Effect of High and Low Doses of Vitamin D on Insulin Resistance in Healthy Women

Shareefa AlGhamdi (✉ saaalghamdi1@kau.edu.sa )
King Abdulaziz University

Hanan AlHarthi
King Abdulaziz University

Sawsan Khoja
King Abdulaziz University

Amin AlJefri
King Abdulaziz University

Huda F. AlShaibi
King Abdulaziz University

Article

Keywords: vitamin D deficiency, insulin resistance, insulin, type 2 diabetes, body mass index, vitamin D, HOMA-IR, T2DM

Posted Date: July 28th, 2022

DOI: https://doi.org/10.21203/rs.3.rs-1825335/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License. Read Full License
Abstract

Vitamin D has been traditionally involved in regulation of bone homeostasis. However, vitamin D has also been linked clinically to various diseases including metabolic syndrome. The aim of this study was to examine the effect of low and high doses of vitamin D supplement on serum level of vitamin D and insulin resistance. A total of 120 females were recruited in this study and supplemented weekly with 25,000 IU vitamin D or 50,000 IU vitamin D for three months. Anthropometric measurements were measured at the beginning of the study. Blood samples were collected at the beginning of the study to determine the baseline of the clinical variables and collecting again after three months. Insulin resistance was measured using HOMA-IR. After vitamin D supplement, a significant increase observed in serum levels of vitamin D in group treated with low dose of vitamin D (LDVD) and highly significant increase in group treated with high dose of vitamin D (HDVD). In a group treated with higher dose (HDVD), a significant improve in insulin sensitives was observed. High dose of vitamin D (50,000 IU) is more effective in both correcting blood level of vitamin D and improving the sensitivity of insulin.

1 Introduction

Vitamin D has an extremely important functions in the body. Vitamin D functions as a hormone, thus it affects various systems in the body. Vitamin D deficiency is one of the public health issues globally. It’s estimated that about 1 billion people worldwide have low blood levels of vitamin D (Sizar et al., 2022). Vitamin D acts more like a hormone rather than a nutrient. Our bodies have a special ability to synthesize vitamin D from sunlight, unlike other vitamins. Its main function is regulating and improving the capacity to absorb calcium to avoid risk of bone fractures (Nair et al., 2012). Because vitamin D deficiency is an independent risk factor for total mortality in the general population, the high prevalence of vitamin D deficiency is a major public health concern (Autier & Gandini, 2007; Melamed et al., 2008). The first recognition of vitamin D deficiency and its negative health consequences was discovered during the early industrialization of northern Europe in the late 19th century. At that time, coal-burning and other modern developments limited sun exposure for children, which resulted in rickets, a bone-deforming disease (Holick, 2008). Vitamin D deficiency is linked mainly to rickets in children and osteoporosis in adults. Over the course of the 20th century, this issue was addressed in various ways. In addition to an adequate amount of sunshine wherever possible, a nutritional approach that focuses on a well-balanced diet has been helpful for several generations of children. Fortification of milk and cereal products, vitamin D supplements, among other proactive measures to assure that vitamin D deficiencies would be minimal. Consequently, rickets is not a major issue in current times. In addition to the effect of vitamin D deficiency on bones, many contradictory studies are being linked vitamin D deficiency to various health issues including obesity, cardiovascular diseases, cancer, diabetes, mental disorders, among others (Feldman et al., 2014; Eid et al., 2019; Alghamdi et al., 2020; Alabajos-Cea et al., 2021).

Among metabolic disorders, vitamin D deficiency has been linked to the obesity, insulin resistance and diabetes (Gedik, & Akalin, 1986; Wongwiwatthanakanukit et al., 2013; Mason et al., 2014). Insulin resistance is a condition with which some people struggle in managing their blood sugar levels. When this condition
occurs, the body's tissues are unable to use blood sugar effectively and they also have difficulty recognizing when the levels of sugar in their bloodstream rise. This leads to high glucose and insulin levels, which can cause weight gain, fatigue, and mood swings among other symptoms.

In several cross-sectional studies, low blood level of vitamin D was found to be associated with higher incidence of obesity (González-Molero et al., 2013), hyperglycemia (Need et al., 2005), diabetes (Barbarawi et al., 2020) and insulin resistance (Liu et al., 2009). Intervention studies have not adequately identified the observed correlations between vitamin D deficiency and poor glucose tolerance and diabetes in humans. If vitamin D treatment improves glucose metabolism, these benefits are most likely to be seen in patients who are low in the vitamin and the results are inconclusive (Ford et al., 2005; Belenchia et al., 2013; Miao et al., 2021).

