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# GLYCEMIC REGULATION AND SLEEP QUALITY: EXPLORING THE CONNECTIONS BETWEEN VITAMIN D STATUS AND ITS IMPACT ON SLEEP PATTERNS, QUALITY, AND HEALTH IN TYPE 2 DIABETES PATIENTS

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## Abstract

***Introduction:*** *Type 2 diabetes (T2D) is greatly influenced by lifestyle factors such as obesity, inactivity, and sleep disturbances, all of which contribute to insulin resistance. Micronutrients such as vitamin D play a vital role in regulating sleep by affecting inflammation and brain receptors involved in the sleep-wake cycle. The link between diabetes and sleep is significant, with many patients experiencing poor sleep quality or insomnia, making it crucial to address these issues for effective management of T2D.*

***Methodology:*** *A group of 200 patients with type II diabetes was selected from the Endocrinology Ward at Lady Reading Hospital (LRH) in Peshawar, following their written consent. A self-developed questionnaire was used to collect data on various demographic factors, including age, gender, marital status, education level, income, and family structure. Biochemical records such as blood glucose levels and serum vitamin D were also gathered. Dietary intake patterns were assessed using a semi-quantitative Food Frequency Questionnaire (FFQ) and the 24-hour dietary recall method. Nutrient analysis was performed using Windiet software. Additionally, sleep quality was evaluated using the Pittsburgh Sleep Quality Index (PSQI). Data analysis included descriptive statistics and logistic regression models.*

***Major Results:*** *The respondents were primarily male (52%), aged 25–60, and mostly belonging to urban (70%) with a high illiteracy rate (55%) and income below 50,000 PKR. A strong family history of diabetes (80.5%) was observed. Glycemic control was poor (9.59 ± 2.41 in males, 9.51 ± 1.76 in females), with elevated blood pressure (DBP: 81.63 ± 3.73 for males, 83.61 ± 4.91 for females; SBP: 125.00 ± 9.96 for males, 122.33 ± 9.44 for females). Serum vitamin D was low (29.16 ± 5.07 among males, 28.95 ± 4.86 among females). Mean dietary vitamin D for ages 24–49 was 1.67 ± 0.44 (males) and 1.31 ± 0.44 (females), and for ages 50+, it was 3.57 ± 0.51 (males) and 3.51 ± 0.37 (females), all below the RDA. The mean score for sleep quality of male respondents for good sleep and poor sleep was (3.44 ± 0.73) and (9.34 ± 3.52), respectively. The same score for female respondents for good sleep and poor sleep*

*was (3.45 ± 0.60) and (10.60 ± 3.33), respectively. Female respondents had high percentages for sleep latency and daytime dysfunction. Overall, females had poor sleep quality after evaluation of all the parameters. The regression statistics showed a surprisingly positive predictability of hyperglycemia (Hba1c) and Vitamin D deficiency (Serum Vitamin D) for all the sleep parameters and total PSQI scores on the Pittsburgh Sleep Quality Index.*

***Conclusion:*** *The current study concludes that poor glycemic control, widespread hypovitaminosis D, poorer sleep quality among most of females than males with imbalanced dietary patterns and an overall poor sleep quality and vitamin D deficiency which need to be addressed both at the individual and clinical levels.*

## INTRODUCTION

The global health landscape has been increasingly burdened by metabolic disorders, particularly diabetes mellitus, which have emerged as a significant public health challenge. According to the International Diabetes Federation, in 2017, it was estimated that nearly 451 million individuals worldwide were living with diabetes [1]. Alarmingly, projections indicate that this figure could rise to approximately 592 million by 2035 and potentially reach 693 million by 2045 [2]. Type 2 diabetes is particularly concerning, as it currently accounts for about 95% of all diagnosed cases of diabetes [3]. In China, the situation is especially dire, with a diabetes prevalence rate of approximately 9.75%, which places a considerable burden not only on affected individuals but also on their families and broader society [4,5]. Diabetes is characterized as a progressive, chronic disease capable of adversely affecting multiple organ systems, leading to a series of serious health complications. These complications are typically categorized into microvascular and macrovascular issues. Microvascular complications may include nephropathy (kidney damage), retinopathy (damage to the retina), and neuropathy (nerve damage), while macrovascular complications can involve conditions such as ischemic heart disease, cerebrovascular disease (including strokes), and peripheral vascular disease. Given the upward trend in diabetes prevalence, it is crucial to develop a refined understanding of both clinical and behavioral risk factors that contribute to poor diabetes outcomes [6]. A variety of behavioral risk factors have been linked to the worsening of diabetes complications, including smoking, physical inactivity, and inadequate dietary choices [7-10]. Recently, sleep disorders have garnered attention as emerging behavioral risk factors closely associated with diabetic complications [11]. Severe forms of sleep disorders can severely disrupt various aspects of an individual's physical, mental, social, and emotional well-being, ultimately causing significant distress during waking hours. The International Classification of Sleep Disorders identifies over 80 distinct types of sleep disorders [12]. Among these, insomnia, restless leg syndrome, sleep paralysis, and sleep apnea are the most prevalent [13]. Research indicates that insomnia affects between 6% to 15% of the population, while restless leg syndrome impacts approximately 6%. Similarly, sleep paralysis afflicts around 6% of individuals, and sleep apnea affects between 2% to 4% of the general population. Existing literature highlights a notable connection between sleep disturbances and diabetes [14, 15].

A previous systematic review and meta-analysis suggested that both the quantity and quality of sleep can significantly influence the risk of developing type 2 diabetes [16]. Obstructive sleep apnea (OSA), a sleep problem common in overweight and obese individuals, is a modifiable risk factor affecting insulin resistance, which may influence the development of type 2 diabetes. This suggests that sleep and T2D are related. Additionally, it has been discovered that both the amount and quality of sleep might predict the onset of type 2 diabetes [17, 18]. Among its many roles, vitamin D largely controls osteomineral physiology, especially calcium metabolism. Nevertheless, recent data suggests that the pleiotropic benefits of vitamin D and its metabolites go beyond parathyroid gland activity and the regulation of bone metabolism, with products connected to additional possible domains that are primarily related to sleep [19]. Although the exact

causes of this link are yet unknown, theories have been put out about the impact of pro-inflammatory mediators and vitamin D receptors found intracellularly in parts of the brain that control the sleep-wake cycle [20].

A greater understanding of the intricate relationship between sleep and diabetes is essential, as it could facilitate the development of strategies aimed at reducing diabetes incidence and improving patient outcomes. Several research studies have identified sleep disorders as novel risk factors contributing to the onset and progression of diabetes. These disorders can disrupt the body's metabolic processes through neuro-endocrine pathways, affecting overall health. Individuals experiencing sleep disorders—whether due to diminished sleep quality or insufficient sleep duration—often find a decrease in insulin sensitivity [21]. This decrease can lead to elevated blood glucose levels, thereby exacerbating the progression of diabetes [22]. Additionally, sleep disorders may stimulate the hypothalamic–pituitary–adrenocortical system, resulting in the release of excess glucocorticoids [23]. This hormonal response can lead to increased glucose production while simultaneously decreasing glucose consumption, ultimately impairing glycemic control. Consequently, maintaining good sleep quality is essential for effective glycemic control, which is vital for enhancing the quality of life for diabetes patients [24, 25]. However, it is noteworthy that most current research focusing on sleep issues in diabetic patients primarily addresses obstructive sleep respiratory diseases [26]. Moreover, many of these studies employ complex evaluation methodologies that are not easily applicable in everyday clinical settings. Furthermore, a limited number of Pakistani studies have explored sleep disorders in diabetic patients, leading to restricted generalizability due to narrow sample demographics, often focusing exclusively on either elderly populations or females. The objective of our research was to provide robust evidence that clarifies the relationship between sleep quality and glycemic control. We analyzed sleep quality and its subsequent impact on glycemic control in individuals diagnosed with type 2 diabetes, thereby laying a foundation for future practical interventions. To the best of our knowledge, there has been no comprehensive study that systematically quantified and summarized the prevalence of sleep disorders among individuals with diabetes or thoroughly examined the potential associations between sleep disorders and various diabetes outcomes. Therefore, this cross-sectional study aims to (a) summarize the prevalence of diagnosed sleep disorders in people with diabetes; (b) explore the associations between sleep disorders and glycemic control in this population; and (c) investigate the interrelationship between vitamin D status, hyperglycemia, and sleep disorders. By deepening our understanding of the connections between sleep disorders and diabetes outcomes, we aim to shed light on implications for public health and clinical practice, paving the way for the development of more effective management strategies for diabetes, improved diabetes control, and the prevention of associated complications.

