Section: Biochemistry

Original Research Article

# EVALUATING THE CORRELATION OF HYPOVITAMINOSIS D AND SERUM PTH WITH ALTERED LIPID PROFILE IN ADULT OVERWEIGHT AND OBESE INDIVIDUALS: A CROSS-SECTIONAL STUDY

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ABSTRACT

**Background:** Obesity is a globally rising public health burden and is frequently associated with metabolic abnormalities, including Vitamin D deficiency, hyperlipidemia and altered calcium-PTH regulation.

**Materials and Methods:** This cross-sectional study aimed to determine the correlation between Hypovitaminosis D, serum PTH levels and lipid profile in overweight and obese individuals. A total of 70 adult participants (35 overweight and 35 obese), aged ≥18 years and having BMI≥25 Kg/m$^2$, were recruited from IPD and OPD of Medicine department at KCGMC, Karnal.

**Results:** Vitamin D deficiency (<30 ng/ml) was seen in most participants, with several exhibiting severe deficiency (<10 ng/ml). Serum PTH levels showed an inverse relationship with vitamin D, increasing significantly in individuals with lower vitamin D levels. Dyslipidemia was highly prevalent, with raised triglycerides and low HDL particularly pronounced in obese individuals. A statistically significant negative correlation was observed between vitamin D and BMI( r=-0.115,p=0.016) among overweight individuals and between vitamin D and triglycerides (r=-0.247, p=0.159)among obese individuals. PTH showed statistically significant positive association with BMI (r=0.355,p=0.036) among obese individuals a positive association with BMI and LDL cholesterol. PTH showed a statistically significant positive correlation with triglyceride( r=0.563, p=0.001) ,a statistically significant negative correlation with HDL(r= - 0.339, p=0.047) and a statistically significant positive correlation with VLDL( r=0.560, p=0.001) among obese individuals.

**Conclusion:** Findings suggest that vitamin D deficiency and elevated PTH may contribute to lipid derangements in overweight and obese individuals. Early biochemical screening and targeted supplementation may improve metabolic status and help in reducing long term cardiovascular risk.

**Keywords:** Body Mass Index, Low Density Lipoprotein, High Density Lipoprotein, Cardiovascular Diseases, Obesity, Hypovitaminosis D.

## INTRODUCTION

Obesity is a rising global epidemic,[1] affecting over 800 million individuals including over 670 million adults and at least 120 million children and adolescents, according to statistics from 2016. The World Health Organisation (WHO) projects that by 2025, approximately 167 million additional people

will experience adverse health outcomes associated with being overweight and obese.[2] In India, its prevalence has reached 40.3%, with higher rates in urban (44.17%) and female (41.88%) populations in 2022.[3]

Individuals with obesity often show lack of micronutrients, mainly vitamin D, which is surprising because obese individuals usually consume excess calories and energy. Obesity can negatively affect the health in many ways, increasing the risk of CVD, type 2 diabetes mellitus, musculoskeletal problems like osteoarthritis, and certain cancers including breast and endometrial cancer.[1]

Vitamin D acts as a steroid-like hormone and plays an important role in protecting the body from several diseases such as heart diseases, rheumatoid arthritis and chronic obstructive pulmonary disease (COPD). Its biologically active metabolite 1,25-dihydroxy vitamin D [1,25 (OH)2D], helps in regulation of calcium absorption in the intestines and maintains phosphate balance, which is essential for bone growth and mineralisation.[4]

Vitamin D is produced in the body from the cholesterol precursor 7-dehydrocholestrol found in the skin. When the skin is exposed to sunlight, this compound is converted to cholecalciferol (vitamin D3). In the liver, vitamin D3 is further converted into 25-hydroxy cholecalciferol with the help of 25-hydroxylase, NADPH, cytochrome P450 and oxygen. This form serves as the main circulating and storage form of vitamin D. In the kidneys, 25-hydroxy cholecalciferol is then converted into 1,25-dihydroxy cholecalciferol (calcitriol) by the enzyme 1-alpha hydroxylase, which is the active form of vitamin D3 in the body.[5]

Vitamin D is a fat-soluble hormone, and around 80-90% of it is produced through exposure to sunlight. The remaining 10-20% comes from dietary sources such as milk, oily fish and egg yolk. The recommended daily intake of vitamin D is 400 IU for infants, 600 IU for children and adults, and higher amounts are advised during pregnancy and lactation. For obese individuals, a daily intake of 800 IU is suggested.[6]

