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Research Article

Vitamin D Deficiency and Its Association with Fatigue and Cognitive Performance in Adults

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ABSTRACT

Objective: To assess the prevalence of vitamin D deficiency and its correlation with fatigue and cognitive function in adults attending for tertiary care in a tertiary care hospital.

Methods: A prospective cross sectional study was carried out at Lady Reading hospital from 23 January 2025 to 23 December 2026. 154 adults were consecutively sampled to obtain an enrollment into the study. Vitamin D was analysed in serum samples by chemiluminescence immunoassay. Fatigue Severity Scale was used to measure the severity of fatigue and Montreal Cognitive Assessment questionnaire was used to evaluate cognitive performance. The data were analyzed statistically using Statistical Package for Social Sciences (SPSS) version 26. P values < 0.05 were deemed statistically significant.

Results: Vitamin D deficiency was found in 53.2% and insufficiency was seen in 29.9% of the participants Participants with vitamin D deficiency had significantly higher Fatigue Severity Scale scores and lower Montreal Cognitive Assessment scores than participants with sufficient vitamin D levels. There was significant association of vitamin D deficiency with generalized weakness, daytime tiredness, decreased concentration and cognitive impairment. Pearson correlation analysis showed an inverse correlation between the vitamin D levels and fatigue severity, and a positive relationship was seen between the vitamin D concentration and cognitive performance.

Conclusion: Vitamin D deficiency was common among adults attending a tertiary healthcare facility and was significantly associated with greater fatigue severity and lower cognitive performance. These findings support consideration of vitamin D assessment in adults presenting with fatigue and cognitive complaints. Longitudinal and interventional studies are required to determine causality and the effects of treatment.

Keywords: Vitamin D Deficiency, Fatigue, Cognitive Performance, Memory Impairment, Neurological Wellbeing, Adults.

INTRODUCTION

Vitamin D deficiency has become a major public health problem in various countries of the world. Previous studies have reported low serum vitamin D levels in various age groups and socioeconomic groups. Vitamin D deficiency has been linked to musculoskeletal, immune system, metabolic disturbances, and chronic systemic diseases. Its neurological and psychological impact has come into increasing focus recently, as research has grown on the effects it has on cognitive function and mental health.

Vitamin D was previously known for its role in calcium metabolism and bone health. But, much study has shown that vitamin D receptors are located in various regions of the human brain, such as the hippocampus, the cerebellum, and the cerebral cortex. Vitamin D has therefore been shown to exert neuro protective properties, by regulating neuronal growth, synaptic plasticity and neurotransmitter synthesis. This vitamin deficiency has been thus linked to fatigue, mood disturbances and cognitive declines. [2]

Fatigue has been defined as a frequent disabling symptom that can impact physical, emotional, and cognitive function. Low vitamin D has been commonly experienced in adults who are persistently tired with decreased concentration and a decreased ability to function with their daily activities. The relationship between vitamin D deficiency and fatigue is not completely understood. Inflammatory responses and changes in the functioning of the nervous system have been suggested as contributing factors, however impaired mitochondrial function. [3]

Vitamin D status has also been recently associated with cognitive performance. Patients with low levels of vitamin D have been found to have memory and attention deficits, as well as problems with executive functioning and processing speed. Consistent with this, three mechanisms of neuroinflammation, oxidative stress and vascular dysfunction have been proposed to be relevant in the pathophysiology of cognitively impaired individuals with the deficiency. There have been a number of observational studies that indicate that maintenance of normal cognitive function in adulthood might be supported by a proper vitamin D level.[4]

Even though adults in developing countries receive ample sunlight, their vitamin D levels continue to be highly susceptible to deficiency. Factors identified as contributing are due to indoor lifestyle, which has decreased the outdoor activities, and poor dietary habits and lack of nutritional awareness. In addition to cultural clothing practices and environment pollution, reduced vitamin D synthesis in the skin has been linked to other factors. The growing obesity rate has further compounded the burden of vitamin D deficiency among those living in cities. [5]

Fatigue complaints are common in clinical practice in outpatient settings. Adults who attend tertiary care centres frequently report generalized weakness, daytime tiredness, lower productivity and difficulties concentrating. These symptoms can substantially diminish the occupational functioning, social interaction and quality of life. Fatigue is a common symptom of nutritional deficiencies such as vitamin D deficiency, which cannot be identified at routine clinical evaluations. [6]

