E-ISSN 2250-0944
ISSN 2250-1150
doi: 10.31838/ijprt/16.01.213

Research Article

Impact of Hydration Status on Cognitive Performance

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Received: 21.02.26, Revised: 19.03.26, Accepted: 22.04.26

ABSTRACT
Background: Adequate hydration is essential for maintaining physiological balance and optimal brain function. Even mild dehydration has been suggested to impair cognitive processes such as attention, memory, and executive function. Despite growing interest, findings across studies remain inconsistent due to variations in methodology, population characteristics, and definitions of hydration status. Understanding this relationship is particularly important in environments where dehydration risk is elevated, such as hot climates or during prolonged physical or mental activity.
Objective: This study aimed to evaluate the impact of hydration status on cognitive performance and to determine whether mild dehydration significantly affects specific cognitive domains in healthy adults.
Methodology: A cross-sectional study was conducted involving 120 healthy participants aged 18–35 years. Hydration status was assessed using urine specific gravity and self-reported fluid intake. Participants were categorized into euhydrated and mildly dehydrated groups. Cognitive performance was evaluated using a standardized battery of neuropsychological tests measuring attention, working memory, processing speed, and executive function. Statistical analyses, including independent t-tests and multiple regression models, were used to examine differences between groups and control for potential confounding factors such as age, sleep quality, and physical activity.
Results:
The study included 120 participants, divided into euhydrated (n=62) and mildly dehydrated (n=58) groups. Findings showed that mildly dehydrated participants performed significantly worse in attention ($p<0.001$) and working memory ($p<0.001$) compared to the euhydrated group. No significant differences were observed in processing speed ($p=0.12$) and executive function ($p=0.21$). Urine specific gravity confirmed hydration classification, with higher values in the dehydrated group. Regression analysis identified hydration status as a significant predictor of attention even after adjusting for confounders. Overall, mild dehydration selectively impaired certain cognitive domains, particularly those related to attention and short-term memory performance.

Keywords: Hydration Status, Cognitive Performance, Dehydration, Attention, Working Memory, Fluid Intake.

INTRODUCTION

Water is a vital component of human physiology, constituting approximately 60% of total body weight and playing a central role in maintaining homeostasis. It is essential for numerous biological processes, including thermoregulation, metabolic reactions, nutrient transport, and waste elimination. In addition to its systemic functions, water is critical for optimal brain performance. The central nervous system is particularly sensitive to fluctuations in fluid balance, and even minor changes in hydration status may influence cognitive processes. As cognitive performance underpins learning, decision-making, and productivity, understanding factors that may impair or enhance it such as hydration have become increasingly important(1).

Hydration status refers to the equilibrium between fluid intake and fluid loss. When fluid intake adequately compensates for losses, the body is in a state of euhydration. Conversely, dehydration occurs when fluid loss exceeds intake, leading to a deficit that can disrupt normal physiological functioning. Dehydration can range from mild to severe; however, mild dehydration—typically defined as a loss of 1–2% of body weight is the most common form experienced in everyday life. This level of dehydration can occur due to inadequate water consumption, exposure to high temperatures, prolonged physical activity, or illness. While severe dehydration is known to have serious health consequences, the cognitive effects of mild dehydration remain an area of active research and debate(2).

The brain relies on a stable internal environment to function efficiently. Adequate hydration supports cerebral blood flow, maintains electrolyte balance, and facilitates neurotransmitter activity. Disruptions in hydration may impair these processes, potentially affecting attention, memory, and executive functioning. Several physiological mechanisms have been proposed to explain this relationship. For instance, reduced plasma volume during dehydration may limit oxygen and glucose delivery to the brain. Additionally, imbalances in electrolytes such as sodium and potassium can interfere with neuronal signaling. Dehydration has also been associated with increased fatigue, reduced alertness, and mood disturbances, all of which can indirectly influence cognitive performance[3].

A growing body of literature has investigated the relationship between hydration status and cognitive performance, yielding mixed findings. Some studies have reported that mild dehydration negatively affects cognitive domains such as attention, working memory, and psychomotor skills. For example, experimental studies involving fluid restriction have demonstrated declines in vigilance and short-term memory, particularly in tasks requiring sustained mental effort. Other research has highlighted that dehydration may impair mood and increase perceived task difficulty, which can further influence performance outcomes. These findings suggest that even subtle fluid imbalances may have measurable effects on brain function[4].