A deficiency of vitamin D may result in reduced insulin production and secretion, which can contribute to the development of insulin resistance, type 2 diabetes mellitus, obesity and metabolic syndrome1. Metabolic syndrome is defined as a cluster of metabolic and vascular abnormalities that increase the risk of chronic diseases like hypertension, central obesity, hyperglycemia, elevated serum levels of triglycerides & cholesterol, reduced levels of HDL.[7] Higher parathyroid hormone (PTH) concentrations have also been linked to this condition.[8] Vitamin D deficiency becomes more common as body fat increases, because adipose tissue stores vitamin D and reduce its availability in the bloodstream. Vitamin D also plays a crucial role in regulating energy use within the fat tissue by influencing fatty acid oxidation, insulin sensitivity, and the production of adipokines.[9]

Adipose tissue releases several bioactive substances called adipokines, such as adiponectin, leptin, tumor necrosis factor-alpha (TNF-α), resistin, and plasminogen activator inhibitor-1. These molecules take part in carbohydrate and fat metabolism.[10] Fatty acid oxidation provides a major source of energy for the body, especially in the liver and muscles. Many adipokines, including adiponectin, IGFBP2 (insulin-like growth factor binding protein-2) and FGF21 (fibroblast growth factor 21), help in regulation of lipid metabolism and energy utilization.[11] When vitamin D deficiency is present, disturbance in adipokine activity may occur, contributing to abnormal lipid patterns and increased cardiovascular risk. Dyslipidemia (imbalanced blood lipid levels) promotes fat accumulation within blood vessels and speeds up atherosclerosis. This altered lipid profile typically includes elevated triglycerides, VLDL, LDL, and apolipoprotein B, along with reduced HDL cholesterol1.

Previous study also suggests that vitamin D may improve lipid profiles by lowering triglycerides, total cholesterol and LDL cholesterol. This effect may occur through increased bile acid production, improved calcium absorption, and reduced fat absorption. Vitamin D may also influence the conversion of cholesterol into bile acid in the liver.[4]

PTH works together with vitamin D to maintain normal blood calcium levels by acting on the bones, kidneys, and intestines. PTH levels normally range between 10-55pg/ml. It has effects opposite to calcitonin, which reduces the blood calcium levels. Because vitamin D and PTH interact closely in calcium regulation and metabolism, their relationship with metabolic syndrome has also been explored and a negative correlation between vitamin D levels & BMI and a positive association between PTH concentrations and metabolic syndrome was observed[8]. Dyslipidemia, characterized by high triglycerides, LDL and low HDL, further aggravates cardiovascular risk among overweight and obese individuals[1].

A limited number of research has been done in India on the interrelationship between vitamin D, PTH and lipid profile in overweight and obese adults. This study was therefore conducted to investigate serum vitamin D, PTH and lipid profile differences in overweight and obese subjects, and determine their correlations, to support the evidence-based preventive strategies.

## MATERIALS AND METHODS

**Study design and Settings:** A cross-sectional study was carried out in the Department of Biochemistry in association with the Department of Medicine, KCGMC, Karnal from where overweight and obese

individuals (attendants accompanying patients) with BMI≥25 Kg/m$^2$ in the age group 18 years and above were included in this study.

**Study Population:** A total of 70 (35 overweight and 35 obese) individuals aged 18 years and above with BMI ≥25 Kg/m$^2$ were enrolled in this cross-sectional study.

**Inclusion Criteria:**

The adult overweight and obese individuals (attendants of patients) with BMI≥25 Kg/m$^2$ coming to IPD and OPD of Medicine ward of KCGMC, Karnal.

**Exclusion Criteria:**

1. Individuals with chronic liver disease and kidney diseases.
2. Individuals with Autoimmune diseases.
3. Individuals on vitamin supplementation since 1 year.
4. Individuals on Hypolipidemic drugs.

A detailed clinical history and physical examination was done and blood samples were taken from all the participants. The samples were processed within one hour of collection. Serum vitamin D and PTH were determined by using Orthodiagnostic CLIA analyser and routine investigations including lipid profile were done on Cobas 501 autoanalyser.