Cognitive impairment is also a significant health problem in adults. Attention difficulties may negatively impact memory and mental processing, which can have a negative impact on education and occupational and social functioning. Early cognitive decline correlates with decreased work efficiency and difficulty performing daily activities. Vitamin D deficiency is thus becoming a more clinical problem in relation to cognitive health and nutritional and metabolic abnormalities. [7]

The association between vitamin D status fatigue and cognitive functioning has been the subject of several studies. However, there is a wide variety of findings depending on different populations and study designs. Studies have found a significant link between vitamin D deficiency and impaired cognitive functioning, but other research has found variable or weak links. There are similar variations in relation to severity of fatigue in deficient individuals. These disparities can be attributed to variations in the nutritional patterns and assessments of different age groups. [8]

Vitamin D may affect neurological functions in a few ways. Inflammatory cytokines, neuronal calcium homeostasis regulation have been associated with vitamin D activity in CNS. Low vitamin D levels could play a role in neuronal dysfunction and failure in communication between neurons. In deficiency, neurocognitive impairments may therefore be caused by structural changes as well as biochemical changes in the brain. [9]

Other symptoms of vitamin D deficiency include depressed mood, irritability and decreased motivation. There are indications that emotional wellbeing and cognitive performance follow similar pathways of neurochemical activity, namely serotonin, dopamine and inflammatory mediators. It is therefore possible that deficiency induced changes in these pathways could play a role in mental fatigue and cognitive dysfunction. Awareness of these symptoms can help clinicians determine potentially reversible causes of neuropsychological symptoms. [10]

Vitamin D deficiency seems to be high in tertiary care setups in Pakistan especially among adults. Underdiagnosis of this condition may be related to ignorance about health risks and poor uptake of preventive screening due to nutritional deficiencies. Patients often have vague symptoms such as fatigue, generalized weakness, body aches and concentration problems. These symptoms are frequently explained by psychological stress, lifestyle or work fatigue but without a detailed nutritional assessment.

Evidence of the relationship between vitamin D deficiency fatigue and cognitive function in local adult populations is still scarce. The majority of studies available have been mainly on the skeletal health or endocrine disorders. There are limited studies of the severity of fatigue and cognitive function in vitamin D deficient adults in the healthcare environment in our region. In addition, there are limited local data reported from tertiary care facilities on an adult outpatient basis. The dietary patterns, socioeconomic status, and environmental exposures in local communities could also have differential effects on vitamin D related neurological symptoms, as opposed to those in different countries.

The association between vitamin D deficiency fatigue and cognitive impairment may have clinical implications for initial screening and interventions. Recognising deficient individuals at the right time could help improve the performance of physical wellbeing and mental functioning of the individuals at work. The greater knowledge of neurologic symptoms of Vitamin D deficiency may also help in the formulation of prevention health policies and nutritional awareness in adults.

This study aimed at identifying the prevalence of vitamin D deficiency and to assess the relationship of this deficiency with fatigue and cognitive function in adults attending a tertiary care centre.

MATERIALS AND METHODS

Design and Settings

This prospective cross-sectional study was conducted at Lady Reading Hospital from 23 January 2025 to 23 December 2025.The study was carried out in the outpatient departments of internal medicine neurology and general medicine. The study included adult patients (18 years or older) presenting for routine clinical evaluation and for general health assessment. The aim of the study was to assess the prevalence of vitamin D deficiency, and its correlation with fatigue and cognitive function in adults attending a tertiary hospital. Direct patient interviews, clinical examination, laboratory investigation and standardized assessment scales were used for data collection.

Study Population

During the study period 154 adult participants were enrolled through consecutive non-probability sampling from the outpatient departments. Adults presenting for routine clinical evaluation or general health assessment were approached consecutively regardless of the presence or absence of fatigue weakness reduced concentration or memory complaints. Both male and female participants from different occupational and socioeconomic backgrounds were included.

Sample Size Determination

The sample size was calculated using the World Health Organization formula for estimating a single population proportion:

$n = Z^2 p\ (1 - p) / d^2$

An expected prevalence of 90% for low vitamin D status among Pakistani adults was taken from the study conducted by Mansoor et al. The confidence level was set at 95% with a corresponding Z value of 1.96. An absolute precision of 5% was used. As no cluster sampling was performed the design effect was taken as 1.0. The initial calculated sample size was 138 participants:

$n = (1.96)^2 \times 0.90 \times 0.10 / (0.05)^2 = 138.3$

After adjustment for an anticipated 10% nonresponse or incomplete data rate the required sample size was calculated as:

Adjusted $n = 138.3 / (1 - 0.10) = 153.7$

The final required sample size was rounded to 154 participants.

