation in the form of Lipoproteins(Lps). Among the subfractions of Lps Low Density Lipoproteins(LDL-C) are susceptible to oxidation and are atherogenic. Cholesterol esters are synthesised by Lecithin Cholesterol Acyl Transferase(LCAT) , Hormone sensitive Lipase(HL) regulates hydrolysis of High Density Lipoproteins(HDL) and Lipoprotein Lipase(LPL) catabolizes Triglycerides(Tgs). The activity of LCAT, HL & LPL regulated by thyroid hormones. In obesity TSH and T4 were found to be elevated[7,8] and interconversion of T3 & T4 was found to be high in Obesity as a protective mechanism to combat fat accumulation by increasing energy expenditure as well as basal metabolic rate.[9,10].

Presently Lipid indices were being considered as better markers of risk of cardiovascular disease rather than individual lipid fractions especially when they are virtually within normal limits.
AIP acts as a surrogate marker of apolipoprotein(B) , and it accurately reflects the status of atherogenic LDL-C and antiatherogenic HDL-C.
Castelli's risk index -I (TC/HDL-C) indicates intima-media thickness in carotid arteries and higher values are associated with coronary plaque formation [11]
Low Density Lipoprotein has 3 subclasses according to size and density. Large(buoyant) - 26.0-28.5nm, Intermediate - 25.5 - 26.4nm and Small , dense LDL-24.2 -25.5nm were 3 subclasses .[12]These phenotypes can be seggregated by HPLC, GGE(Gradient Gel Electrophoresis) and NMR(Nuclear Resonance Imaging).sdLDL was calculated using the formula suggested by Sabita Palazy et al [13] Atherogenic coefficient is ratio of TC-HDLc / HDL-C.

II. Material and Methods

The present study was undertaken at GGH , Guntur, a tertiary care hospital from August 2019 to February 2020. The individuals were attending medicine OPD for treatment of obesity. 150 Obese subjects with BMI of >30 were selected for the present study. Informed written consent was obtained from them to participate in the study. Anthropometric data was recorded - Height, Weight, Abdominal circumference, waist circumference. Their fasting venous blood samples were collected under asceptic conditions. The blood samples were analysed for FBS, Urea, Creatinine, Triglycerides(TG), Total Cholesterol(TC), High Density Lipoproteins (HDL), Total Triiodotyronine(T3), Total Thyroxine(T4) and Thyroid stimulating hormone(TSH). FBS,Urea, creatinine & Lipid profile was done on Johnson & Johnson Vitros 250 dry chemistry analyser and Thyroid profile was done on Beckman Coultier Access 2 -Chemiluminiscence assay.
Low Density Lipoproteins & Very Low Density Lipoproteins were calculated as follows using Friedwald's formula.[13]
VLDL = TG/5 and LDL = (TC) - (VLDL-HDL).
Depending on TSH & T4 values they were classified into 3 groups viz; Euthyroid (77), Hypothyroid(45) and Hyperthyroid (28).
Inclusion Criteria : Obese individuals with BMI of >30 with FBS value <126mgs/dl , Urea (20-40mgs/dl) and Creatinine (0.6-1.2mgs/dl). All the individuals were normotensive.
Exclusion criteria : Past history of Acute MI, Known Diabetics on treatment, individuals on medication like OC Pills, Antiepileptics or Antipsychotics. Other endocrine disorders were ruled out by taking relevant history.
Statistical analysis : Done by NNCSS 2021 v21.0.2.Data was expressed as Mean ± Standard Deviation(SD).Statistical comparision of means between the 3 groups and within the same group were done by oneway ANOVA(Analysis of Variance). Spearman's Rho correlation was done to study the association between parameters. Area Under Curve (AUC) was done between the 3 groups for lipid ratios to understand their significance & interrelation. P value of < 0.05 was considered as statistically significant.