However, not all studies have found significant associations between hydration and cognition. Some research conducted under controlled laboratory conditions has reported minimal or no cognitive impairment with mild dehydration, especially when participants are otherwise healthy and well-rested. These inconsistencies may be attributed to differences in study design, sample size, participant characteristics, and assessment tools. For instance, variations in age, gender, baseline hydration levels, and environmental conditions can influence how individuals respond to dehydration. Additionally, the methods used to measure hydration status—such as urine specific gravity, plasma osmolality, or self-reported fluid intake may yield differing results, complicating comparisons across studies[4].

Environmental and contextual factors further contribute to the complexity of this relationship. Individuals living in hot climates or engaging in physically demanding activities are at greater risk of dehydration due to increased fluid loss through sweating. In such conditions, the cognitive effects of dehydration may be more pronounced. This is particularly relevant for students, professionals, and athletes who must maintain high levels of mental performance despite environmental stressors. Moreover, lifestyle factors such as diet, caffeine consumption, sleep quality, and physical activity levels can independently affect both hydration status and cognitive outcomes, acting as potential confounders in research studies[5].

Despite the increasing interest in this topic, gaps remain in existing literature. Many studies focus on specific populations, such as children, athletes, or military personnel, limiting the generalizability of findings to the broader adult population. Additionally, inconsistencies in research methodologies and cognitive assessment tools make it difficult to draw definitive conclusions. There is a need for more standardized and comprehensive studies that examine multiple cognitive domains while controlling confounding variables.

Therefore, this study aims to investigate the impact of hydration status on cognitive performance in healthy adults. By assessing key domains such as attention, working memory, processing speed, and executive function, this research seeks to provide a clearer understanding of how mild dehydration may influence cognitive abilities. The findings are expected to contribute to the existing body of knowledge and highlight the importance of maintaining adequate hydration for optimal cognitive functioning, particularly in environments where the risk of dehydration is elevated[6].

METHODOLOGY

Study Design and Setting:

This study adopted a cross-sectional analytical design to examine the relationship between hydration status and cognitive performance among healthy adults. Data collection was carried out over a three-month period from October to December 2025 in a controlled academic setting to ensure standardization of testing conditions and minimize environmental variability.

Study Population and Sampling

A total of 120 participants aged 18–35 years were recruited using a convenience sampling technique. All participants were informed about the purpose and procedures of the study prior

to enrollment, and written informed consent was obtained.

Inclusion Criteria

Participants were eligible for inclusion if they met the following criteria:

- Healthy adults aged between 18 and 35 years
- No history of chronic medical conditions
- Not currently taking medications that could affect hydration status or cognitive function
- Normal or corrected-to-normal vision
- Willingness to participate and provide informed consent

Exclusion Criteria

Participants were excluded if they met any of the following conditions:

- History of neurological or psychiatric disorders
- Presence of chronic illnesses such as cardiovascular disease, kidney disease, or diabetes
- Recent acute illness or infection
- Sleep deprivation (less than 6 hours of sleep prior to testing)
- Consumption of excessive caffeine or alcohol within 24 hours before assessment
- Engagement in strenuous physical activity within 24 hours prior to testing
- Use of diuretics or other medications influencing fluid balance

Assessment of Hydration Status

Hydration status was determined using urine specific gravity (USG). Midstream urine samples were collected from participants on the day of assessment and analyzed using a refractometer. Based on USG values, participants were categorized into two groups: euhydrated (USG ≤ 1.020) and mildly dehydrated (USG > 1.020). A supplementary questionnaire was also administered to gather information on daily fluid intake and lifestyle behaviors.

Assessment of Cognitive Performance

Cognitive performance was evaluated using a standardized battery of neuropsychological tests. The assessment covered key cognitive domains, including attention, working memory, processing speed, and executive function. All tests were administered in a quiet, controlled environment and followed a fixed sequence to ensure consistency across participants.