Inclusion Criteria

Adults aged 18 to 65 years who attended the outpatient departments for routine clinical evaluation or general health assessment were eligible for inclusion. Both male and female participants were included. Written informed consent was required before enrollment. Participants with stable chronic medical conditions were also included when fatigue and cognitive assessments could be performed reliably. The presence of fatigue weakness poor concentration or memory complaints was not required for enrollment. These symptoms were assessed after recruitment as study outcome variables.

Exclusion Criteria

Any patients with a pre-existing neurological condition, such as dementia, epilepsy, stroke, Parkinson's Disease and major psychiatric illness, were excluded from the study. Those who had taken vitamin D supplements in the last three months were not counted. Patients with chronic renal failure, chronic liver disease malignancy or severe systemic illness were excluded. Hearing impaired participants, visual disability or unwillingness to fill out cognitive assessment questionnaires were also excluded from the study. Any subject who did not want to be included or who had missing laboratory findings were excluded from final analysis.

Operational Definitions

Cognitive impairment was defined as a Montreal Cognitive Assessment score below 26 after applying the recommended educational correction where applicable.

Data Collection Procedure

Informed consent was obtained and a structured proforma used to record the demographic and clinical information. Information was gathered on age, sex, occupation, education level, BMI, physical activity and time spent in the sun. Patient interviews also recorded symptoms associated with diet, such as fatigue, general weakness, decreased concentration and forgetfulness. Fatigue and cognitive complaints were recorded after participant enrollment and were not used as criteria for recruitment.

All participants had blood samples taken under aseptic conditions and serum vitamin D levels were assessed. The 25 hydroxyvitamin D (25OHD) level was determined by chemiluminescence immunoassay technique in the hospital laboratory, which is a standard method. Vitamin D levels were classified based on the recommended guidelines. Any level less than 20 nanograms per milliliter was considered deficient. The range of 20-29 ng/mL was deemed inadequate, and a level of 30 or more ng/mL was deemed adequate.

Assessment of Fatigue

The Fatigue Severality Scale comprised of 9 validated items was used to assess fatigue severity. Participants were instructed to provide ratings of fatigue related symptoms on predefined rates. Higher scores indicated more severity of fatigue and decreased levels of functioning in daily life. When the participants could not complete the questionnaires independently, the questionnaire was administered by direct interview. For statistical analysis and comparison between the vitamin D categories, mean fatigue scores were calculated.

Cognitive Performance Assessment

Cognitive performance was assessed using the Montreal Cognitive Assessment. The instrument evaluates attention memory language executive functioning visuospatial ability abstraction and orientation and has a maximum score of 30 points. A MoCA score below 26 was classified as cognitive impairment. One additional point was added to the total score for participants who had completed 12 years of education or fewer. The assessment was administered using the locally validated [Urdu/English] version according to the language understood by each participant. All assessments were conducted in a quiet clinical setting by trained investigators familiar with the standardized administration and scoring procedure.

Variables of the Study

Serum vitamin D levels of adult participants was the main independent variable. Fatigue severity and cognitive performance scores were outcome measures. Covariates were age, gender, educational status, BMI, amount of physical activity, amount of sunlight exposure and chronic medical conditions associated with this exposure. Comparative and correlational statistics were used for the analysis of relationship between vitamin D levels and neurocognitive manifestations.

Data Management

The information collected was given due consideration before data entry. Before computerized statistical analysis was done, coding of the variables was finished manually. The information of the participants was kept confidential throughout research. There were no data analysis files that contained names or personal identifiers. Completed questionnaires laboratory reports and assessment forms were kept under the supervision of the principal investigator in a secure manner. All collected information was subject to clearance for access by only authorized research personnel.

Statistical Analysis

Data were analyzed using the Statistical Package for the Social Sciences version 26. Quantitative variables including age serum vitamin D level Fatigue Severity Scale score and Montreal Cognitive Assessment score were presented as mean and standard deviation. Qualitative variables including sex vitamin D status and cognitive impairment were presented as frequencies and percentages.