III. Results :-

Mean , SD of biochemical parameters and Lipid ratios was shown in Table 1. Females were included more in the study than males. Only marginal difference was observed between the mean values of euthyroid, hypothyroid and hyperthyroid groups.Oneway ANOVA showed significant elevation of T4 , TSH , TG, TC, HDL & LDL within the same group as well as amongst the three groups- Table 2, 5, 6 & 7 (p value < 0.00001). Among atherogenic Lipid ratios AIP, CRI-1, CRI-2, sdLDL & Ac correlated significantly with T4 and TSH within hypothyroid obese individuals Table-3 & 4 (p value < 0.00001). Statistically negative correlation was observed between TSH,T3 & T4 and lipid ratios in all 3 groups according to Spearman's Rho Correlation Table 8, 9 and 10 with r value less than 1 .

Area Under Curve (AUC) of AIP was not significant in hyperthyroid / hypothyroid obese individuals compared to euthyroid individuals (0.6)Figure-1. Whereas AUC of CRI-1 , CRI-2 and sdLDL was significant in hyperthyroid /hypothyroid individuals compared to euthyroid individuals (>7.5; 6 & > 4.5 and >7.5 respectively) Figure 2, 3 and 4. Atherogenic coefficient did not show significant elevation in hyperthyroid obese individuals(< 0.5) compared to hypothyroid obese individuals (> 6.5)Figure 5. Means CRI-1, CRI-2 and sdLDL ratios would identify the risk of atherogenesis irrespective of thyroid status in obese individuals. AIP(-10 log of TG and HDL) and AC(a ratio of (TC—HDLc)/ HDLc) in this study did not signify the risk of atherogenicity in euthyroid, hypothyroid and hyperthyroid obese individuals. T3, T4 & TSH correlated negatively with AIP.CRI-1&2 , sdLDL and AC in all 3 groups(r value < 1.0)Table 8, 9 & 10 except positive correlation of T4 with CRI-1&2 and AC in Euthyroid subjects (p value <0.037, <0.01 & < 0.035 respectively)Table 8, 9 & 10. Significant correlation was not observed in this study between T3,T4 and TSH and lipid ratios whereas the study done by Hou Zhenjiang et al.established highly significant positive correlation in hypothyroid individuals.[15]Multiple regression analysis was done considering TSH as dependent variable and lipid ratios as independent variables. It was found that sdLDL was associated with TSH in euthyroid, hypothyroid & hyperthyroid groups (p value <0.01; <0.007 & <0.01) Table 11 whereas other ratios correlated poorly with TSH.

Area Under Curve(AUC) of AIP was 0.5 (Figure-1) in hyperthyroid, hypothyroid Vs euthyroid cases and that of CRI-1 (Figure 2) was >7.5; CRI-2(Figures 3) was **4.0** & 6.0; sdLDL(Figure4) was >7.5 and AC(Figure 5) was <0.5 & > 6.5 at 95% confidence interval. This is in accordance with the study conducted by Nimmanapalli HD et al [16]

Table-1

MEAN & SD OF BIOCHEMICAL PARAMETERS(N=Number of cases)

	HYPOTHYROID	HYPERTHYROID	EUTHYROID
N M F	15 30	5 23	15 62
BMI (>30)	38.4 ± 4.48	33.9 ± 6.3	36.8 ± 4.47
T3(0.87-1.78mg/ml)	10.9 ± 30.89	22.87 ± 39.6	1.33 ± 1.84
T4(4.82-15.65mg/dl)	7.8 ± 1.92	10.92 ± 3.25	8.61 ± 1.89
TSH(0.4-5.6IU/dl)	10.8 ± 4.7	0.4 ± 0.15	2.03 ± 0.59
TG(>150mgs/dl)	139.4 ± 46.08	183.8 ± 94.47	168.15 ± 48.26
TC(>200mgs/dl)	173.9 ± 33.07	214.8 ± 36.02	184.07 ± 31.21
HDL(35-55mgs/dl)	37.2 ± 4.84	38.2 ± 4.66	39.4 ± 5.44
LDL(>130mgs/dl)	112.2 ± 38.32	123.8 ± 13.3	112.2 ± 29.74
AIP	0.21 ± 0.12	0.31 ± 0.19	0.24 ± 0.12
CRI-1	4.7 ± 1.22	5.72 ± 1.45	4.71 ± 1.17
CRI-2	3.1 ± 1.25	3.28 ± 0.59	2.91 ± 0.77
sdLDL	3.78 ± 1.35	4.82 ±2.25	4.26 ± 1.77
AC	3.77 ± 1.24	4.73 ± 1.44	3.74 ± 0.91