In Saudi Arabia, rising prevalence of obesity and diabetes is a serious public health problem of the 21st century and it is increasing at an alarming rate (Khoja et al., 2018; Al-Hanawi et al., 2020a; Al-Hanawi et al., 2020b; Al-Hanawi 2021). On the other hand, the prevalence of vitamin D deficiency in Saudi population is very high where in western region, for example, has been estimated to be 80% (Ardawi et al., 2011) and in other regions has reached approximately 50% in students and 44% in employees indicating a serious health concern that needs an effective awareness program (Kaddam et al., 2017).

The aim of the present study was to investigate the effect of two different doses (high & low dose of vitamin D) on both insulin resistance and the level of serum vitamin D in Saudi healthy women who don't have diabetes and then examining how normalizing the level of vitamin D could affect insulin resistance. If correcting vitamin D deficiency improves insulin sensitivity, it may slow the progression of type 2 diabetes and the metabolic syndrome, which includes insulin resistance as a key component.

2 Materials And Methods

2.1 Study Design:

The current study was approved by the Unit of Biomedical Ethics at king Abdulaziz University. All experiments were performed in accordance with relevant guidelines and regulations. All participants signed a consent form indicating their informed consent and held the right to drop out of the study at any time. A cohort of 120 women aged 18–54 years were recruited from the local community in Jeddah, Saudi Arabia by local advertisements. This study was carried out between May 2017 and January 2018 (to cover mix seasons of the year) as an intervention prospective cohort study. The health status of all participants was verified by a physician at the family medicine department in KAUH. Eligible participants were then blindly divided into two groups, each composing of 60 participants. The first group was assigned as low dose vitamin D (LDVD) group, treated with (25000 IU / week). The second group was supplemented with high dose of vitamin D3 (HDVD) (50000 IU / week) and assigned as high dose vitamin D (HDVD) group. At the beginning of the study, a baseline fasting blood samples were collected to measure the biochemical variables of each group and to compare between the LDVD and HDVD
groups. The participants from each group were asked to take orally one tablet of vitamin D3 for 3 months (one tablet 25000 IU or 50000 IU per week). The vitamin D3 serum levels (25 OH vitamin D) and other biochemical markers were examined again at the end of the study.

2.2 Exclusion Criteria

Participants who were unable to provide informed consent were excluded. Women who were pregnant, lactating or menopause were also excluded from the study. Exclusion criteria also included regular use of vitamin D supplements; more than 10 micrograms (400 IU) vitamin D daily, history of chronic and acute diseases, prescribed Ca supplements, PTH and history of diseases that might limit their ability to participate in the study (physically or mentally) and/or affect the results including medications disturbing vitamin D and glucose metabolism.

2.3 Anthropometric Data

All the anthropometric data and lifestyle characteristics of all participants were collected from the questionnaire through a personal interview. The main collected data including age, marital status, level of education, past medical history, smoking, physical activity, vitamin d and Ca supplementations, use of pharmaceutical drugs, dairy consumption, sun's exposure, clothing case, and sunblock usage. Subjects were weighed (while wearing minimal clothing) on an electric scale (Kg), height without shoe was measured (cm) and waist was measured (cm). Body mass index (BMI) was calculated using weight in kilograms divided by height in meters squared. Body fat percentage (BFP) was measured by electric scale. Blood pressure and heart rate were also recorded.

2.4 Biochemical Analysis

All materials and reagents used in the laboratory experiments of this study were of analytical grade. The laboratory works were carried out in Chemistry Lab at King Abdulaziz University Hospital (KAUH). In brief, after overnight fasting for at least 8 hours, blood samples were collected, and serum was prepared. Vitamin D (25OH vitamin D3), parathyroid hormone (PTH), calcium (Ca), magnesium (Mg), Phosphorus (P), lipid profile (triacylglycerol TAG, low density lipoprotein LDL, high density lipoprotein HDL and cholesterol CHOL) albumin, creatinine, C-reactive protein (CRP), glucose and insulin were all measured using fully automated systems at KAUH. All measurements were repeated by the end of study after completion three months of supplement with low and high doses of vitamin D. Insulin resistance was measured using HOMA-IR (Homeostatic Model Assessment for Insulin Resistance) according to the equation:

\[
\text{HOMA-IR} = \frac{\text{fasting glucose (mmol/L)}}{22.5} \times \frac{\text{fasting insulin (\(\mu\text{U/mL}\))}}{\text{fasting glucose (mmol/L)}}
\]

The normal HOMA-IR value of healthy human ranges from 1.7-2.0 with significant insulin resistance: > 2.9 (Salgado et al., 2010).