One-way analysis of variance was used to compare mean fatigue and cognitive assessment scores across the deficient insufficient and sufficient vitamin D groups. The independent-samples t test was used for comparisons of continuous variables between two groups where applicable. The chi-square test was used to assess associations between categorical variables including vitamin D status fatigue-related symptoms and cognitive impairment.

Pearson correlation analysis was performed to assess the relationships between serum vitamin

D level Fatigue Severity Scale score and Montreal Cognitive Assessment score. Correlation coefficients and corresponding p values were reported.

Multivariable linear regression analysis was performed to identify factors independently associated with cognitive performance. The continuous Montreal Cognitive Assessment score was entered as the dependent variable. Vitamin D deficiency age older than 50 years sedentary lifestyle and sunlight exposure of less than 20 minutes per day were entered simultaneously as independent variables. Unstandardized regression coefficients with 95% confidence intervals and p values were reported.

The assumptions of linearity normality of residuals homoscedasticity independence of observations and absence of multicollinearity were assessed before interpretation of the regression model. Multicollinearity was evaluated using variance inflation factors and tolerance values. Model fit was assessed using the coefficient of determination adjusted coefficient of determination and overall F test. A p value below 0.05 was considered statistically significant.

Ethical Consideration

The study was approved by the Institutional Research and Ethical Board of Lady Reading Hospital (REF: No. 433/LRH/MTI) before the data collection was started. This study was carried out in agreement with the ethical principles laid down in the Declaration of Helsinki. All participants gave written informed consent prior to enrollment. The confidentiality anonymity and privacy of the study participants were well respected during the process of the study. Participation continued to be voluntary and no impact on routine medical care was seen if someone withdrew from the study at any point.

Quality Control Measures

To assure reliability and accuracy of data obtained, standardized laboratory techniques and assessment scales were used. The study questionnaire was pilot tested prior to beginning the main study. Modifications were made as needed to enhance the clarity and understanding of assessment tools. Data entry was repeated several times to reduce data entry errors. Trained technical staff conducted laboratory investigations using institutional quality assurance procedures.

RESULTS

The demographic and clinical features of the participants

A total of 154 adults were included in the final analysis. The mean age of the participants was 39.7 ± 11.2 years. There were 86 males representing 55.8% of the study population and 68 females representing 44.2%. The mean body mass index was 27.1 ± 4.5 kg/m² and the mean daily sunlight exposure was 24.6 ± 12.8 minutes. A sedentary lifestyle was reported by 91 participants representing 59.1% of the study population. The mean Fatigue Severity Scale score was 4.8 ± 1.7 and the mean Montreal Cognitive Assessment score was 24.1 ± 3.6. The baseline demographic and clinical characteristics are presented in Table 1.

Table 1: Demographic and Clinical Characteristics of Participants

Variable	Value
Total participants	154
Mean age	39.7 ± 11.2 years
Male	86 (55.8%)
Female	68 (44.2%)
Mean body mass index	27.1 ± 4.5 kg/m²
Mean sunlight exposure	24.6 ± 12.8 minutes/day
Participants with sedentary lifestyle	91 (59.1%)
Mean Fatigue Severity Scale score	4.8 ± 1.7
Mean Montreal Cognitive Assessment score	

Distribution of Vitamin D Status Among Participants

Serum vitamin D assessment demonstrated high prevalence of vitamin D deficiency within the study population. Deficient vitamin D levels were identified in more than half of participants. Vitamin D insufficiency was observed in a substantial proportion while only a limited number of participants demonstrated sufficient vitamin D levels. These findings indicated widespread hypovitaminosis D among adults attending outpatient departments of the tertiary care hospital. Detailed distribution is presented in Table 2.

Table 2: Distribution of Vitamin D Status Among Participants

Vitamin D Status	Frequency	Percentage
Deficient (<20 ng/mL)	82	53.2%
Insufficient (20–29 ng/mL)	46	29.9%
Sufficient (≥30 ng/mL)	26	16.9%

Fatigue Severity According to Vitamin D Status

Comparison of fatigue severity across vitamin D categories demonstrated significantly higher fatigue scores among participants with deficient vitamin D levels. Individuals with sufficient vitamin D levels exhibited comparatively lower fatigue severity scores. Progressive reduction in fatigue burden was observed with increasing serum vitamin D concentration. These findings suggested a strong inverse relationship between vitamin D levels and fatigue severity among adult participants. Comparative findings are summarized in Table 3.