Table -2

HYPOTHYROID CASES- ONEWAY ANOVA (N=45)					
	Mean	±Std.Dev	F-ratio	P-value	Significance
T3	10.97	± 30.898			
T4	7.86	± 1.922			
TSH	10.85	± 4.701			
TG	139.4	± 46.08			
TC	173.9	± 33.077	78.74845	< 0.00001	significant at $p < .05$
HDL	37.2	± 4.849			
LDL	112.2	± 34.321	45.02086	< 0.00001	significant at $p < .05$

Table 3 :- ANOVA OF MEAN ± SD OF TSH , CRI-1& 2, AIP , sdLDL AND AC IN HYPOTHYROID CASES (N = 45)

HYPOTHYROID CASES							
	TSH	AIP	CRI-1	CRI-2	sdLDL	AC	
N	45	45	45	45	45	45	*p*-value < .00001
MEAN	10.85	0.21	4.77	3.13	3.78	3.77	
Std.Dev	±4.701	± 0.12	± 1.22	± 1.25	± 1.34	± 1.24	
F IS 31.226 FOR AIP,sdLDL & AC.				F IS 28.301 FOR CRI-1 & 2			
The result is significant at $p < .05$							

Table 4 :-

ANOVA OF Mean ± SD OF T4, AIP, CRI-1&2, sdLDL & AC IN HYPOTHYROID CASES (N = 45)							
	T4	AIP	CRI-1	CRI-2	sd LDL	AC	
MEAN	7.86	0.21	4.77	3.13	3.78	3.77	$F = 44.648$ $p- < .00001$.
SD	1.82	0.12	1.22	1.25	1.34	1.24	
The result is significant at $p < .05$							

Table 5
ANOVA of Mean ±SD OF TSH & TG, TC, HDL & LDL IN Hypothyroid (45) & Hyperthyroid (28) cases

	F -ratio	P value	significance
TG	26.563	< 0.00001	Significant
TC	141.85	< 0.00001	Significant
HDL	125.189	< 0.00001	Significant
LDL	67. 327	< 0.00001	Significant
The result is significant at $p < .05$			

Table -6
ANOVA OF Mean ± SD OF TSH & TG, TC , HDL & LDL IN HYPERTHYROID (28) Vs EUTHYROID(77) CASES

	F -ratio	P value	Significance
TG	94.397	< 0.00001	Significant
TC	369.512	< 0.00001	Significant
HDL	170.449	< 0.00001	Significant
LDL	518.814	< 0.00001	Significant
The result is significant at $p < .05$			

Table 7
ANOVA MEAN ± SD OF TSH & TG, TC, HDL and LDL IN EUTHYROID(77) Vs HYPOTHYROID (45)CASES

	F -ratio	**P value**	**Significance**
TG	**133 . 373**	**< 0.00001**	**Significant**
TC	**382.660**	**< 0.00001**	**Significant**
HDL	**441.664**	**< 0.00001**	**Significant**
LDL	**148.732**	**< 0.00001**	**Significant**
The result is significant at $p < .05$			

Spearman's Rho Correlation

Where the value $r = 1$ means a perfect positive correlation and the value $r = -1$ means a perfect negative correlation

Table -8 EUTHYROID CASES

	AIP	CRI-1	CRI-2	sdLDL	AC
TSH rs p(2-tailed)	0.211 0.288	0.170 0.394	0.127 0.527	0.013 0.946	0.133 0.507
T3 rs p(2-tailed)	0.098 0.626	0.257 0.195	0.335 0.068	0.082 0.684	**0.223** **0.261**
T4 rs p(2-tailed)	0.339 0.082	0.402 0.037	0.484 0.010	0.289 0.142	0.405 0.035