**Statistical Analysis:** The data collected was analysed using SPSS software version 20. Categorical data was summarized as number and percentages, and numerical data was summarized as mean and S.D. (median and minimum–maximum when necessary). Kolmogorov–Smirnov test was used to test whether numerical data conformed to normal distribution. Intergroup comparison of numerical data was carried out with independent groups T-test when the assumptions were met, and with the Mann–Whitney U test when assumptions were not met. The correlation between vitamin D, serum PTH and lipid profile were analysed with the Pearson correlation coefficient. A p value of ≤0.05 was used to determine statistical significance in all tests.

## RESULTS

In this study, a total of 70 (35 overweight and 35 obese) individuals who visited to the IPD of medicine department at KCGMC, Karnal between October 2024 to August 2025 were included. The demographic information of participants was checked and research hypothesis was tested leading to the following results.

**Table 1: Comparison of Age & BMI between study groups. A p value of ≤0.05 was statistically significant**

| BMI (Kg/m2) | | N | Mean | Std. Deviation | t-value | p-value |
|---|---|---|---|---|---|---|
| Age (yr) | Overweight | 35 | 38.286 | 13.951 | .307 | .760 |
| | Obese | 35 | 39.229 | 11.627 | | |

[Table 1 & Figure 1] shows distribution of age among the study groups. The mean age of overweight group was 38.28 ± 13.95 years, while the obese group had a mean age of 39.23 ± 11.63 years. The difference in age between the two groups was not statistically significant (t=0.307, p=0.760). This indicates that the age distribution was similar in both groups, and age did not show any meaningful association with BMI category in the study population.

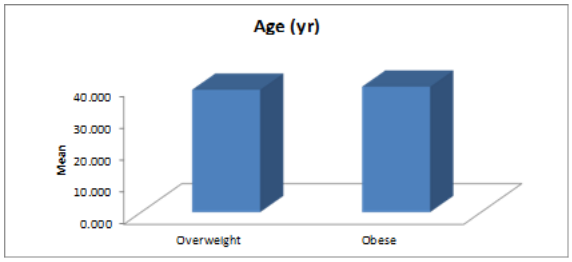


**Figure 1: Age distribution between study groups**

**Table 2: Comparison of lab findings among study groups (overweight & obese). A p value of ≤0.05 was statistically significant**

| Parameter | BMI (Kg/m²) | N | Mean | Std. Deviation | t-value | p-value |
|---|---|---|---|---|---|---|
| Total Cholesterol (mg/dl) | Overweight | 35 | 168.703 | 61.086 | .794 | .430 |
| | Obese | 35 | 158.663 | 43.116 | | |
| Triglycerides (mg/dl) | Overweight | 35 | 199.851 | 148.021 | .947 | .347 |
| | Obese | 35 | 171.946 | 92.187 | | |
| LDL (mg/dl) | Overweight | 35 | 98.143 | 43.436 | .566 | .573 |
| | Obese | 35 | 92.651 | 37.509 | | |
| HDL (mg/dl) | Overweight | 35 | 34.783 | 14.544 | .345 | .731 |
| | Obese | 35 | 33.680 | 12.126 | | |
| VLDL | Overweight | 35 | 39.943 | 29.581 | .946 | .348 |
| | Obese | 35 | 34.371 | 18.420 | | |
| **Parameter** | **BMI (Kg/m²)** | **N** | **Mean** | **Std. Deviation** | **t-value** | **p-value** |
| S. Calcium (mg/dl) | Overweight | 35 | 9.373 | 1.074 | 1.219 | .227 |
| | Obese | 35 | 9.107 | .722 | | |
| S. Phosphorous (mg/dl) | Overweight | 35 | 3.767 | 2.397 | .189 | .851 |
| | Obese | 35 | 3.686 | .846 | | |
| Serum ALP (U/L) | Overweight | 35 | 121.983 | 34.252 | .557 | .579 |
| | Obese | 35 | 128.080 | 54.949 | | |
| Vitamin D (ng/ml) | Overweight | 35 | 23.757 | 9.494 | .682 | .497 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | Obese | 34 | 26.359 | 20.399 | | |
| Serum PTH (pg/dl) | Overweight | 35 | 38.123 | 35.702 | .859 | .394 |
| | Obese | 35 | 32.126 | 20.804 | | |