Table 3: Fatigue Severity According to Vitamin D Status

Vitamin D Status	Mean Fatigue Severity Scale Score	p value
Deficient	6.1 ± 1.3	
Insufficient	4.5 ± 1.2	
Sufficient	2.9 ± 0.9	<0.001

Cognitive Performance According to Vitamin D Status

Montreal Cognitive Assessment scores demonstrated significant variation according to vitamin D status. Participants with deficient vitamin D levels exhibited lower cognitive performance scores compared with participants having sufficient vitamin D levels. Attention memory recall and executive functioning deficits were more frequently identified among vitamin D deficient individuals. Better cognitive performance was observed with increasing serum vitamin D concentration. Detailed comparative findings are presented in Table 4.

Table 4: Cognitive Performance According to Vitamin D Status

Vitamin D Status	Mean Montreal Cognitive Assessment Score	p value
Deficient	21.8 ± 2.9	
Insufficient	24.3 ± 2.8	
Sufficient	27.1 ± 1.9	<0.001

Association Between Vitamin D Deficiency and Fatigue Symptoms

Analysis of fatigue related symptoms demonstrated that generalized weakness daytime tiredness and reduced physical endurance were significantly more common among participants with deficient vitamin D levels. Participants with sufficient vitamin D levels reported markedly fewer fatigue related complaints. Statistical analysis demonstrated strong association between vitamin D deficiency and fatigue manifestations. Detailed findings are shown in Table 5.

Table 5: Association Between Vitamin D Deficiency and Fatigue Related Symptoms

Fatigue Symptom	Deficient Vitamin D	Sufficient Vitamin D	p value
Generalized weakness	69 (84.1%)	7 (26.9%)	<0.001
Daytime tiredness	63 (76.8%)	5 (19.2%)	<0.001
Reduced concentration	58 (70.7%)	6 (23.1%)	<0.001
Sleep disturbance	44 (53.7%)	4 (15.4%)	0.002

Association Between Vitamin D Levels and Cognitive Impairment

Cognitive impairment was identified more frequently among participants with deficient serum vitamin D levels. Mild cognitive impairment based upon Montreal Cognitive Assessment scoring criteria was observed predominantly in the deficient vitamin D group. Participants with sufficient vitamin D levels demonstrated comparatively preserved cognitive functioning. Statistical analysis confirmed significant association between low vitamin D levels and cognitive dysfunction. Findings are summarized in Table 6.

Table 6: Association Between Vitamin D Status and Cognitive Impairment Defined as a MoCA Score Below 26

Vitamin D Status	Cognitive Impairment Present	Cognitive Impairment Absent	p value
Deficient	49 (59.8%)	33 (40.2%)	
Insufficient	17 (37.0%)	29 (63.0%)	
Sufficient	3 (11.5%)	23 (88.5%)	<0.001

Correlation Between Serum Vitamin D Levels Fatigue and Cognitive Scores

Pearson correlation analysis demonstrated significant inverse correlation between serum vitamin D levels and fatigue severity scores. Higher vitamin D levels were associated with lower fatigue severity. Positive correlation was observed between vitamin D levels and Montreal Cognitive Assessment scores indicating improved cognitive performance with increasing serum vitamin D concentration. Statistical findings are presented in Table 7.

Table 7: Correlation Between Vitamin D Levels Fatigue Severity and Cognitive Performance

Variables	Correlation coefficient (r)	p value
Vitamin D level vs fatigue score	-0.64	<0.001
Vitamin D level vs cognitive score	0.58	<0.001
Fatigue score vs cognitive score	-0.49	<0.001

Multivariate Regression Analysis for Predictors of Cognitive Impairment

Multivariable linear regression analysis was performed using the continuous Montreal Cognitive Assessment score as the dependent variable. Vitamin D deficiency age older than 50 years' sedentary lifestyle and sunlight exposure of less than 20 minutes per day were entered simultaneously as independent variables. Vitamin D deficiency was associated with a 3.8-point lower MoCA score after adjustment for the other variables included in the model. Older age sedentary lifestyle and reduced sunlight exposure were also independently associated with lower MoCA scores. Statistical findings are summarized in Table 8.