Table- 9 HYPERTHYROID CASES

	AIP	CRI-1	CRI-2	sdLDL	AC
TSH- r_s p(2-tailed)	0.447 0.450	0.223 0.717	0.447 0.450	0.447 0.450	0.223 0.717
T3 r_s p(2-tailed)	0.4 0.504	0.1 0.927	0.5 0.371	0.4 0.504	0.1 0.872
T4 r_s p(2-tailed)	0.615 0.269	0.051 0.934	0.051 0.934	0.615 0.269	0.051 0.934

Table - 10 HYPOTHYROID CASES

	AIP	CRI-1	CRI-2	sdLDL	AC
TSH- r_s p(2-tailed)	0.079 0.828	0.115 0.750	0.188 0.602	0.115 0.749	0.006 0.986
T3 r_s p(2-tailed)	0.273 0.444	0.091 0.802	0.109 0.763	0.280 0.432	0.091 0.802
T4 r_s p(2-tailed)	0.042 0.907	0.273 0.444	0.340 0.335	0.024 0.946	0.212 0.555

Table 11

Multiple regression analysis with TSH as dependent variable

	AIP		CRI-1		CRI-2		sdLDL		AC	
	SE	P	SE	P	SE	P	SE	P	SE	P
EUT	2.65	0.25	0.57	0.25	1.56	0.95	0.001	0.01	0.09	0.23
HYPO	2.75	0.34	0.31	0.18	0.31	0.66	0.002	0.007	0.03	0.02
HYPER	1.12	0.20	0.06	0.37	0.92	0.76	0.0006	0.01	0.17	0.08

Figure 1

AUC - AIP - X-axis (Euthtyroid cases), Y-axis Hypothyroid & Hyperthyroid cases

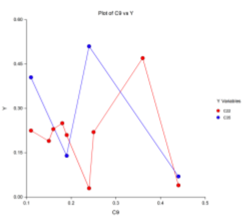


Figure-2

AUC - CRI-1 - X- axis (Euthyroid)cases , Y-axis Hypothyroid , **Hyperthyroid cases**

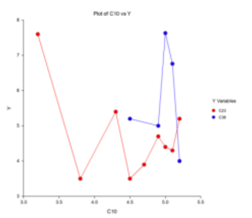


Figure -3

AUC - CRI-2 - X-axis (Euthtyroid cases), Y-axis (Hypothyroid & Hyperthyroid) cases

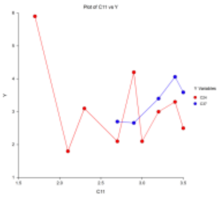


Figure -4
AUC - sdLDL - X-axis (Euthtyroid cases), Y-axis (Hypothyroid & Hyperthyroid) cases

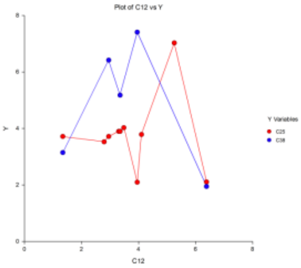
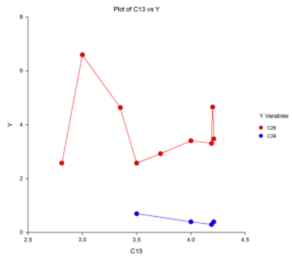


Figure -5
AUC - AC - X-axis (Euthtyroid cases), Y-axis (Hypothyroid & Hyperthyroid) cases