[Table 2] shows comparison of lab findings among study groups. The overweight group showed a mean total cholesterol level of 168.7 ± 61 mg/dl, while the obese group had a mean value of 158.6 ± 43 mg/dl [Figure 2]. Mean triglyceride levels were 199.8 ± 148 mg/dl in the overweight group and 171.9 ± 92 mg/dl in the obese group [Figure 3]. Mean LDL levels were 98.15 ± 43 mg/dl in overweight participants and 92.65 ± 37.5 mg/dl in obese participants [Figure 4]. Mean HDL levels were 34.8 ± 14.5 mg/dl in overweight group and 33.7 ± 12 mg/dl in obese group [Figure 5]. Mean VLDL levels were 40 ± 29.6 among Overweight and 34.4 ± 18.4 among obese individuals [Figure 6]. Mean serum calcium levels were 9.4 ± 1 mg/dl in overweight and 9.1 ± 0.7 mg/dl in obese people [Figure 7]. Mean serum phosphorous levels were 3.7 ± 2.4 mg/dl in overweight and 3.7 ± 0.8 mg/dl in obese individuals [Figure 8]. Mean serum ALP levels in overweight was 122 ± 34.3 U/L and in obese was 128 ± 55 U/L [Figure 9]. Mean vitamin D levels were 23.8 ± 9.5 ng/ml in overweight group and 26.4 ± 20.4 in obese group [Figure 10], whereas mean serum PTH levels were 38.1 ± 35.7 and 32.1 ± 20.8 pg/dl respectively [Figure 11].