2.5 Statistical Analysis
The data obtained during the study were analyzed utilizing IBM SPSS Statistics for Windows, version 23 (IBM SPSS, IBM Corp., Armonk, N.Y., USA). Graphs were generated by GraphPad Prism, version 8.0. Shapiro–Wilk test was utilized to evaluate normal value distribution. Data were expressed as mean +/- standard error of mean (minimum – maximum). Significance between LDVD and HDVD was conducted using Mann Whitney test for non-normally distributed data and unpaired student "t" test for normally distributed data. To compare between before and after treatment of the same group, Wilcoxon test used for non-normally distributed data and paired student "t" test for normally distributed data. The difference was considered significant if P-value < 0.05.

3 Results

3.1 Demographic and Anthropometric Data

The demographic and anthropometric data of all participants are summarized in Table- 1. Age and BFP data were not normally distributed, thus minimum and maximum are presented. None of the participants were smokers. All participants were of Saudi nationality. The education level of all participants varies between high school (20%, n = 24), bachelor (69.2, n = 83) and postgraduates (10.8%, n = 13).

Table 1 Anthropometric and demographic data of the study groups
<table>
<thead>
<tr>
<th></th>
<th>LDVD <em>(n = 60)</em></th>
<th>HDVD <em>(n = 60)</em></th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Nationality</strong></td>
<td>Saudi 100%</td>
<td>Saudi 100%</td>
<td>NS</td>
</tr>
<tr>
<td><strong>Age (years)</strong></td>
<td>33.20 ± 2.56</td>
<td>26.18 ± 1.62</td>
<td>NS</td>
</tr>
<tr>
<td>(20–54)</td>
<td></td>
<td>(18–49)</td>
<td></td>
</tr>
<tr>
<td><strong>Weight (Kg)</strong></td>
<td>70.68 ± 3.55</td>
<td>67.37 ± 2.49</td>
<td>p &lt; 0.05</td>
</tr>
<tr>
<td><strong>Hiegt (cm)</strong></td>
<td>156.7 ± 1.23</td>
<td>158.1 ± 1.19</td>
<td>NS</td>
</tr>
<tr>
<td><strong>BMI</strong></td>
<td>28.57 ± 1.49</td>
<td>26.81 ± 1.45</td>
<td>NS</td>
</tr>
<tr>
<td><strong>Waist circumference (cm)</strong></td>
<td>85.66 ± 2.99</td>
<td>82.51 ± 2.01</td>
<td>NS</td>
</tr>
<tr>
<td><strong>Body fat PERCENTAGE (BF%)</strong></td>
<td>32.66 ± 1.72</td>
<td>29.36 ± 1.23</td>
<td>p &lt; 0.05</td>
</tr>
<tr>
<td>(14.60–44.70)</td>
<td></td>
<td>(13.50–39.0)</td>
<td></td>
</tr>
<tr>
<td><strong>Systolic blood pressure (SBP) (mmHg)</strong></td>
<td>119.1 ± 2.47</td>
<td>119.3 ± 2.72</td>
<td>NS</td>
</tr>
<tr>
<td><strong>daiastolic blood pressure (DBP) (mmHg)</strong></td>
<td>73.04 ± 2.04</td>
<td>72.32 ± 2.91</td>
<td>NS</td>
</tr>
<tr>
<td><strong>Heart rate (HR)</strong></td>
<td>81.61 ± 3.01</td>
<td>84.79 ± 2.39</td>
<td>NS</td>
</tr>
<tr>
<td><strong>Smoking</strong></td>
<td>0%</td>
<td>0%</td>
<td>NS</td>
</tr>
</tbody>
</table>

### 3.2 Veil Style and Sun Exposure

All women in this study wear a headscarf, given the environment and religious culture in society. However, the veil level was different, 5.1%, wear full veil of the body covering the eyes and hands. 85.7% wear full veil of body with a face covering but without eyes and hands. This group formed the majority of the participants. Approximately 9.2% wear full veil of body but without covering the face and hands.