## 2. Methodology:

### 2.1 Study Design and Sample:

The current prospective analytical cross-sectional investigation was carried out at the Diabetes and Endocrinology Department of Lady Reading Hospital, a tertiary care hospital in District Peshawar. The Institutional Ethical Approval Committee of the College of Home Economics at the University of Peshawar and the Institutional Review & Ethics Board (IRB) of Lady Reading Hospital approved the study in compliance with the ethical guidelines of the Helsinki Protocols, and patient safety and privacy were ensured. The projected sample size for the current trial was 189 at a 95% confidence interval and a 1% likelihood of comorbidity (from December 2022 to March 2023). For the current 200 adult patients with Type 2 Diabetes Mellitus were randomly selected after getting written consent

#### 2.1.1 Inclusion Criteria:

The inclusion criteria for the study consisted of patients with Type 2 diabetes, aged between greater than 25 and less than 60 years. Additionally, eligible participants had not received any Vitamin D supplementation in the past six months and had no serious history of diabetes related comorbidities.

#### 2.1.2 Exclusion Criteria:

The exclusion criteria for the study included Type 2 diabetic patients with amputations, a recent history

of infections, those with severe comorbidities, as well as pregnant and lactating mothers.

**2.2 Data Collection:**
A self-constructed questionnaire and standardized semi-quantitative FFQ, 24-hour recall and Pittsburgh Sleep Quality Index (PSQI) were used to attain the required data.

**2.2.1 Sociodemographic Data:**
Sociodemographic data include name, gender, age, area name, educational background, occupation of the patient, family income and family system respectively.

**2.2.2 Biochemical Data:**
Biochemical data was collected to assess the different values including blood glucose level (Fasting blood glucose (FBG), Random blood glucose (RBG) and HbA1C, blood pressure (Diastolic blood pressure and Systolic Blood Pressure) and Serum Vitamin D.

**2.2.3 Nutrient Intake:**
To determine their nutrient intake, participants were questioned about their food intake during the previous 24-hour period. Using Windiet (2005) Software, the nutritional analysis was done.

**2.2.4 Determination of Sleep Quality**
The Pittsburgh Sleep Quality Index (PSQI) is a retrospective self-report questionnaire that assesses sleep quality over the previous month and is possibly the most widely used one. The questionnaire evaluates seven clinically determined dimensions of sleep difficulties: daytime dysfunction, habitual sleep efficiency, sleep disruptions, usage of sleeping drugs, and sleep quality, sleep latency, and length. These sleep domains are assessed as one component of overall sleep quality when taken as a whole [27]

**Components of the PSQI:**

- **Subjective sleep quality:** Assesses the individual's overall perception of their sleep quality.
- **Sleep latency:** Measures the time it takes to fall asleep.
- **Sleep duration:** Determines the amount of time spent asleep.
- **Habitual sleep efficiency:** Calculates the percentage of time spent asleep while in bed.
- **Sleep disturbances:** Evaluates the frequency and severity of sleep disturbances.
- **Use of sleeping medication:** Assesses the frequency of medication use to aid sleep.
- **Daytime dysfunction:** Evaluates the impact of sleep problems on daytime functioning.

**Scoring and Interpretation:**

- Each component is scored on a scale of 0 to 3, with higher scores indicating greater problems.
- The seven component scores are summed to create a global PSQI score, ranging from 0 to 21.
- A cutoff score of 5 is often used to identify individuals with poor sleep quality, according to a validation study.

**2.2.6 Statistical Analysis:**
Data were analyzed by using the latest Statistical Package for Social Sciences (SPSS) version 20 for entering and analysis of collected data. Descriptive statistic was used to determine frequencies, mean, and standard deviation for different variables and Linear Regression statistical models were developed to assess the association assess sleep and other study parameters.

**3. Results and Discussion:**
**3.1 Sociodemographic results:**
This demographic data (Figure 1) provides insights into the social, economic, and educational backgrounds of the population in this study, highlighting variations in income, education, and family structure. The sample consists of nearly equal numbers of genders, with 104 males and 96 females. The majority of respondents, totaling 140, are from urban areas, whereas 60 are from rural areas. In education, 110 individuals lack formal education, which slightly exceeds the 90 who are educated, suggesting potential socioeconomic limitations. Of the various occupational backgrounds, 84 are housewives, 67 are employed in jobs, 39 are engaged in business and only 10 are unemployed. The majority of individuals (171) have an income ranging from 30,000 to 50,000, while a smaller group (29)

earns between 50,000 and 1 lakh, indicating an overall modest income level. In conclusion, 133 respondents reside in extended families, whereas 67 live in nuclear families, indicating a predominance of extended family structures.

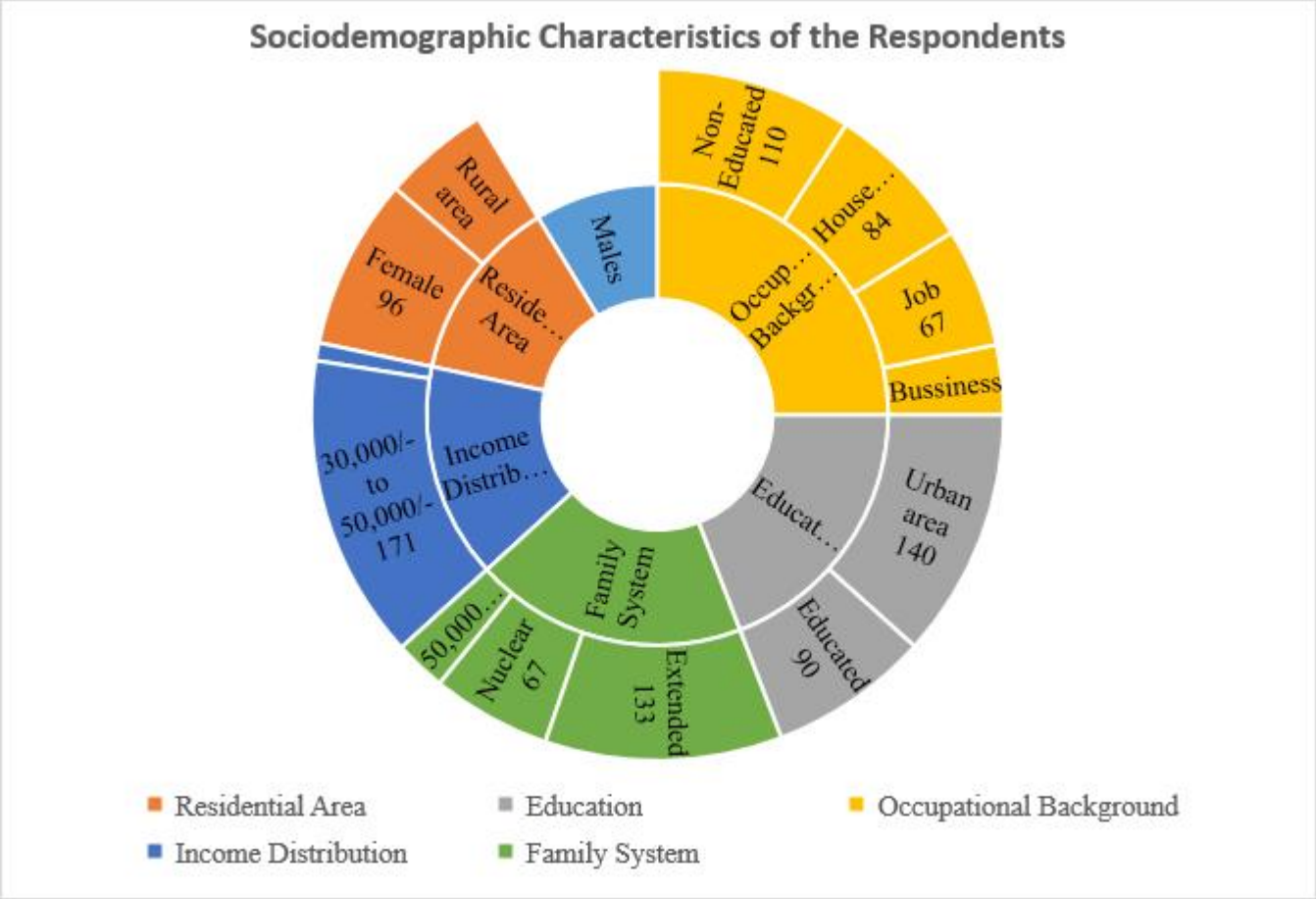



**Figure 1: Sociodemographic results of the Respondents**

### 3.2: Biochemical Record

#### 3.2.1: Biochemical results:

Table 2 compares various health parameters (blood glucose, lipid profile, blood pressure, complete blood count, and CRP) between male and female subjects, with P-values indicating statistical significance. For **blood glucose**, fasting and random levels show higher levels between genders, while Hba1c levels are elevated for both males (9.59 ± 2.41) and females (9.51 ± 1.76), exceeding the reference range (4.5–7.0%). For **blood pressure**, males have slightly higher systolic pressure, but diastolic pressure is higher in females. Managing T2DM is challenging, as many individuals struggle to maintain blood glucose levels, increasing the risk of complications due to factors like lifestyle, medication adherence, and the disease's progressive nature [28].