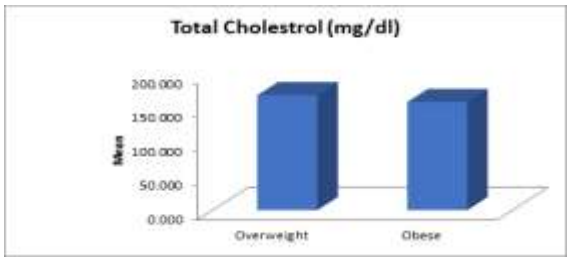


**Figure 2: Distribution of total cholesterol in overweight and obese subjects**


**Figure 3: Distribution of triglycerides in overweight and obese subjects**

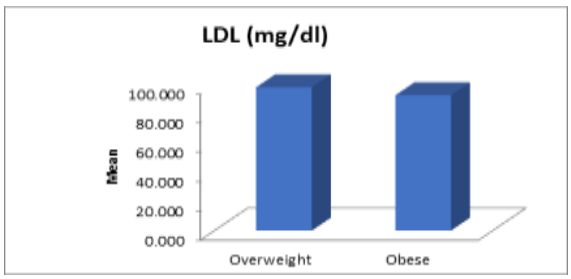


**Figure 4: Distribution of LDL in overweight and obese subjects**

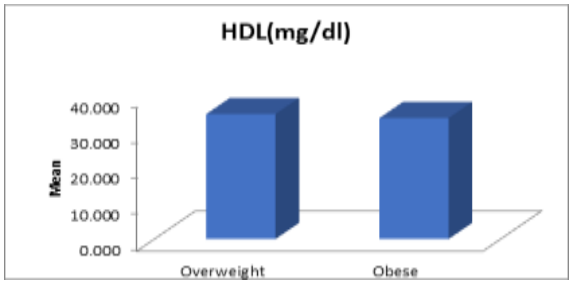


**Figure 5: Distribution of HDL in overweight and obese subjects**

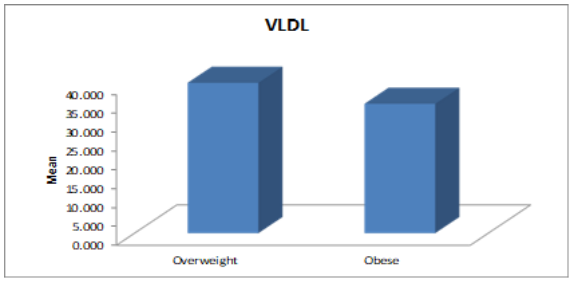


**Figure 6: Distribution of VLDL in overweight and obese subjects**

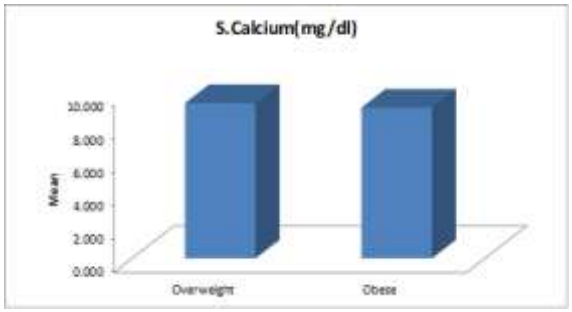


**Figure 7: Distribution of serum calcium in overweight and obese subjects**

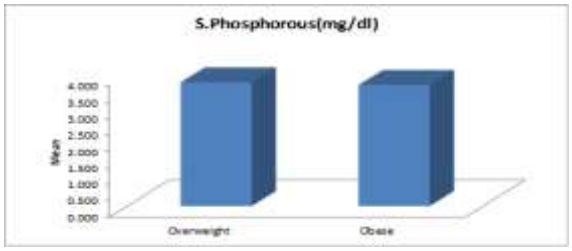


**Figure 8: Distribution of serum phosphorous in overweight and obese subjects**

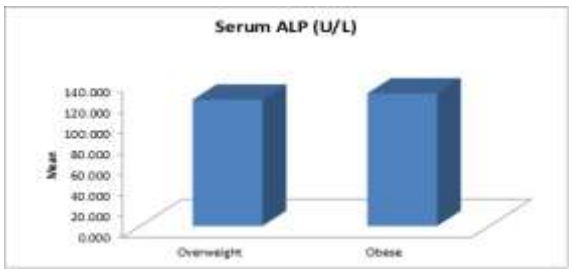


**Figure 9: Distribution of serum ALP in overweight and obese subjects**

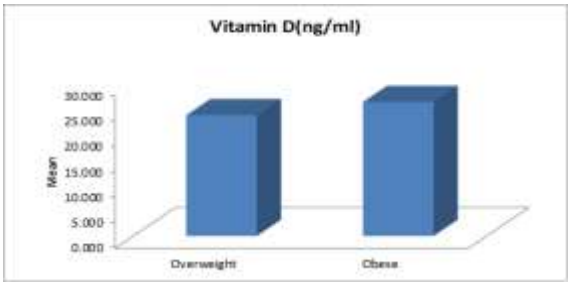


**Figure 10: Distribution of vitamin D in overweight and obese subjects**

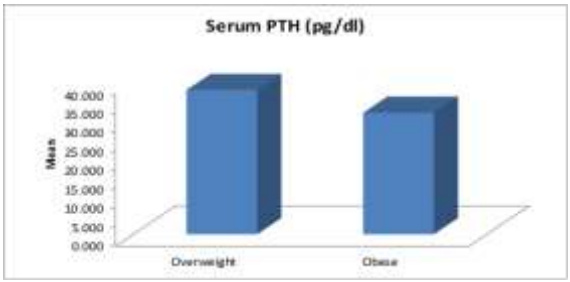


**Figure 11: Distribution of serum PTH in overweight and obese subjects**

**Table 3: Correlation of age, height, weight and BMI with lipid profile & mineral profile in Overweight individuals BMI (Kg/m²): Overweight**

| Parameter | | Age (yr) | Height (m) | Weight (Kg) | BMI (Kg/m²) |
|---|---|---|---|---|---|
| Total Cholesterol (mg/dl) | Pearson Correlation | .026 | .346* | .403* | .272 |
| | p value | .882 | .041 | .016 | .114 |
| Triglycerides (mg/dl) | Pearson Correlation | -.032 | .072 | .182 | .249 |
| | p value | .853 | .680 | .294 | .149 |
| LDL (mg/dl) | Pearson Correlation | -.092 | .278 | .392* | .259 |
| | p value | .641 | .112 | .014 | .133 |
| HDL (mg/dl) | Pearson Correlation | -.028 | .208 | .083 | -.074 |
| | p value | .875 | .230 | .635 | .676 |
| VLDL | Pearson Correlation | -.031 | .070 | .181 | .251 |
| | p value | .860 | .688 | .298 | .146 |
| S. Calcium (mg/dl) | Pearson Correlation | -.054 | .202 | .217 | .028 |
| | p value | .735 | .244 | .212 | .872 |
| S. Phosphorous (mg/dl) | Pearson Correlation | -.048 | .146 | .103 | -.042 |
| | p value | .786 | .402 | .550 | .809 |
| Serum ALP (U/L) | Pearson Correlation | .186 | -.115 | -.044 | .224 |
| | p value | .284 | .508 | .788 | .195 |
| Vitamin D (ng/ml) | Pearson Correlation | .172 | .285 | .269 | -.115 |
| | p value | .323 | .176 | .118 | .509 |
| Serum PTH (pg/dl) | Pearson Correlation | .083 | -.401* | -.314 | .021 |
| | p value | .617 | .017 | .067 | .907 |

* Correlation is significant at the 0.05 level (2-tailed).