Data Analysis

Data were analyzed using software SPSS version 26. Descriptive statistics were used to summarize demographic and baseline characteristics. Independent t-tests were conducted to compare cognitive scores between hydration groups. Multiple regression analysis was performed to adjust for potential confounding variables such as age, gender, sleep quality, and physical activity. A p-value of less than 0.05 was considered statistically significant.

Ethical Considerations

Ethical approval for the study was obtained from the relevant institutional review board. All participants provided informed consent prior to participation. Confidentiality and anonymity of participant data were strictly maintained throughout the study.

RESULTS

A total of 120 participants completed the study. Participants were categorized into two groups based on hydration status: euhydrated (n = 62) and mildly dehydrated (n = 58). The results are presented below with detailed tables and corresponding descriptions.

Table 1: Demographic Characteristics of Participants

Variable	Euhydrated (n=62)	Dehydrated (n=58)	p-value
Age (years, mean ± SD)	24.3 ± 3.8	25.1 ± 4.1	0.28
Gender (M/F)	30 / 32	28 / 30	0.91
Sleep (hours)	7.2 ± 0.8	7.0 ± 0.9	0.19
Fluid Intake (L/day)	2.3 ± 0.5	1.5 ± 0.4	<0.001*

There were no statistically significant differences between the two groups in terms of age, gender distribution, or average sleep duration ($p > 0.05$), indicating that the groups were comparable. However, daily fluid intake was significantly lower in the dehydrated group ($p < 0.001$), supporting the classification of hydration status.

Table 2: Hydration Status (Urine Specific Gravity)

Group	USG (mean ± SD)
Euhydrated	1.015 ± 0.003
Dehydrated	1.024 ± 0.002

The mean urine specific gravity (USG) values confirmed clear differentiation between the two groups. The dehydrated group had significantly higher USG values, indicating reduced hydration levels compared to the euhydrated group.

Table 3: Cognitive Performance Scores

Cognitive Domain	Euhydrated (Mean ± SD)	Dehydrated (Mean ± SD)	p-value
Attention	88.5 ± 6.2	81.3 ± 7.1	<0.001*
Working Memory	85.7 ± 5.9	79.8 ± 6.5	<0.001*
Processing Speed	90.2 ± 7.0	88.1 ± 6.8	0.12
Executive Function	87.4 ± 6.5	85.9 ± 6.9	0.21

Participants in the euhydrated group performed significantly better in attention and working memory tasks compared to the dehydrated group ($p < 0.001$). However, differences in processing speed and executive function were not statistically significant ($p > 0.05$), suggesting that mild dehydration may selectively affect certain cognitive domains.

Table 4: Multiple Regression Analysis (Predictors of Attention Score)

Variable	β Coefficient	Standard Error	p-value
Hydration Status	0.42	0.08	<0.001*
Age	-0.09	0.05	0.11
Sleep Duration	0.15	0.07	0.04*
Physical Activity	0.12	0.06	0.06

Multiple regression analysis revealed that hydration status was a significant predictor of attention scores ($p < 0.001$), even after adjusting for confounding variables. Sleep duration also showed a modest but significant positive association with attention ($p = 0.04$). Other variables were not statistically significant predictors.

The findings indicate that mild dehydration is associated with reduced performance in specific cognitive domains, particularly attention and working memory. Other domains such as processing speed and executive function were less affected. These results suggest that maintaining adequate hydration may be important for optimal cognitive functioning, especially for tasks requiring sustained attention and short-term memory.

DISCUSSION

The present study examined the impact of hydration status on cognitive performance among healthy young adults, with a particular focus on key domains such as attention, working memory, processing speed, and executive function. The findings indicate that mild dehydration is associated with a significant decline in attention and working memory, while its effects on processing speed and executive function appear to be minimal. These results contribute to the growing body of evidence suggesting that even subtle changes in hydration status can influence specific aspects of cognitive functioning[7].

One of the primary findings of this study is the significant reduction in attention scores among mildly dehydrated participants. This is consistent with previous research indicating that attention is particularly sensitive to physiological changes, including fluid imbalance. Sustained attention requires continuous mental effort and optimal neural efficiency, both of which may be compromised under conditions of dehydration. A possible explanation lies in reduced cerebral blood flow and altered neurotransmitter activity, which may impair the brain's ability to maintain focus over extended periods. Additionally, dehydration has been associated with increased fatigue and decreased alertness, which can further contribute to diminished attentional capacity[8].