**Table 2: Biochemical Results of the Respondents**

| Parameters | Male | | Female | | P-value | Reference Value |
|---|---|---|---|---|---|---|
| | Interquartile Range | Mean ± SD value (P-value) | Interquartile Range | Mean ± SD value (P-value) | | |
| **Blood Glucose** | | | | | | |
| Fasting Blood Glucose | 105 – 277 | 172.61 ± 47.36 (0.813) | 100 – 275 | 159.72 ± 42.11 (0.485) | 0.555 | 100 – 125 mg/dL |
| Random | 201 - 560 | 285.88 ± 60.40 | 200 – 500 | 290.13 ± 70.42 | 0.459 | 140 – 199 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Blood Glucose | | (0.003) | | (0.551) | | mg/ dL |
| HbA1C | 7.05 - 14.20 | 9.59 ± 2.41 (0.110) | 7.1 – 14 | 9.51 ± 1.76 (0.616) | 0.306 | 4.5 – 7.0 % |
| **Blood Pressure** | | | | | | |
| Diastolic BP | 80 – 96 | 81.63 ± 3.73 (0.011) | 80 – 95 | 83.61± 4.91 (0.682) | 0.041 | > 80 mm Hg |
| Systolic BP | 118 - 170 | 125.00 ± 9.96 (0.247) | 100 – 165 | 122.33± 9.44 (0.008) | 0.022 | ≥ 120 mm Hg |

**3.2.2: Vitamin D results:**

Table 3 compares vitamin D levels in males and females across different categories. For **moderate to severe deficiency** (<10 ng/ml), males and females show similar mean values (8.95 ± 0.98 and 8.85 ± 0.88, respectively), with no significant difference (p-value = 0.662). In the **mild/borderline deficiency** range (10-20 ng/ml), males have a mean of 14.97 ± 2.76, while females have 16.14 ± 2.88, with no significant difference (p-value = 0.367). For **hypovitaminosis** (20-40 ng/ml), both genders have similar mean values around 29, with no significant difference (p-values 0.370 and 0.359). In the **optimum level** (40-100 ng/ml), male patients had a mean of 46.40 ± 2.93, and females had 47.03 ± 2.91, again with no significant difference (p-value = 0.219). No data is provided for the **toxic level** (>100 ng/ml). The table indicates that there are no significant gender-based differences in vitamin D levels across the various categories. The findings show that HbA1C levels were higher than reference values, and the diet was insufficient based on WHO RDA, with many participants in the hypovitaminosis D. These results are in agreement with other such study which reported patients with impaired glucose metabolism the vitamin D status is inversely associated with levels of circulating markers of oxidative stress and endothelial dysfunction, especially in subjects with hypovitaminosis D. It was found that hypovitaminosis D increased cardiovascular risk and oxidative stress in hyperglycemic patients increasing their risk of cardiovascular diseases [28, 29]

**Table 3: Serum Vitamin D Profiles of the Patients**

| **Parameters** | **Male** | | **Female** | | **Levels of Vitamin D** |
|---|---|---|---|---|---|
| | **Range (Min – Max)** | **Mean ± SD P- value** | **Range (Min – Max)** | **Mean ± SD p- value** | |
| Moderate to severe | 7.50 – 9.60 | 8.95 ± 0.98 (0.063) | 8.00 – 10.00 | 8.85 ± 0.88 (0.662) | < 10 ng/ ml |
| Mild/ borderline | 10.30 – 19.90 | 14.97 ± 2.76 (0.125) | 10.16 – 19.95 | 16.14 ± 2.88 (0.367) | 10-20 ng /ml |
| Hypovitaminosis | 20.96 – 38.90 | 29.16 ± 5.07 (0.370) | 20.96 – 39.42 | 28.95 ± 4.86 (0.359) | 20-40 ng/ml |
| Optimum level | 41.70 – 52.62 | 46.40 ± 2.93 (0.219) | 43 – 52.28 | 47.03 ± 2.91 (0.069) | 40-100 ng/ml |
| Toxic level | ------ | ------ | ------ | ------ | >100 ng/ml |

**3.3: Dietary/ Nutrient Intake of Vitamin among the Patients**

Table 4 outlines vitamin D intake among males and females, with reference to the Recommended Daily Allowances (RDA). The mean Vitamin D (Ages 25-49) among males averages 1.67 ± 0.44 µg/day and females 1.31 ± 0.44 µg, below the RDA of 2.5 µg/day. While the mean Vitamin D (Ages 50+): Both sexes are below the 5 µg/day RDA, with males averaging 3.57 ± 0.51 µg and females 3.51 ± 0.37 µg. A statistically significant association between vitamin D levels and the gender of the participants could not be found in the present study. This was similar to the result seen in the retrospective study conducted in the southern part of India, where, on comparing the genders, it was seen that the percentage of males and

females with these conditions was similar [30]. Similar results were reported in a cross-sectional study of participants from the UAE, India, Pakistan, and Egypt that investigated the relationship between vitamin D insufficiency in obesity and several other metabolic variables. Gender and vitamin D levels have not been proven to be significantly correlated. Nevertheless, it has been found that age and vitamin D levels are positively associated [31]

**Table 4: Nutrient Intake Analysis of the Respondents**

| Nutrients | Male | | Female | | RDA / day |
|---|---|---|---|---|---|
| | Range (Min – Max) | Mean ± SD (P – value) | Range (Min – Max) | Mean ± SD (P – value) | |
| **Vitamin D (Age: 25 – 49)** | 1.07 - 3.09 | 1.67 ± 0.44 (0.323) | 0.55 – 2.90 | 1.31 ± 0.44 (0.068) | 2.5 µg/ day |
| **Vitamin D (Age: 50+)** | 1.35 – 4.34 | 3.57 ± 0.51 (0.419) | 2.58 – 4.16 | 3.51 – 0.37 (0.079) | 5 µg/ day |

**3.4 Sleep Quality Indices of the respondents**

Table 5 shows results of Pittsburgh's sleep quality index data among male and female T2DM patients. The respondent's sleep quality assessment was done with the help of 5 sub divisions of the PSQI. The very first parameter "total sleep quality" tells about the overall sleep quality calculated from the sum of scores of subdivisions in male respondents, here, the highest percentage (39.4%) was recorded for the response "very good", 25.0% was recorded for the response "fairly good" and 29.8% was recorded for the response "fairly bad" although considerable percentage (3.1%) was recorded for the response "very bad". Same is the case with female respondents, the highest percentage (39.6%) was recorded for the response "very good", 31.3% was recorded for the response "fairly good" and 26% was recorded for the response "fairly bad" although considerable percentage (5.8%) was recorded for the response "very bad". Parameter (1) subjective sleep quality; is the sleep quality reported by the study sample in response to a question. In subjective sleep quality highest percentage (39.4%) was recorded for the response "fairly good" which is an agreement to the calculated sleep quality, while (33.7%) response in subjective sleep quality were recorded for the response "very good" which is almost an agreement with the calculated sleep quality parameter's responses. So, if we take majority responses in to consideration, then according to the majority responses the overall sleep quality of the respondents was fairly good in male respondents. While the recorded subjective sleep quality was fairly bad in the majority of the female respondents, as the highest percentage (33.3%) was recorded for the response "fairly bad". The next parameter "sleep latency" was recorded to have high percentage (33.7%) for the response "once in a week" and was followed by "1 – 2 times a week" with a percentage (30.8%) which means that the majority of sample were facing sleep latency only once a week by male respondents. In female respondents the "sleep latency" was recorded to have high percentage (30.2%) for the response "1 – 2 times a week" and "once a week" with a percentage (28.1%) which means that the majority of sample were facing sleep latency 1 – 2 times a week. The parameter (3) sleep disturbances; was recorded to have highest percentage (39.4%) for response "1 – 2 times a week" in males while females have highest recorded percentage (35.4%) for response "once a week", which means that the respondents were less bothered by sleep disturbances with a frequency of once or twice a week. The next subdivision is "use of sleep medication" and has the highest percentage (78.8%) for males and (81.3%) for females in response to "not in the past month", which indicates lesser use of sleep medications by the respondents. In the end of table "day time dysfunction" (parameter 5) was assessed and highest percentage (44.2%) in male and (42.7%) in female was observed for the response "not in the past month" and was followed by the response "once in a week" with a percentage (26.9%) in male and

(28.1%) in female which is a sign that majority of the study sample was not facing problems with their day-to-day activities or some of them were facing day time dysfunction but not quite frequently.