The [Table 3] presents correlation coefficients between BMI (kg/m²) and various biochemical markers in overweight individuals. It shows a negative correlation between vitamin D levels and BMI (r = -0.115) and serum PTH values positively correlated with BMI (r = 0.021), but these were statistically not significant. The significant negative correlation between height and serum PTH (r = -0.401, p = 0.017) suggests increased PTH with reduced height. Weight also shows significant positive correlations with total cholesterol (r= 0.403, p= 0.016) and LDL (r= 0.342, p= 0.044) indicating that with increase in weight the chances of increase in total cholesterol and LDL levels are high. Age also shows a negative correlation with lipid profile but it is statistically not significant.

**Table 4: Correlation of age, height, weight and BMI with lipid & mineral profile in Obese individuals BMI (Kg/m²): Obese**

| Parameter | | Age (yr) | Height (m) | Weight (Kg) | BMI (Kg/m²) |
|---|---|---|---|---|---|
| Total Cholesterol (mg/dl) | Pearson Correlation | .263 | -.129 | .007 | .147 |
| | p value | .119 | .460 | .966 | .400 |
| Triglycerides (mg/dl) | Pearson Correlation | .326 | .488** | .224 | .251 |
| | p value | .056 | .003 | .195 | .145 |
| LDL (mg/dl) | Pearson Correlation | .099 | .097 | .131 | .070 |
| | p value | .594 | .579 | .454 | .688 |
| HDL (mg/dl) | Pearson Correlation | -.161 | .037 | .030 | -.017 |
| | p value | .336 | .833 | .866 | .924 |
| VLDL | Pearson Correlation | .329 | .488** | .223 | .253 |
| | p value | .054 | .003 | .190 | .143 |
| S. Calcium (mg/dl) | Pearson Correlation | -.074 | .008 | -.044 | -.098 |
| | p value | .672 | .963 | .803 | .574 |
| S. Phosphorous (mg/dl) | Pearson Correlation | .051 | .185 | .243 | .182 |
| | p value | .769 | .260 | .160 | .298 |
| Serum ALP (U/L) | Pearson Correlation | .265 | .283 | -.186 | .037 |
| | p value | .124 | .100 | .283 | .834 |
| Vitamin D (ng/ml) | Pearson Correlation | -.020 | .202 | .131 | .019 |
| | p value | .911 | .253 | .394 | .915 |
| Serum PTH (pg/dl) | Pearson Correlation | -.032 | -.040 | .147 | .355* |
| | p value | .854 | .820 | .399 | .036 |

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

The [Table 4] shows that in the obese group, most biochemical variables do not have statistically significant linear correlations with age, height, weight, or BMI, except for a few specific relationships. Triglycerides and VLDL show a statistically significant negative correlation with height ($r \approx -0.49$, $p < 0.01$), suggesting that among obese participants, shorter stature is associated with higher triglyceride rich lipoproteins.
Serum PTH shows a statistically significant positive correlation with BMI ($r = 0.355$, $p < 0.05$), indicating that higher BMI is associated with higher PTH levels in this study.

