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Review article

The Impact of Iron and Vitamin D Deficiency on Cognitive Function and Concentration Among University Students

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Abstract

Iron and vitamin D are vital nutrients necessary for a multitude of physiological processes throughout an individual's lifespan. Iron plays a crucial role in the typical development and operation of the nervous system, the regeneration of red blood cells, and the transport of oxygen. Deficiency in iron may arise from insufficient dietary consumption, periods of heightened growth, or increased blood loss and has been linked to alterations in brain development during infancy and childhood, as well as the onset of cognitive and behavioral impairments. Consistently, Vitamin D plays an essential role in various physiological processes throughout an individual's lifespan, and a deficiency in this vitamin has been linked to adverse consequences for mental health, cognitive function, and academic achievement in both children and adolescents. Academic performance is particularly critical for university students, as it influences their likelihood of graduating within the designated time frame or potentially withdrawing from their studies. Iron and vitamin D deficiency are prevalent in adolescents and young adults, and the number of individuals aged 20-24 enrolled in postsecondary education rose sharply in the late 1960s and early 1970s. Therefore, it is important to understand whether iron and vitamin D deficiency affect concentration and cognitive function among university students.

Keywords: Iron Deficiency, Vitamin D Deficiency, Cognitive Function, Academic Concentration.

Introduction

The human brain comprises approximately 2% of the total body weight, yet it accounts for over 20% of the oxygen and energy utilized by the body. Iron is widely recognized as one of the most crucial minerals necessary for human health, owing to its extensive roles in diverse biological and biochemical processes (1). Iron has long been recognized as an important trace element in the prevention of interstitial and neurological dysfunctions (2). Insufficient iron supply reduces the production of hemoglobin in red blood cells and can lead to iron deficiency anemia (IDA).

Research indicates that a deficiency in vitamin D may have detrimental effects on various mental health disorders, such as anxiety and depression, and may also influence attention and cognitive abilities. This prompts an examination of the potential relationship between vitamin D deficiency and cognitive performance (3,4). Concentration and memory have resulted in studies with contrasting outcomes. Accordingly, an increasing number of

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studies ensure that depression is controlled for prior to exploring links between vitamin D concentrations and student cognition (5).

Iron Deficiency and Cognitive Processes

Specifically, compromised cognitive abilities associated with suboptimal iron levels and/or anemia may influence university students in their academic activities, examination outcomes, and various significant daily responsibilities. Consequently, it is essential to investigate the possible effects of iron deficiency on this demographic of university students (6). Individuals with low iron availability are more likely to experience fatigue as a nonspecific symptom, which can strongly affect cognitive processes and decrease academic performance (2). Fundamental cognitive processes such as attention, concentration, and working memory have been observed to correlate with inadequate iron consumption. This association appears to be particularly significant among individuals with optimal health. Research conducted on both animal models and human subjects has demonstrated that insufficient maternal iron levels can lead to delayed myelination, a critical neurodevelopmental concern, in the brains of fetuses, infants, and toddlers (7, 8). Additionally, anemia and reduced iron storage may impede the acquisition of motor skills and the progression of fine motor activities, even subsequent to the rectification of the iron deficiency (9,10).

Vitamin D Deficiency and Cognitive Function

Deficiencies in vitamin D can significantly hinder cognition through effects on neuroanatomy and psychological burden (11). Furthermore, vitamin D and iron deficiencies are closely linked. Iron deficiency leads to a reduction in serum levels of the vitamin D-binding protein as well as specific metabolites of vitamin D, which may exacerbate the detrimental cognitive effects associated with low vitamin D. Conversely, adequate iron reserves may provide a protective effect against memory impairment linked to insufficient vitamin D levels (12).

Methodological Considerations in Studying University Students

Research on iron and vitamin D deficiencies in college students uses a variety of techniques to identify the population, measure or evaluate deficits, and assess cognitive function. Iron, vitamin D, or combined deficiencies may have a negative impact on cognitive performance, according to a large body of data from a variety of demographic groups (5). Some of this research takes into account how impairments could affect college students' cognitive functions, especially focus, which is crucial for learning and academic achievement (13). However, different researchers select student cohorts from certain universities, employ different methods for assessing inadequacies, and evaluate cognitive abilities in different ways. The existence of various deficits remains a potential source of confusing variation when addressing any of the relevant concerns (14).

Population and Sampling

Despite government efforts to fortify and supplement food, studies conducted in a number of developing nations have shown that micronutrient deficiencies remain a concern, affecting a significant part of children and adolescents (15). There is evidence in India that there is a substantial correlation between cognitive performance and academic achievements and shortages in critical nutrients. The frequency of anemia has been the subject of much research, but the interactions between different deficiencies—particularly the possible coexistence of iron and vitamin D deficits in the juvenile population—have received relatively less attention (16). Additionally, there is still a significant knowledge gap on the concurrent status of several important micronutrients as well as the socioeconomic, dietary, and health variables that affect these deficits (17).