**Table 5: Sleep quality distribution of the respondents**

| Parameters | Very good | | Fairly good | | Fairly bad | | Very bad | |
|---|---|---|---|---|---|---|---|---|
| | Male % | Female % | Male % | Female % | Male % | Female % | Male % | Female % |
| **Total sleep quality** | 39.4 | 39.6 | 25.0 | 31.3 | 29.8 | 26.0 | 3.1 | 5.8 |
| Subjective sleep quality | 33.7 | 26.0 | 39.4 | 31.3 | 18.3 | 33.3 | 8.7 | 9.4 |
| | **Not in the past month** | | **Once in a week** | | **1 -2 times a week** | | **3 or more times a week** | |
| | Male % | Female % | Male % | Female % | Male % | Female % | Male % | Female % |
| Sleep latency | 17.3 | 25 | 33.7 | 28.1 | 30.8 | 30.2 | 18.3 | 16.7 |
| Sleep disturbance | 10.6 | 8.3 | 35.6 | 35.4 | 39.4 | 31.3 | 14.4 | 25 |
| Use of sleep medication | 78.8 | 81.3 | 10.6 | 3.1 | 1.9 | 2.1 | 8.7 | 13.5 |
| Daytime dysfunction | 44.2 | 42.7 | 26.9 | 28.1 | 25 | 26 | 3.8 | 3.1 |

**3.5: Mean Sleep quality scores of the Participant**

Table 6 indicates the Global PSQI score that assesses overall sleep quality, with lower scores indicating better sleep quality and higher scores indicating poorer sleep quality. The table breaks down the number of individuals falling within these score ranges, offering insights into the distribution of sleep quality within the T2DM respondents. The mean and standard deviation of good quality sleep was (3.44 ± 0.73) with ranges (2 - 4), while the mean and standard deviation of poor-quality sleep was (9.34 ± 3.52) with (5 – 17) ranges among male respondents. While among females the mean and standard deviation of good quality sleep was (3.45 ± 0.60) with ranges (2 - 4), while the mean and standard deviation of poor-quality sleep was (10.60 ± 3.33) with (5 – 17) ranges. The P-values suggest the level of statistical significance in this distribution, though not showing significant differences between sleep quality and HbA1 C levels. Female respondents have higher percentage of bad sleep than male respondents. Eighty-one per cent of T2DM patients report poor quality sleep. Women, smokers, jobless people, insulin users, and people with uncontrolled diabetes appear to be substantially more likely to have poor sleep quality [32].

**Table 6: Sleep quality distribution of the respondents**

| | MALE | | FEMALE | | P-Value |
|---|---|---|---|---|---|
| | Range | Mean ± SD | Range | Mean ± SD | |
| Global PSQI score | Min - Max | P-Value | Min - Max | P-Value | |
| **1 – 4 (Good sleep)** | 2.00 – 4.00 | 3.44 ± 0.73 (0.040) | 2.00 – 4.00 | 3.45 ± 0.60 (---) | 0.058 |
| **5 – 17 (Poor sleep)** | 5.00 – 17.00 | 9.34 ± 3.52 (0.533) | 5.00 – 17.00 | 10.60 ± 3.33 (0.427) | 0.237 |

**3.6: Assessment of the Sleep Quality Based on Hba1C Distribution**

Table 7 shows comparison of overall sleep quality and subdivision of the PSQI with HbA1C levels. Subjective sleep quality is seen to have mean (1.13 ± 0.94) with min–max range (0 – 3). The corresponding P-value (0.905) is a comparison with HbA1C, which shows no significance between subjective sleep and HbA1C. The next parameter "sleep latency" have mean (1.44 ± 1.01) with range (0

– 3) the corresponding P-value (0.508) presents no significance. “Sleep disturbances have mean (1.65 ± 0.90) with range (0 – 3), P-value (0.710) showing no significance. Day time dysfunction had mean (0.89 ± 0.90), range (0 – 3), P-value (0.829) with no significance. The parameter “use of sleep medication” had mean (0.44 ± 0.97), range (0 – 3), P-value (0.490) with no significance. Parameter “Global PSQI Score” is the total score calculated by the sum of subdivisions and represents the total sleep quality of the sample with mean (9.09 ± 4.31), range (2 – 17), P-value (0.997) which shows that the total sleep quality of the sample had no significant relationship with HbA1C levels. According to a University of Pittsburgh study, almost half of type 2 diabetes individuals probably consider themselves to be "poor sleepers”. The same study also revealed that the sleep quality correlated well with further diabetic quality of life scores. In general, patients with other chronic conditions were also more prone to experience insomnia. In a large sample of 3282 adults, data was collected along with self-reported sleep habits and current health. The adjusted odd ratios for insomnia were 1.4% in patients with DM, compared with people without this disorder and was reported to be a major risk factor for increasing the severity of diabetes [34].

**Table 7: Comparisons of the Mean sleep quality with Hba1c Among the Respondents**

| Parameters | Range Min - Max | Mean ± SD | P-Value |
|---|---|---|---|
| **Subjective sleep quality** | 0.00 – 3.00 | 1.13 ± 0.94 | 0.905 |
| **Sleep latency** | 0.00 -3.00 | 1.44 ± 1.01 | 0.508 |
| **Sleep disturbance** | 0.00 – 3.00 | 1.65 ± 0.90 | 0.710 |
| **Day time dysfunction** | 0.00 – 3.00 | 0.89 ± 0.90 | 0.829 |
| **Use of sleep medication** | 0.00 – 3.00 | 0.44 ± 0.97 | 0.490 |
| **Pittsburgh Sleep Quality Index score** | 2.00 – 17.00 | 9.09 ± 4.31 | 0.997 |

**5.7: Regression Statistics of the Predictability Of Hba1c and Serum Vitamin for Sleep Quality**

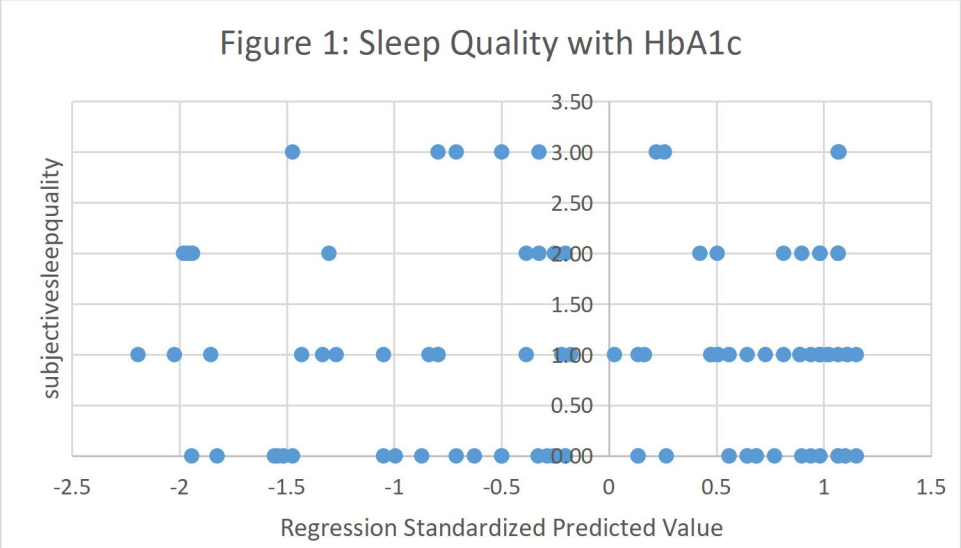
Two regression statistical models (Table 8) analyzed HbA1c and serum vitamin D as predictors of subjective sleep quality, sleep latency, sleep disturbance, daytime dysfunction, the use of sleep medications, and total Pittsburgh Sleep Quality Index (PSQI) scores for both male and female patients. Surprisingly, the data revealed that both Hba1c and serum vitamin D are strong predictors of the PSQI parameters and total PSQI scores in both genders. Participants with sleep disorders also exhibited significantly higher fasting plasma glucose (FPG), 2-hour plasma glucose (2hPG), and HbA1c levels (all $p < 0.05$). This finding further suggests that sleep disorders in diabetic patients can lead to elevated blood glucose and poor glycemic control [35, 36]. The circadian regulation of sleep plays a crucial role in insulin production, insulin sensitivity, and glucose consumption. Evidence indicates that a lack of 3 hours of sleep can lead to a 1.1% elevation in HbA1c levels within a single night. Moreover, with a 0.5 increase in the PSQI global score, HbA1c can rise by 1.9%. Additionally, the PSQI factor "sleep efficiency" is one of the components that can influence glycemic control. Logistic regression analysis shows that sleep latency, sleep disturbance, and daytime dysfunction are risk factors for poor glycemic control. These values indicate that a one-point increase in the scores for sleep latency, sleep disturbance, and daytime dysfunction would substantially increase the risk for poor glycemic control across all parameters [37]. In conclusion, sleep plays a critical role in glycemic control for patients with type 2 diabetes. Increasing evidence suggests that vitamin D deficiency is associated with poor sleep quality, reduced sleep duration, and an increased risk of sleep disorders [38, 39]. Similar associations have been observed in various populations, including the elderly, community dwellers, and individuals with obesity [40, 41]. An 8-week randomized controlled trial found that high-dose vitamin D supplementation alleviated fatigue, reduced anxiety, and improved cognitive function [42]. However, it is important to note that not all studies support the positive effects of vitamin D on sleep.