**Table 5: Correlation between different laboratory tests assessed during study in overweight individuals**

| Parameter | | S. Calcium (mg/dl) | S. Phosphorous (mg/dl) | Serum ALP (U/L) | Vitamin D (ng/ml) | Serum PTH (pg/dl) |
|---|---|---|---|---|---|---|
| Total Cholesterol (mg/dl) | Pearson Correlation | .804** | -.069 | .199 | .429* | -.142 |
| | p value | .000 | .692 | .252 | .010 | .416 |
| Triglycerides (mg/dl) | Pearson Correlation | .358* | -.111 | .003 | .078 | -.086 |
| | p value | .030 | .525 | .979 | .671 | .624 |
| LDL (mg/dl) | Pearson Correlation | .637** | -.139 | -.133 | .389* | -.074 |
| | p value | .000 | .424 | .447 | .021 | .676 |
| HDL (mg/dl) | Pearson Correlation | .628** | -.114 | .250 | .362* | -.125 |
| | p value | .000 | .514 | .148 | .033 | .463 |
| VLDL | Pearson Correlation | .358* | -.110 | .007 | .076 | -.086 |
| | p value | .030 | .529 | .967 | .670 | .625 |

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

[Table 5] shows a positive correlation of serum calcium with total cholesterol ($r = 0.804$, $p < 0.01$), LDL ($r = 0.652$, $p < 0.01$), HDL ($r = 0.628$, $p < 0.01$), Triglycerides ($r = 0.368$, $p < 0.05$) and VLDL ($r = 0.368$, $p < 0.05$) which are statistically significant ($p<0.05$) indicating that deranged lipid profileis associated with altered blood calcium levels.
Serum phosphorous showed a negative correlation with total cholesterol ($r= -0.069$, $p>0.05$), triglycerides ($r= -0.111$, $p> 0.05$), LDL ($r= -0.139$, $p> 0.05$), HDL ($r= -0.114$, $p> 0.05$) and VLDL ($r= -0.110$, $p> 0.05$) indicating that with the deranged lipid profile the serum phosphorous levels were decreases in overweight individuals. But the correlation is not significant statistically.
Vitamin D demonstrates a significant positive correlation with total cholesterol ($r= 0.429$, $p< 0.05$), LDL ($r= 0.389$, $p< 0.05$) and HDL ($r=0.362$, $p< 0.05$) indicating that vitamin D levels get decreased with the deranged lipid profile among overweight individuals.. Serum PTH shows a negative correlation with the lipid profile but it was not statistically significant. Serum phosphorous also shows a negative correlation with lipid profile but it's also not significant statistically.

**Table 6: Correlation between different laboratory tests assessed during study in obese individuals**

| Correlations | | | | | | |
|---|---|---|---|---|---|---|
| | | S.Calcium(mg/dl) | S.Phosphorous(mg/dl) | Serum ALP (U/L) | Vitamin D(ng/ml) | Serum PTH (pg/dl) |
| Total Cholestrol (mg/dl) | Pearson Correlation | .383* | .162 | -.251 | .129 | -.010 |
| | p-value | .023 | .354 | .146 | .465 | .952 |
| Triglycerides (mg/dl) | Pearson Correlation | -.220 | -.108 | .420* | -.247 | .563** |
| | p-value | .204 | .536 | .012 | .159 | .000 |
| LDL (mg/dl) | Pearson Correlation | .483** | .217 | -.469** | .205 | -.203 |
| | p-value | .003 | .210 | .004 | .245 | .242 |
| HDL(mg/dl) | Pearson Correlation | .445** | .180 | -.445** | .381* | -.339* |
| | p-value | .007 | .300 | .007 | .026 | .047 |
| VLDL | Pearson Correlation | -.220 | -.109 | .419* | -.243 | .560** |
| | p-value | .204 | .533 | .012 | .166 | .000 |
| **. Correlation is significant at the 0.01 level (2-tailed). | | | | | | |
| *. Correlation is significant at the 0.05 level (2-tailed). | | | | | | |

In [Table 6], serum calcium showed a significant positive correlation with total cholesterol ($r= 0.383$, $p<0.05$), LDL ($r= 0.483$, $p <0.01$) and HDL ($r= 0.445$, $p<0.01$).) indicating increase in total cholesterol and LDL levels are associated with altered the blood calcium levels. Serum ALP demonstrated a strong inverse relation with LDL ($r= -0.469$, $p< 0.01$) and HDL ($r= -0.445$, $p< 0.01$), and a positive correlation with triglycerides ($r= 0.420$, $p< 0.05$).). Serum vitamin D levels showed a

significant positive correlation with HDL (r= 0.381, p< 0.05) indicating that with increase in vitamin D level is associated with rise in HDL levels (good cholesterol). A statistically non- significant inverse correlation with triglycerides (r= -0.247, p>0.05) and VLDL (r= -0.243, p>0.05) indicating that higher serum triglycerides level may be associated with falling vitamin D level. Serum PTH showed statistically strong positive correlations with triglycerides (r= 0.563, p< 0.01), VLDL (r= 0.560, p< 0.01) and a negative correlation with serum HDL (r= -0.339, p< 0.05) suggesting that rise in serum PTH levels may be associated with deranged lipid profile in obese individuals.