According to the questionnaire there was a variation in the time of exposure to the sun. Most of the participants (53.3%) used to expose to the sun from 8 to 11 am. While 20.3%, and 2% used to expose to the sun from 11 am to 3 pm and from 3 to 5 pm, respectively. About 24.2% were never intentionally exposed to the sun. There was also a difference in the duration of sun exposure per day. About 40.8%, usually expose to the sun for a quarter of an hour and about 38.8% for half an hour. While the rest of the participants usually expose for less than quarter of an hour. All these data are presented in Fig. 1.

### 3.3 Biochemical Measurements

To assess the health status of the participants, the baseline levels of lipid profile, magnesium (Mg), phosphorus (P), parathyroid hormone (PTH), albumin, C-reactive protein (CRP) and creatinine were
measured at the beginning of the study. After 3 months of vitamin D supplement with low and high dose of vitamin D the serum levels of these markers were measured again. The health biochemical measurements are presented in Table-2. The results showed that they were in normal levels and no significant change observed after vitamin D supplements except for high-sensitivity CRP which significantly decreased in both LDVD and HDVD groups.

Table2 Biochemical measurements

<table>
<thead>
<tr>
<th></th>
<th>LDVD-B</th>
<th>LDVD-A</th>
<th>HDVD-B</th>
<th>HDVD-A</th>
</tr>
</thead>
<tbody>
<tr>
<td>CA (mmol/L)</td>
<td>2.164 ± 0.02</td>
<td>2.23 ± 0.03</td>
<td>2.224 ± 0.013</td>
<td>2.181 ± 0.02</td>
</tr>
<tr>
<td>Albumin (g/L)</td>
<td>36.0 ± 0.77</td>
<td>36.26 ± 0.89</td>
<td>38.75 ± 0.58</td>
<td>38.74 ± 0.64</td>
</tr>
<tr>
<td>P (mmol/L)</td>
<td>1.042 ± 0.03</td>
<td>1.03 ± 0.32</td>
<td>1.03 ± 0.03</td>
<td>1.05 ± 0.02</td>
</tr>
<tr>
<td>PTH (pmol/L)</td>
<td>5.43 ± 1.65</td>
<td>5.46 ± 1.84</td>
<td>(4.43 ± 1.42)</td>
<td>(4.39 ± 1.01)</td>
</tr>
<tr>
<td>MG (mmol/L)</td>
<td>0.873 ± 0.02</td>
<td>0.875 ± 0.02</td>
<td>0.853 ± 0.01</td>
<td>0.839 ± 0.01</td>
</tr>
<tr>
<td>TAG (mmol/L)</td>
<td>0.933 ± 0.12</td>
<td>0.923 ± 0.08</td>
<td>0.745 ± 0.06</td>
<td>0.7175 ± 0.05</td>
</tr>
<tr>
<td>HDL (mmol/L)</td>
<td>1.628 ± 0.07</td>
<td>1.741 ± 0.08</td>
<td>1.665 ± 0.05</td>
<td>1.679 ± 0.05</td>
</tr>
<tr>
<td>ldl (mmol/L)</td>
<td>2.656 ± 0.17</td>
<td>2.671 ± 0.17</td>
<td>2.503 ± 0.11</td>
<td>2.564 ± 0.12</td>
</tr>
<tr>
<td>Chol (mmol/L)</td>
<td>4.713 ± 0.21</td>
<td>4.579 ± 0.19</td>
<td>4.529 ± 0.13</td>
<td>4.429 ± 0.12</td>
</tr>
<tr>
<td>High-sensitivity CRP (mg/L)</td>
<td>7.859 ± 0.13</td>
<td>5.522 ± 0.65</td>
<td>5.852 ± 0.83</td>
<td>5.71 ± 0.647</td>
</tr>
<tr>
<td>Creatinine (µmol/L)</td>
<td>56.26 ± 2.02212</td>
<td>56.65 ± 2.07</td>
<td>52.93 ± 1.553</td>
<td>54.52 ± 1.75</td>
</tr>
</tbody>
</table>