**Table 8: HbA1c and Serum Vitamin D as a Predictor with Sleep Parameters**

| Model 1: Regression Model of Sleep Parameters in Male | | | | | | |
|---|---|---|---|---|---|---|
| **Dependent Variable** | **Independent Variable** | **Unstandardized B** | **Coefficients Std. Error** | **Standardized Coefficients Beta** | **t** | **Sig** |
| Subjective sleep quality | HbA1c | 1.027 | .365 | | 2.812 | .006 |
| | | -.001 | .039 | -.002 | -.022 | .983 |
| | Serum Vitamin D | .811 | .179 | | 4.537 | .000 |
| | | .007 | .005 | .133 | 1.358 | .177 |
| Sleep latency | HbA1c | 1.359 | .385 | | 3.532 | .001 |
| | | .016 | .041 | .038 | .379 | .705 |
| | Serum Vitamin D | 1.560 | .190 | | 8.215 | .000 |
| | | -.002 | .006 | -.037 | -.370 | .712 |
| Sleep disturbance | HbA1c | 1.664 | .339 | | 4.915 | .000 |
| | | -.010 | .036 | -.026 | -.266 | .791 |
| | Serum Vitamin D | 1.752 | .166 | | 10.556 | .000 |
| | | -.006 | .005 | -.121 | -1.227 | .223 |
| Daytime dysfunction | HbA1c | .965 | .358 | | 2.695 | .008 |
| | | -.009 | .038 | -.023 | -.232 | .817 |
| | Serum Vitamin D | 1.033 | .176 | | 5.868 | .000 |
| | | -.005 | .005 | -.097 | -.981 | .329 |
| Use of sleep medication | HbA1c | .609 | .350 | | 1.739 | .085 |
| | | -.023 | .038 | -.060 | -.606 | .546 |
| | Serum Vitamin D | .290 | .173 | | 1.677 | .097 |
| | | .004 | .005 | .076 | .769 | .444 |
| Pittsburgh Sleep Quality Index score | HbA1c | 7.349 | 1.805 | | 4.071 | .000 |
| | | .202 | .194 | .103 | 1.044 | .299 |
| | Serum Vitamin D | 8.480 | .893 | | 9.500 | .000 |
| | | .023 | .026 | .089 | .904 | .368 |
| **Model 2: Regression Model of Sleep Parameters in Female** | | | | | | |
| Subjective sleep quality | HbA1c | 1.429 | .427 | | 3.350 | .001 |
| | | -.018 | .044 | -.042 | -.407 | .685 |
| | Serum Vitamin D | 1.447 | .204 | | 7.082 | .000 |
| | | -.006 | .006 | -.106 | -1.038 | .302 |
| Sleep latency | HbA1c | 1.076 | .464 | | 2.318 | .023 |
| | | .033 | .048 | .070 | .684 | .496 |
| | Serum Vitamin D | 1.094 | .221 | | 4.943 | .000 |
| | | .009 | .006 | .153 | 1.498 | .137 |
| Sleep disturbance | HbA1c | 2.006 | .417 | | 4.809 | .000 |
| | | -.030 | .043 | -.070 | -.683 | .497 |
| | Serum Vitamin D | 1.534 | .200 | | 7.673 | .000 |
| | | .006 | .006 | .114 | 1.111 | .269 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Day time dysfunction | HbA1c | 1.457 | .398 | | 3.656 | .000 |
| | | -.060 | .041 | -.147 | -1.446 | .152 |
| | Serum Vitamin D | .831 | .194 | | 4.291 | .000 |
| | | .002 | .006 | .039 | .381 | .704 |
| Use of sleep medication | HbA1c | 1.220 | .466 | | 2.617 | .010 |
| | | -.079 | .048 | -.166 | -1.633 | .106 |
| | Serum Vitamin D | -.084 | .218 | | -.388 | .699 |
| | | .018 | .006 | .291 | 2.946 | .004 |
| Pittsburgh Sleep Quality Index score | HbA1c | 7.585 | 1.861 | | 4.077 | .000 |
| | | .163 | .193 | .087 | .844 | .401 |
| | Serum Vitamin D | 8.549 | .896 | | 9.542 | .000 |
| | | .018 | .025 | .074 | .718 | .475 |