Similarly, working memory performance was significantly lower in the dehydrated group compared to the euhydrated group. Working memory is a critical cognitive function involved in temporarily storing and manipulating information, and it is highly dependent on the prefrontal cortex. Dehydration may disrupt the optimal functioning of this brain region through mechanisms such as electrolyte imbalance and reduced neuronal efficiency. These findings align with earlier studies that have reported impairments in short-term memory and information processing under conditions of fluid restriction.

In contrast, the study did not find statistically significant differences in processing speed and executive function between the two groups. This suggests that these cognitive domains may be more resilient to mild dehydration, at least within the range observed in this study. It is possible that more severe levels of dehydration or prolonged exposure to fluid deficit are required to produce measurable impairments in these areas. Alternatively, the cognitive tasks used to assess these domains may not have been sufficiently sensitive to detect subtle differences. This highlights the importance of selecting appropriate and sensitive assessment tools in cognitive research[9].

The results of the regression analysis further support the role of hydration status as an independent predictor of attention performance, even after controlling for potential confounding variables such as age, sleep duration, and physical activity. This strengthens the argument that hydration is not merely a secondary factor but may play a direct role in influencing cognitive outcomes. The observed association between sleep duration and attention also underscores the multifactorial nature of cognitive performance, where multiple physiological and lifestyle factors interact.

These findings have important practical implications, particularly for individuals who are required to maintain high levels of cognitive performance in daily life, such as students, professionals, and individuals working in demanding environments. In hot climates or situations involving prolonged physical or mental exertion, the risk of dehydration is increased, potentially exacerbating its cognitive effects. Promoting adequate fluid intake may serve as a simple and effective strategy to support cognitive health and performance[10].

Despite its contributions, this study has several limitations that should be acknowledged. The cross-sectional design limits the ability to establish causality between hydration status and cognitive performance. Additionally, the use of convenience sampling may reduce the generalizability of the findings to broader populations. Future research should consider longitudinal or experimental designs, larger and more diverse samples, and the inclusion of more precise measures of hydration and cognitive function.

In conclusion, the present study demonstrates that mild dehydration can negatively affect specific cognitive domains, particularly attention and working memory. These findings emphasize the importance of maintaining adequate hydration for optimal cognitive functioning and highlight the need for further research to better understand the underlying mechanisms and broader implications.

Implications

The findings of this study highlight the importance of maintaining adequate hydration for optimal cognitive functioning, particularly in tasks requiring attention and working memory. These results have practical implications for students, professionals, and individuals working in cognitively demanding or high-temperature environments, where the risk of dehydration is elevated. Promoting regular fluid intake may serve as a simple, cost-effective strategy to enhance mental performance and reduce cognitive fatigue. Additionally, institutions such as schools and workplaces should consider implementing hydration awareness programs to support productivity and well-being. Further research can inform evidence-based guidelines for daily fluid intake tailored to cognitive health.

Limitations

This study has several limitations that should be considered. The cross-sectional design limits the ability to establish a causal relationship between hydration status and cognitive performance. The use of convenience sampling may reduce the generalizability of the findings to wider populations. Additionally, hydration status was assessed using a single measure, which may not fully capture dynamic fluid balance. Self-reported data on fluid intake and lifestyle factors may be subject to bias. Environmental conditions and dietary intake were not strictly controlled, which could influence results. Future studies should use longitudinal designs, larger samples, and more comprehensive hydration assessment methods.

CONCLUSION

This study demonstrates that mild dehydration is associated with reduced cognitive performance, particularly in attention and working memory, among healthy young adults. While processing speed and executive function were not significantly affected, the findings suggest that even slight fluid imbalance can influence specific mental processes. Hydration status emerged as an important independent factor in cognitive functioning after controlling for key confounders. These results highlight the importance of maintaining adequate hydration for optimal brain performance in daily life. Further research is needed to explore long-term effects, underlying mechanisms, and broader population differences to strengthen current evidence and recommendations.

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