a LDVD-B vs. LDVD-A  
b HDVD-B vs. HDVD-A
3.4 Vitamin D, PTH and calcium

The biochemical measurements of serum vitamin D, PTH and calcium were measured at the beginning of the study to determine the baseline levels. These data are presented in Figure- 2. No significant difference has been observed in serum 25 (OH) vitamin D level between LDVD and HDVD groups. All groups were characterized by low serum levels of vitamin D showing that participants have vitamin D insufficiency\deficiency (< 50 nmol/L). After 3 months. in LDVD group, a small but significant difference (p = 0.041) has been observed before vitamin D supplements (40.48 ± 4.39) nmol/L and after supplements (58.10 ± 6.53) nmol/L. In HDVD group, a highly significant difference has been observed before vitamin D supplements (32.15 ± 2.85) nmol/L and after supplements (100.02 ± 7.24) nmol/L, (P < 0.0001). Also, a significant higher vitamin D levels seen in HDVD comparing to LDVD (P < 0.01). PTH was slightly but significantly decreased in HDVD group after 3 months of vitamin D supplement and comparing to LDVD group. No significant difference has been observed.

3.5 Glucose, insulin and HOMA-IR

The fasting levels of glucose and insulin as well as HOMA-IR are presented in Fig. 3. No significant difference was observed in serum fasting glucose level confirming that all participants are diabetics and thus having normal blood glucose level. The mean values of HOMA-IR in LDVD group before and after treatment were (2.40 ± 0.26 and 3.02 ± 0.34, respectively). In HDVD, the mean values before and after treatment were (2.89 ± 0.23 and 1.79 ± 0.11, respectively). A significant decrease in serum insulin levels accompanied by a significant decrease in insulin resistance measured by HOMA-IR was observed in group treated with HDVD comparing to the LDVD group. In LDVD group, insulin levels and HOMA-IR were increased after 3 months of supplement comparing to the baseline levels (p = 0.043).

Pearson analyses were performed to assess the relationships between serum vitamin D level, serum insulin level and insulin resistance degree measured by HOMA-IR. No correlation observed between vitamin D and glucose. The results showed no significant correlation between vitamin D, insulin level and HOMA-IR in LDVD group. However, a significant opposite correlation was observed between vitamin D and insulin level (r= -0.236, P < 0.05) and HOMA-IR (r= -0.341, P < 0.05) in HDVD group.

Table 4 Pearson correlation coefficient of vitamin D with insulin levels, glucose and HOMA-IR after treatment with low and high doses of vitamin D.
4 Discussion

Vitamin D deficiency is a global health issue (Bouillon et al., 2022). Vitamin D deficiency has long been linked to various skeletal disorders. In the recent decades vitamin D has been linked to other diseases including diabetes, obesity, insulin resistance among others (Holick, 2008). Obesity is the major leading cause of insulin resistance (Kahn et al, 2006). The aim of the present study was to assess the effect of two different doses of vitamin D on the insulin resistant in healthy women.

This study identified several demographic and lifestyle factors related with vitamin D levels. Studies stated that vitamin D intake, age, body mass index, blood pressure and body fat levels are main determinants of the serum 25(OH)2 D3 concentration (The participants in this study were Saudi females and according to the data analysis most participants (82.5%) were characterized by body mass index (BMI) higher than 25 indicating that the majority of the participants are overweight and obese. According to the results of a recent published study the prevalence of obesity in Saudi population was 24.7% (Althumiri et al., 2021). It is worth noting that the weight of most participants is not considered very high, however, their mean height ranges between (156–158 cm) hence explaining the increase seen in BMI. Therefore, it is recommended to inform females in this population to use BMI rather than absolute weight in monitoring and assessing the degree of being overweight and obese.

The present study showed that the participants are characterized by vitamin D deficiency where 76% had a serum vitamin D level less than 50 nmol/L. These results are in accordance with many previous studies that showed a prevalent incidence of vitamin D deficiency in the Saudi population of different age and gender groups (AlFaris et al., 2019). The incidence is more prominent in females in the Saudi population.
(Hussain et al., 2014; Alzaheb, 2018). The results also showed that most participants were wearing veils and that the time and duration of sun exposure is inadequate. According to Alshahrani and his colleagues, the peak time for vitamin D production is from 10.00 am until 2.00 pm (Alshahrani et al., 2013). Thus, the vitamin D insufficiency seen in this study might be attributed to several factors such as low vitamin D intake, wearing veils, as well as time and duration of sun exposure. About 40.8% of the participants indicated that they are exposed to the sun for about 15 minutes only per day. The results also showed that supplement with higher dose of vitamin D (50,000 IU) is more beneficial than lower dose (25,000 IU) in correcting the level of serum 25 (OH) D3. Thus, it is recommended for Saudi females to use a higher dose of vitamin D to achieve and maintain the optimal level of vitamin D as well as increasing the exposure time to the sun. Fortified foods and reasonable dietary supplements as well as sensible sun exposure are recommended to achieve an acceptable range of vitamin D in general population and prevent vitamin D deficiency.