IV. Discussion

Cardiovascular disease is leading cause of death in developing countries.Dyslipidemia was a proven risk factor. Situations leading to dyslipidemia include Diabetes Mellitus, Metabolic syndrome, Thyroid disorders and Obesity. Reduced HDL, elevated Triglycerides, LDL & TC aggravate atherosclerosis.[14] Thyroid dysfunction adversely effects lipid profile. [17] Lipid ratios indicate risk of atherosclerosis when the individual biochemical values are virtually within normal limits . In the present study the same findings were observed in all 3 groups irrespective of the thyroid status though the individuals have a BMI of >30kgs/mt^2.(Table-1). Where as lipid ratios were surely on higher range in all 3 groups.LDL/HDL ratio was <3.0 in Hyperthyroid subjects (2.91 ± 0.77) whereas in hypothyroid & euthyroid subjects it was > 3.0(3.28 ± 0.59 & 3.31 ± 1.25 respectively) . Both TSH & T4 were positively related to individual lipid parameters as well as with lipid ratios in Hypothyroid obese individuals (p value < 0.00001) Table 2, 3 &4.This finding is consistent with that of James et al[18]. Individual biochemical values of lipoproteins correlated significantly positively with TSH between hyperthyroid-Hypothyroid(Table-5); hyperthyroid-euthyroid(Table-6) & hypothyroid -eurthyroid (Table-7) individuals p value <0.00001 at a significant level of p <0.05. T3, T4 &TSH correlated negatively with lipid ratios in Spearman's Rho correlation analysis (Table 8, 9 & 10)as well as in Multiple regression analysis(Table 12) except sdLDL (TG/HDL-C) that showed significant correlation with TSH in all 3 groups (p value <0.01, <0.007 & <0.01).It was suggested by Dobiasova et al that high TG and low HDL-C concentrations induce a surge in sdLDL. The finding was consistent with that of Marwaha et al[19] who suggested that TSH levels of >10IU/L were associated with higher TG, LDL-C and low HDL-C concentrations. Further , Cerbone et al[20] suggested increased TG/HDL-C ratio aggravates atherogenic risk and helps in identifying subjects with cardiovascular disease. Similarly Subramanian S et al[21] suggested that small dense LDL are more susceptible to oxidation ,partly due to less free Cholesterol content. sdLDL were relatively slowly metabolised which enhances their atherogenecity.[22]

V. Conclusion

Typical dyslipidemia of Obesity includes increased TGs, decreased HDL-C and elevated LDL-C & small, dense LDL. Thyroid disorders and obesity are prevalent in South India. Preventable vascular complications could be predicted much in advance using different lipid ratios rather than direct biochemical parameters.Non-HDL fraction (TC-HDL-C) was suggested as a surrogate marker for sdLDL as simple inexpensive method of predicting atherosclerosis. The study could be done for a longer period with clinical follow-up using Electrocardio graph, 2DEcho studies and patient outcome.

Conflict of Interest / Financial support : None

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Abbreviations

T3 - Triiodothyronine
T4 - Thyroxine
TSH - Thyroid stimulating hormone
TC - Total Cholesterol
TG - Triglycerides
HDL-C- High Density Lipoproteins
LDL-C - Low Density Lipoproteins
AIP - Atherogenic Index of Plasma
CRI - Castelli's Risk Index
sdLDL -small dense LDL
AC - Atherogenic coefficient

References

[1]. National Family Health Survey - 5 (2019-20) phase 1, Andhra Pradesh State

[2]. National Cholesterol Education Program (NCEP). Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III)

[3]. Palazhy S, Kamath P, Vasudevan DM (2014) Estimation of Small, Dense LDL Particles Using Equations Derived From Routine Lipid Parameters as Surrogate Markers. Biochem Anal Biochem 3: 146. Volume 3 • Issue 1 • 1000146 Biochem Anal Biochem ISSN: 2161-1009

[4]. Millán J, Pintó X, Muñoz A, Zúñiga M, Rubiés-Prat J, Pallardo LF, Masana L, Mangas A, Hernández-Mijares A, González-Santos P, Ascaso JF, Pedro-Botet J. Lipoprotein ratios: Physiological significance and clinical usefulness in cardiovascular prevention. *Vasc Health Risk Manag.* 2009;5:757–765. [PMC free article] [PubMed] [Google Scholar]

[5]. Fruchart JC, Davignon J, Hermans MP, Al-Rubeaan K, Amarenco P, Assmann G, et al. Residual macrovascular risk in 2013: what have we learned? *Cardiovasc Diabetol.*(2014)13:26. PubMed Abstract | CrossRef Full Text | Google Scholar

[6]. Damiano F, Rochira A, Gnoni A, Sicurella L. Action of thyroid hormones, T3 and T2, on hepatic fatty acids: differences in metabolic effects and molecular mechanisms. *Int J Mol Sci.* (2017) 18:744. PubMed Abstract | CrossRef Full Text | Google Scholar