## DISCUSSION

Obesity is complex, systemic and rooted in sedentary life style of modern people. Obesity has now been recognised as a global epidemic.

In this study the difference in age between the two groups was not statistically significant (t=0.307, p=0.760) indicating that the age was not associated with BMI category in the study population.[13] This suggests that factors other than age may play a more substantial role in influencing BMI among participants.

Our study showed a positive correlation of serum calcium with the deranged lipid profile including total cholesterol, triglycerides, LDL, HDL and VLDL in both the groups, suggesting that higher serum calcium levels might be associated with altered lipid profiles, potentially increasing cardiovascular risk in the overweight and obese individuals.

A 2023 study on adults in Taiwan confirmed that higher serum calcium was associated with an increased risk of metabolic syndrome and deranged lipid profile, but notably this correlation was significant only in overweight and obese individuals.[14] Another study from South Italy has also found a positive correlation between higher serum calcium and deranged lipid profiles, including total cholesterol, triglycerides and LDL, particularly in men and postmenopausal women.[15] But in our study serum calcium also showed positive correlation with HDL in both overweight and obese individuals which was contrary to the previous studies.[16]

Vitamin D also, showed a significant positive correlation with total cholesterol, LDL and HDL in overweight and obese individuals. This finding was contrary to the previous study done by Huang X et al, which revealed that vitamin D deficiency was associated with increased levels of total cholesterol, triglycerides and LDL while decreased levels of HDL[1].

Serum PTH has shown a positive correlation with the body mass index, and similar finding was stated in a study by Bolland et al,[17] comparing BMI with PTH in both obese and nonobese adults and concluded that fat mass significantly affects serum PTH, independent of the relationship between vitamin D and parathyroid hormone. Serum PTH also showed a positive association with triglycerides & VLDL and a negative correlation with serum HDL levels, indicating that deranged lipid profile may be associated with higher serum PTH levels in obese. This study depicts similar results as observed in previous studies which showed that the relationship between obesity and raised PTH was significant among severely deficient vitamin D patients.[18]

Serum ALP showed a positive association with triglycerides & VLDL and a negative association with LDL & HDL independent of age, sex, and BMI, suggesting potential atherogenic characteristic of ALP.[19] Similar results were found in one study in which serum ALP levels were positively correlated with the triglyceride to HDL cholesterol ratio and that higher ALP was linked to metabolic syndrome components, including hypertriglyceridemia and low HDL cholesterol.[20]

One of the previous studies by Jiang et al showed that low LDL and high HDL-cholesterol levels, which is considered beneficial, showed a negative correlation between liver function as measured by elevated levels of transaminase enzyme and ALP.[21] Individuals on lipid-lowering drugs or with BMI < 30 are more likely to have normal liver function than the others with elevated lipid levels.

Based on the findings of this study, it is clear that deranged lipid profile is associated with vitamin D deficiency and increasing BMI with higher PTH levels. This supports the hypothesis that obesity is associated with decrease in active serum Vitamin D levels as a result of sequestration in adipose tissue and consequent higher serum PTH levels in obese as compared to overweight subjects.

This study suggests that improving lipid profile and vitamin D supplementation in overweight and obese patients might help in decreasing the risk of metabolic syndrome and cardiovascular morbidity associated with the higher BMI. Moreover investigations like Vitamin D, PTH and ALP may help supplement lipid profile in early diagnosis of metabolic syndrome, however this warrants studies on larger cohorts and validated cutoff values for confirming the diagnosis.

## CONCLUSION

In this study we found the positive correlation between vitamin D deficiency and lipid profile levels. Vitamin D also showed positive correlation with HDL (good cholesterol) which was a new finding. Serum PTH showed a stronger positive correlation with triglyceride and VLDL, and negative correlation with HDL in obese subjects. On the other hand, PTH had a strong positive correlation with BMI in obese subjects. Therefore, supplementation with Vitamin D along with life

style modification may help further reduce long term adverse effects of deranged lipid profile in obese subjects.

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