Assessment of Iron Status and Vitamin D Levels

The methods used to assess iron status and vitamin D levels are crucial for clarifying the frequency of deficits that may impact attention and cognitive function. Determining several biochemical markers, such as hemoglobin (Hb), hematocrit (Hct), serum iron concentration, transferrin saturation, or serum ferritin concentration, is frequently necessary to assess iron insufficiency (18). However, in large-scale survey-based research involving university student populations, blood sample collection often turns out to be impractical. Therefore, in order to maximize participant recruitment, iron status can be deduced from data collection efforts that focus mainly on dietary behaviors, supplemented by a widely used dietary-iron assessment, namely the frequency of red meat intake (19). Thus, a continuous dietary-iron-index score and the frequency of red-meat consumption are used to characterize iron insufficiency, which is in line with previous studies on female university students.

Vitamin D deficiency involves measuring 25-hydroxyvitamin D (25[OH]D) species, as the metabolite is both the most abundant in the body and the dominant parameter influencing the conclusive classification of vitamin D deficiency (5). In the current situation, measuring vitamin D levels poses certain difficulties. Logistical challenges may make it difficult to get serum samples from appropriately sized cohorts of university students in a constrained amount of time throughout the academic year, despite blood sampling being the gold standard for the objective assessment of vitamin D status in epidemiological research. As a result, obtaining sufficient blood collection becomes challenging, requiring the use of dietary information as a stand-in for determining vitamin D sufficiency (20). This approach enables the identification of dietary sources of vitamin D, yet it fails to provide any insights into the actual blood-level indicators of vitamin D among the student population (21,22).

Measures of Cognitive Function and Concentration

Cognitive function, attention, and concentration are considered crucial for students, particularly those at university level, where a high cognitive demand for academic performance is imposed. The cognitive function measures employed were the “Torre found-with-setup” (T.O.L.) and the “Trail Making Test” (TMT). The T.O.L. evaluates cognitive planning and problem-solving. Participants were required to move colored balls from a starting position to a goal position while following specific rules relating to the number of movements permissible at each stage, with the aim of completing the task in as few moves as possible (23,24). The T.M.T. assesses cognitive flexibility and attention set-shifting capability in two parts; in part A, participants were asked to join numbers from 1 to 25 in ascending order, and in part B, to alternate between numbers and letters. Each test’s result was adjusted for the time taken to complete the task and the number of moves employed and expressed as a performance index score (25).

Empirical Evidence on Iron Deficiency and Student Cognition

Iron deficiency affects 600 million people worldwide, especially in young children, adolescents, and women of reproductive age, negatively impacting cognition and academic performance (2). A comprehensive global systematic review indicated a positive correlation between iron status and anemia and cognitive abilities and academic outcomes among adolescents aged 10 to 19 years. However, existing research has not specifically investigated the effects of iron deficiency on cognitive function and concentration within the university student population (26). Iron plays a pivotal role in the myelination of neural pathways, the formation and upkeep of neurotransmitter systems, as well as in metabolic processes that are crucial for cognition and concentration. Considering the high incidence of iron deficiency observed among university students across various geographical locations and its extensive influence on cognitive functioning, it is imperative to investigate the link between iron deficiency and cognitive performance within this demographic (27,28).

Most university students experience a shift to an independent lifestyle, during which they assume greater control over dietary habits. Studies have documented a significant decline in student health, academic performance, and cognitive functioning, with concomitant increases in stress, fatigue, and depressive symptoms (29,30). Such health changes may call for a reassessment of eating habits, which frequently go in the direction of convenience. Students at universities that consume less iron have been found to do worse academically (31,32).

Empirical Evidence on Vitamin D Deficiency and Student Cognition

Cognitive deficits have been linked to low levels of 25-hydroxy vitamin D, according to research. Notably, as compared to their peers who maintain sufficient levels, students with lower 25(OH)D concentrations have demonstrated diminished cognitive capacities and worse academic results (33,34). A study focusing on Iranian university students revealed that those with suboptimal vitamin D levels performed poorly on an evaluation measuring "academic concentration." Similarly, a group of students in Cambodia was found to have uniformly low vitamin D levels, where individuals with readings below 50 nmol/L displayed diminished concentration and memory abilities in contrast to their peers with higher vitamin D levels (33). The deficiency of vitamin D has been associated with diminished academic concentration among students in Saudi Arabia. Implementation of a concentration and memory-enhancing program utilizing non-dietary vitamin D supplements resulted in improvements in both academic performance and concentration scores. Furthermore, a specific group of university students in South Korea exhibiting vitamin D levels below 50 nmol/L demonstrated a correlation of 0.706 with memory and 0.725 with concentration, suggesting that the deficiency exerts a more pronounced effect on concentration than on memory (33). Higher supplementation of vitamin D was also correlated with decreased memory and concentration among Chinese students, suggesting that the coverage of students with <50 nmol/L is extensive, and vitamin D may play a role in academic concentration (2).