**Regression plots of Male Patients for Hba1c and Serum Vitamin D as a Predictor with sleep Parameters**



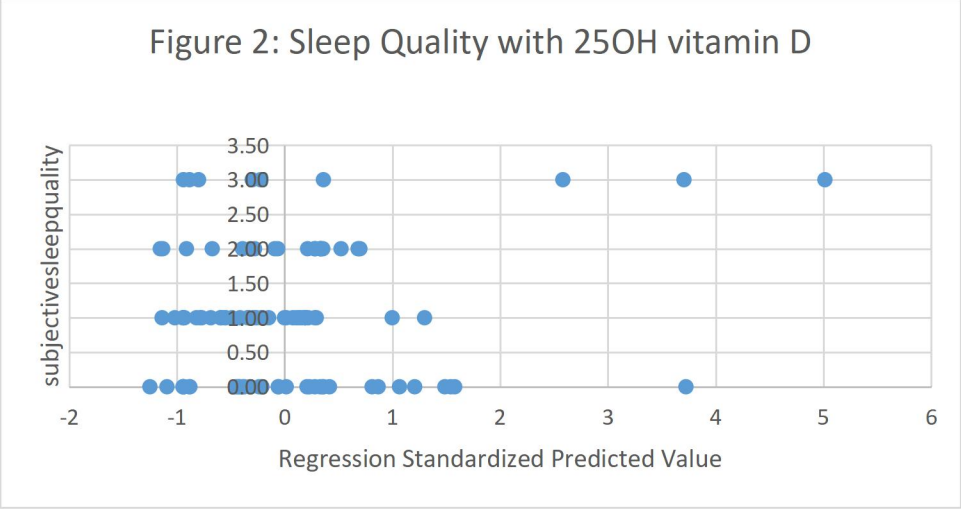



Figure 3: Sleep Latency with HbA1c

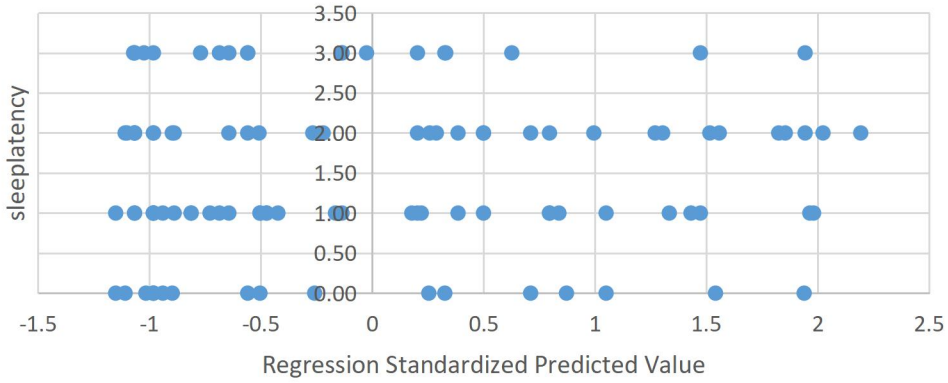



Figure 4: Sleep Latency with 25OH Vitamin D

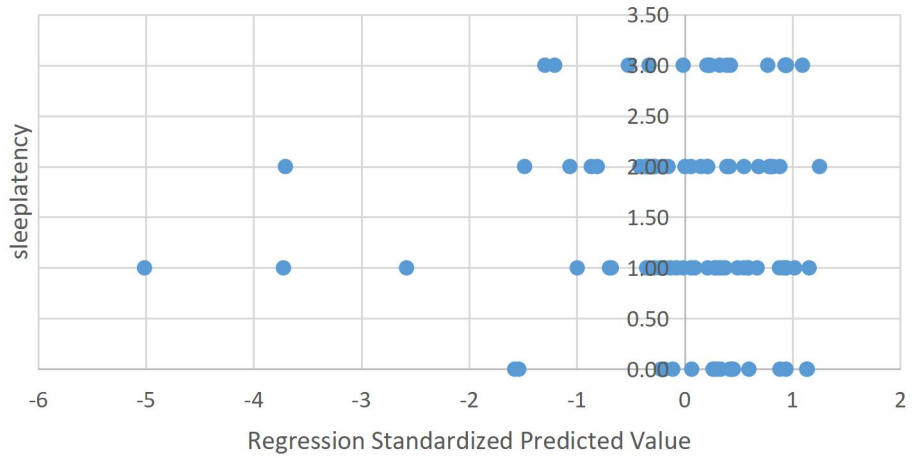



Figure 5: Sleep Disturbance with HbA1c

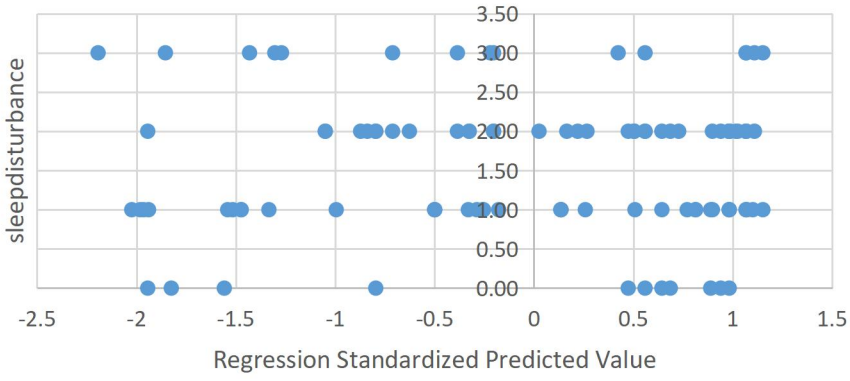


Figure 6: Sleep Disturbance with 25OH VitaminD

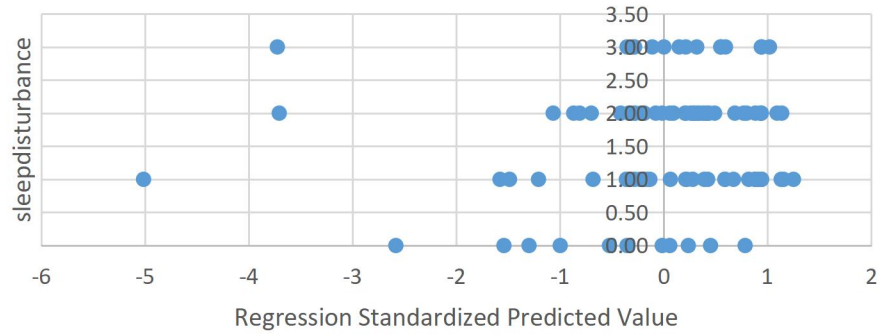