The current results showed that treatment with 50,000 IU of vitamin D for three months increases the sensitivity to insulin level and significantly reducing the insulin resistance index measured by HOMA-IR. In LDVD group, a slight increase seen in circulating insulin level. These results agree with a study conducted in 2021 (Rafiq & Jeppesen, 2021). It has been stated that vitamin D stimulates insulin secretion in the beta cells of the pancreas and improves insulin sensitivity in target cells, i.e., muscle, adipose tissue, and liver (Cade, 1987; Mathieu et al., 2001). Low blood levels of 25(OH) D3 has been linked to hyperglycemia and insulin resistance (Chung et al., 2014; Rafiq & Jeppesen, 2018). Therefore, high doses of vitamin D and not low doses might be implicated positively in ameliorating the insulin sensitivity in overweight people. One assumption could be that serum level of 25 (OH) vitamin D3 should reach a certain blood concentration to affect insulin sensitivity. It is known that insulin secretion is affected by PTH which is mediated by raising the concentration of Ca (Fadda et al., 1990; Chiu et al., 2000). In the present study, HDVD group was characterized by significantly lower level of PTH and non-significantly lower Ca level. Consequently, it is also possible that increased serum level of 25(OH) D3 affects absorption of Ca which is then regulating insulin secretion. Our findings are supported by the previous studies (El Bilbeisi et al., 2021). We also found a significant negative correlation between serum 25(OH) D3 and both insulin resistance and HOMA-IR. These findings are in agreement with other clinical studies (Ogunkolade et al., 2002; Schuch et al., 2013). Vitamin D function is mediated by its receptors (Kato, 2000). Pancreatic beta cells have the receptors for vitamin D (Ozeki et al., 2013), This suggests a role of vitamin D in the functions of the beta cells. Previous studies have demonstrated that knocking out vitamin D receptors and the resulting vitamin D deficiency resulted in impaired insulin secretion-induced by glucose (Gedik & Akalin, 1986; Zeitz et al., 2003). It has also been found that vitamin D can directly increase insulin receptor expression, thereby increasing insulin stimulation of glucose transport (Maestro et al., 2000). Several mechanisms might be contributed to the effect of vitamin D on insulin resistance; however, the exact underlying mechanism is still unclear. Therefore, further research is in need to unmask this mechanism. Altogether, our results suggested that correcting serum level of 25 (OH) D3 might be particularly important in ameliorating insulin resistance and thus reducing the risk of developing diabetes mellitus in overweight\obese population.
Conclusion

Supplement with higher dose of vitamin D (50,000 IU) has a more significant effect in improving the serum level of vitamin D. Supplement with high dose of vitamin D ameliorate insulin resistance and has a positive effect on improving insulin sensitivity in overweight females.

Limitations

The main limitation of this study is the small sample size which might affect the outcomes of some statistical analysis.

Declarations

Acknowledgment:

The authors thank the deanship of scientific research (DSR). This work was supported by the deanship of scientific research (DSR) – King Abdulaziz University – Saudi Arabia under Grant [RG: 38——].(NB: the full fund number will be written in full)

We greatly thank the study participants for their participation and corporation.

Conflict of interest

All authors declare that they have no conflict of interest.

Author Contributions

All authors contributed to this work.

References


Figures
**Figure 1**

Veil style, duration and time of sun exposure of all participants.
Comparison of fasting serum levels of vitamin D, Ca and PTH. Comparison was carried out between LDVD & HDVD groups and their levels before (B) and after (A) treatment of the same group using unpaired & paired student “t” test respectively. Data were considered significant if p < 0.05.
Figure 3

Comparison of measurements of glucose, insulin and HOMA-IR. Comparison was carried out between LDVD & HDVD groups and their levels before (B) and after (A) treatment of the same group using unpaired & paired student “t” test respectively. Data were considered significant if p < 0.05.