[7]. Chomard P, Vernhes G, Autissier N, Debry G. Serum concentrations of total T4, T3, reverse T3 and free T4, T3 in moderately obese patients. *Hum Nutr Clin Nutr.* 1985;39:371–378. [PubMed] [Google Scholar]

[8]. Reinehr T. Obesity and thyroid function. *Mol Cell Endocrinol.* 2010;316:165–171. [PubMed] [Google Scholar]

[9]. De Pergola G, Ciampolillo A, Paolotti S, Trerotoli P, Giorgino R. Free Triiodothyronine and thyroid stimulating hormone are directly associated with waist circumference, independent of insulin resistance, metabolic parameters and blood pressure in overweight and obese women. *Clin Endocrinol (Oxf)* 2007;67:265–269. [PubMed] [Google Scholar]

[10]. Reinehr T, Isa A, Sousa G, de, Dieffenbach R, Andler W. Thyroid hormones and their relation to weight status. *Horm Res.* 2008;70:51–57. [PubMed] [Google Scholar]

[11]. Bhardwaj S, Bhattacharjee J, Bhatnagar MK, Tyagi S. Atherogenic index of plasma, Castelli risk index and atherogenic coefficient– New parameters in assessing cardiovascular risk. Int J Pharm Bio Sci. 2013;3(3):359-64

[12]. Manocha A, Bhargava S, Jain R, Kankra M, Singla P, Chugh P. Non-HDL as a Valid Surrogate Marker of Small Dense LDL in a Young Indian Population. *Indian J Clin Biochem*. 2019;34(3):263-271. doi:10.1007/s12291-018-0758-6

[13]. Friedwald WT, Levy RI, Fredrickson DS. Estimation of the concentration of low density lipoprotein cholesterol without use of preparative ultracentrifuge.Clinical Chemistry. 1972;18(6):499- 504.

[14]. *Harrison's Principles of Internal Medicine.* 16th ed. New York: McGraw-Hill; 2005. pp. 1425–30. [Google Scholar]

[15]. Hou Zhenjiang, Mu Zhaoxin, Zhang Jingyu, Fan Hong, Hou jianzhang. The Correlation of Blood Lipid Profile and its Ratio, Cystatin C and Homocysteine of Thyroid Dysfunction. American Journal of Clinical and Experimental Medicine. Vol. 5, No. 4, 2017, pp. 108-114.

[16]. Nimmanapalli HD, Kasi AD, Devapatla PK, Nuttakki V. Lipid ratios, atherogenic coefficient and atherogenic index of plasma as parameters in assessing cardiovascular risk in type 2 diabetes mellitus. Int J Res Med Sci 2016;4: 2863-9.

[17]. Liberopoulos EN, Elisaf MS. Dyslipidemia in patients with thyroid disorders. Hormones (Athens) 2002; 1: 218-23.

[18]. James S.R, Ray L, Ravichandran K, Nanda S. K, High atherogenic index of plasma in subclinical hypothyroidism : Implications in assessment of cardiovascular disease risk. *Indian J Endocrinol Metab*. 2016;20:656-661[PMC free article] [PubMed][Google Scholar]

[19]. Marwaha RK, Tandon N, Garg MK, Kanwar R, Sastry A, Narang A, Arora S , Bhadra K. Dyslipidemia in subclinical hypothyroidism in an Indian population. *Clin.Biochem*. 2010;44:1214-1217[PubMed][Google Scholar]

[20]. Cerbone M,Capalbo D, Wasniewska M, Mattace Raso G, Alfano S, Meli R De Luca F Salerno M. Cardiovascular risk factors in children with long satanding idiopathic subclinical hypothyroidism. *J Clin Endocrinol Metab* 2014;99:2697-2703{PubMed][Google Scholar]

[21]. Subramanian, S.; Chait, A. Hypertriglyceridemia secondary to obesity and diabetes. *Biochim. Biophys. Acta* **2012**, *1821*, 819–825.

[22]. Packard, C.J. Triacylglycerol-rich lipoproteins and the generation of small, dense low-density lipoprotein. *Biochem. Soc. Trans.* **2003**, *31*, 1066–1069.