Figure 7: Day time sleepiness with HbA1c

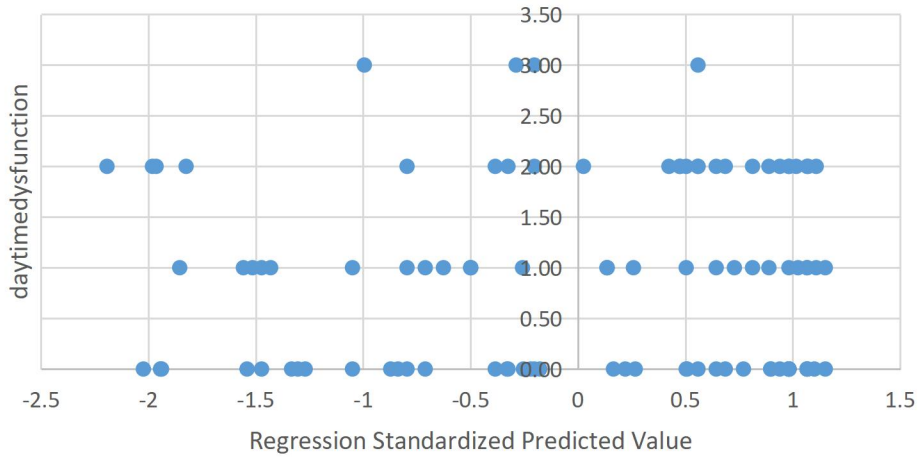



Figure 8: Day time Sleepiness with 25OH Vitamin D

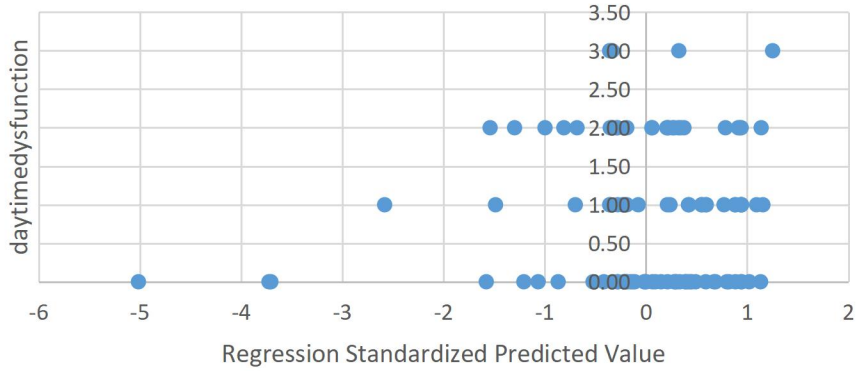


Figure 9: Use of Sleeping pills with HbA1c

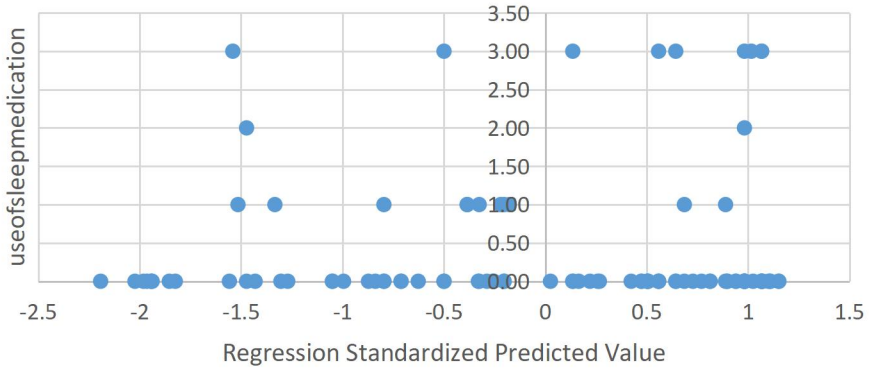



Figure 10: Use of sleeping pills with 25OH Vitamin D

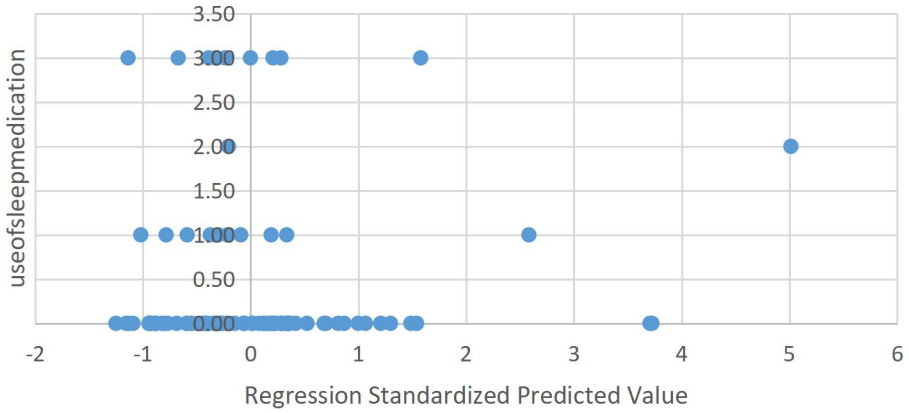
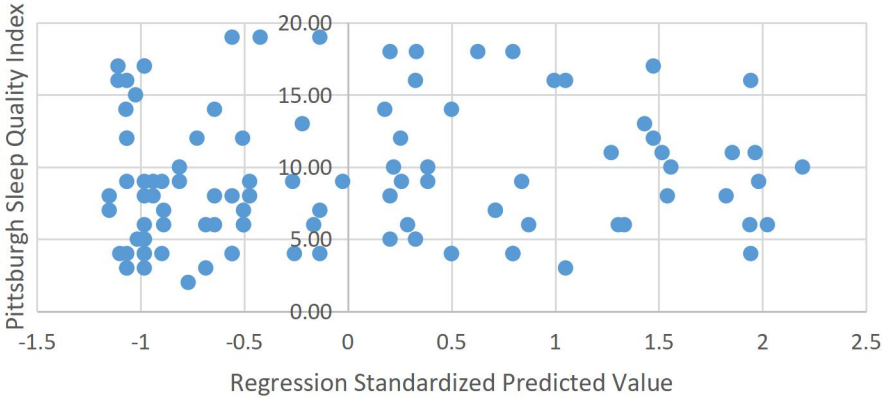
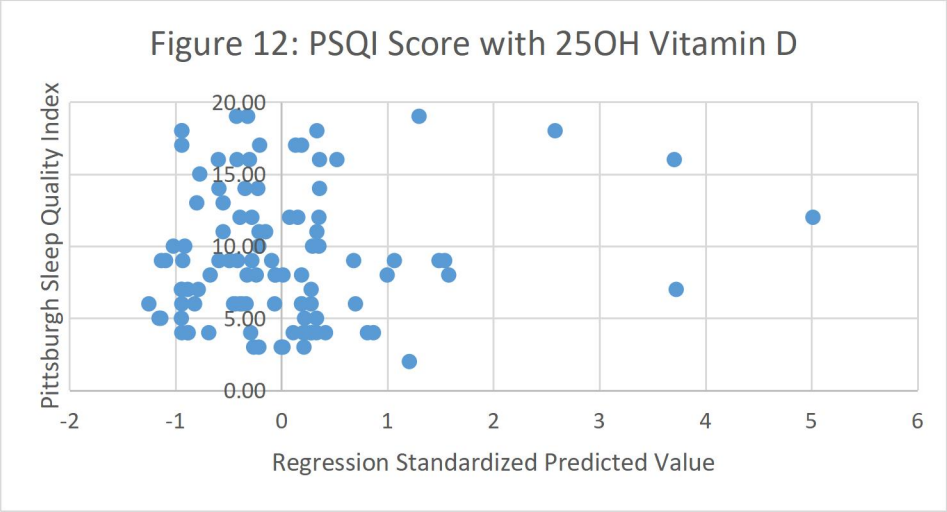
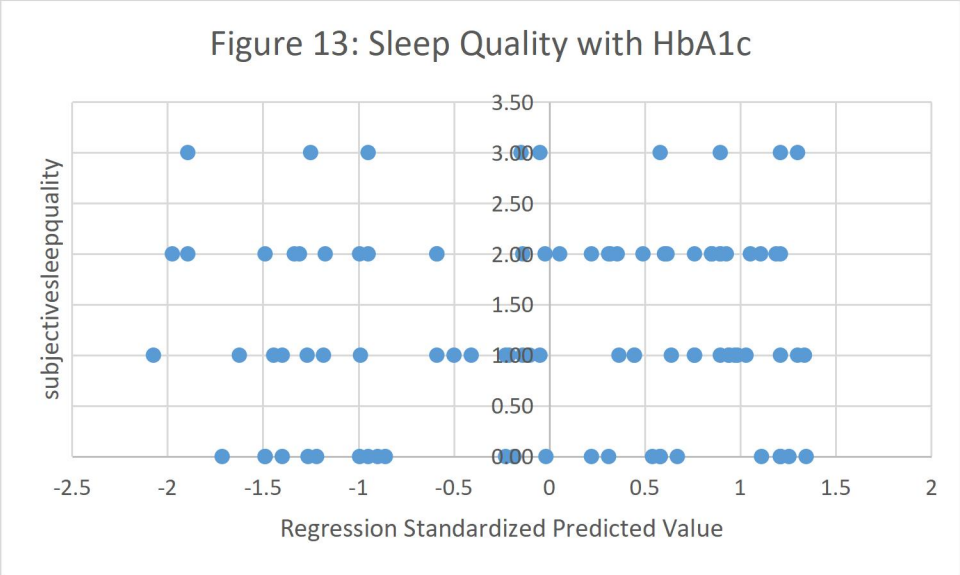