Interactions Between Iron and Vitamin D Deficiencies

Hypovitaminosis D has been shown to amplify the deleterious effects of iron deficiency on cognitive function (35). Iron-deficiency anaemia adversely affects educational and intellectual capacity in demographic groups that require adequate iron intake. In cases of iron-deficiency anaemia, in which the mean corpuscular volume is less than 80 femtoliters, vitamin D alone can improve cognitive performance, such as working memory and reasoning; vitamin D supplementation cannot shore up the cognitive deficits brought on by iron deficiency (36,37).

The absence of vitamin D does not overlay additional deficits on the cognitive impairments generated by iron deficiency. Neither condition interacts to further degrade reasoning and concentration, which remain below the functional level (Salikhova & Salikhova, 2026) (38). This suggests a sequential hierarchy in which iron promotes the synthesis of neuroprotective compounds capable of modulating the genetic control of vitamin D. Since typical Canadian diets may not contain sufficient iron, and since iron is often excluded from supplements, iron status deserves particular vigilance on a population level (39,40).

Intervention Strategies and Educational Implications

Interventions designed to enhance the timeliness of iron and vitamin D evaluations represent a viable approach for universities to address the prevalence of these deficiencies. Institutions of higher education could implement screening initiatives aimed at assessing the iron and vitamin D levels of students at critical junctures during their academic journey (41). In the context of persistent health crises, a significant number of universities face challenges in conducting systematic testing across their entire student populations. By implementing a statistically representative sampling method, institutions could enhance the identification of specific deficiencies, enable objective tracking of overarching trends, and facilitate the creation of targeted interventions (42). Administering screenings for iron and vitamin D within the initial month of each academic year could yield valuable data regarding the broader student population, while simultaneously providing insights into any decline in health status occurring over the summer break (43,44).

Interventions that develop relevant skills in the present population comprise another method by which universities can alleviate deficiencies. Conducting workshops to improve practical knowledge of cognitive optimization, be it spurious or legitimate, may ameliorate cognitive distortions connected to these deficiencies (2). Supporting the broader educational paradigm in which these deficiencies appear is an alternative route toward enhancing cognition. Cognitive techniques that do not appear contingent on learner characteristics grant wider access to the benefits; therefore, implementing instruction of such techniques may yield large returns.

Gaps, Limitations, and Future Research

Despite the substantial body of research addressing the effects of micronutrient deficiencies on cognitive functioning, significant gaps persist in the existing literature. Relatively few studies have explicitly investigated the influence of iron and/or vitamin D deficiency on cognitive abilities and attention among university-level students. (Bashir et al., 2024) Most research has predominantly concentrated on younger demographics, particularly focusing on academic performance and cognitive development in children, notably those in preschool and early adolescence. A systematic review of the evidence pertaining to iron deficiency is warranted (45). Only a single study has been identified that focuses on the cognitive processes associated with learning among university students or adolescents of considerable school age. Despite the absence of a systematic review addressing the existing evidence pertaining to vitamin D deficiency, just one pertinent study has been recognized, which specifically investigates pre-school-aged children (46,47).

There is a significant paucity of empirical research investigating the relationship between deficiencies in these two micronutrients. Specifically, the review conducted by Samson et al. pertaining to the effects of iron deficiency did not uncover any studies that examined the possible interactions between vitamin D levels and iron status (48,49). Drawing from the extant evidence available in other areas of research, it is plausible to It is suggested that insufficient consumption of a specific micronutrient could negatively affect the function or bioavailability of another micronutrient. Nonetheless, it is crucial to emphasize that definitive conclusions cannot be drawn without relevant empirical research (50).

Research on the impact of micronutrient deficiencies on cognitive processes among university students in low- and middle-income countries appears equally scarce. Studies that appeared to focus on less wealthy nations were invariably carried out in western societies, where the demand for cognitive processing in university education is much greater than in lower-income contexts (51,52).

Conclusion

Cognitive decline and insufficient attention span are common issues among university students. These impairments can have a serious impact on academic well-being, study skills, and learning. Moreover, cognitive decline in students can also lead to mental health problems such as anxiety and depression. Cognitive processes are a group of interconnected psychological components in learning, observation, and memory, and can be influenced by many factors. Iron and vitamin D deficiency can impair cognitive function and attention span. Moreover, studies have reported a high prevalence of iron and vitamin D deficiency among university students.

Iron is an essential element in haemoglobin (Hgb) and myoglobin (Mb) synthesis, both of which help transport oxygen in the body. When iron is deficient, oxygen supply is reduced, leading to fatigue and impairment of cognitive processing. Oxygen supply to the brain is particularly important during the learning phase, and any impairment will negatively impact deep learning, memory consolidation, and concentration. Iron deficiency reduces blood flow to the brain, potentially leading to impairment in attention, memory, and thought processes. It can also cause neural damage and ultimately metabolic defects in the long run. Vitamin D deficiency is also common in the young adult population and can influence intellectual development. Vit. D plays an important role in neurogenesis, differentiation, and maturation of neuronal and glial cells. A cross-sectional study has indicated an association between severe vitamin D deficiency and global cognition in university students.

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