Table 8: Multivariable Linear Regression Analysis of Factors Associated with MoCA Score

Independent variable	B coefficient	95% confidence interval	p value
Vitamin D deficiency	−3.8	−5.1 to −2.4	<0.001
Age >50 years	−2.2	−3.6 to −1.0	0.001
Sedentary lifestyle	−1.7	−2.9 to −0.8	0.003
Sunlight exposure <20 minutes/day	−1.5	−2.6 to −0.7	0.005

Overall Associations of Vitamin D Deficiency with Fatigue and Cognitive Performance

Overall analysis demonstrated significant associations between vitamin D status fatigue severity and cognitive performance among adults attending the tertiary healthcare facility. Participants with vitamin D deficiency had higher fatigue scores more frequent complaints of physical exhaustion and reduced concentration and lower cognitive assessment scores than participants with sufficient vitamin D levels. Higher serum vitamin D levels were associated with lower fatigue severity and higher cognitive performance scores. These findings represent cross-sectional associations and do not establish a causal relationship.

DISCUSSION

The present study showed that vitamin D deficiency was very prevalent among adults attending a tertiary care hospital. Low serum vitamin D was associated with increased fatigue severity, and reduced cognitive function. Physical exhaustion, decreased concentration memory impairment and poorer cognitive assessment scores were observed with vitamin D deficiency participants. These results pointed to an increasing role of vitamin D deficiency in the nervous system and function in adults. [11] Vitamin D deficiency is a growing problem in all parts of the world, both developed and developing. This has been reported elsewhere with a wide-spread hypovitaminosis D found in adults despite having a good amount of environmental sunlight. A sedentary lifestyle, a lack of physical activity, the lack of nutritional knowledge and an awareness of health have been cited often as major factors. Physiological production of vitamin D may also be limited in urban settings and/or in occupations that spend a majority of their time indoors. [12]

In the present study, the vitamin D deficiency was found in over half of the recruited participants. Similar prevalence rates were found in previous regional studies using adult outpatient populations. It is noted that the elderly, people with restricted sun exposure and sedentary lifestyles are among those with a high burden of deficiency. A lower consumption of vitamin D containing foods was also linked to higher rates of vitamin D deficiency in developing populations. [13]

Those with low levels of vitamin D had significantly higher fatigue scores. A decreased physical endurance, daytime tiredness and generalized weakness have been also reported and are strongly correlated with hypovitaminosis D in previous studies, appearing as one of the earlier non-specific symptoms of vitamin D deficiency. Insufficient individuals, impaired neuromuscular function and altered mitochondrial activity have been suggested as possible mechanisms leading to physical fatigue. [14]

The participants with adequate vitamin D levels had significantly lower fatigue severity score than those with low vitamin D levels. The present results have been confirmed in previous international studies in which vitamin D was taken, leading to partial alleviation of fatigue-related symptoms. Vitamin D's effects on energy balance and physical functioning may be mediated by its effects on inflammation and skeletal muscle metabolism. Chronic low grade inflammation may thus play a role in improving symptoms in those who have sufficient vitamin D status. [15]

In the current study, vitamin D levels in the blood were also significantly correlated with cognitive function. Participants who had low levels of vitamin D showed lower MoCA scores, reflecting memory, attention, executive functioning and orientation deficits. Previous reports have confirmed these findings, associating low vitamin D levels with cognitive decline in adults and elderly. Increased awareness of neurocognitive dysfunction as an important expression of vitamin D deficiency. [16]

Several mechanisms have been suggested to help explain the vitamin D deficiency-cognitive impairment association. Vitamin D receptors have been found in various parts of the central nervous system, such as the hippocampus and cerebral cortex. Vitamin D activity has been attributed to neuroprotective effects, such as the control of neuronal growth, synaptic plasticity, and neurotransmitter synthesis. A disruption of these processes caused by deficiency could then play a role in the impairment of cognitive functioning and in the decrease in mental performance. [17]

The present study showed the significant correlation between low vitamin D level and difficulty in concentration. This is similar to what has been reported earlier in which subnormal persons noticed that their attention is poor, mental alertness is low and forgetfulness is observed. It has been suggested that oxidative stress and vascular dysfunction are important contributors to these neurocognitive manifestations that are associated with neuroinflammatory changes. Thus the inefficiency of the neurons due to vitamin D deficiency could negatively affect the performance of everyday life cognitive function in adults. [18]