Figure 11: PSQI Score with HbA1c






**Regression Plots of Female Patients For Hba1c And Serum Vitamin D As A Predictor With Sleep Parameters**



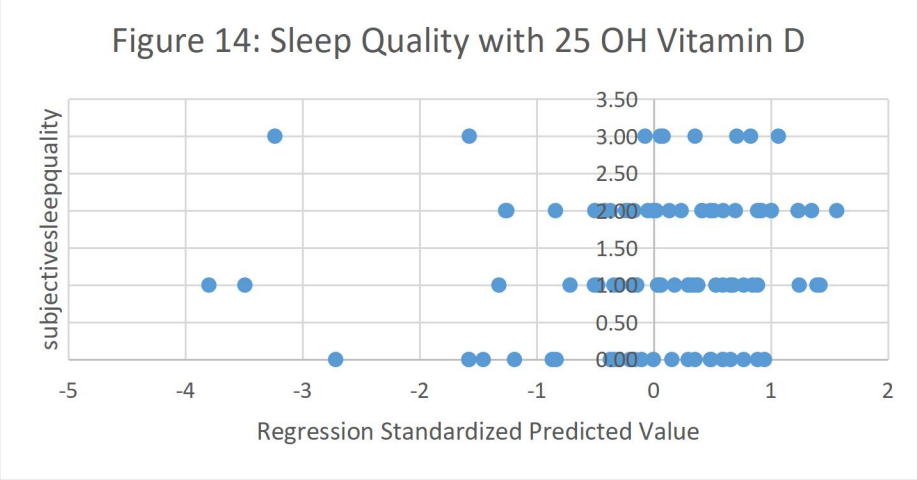



Figure 15: Sleep Latency with HbA1c

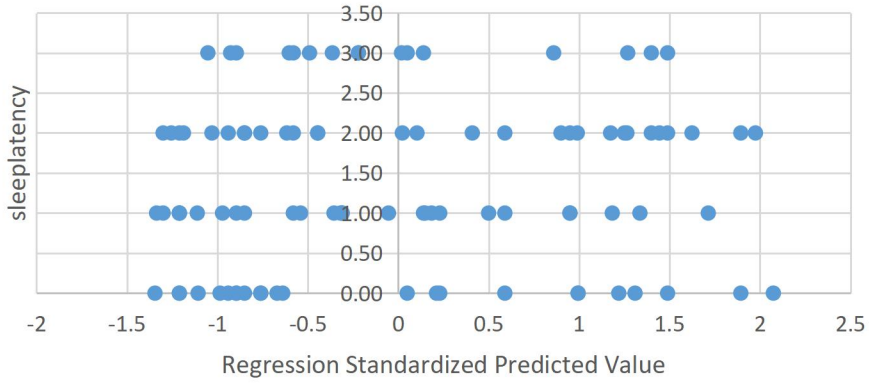



Figure 16: Sleep Latency with 25 OH Vitamin D

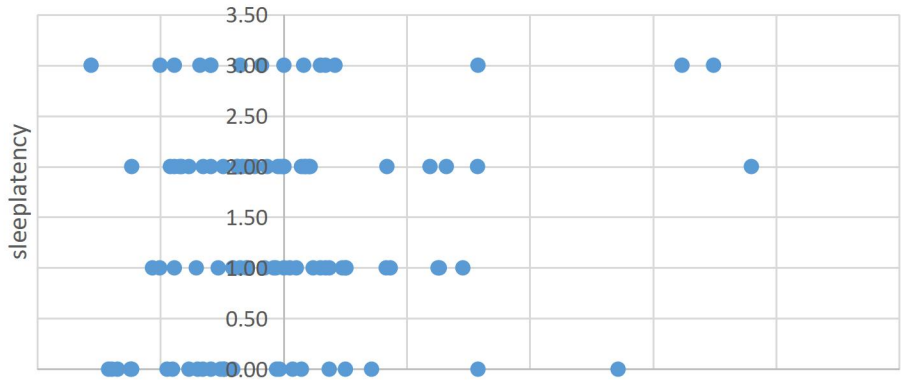



Figure 17: Sleep Disturbance with HbA1c

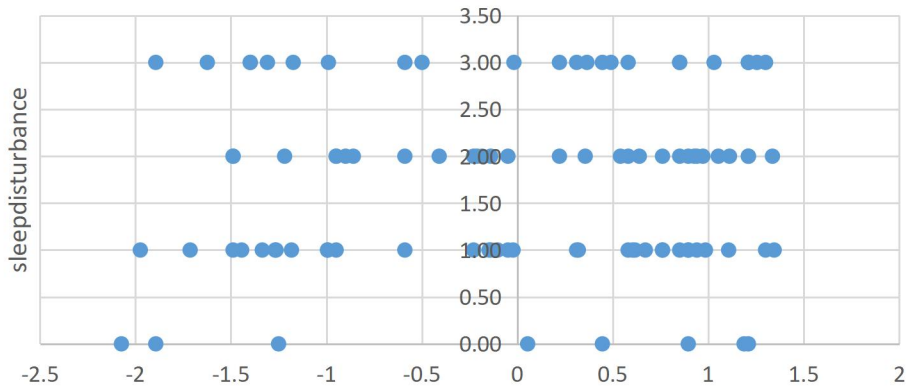


Figure 18: Sleep Disturbance with 25 OH VitaminD

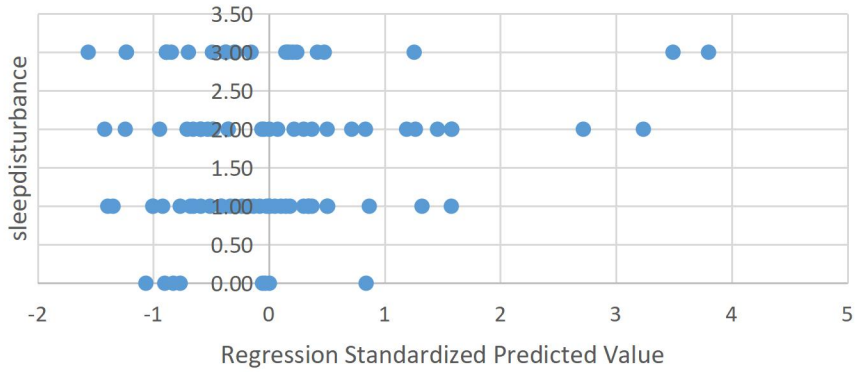



Figure 19: Day time dys with HbA1c

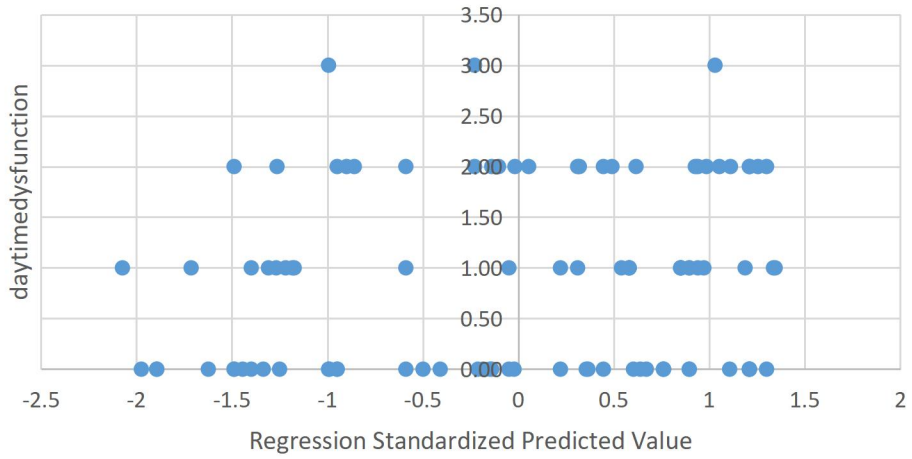



Figure 20: Day time dys with 25OH VitaminD

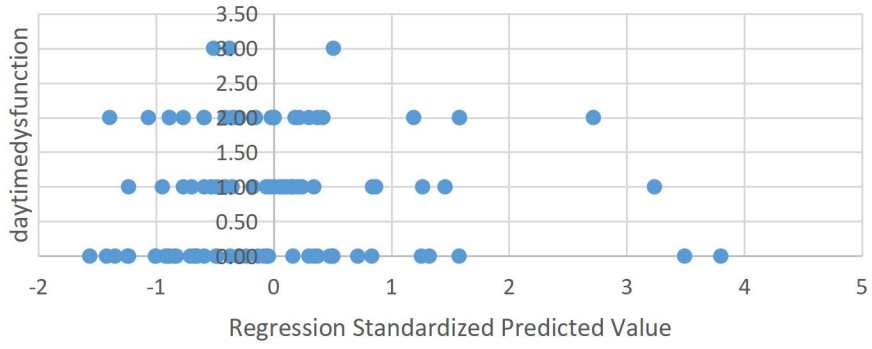


Figure 21: Use of sleeping pills with HbA1c

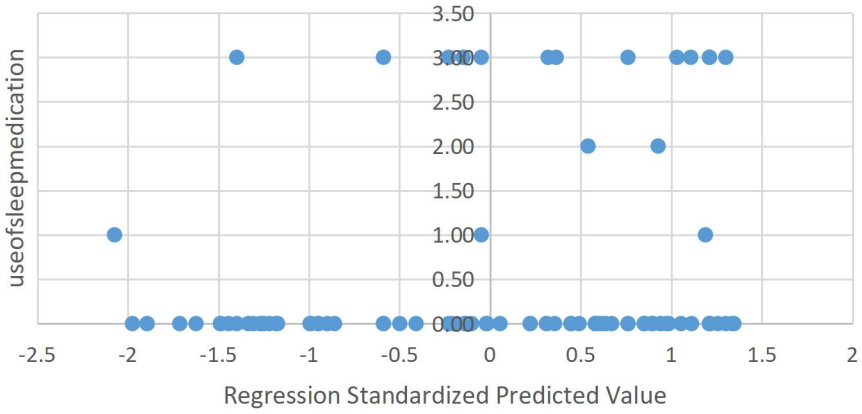



Figure 22: Use of sleeping pills with 25OH VitaminD

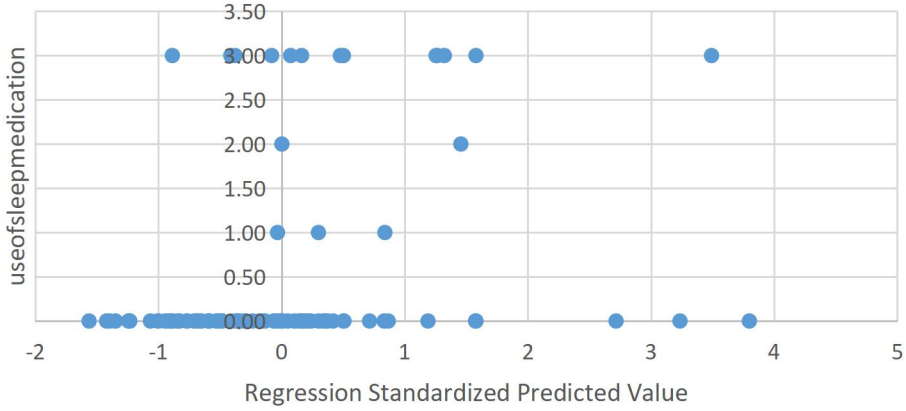
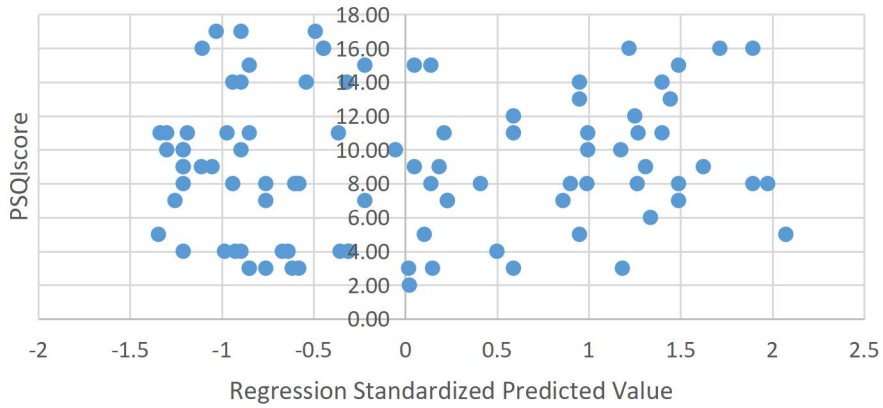
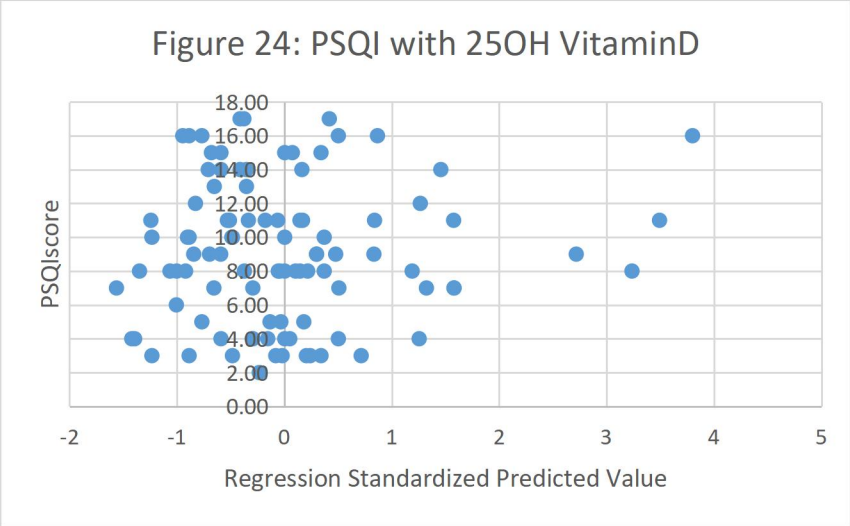



Figure 23: PSQI with HbA1c






## 4. Conclusion

This study provides strong evidence that low serum vitamin D concentrations are associated with an increased risk of sleep disorders in individuals with diabetes. These findings suggest that maintaining adequate vitamin D concentrations may offer a potential strategy to improve sleep health in this population. Having a vitamin D deficiency or sleep disorder can negatively affect the metabolic regulation of control of hyperglycemia and DM. Poorly regulated hyperglycemia, Hypovitaminosis D and poor sleep quality diabetic population make them at high risk of developing comorbidities. We suggest that every diabetic patient should be screened for both vitamin D deficiency and sleep disorders and should be corrected through balanced diets, nutrition education, and self-care.

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