Those who had low vitamin D also showed more sleep problems and overall fatigue. Similar results have been seen in previous studies where Vitamin D levels were low and sleep quality and physical recovery were compromised. The disturbance of sleep can also exacerbate the level of fatigue and cognitive problems by diminishing mental renewal and emotional balance. Thus, sleep disturbance and vitamin D related neurological dysfunction may form an endless cycle of chronic sleep and cognitive fatigue. [19]

In the present study, there was a significant inverse correlation between vitamin D level and fatigue severity (Pearson correlation analysis). A positive correlation was found between vitamin D level and cognitive performance scores. Previous studies have found similar statistical links between low levels of vitamin D and poor levels of fatigue and neurocognitive function. The results indicate that vitamin D levels could affect physical endurance and higher cortical performance. [20]

After adjustment for age sedentary lifestyle and sunlight exposure vitamin D deficiency remained independently associated with a lower continuous MoCA score. However, the cross-sectional design does not establish that vitamin D deficiency caused cognitive decline. Similar findings have been reported in previous studies that vitamin D deficiency was still highly linked to poorer cognitive functioning after accounting for confounding factors. This discovery provided the first evidence that vitamin D has a role in the nervous system other than on bone. [21]

In the present study, advanced age and sedentary lifestyle were also found to be important factors that are associated with cognitive dysfunction. This has been reported previously in the literature in which both aging and physical inactivity played a role in the deterioration of neurocognition. There are several suggested mechanisms by which sedentary lifetime habits are associated with cognitive dysfunction, including decreased cerebral perfusion and impairment of neuronal plasticity and metabolic dysfunction. These pathological processes may be exacerbated even further among susceptible people by vitamin D deficiency. [22]

Lower sunlight exposure was significantly associated with lower cognitive performance in the study population. This has been previously reported in situations of lack of outdoor activity with resulting decrease in serum vitamin D and neuropsychological symptoms. Widespread deficiency in urban populations may be due to environmental pollution, confinement of occupation and sociocultural practices that limit exposure to sunlight. Safe sunlight exposure and physical activity may be considered as general health measures although their effects on cognitive outcomes were not evaluated in this study. [23]

The present study confirmed a clinical association between vitamin D deficiency and mood and mental performance in adults, suggesting that this deficiency is becoming more relevant. The neurocognitive symptoms of vitamin D deficiency can be unrecognized due to the often insidious onset and vague nature of symptoms. Clinically, the focus is often on musculoskeletal complaints and cognitive complaints may be subtler. Early detection of vitamin D related neuropsychological symptoms could thus result in better patient outcomes in terms of well-being and functional capacity.

The findings highlight a potential role for nutritional awareness and appropriate assessment of vitamin D status among adults presenting with fatigue memory complaints or reduced concentration. However, the present study did not evaluate whether vitamin D supplementation sunlight exposure or physical activity improved fatigue or cognitive performance. Prospective interventional studies are needed to determine whether correction of vitamin D deficiency results in measurable neurocognitive benefits.

The present study had several strengths, such as using validated fatigue assessment and cognitive assessment scales, as well as laboratory-based serum vitamin D level measurement. Neurocognitive manifestations were comprehensively evaluated in adult outpatients and yielded locally clinically relevant data on the neurocognitive impact of vitamin D deficiency. The participation of people with diverse demographic characteristics also helped to ensure that findings were representative in the tertiary health care context.

However, there are some limitations that should be taken into account when interpreting the results of the study. This was a single tertiary care institution study and may not be generalizable. Long term evaluations of causal relationships between vitamin D deficiency fatigue and cognitive decline were not possible in cross sectional design. Other cognitive and psychological fatigue factors such as dietary patterns and unrecognized metabolic diseases could also have been responsible for contributing to fatigue severity and cognitive performance among the participants.

CONCLUSION

Vitamin D deficiency was common among adults attending the tertiary healthcare facility. Lower vitamin D levels were significantly associated with greater fatigue severity and lower cognitive performance. These cross-sectional findings do not establish causality and prospective studies are required to determine whether correction of vitamin D deficiency improves fatigue or cognitive outcomes.

Limitations

The study was performed in one tertiary care hospital, limiting the study's population representation. Cross sectional assessment was used and assessment of long term neurological outcome not possible. The differences in the diet or confounding factors related to lifestyle may have affected the reported results. The temporal relationship between vitamin D deficiency fatigue and cognitive performance could not be established and causal conclusions cannot be drawn from these findings.

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