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Original Research Article

HYDRATION STATUS AND ITS IMPACT ON COGNITIVE PERFORMANCE AND REACTION TIME IN YOUNG ADULTS: A COMPARATIVE STUDY

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Abstract

Background: Hydration plays a critical role in maintaining cognitive performance, reaction time, and overall brain function. Even mild dehydration has been associated with impaired memory, reduced alertness, and delayed response times. This study aims to evaluate the impact of hydration status on cognitive function and reaction time in young adults by assessing performance across multiple neurocognitive domains under different hydration conditions. **Materials and Methods:** A randomized cross-sectional study was conducted on 80 healthy young adults (aged 18–30 years). Participants were assigned to either a hydrated group (n=40) or a dehydrated group (n=40) based on controlled fluid intake and urine osmolality levels measured before cognitive testing. Cognitive function was assessed using a standardized neurocognitive battery, evaluating attention, working memory, executive function, and problem-solving ability. Reaction time was measured using computerized response-time tasks under controlled conditions. Additional physiological parameters such as blood pressure, heart rate, and subjective fatigue levels were recorded. Data analysis was performed using independent t-tests and ANOVA to compare cognitive outcomes between hydration groups. **Result:** The dehydrated group exhibited significantly lower cognitive performance, particularly in tasks requiring sustained attention, executive function, and working memory. Reaction times were slower in the dehydrated group, with a mean delay of 12–18% compared to hydrated individuals. Additionally, subjective fatigue, reduced alertness, and increased cognitive effort were reported more frequently among dehydrated participants. In contrast, the hydrated group demonstrated faster reaction times, higher cognitive efficiency, and improved overall neurocognitive performance. **Conclusion:** Mild dehydration negatively affects cognitive function and reaction time in young adults, emphasizing the importance of maintaining adequate hydration for optimal brain function and alertness. These findings are particularly relevant for individuals in academic, occupational, and athletic settings, where quick decision-making and cognitive agility are crucial. Future research should explore long-term hydration strategies and their potential cognitive benefits in real-world environments.

INTRODUCTION

Hydration is a fundamental aspect of physiological regulation, influencing multiple biological processes, including circulatory function, thermoregulation, metabolic homeostasis, and neural activity. Beyond its well-documented role in maintaining physical health, hydration also has a profound impact on cognitive function and neuromotor responses.[1] The human brain is extremely sensitive to changes in fluid balance, and even mild dehydration (1–2% loss of body weight due to fluid deficit) has been shown to affect cognitive performance, mood regulation, and reaction time. While dehydration is often associated with extreme conditions such as prolonged exercise or heat exposure, evidence suggests that everyday mild dehydration—resulting from inadequate fluid intake—can impair cognitive function even in non-strenuous environments.[2]

Hydration is particularly crucial in populations that rely on sustained cognitive effort, decision-making speed, and reaction time, including students, athletes, and professionals working in high-pressure environments.[3] Previous research has demonstrated that dehydration can negatively influence short-term memory, executive function, attention, and psychomotor performance, leading to reduced efficiency in problem-solving, impaired coordination, and slower response times. Despite these findings, many young adults fail to meet daily recommended fluid intake levels, often substituting water with caffeinated, sugary, or alcoholic beverages, which may further contribute to fluid imbalances.[4]

The physiological mechanisms underlying hydration-related cognitive impairment are complex. Dehydration reduces blood volume and cerebral perfusion, leading to decreased oxygen and nutrient delivery to brain tissue. Studies utilizing functional magnetic resonance imaging (fMRI) and electroencephalography (EEG) have shown that dehydration can alter brain activity patterns, particularly in regions involved in attention, working memory, and executive processing.[5] Furthermore, electrolyte imbalances resulting from inadequate hydration can disrupt neuronal signaling, affecting cognitive processing speed and slowing reaction times. This is particularly concerning for individuals engaged in mentally demanding tasks, where even subtle delays in decision-making or neuromotor function can impact performance outcomes.[6]

In addition to objective physiological changes, subjective feelings of fatigue, cognitive effort, and reduced alertness have been reported in dehydrated individuals. Studies have shown that dehydration may increase the perception of task difficulty, leading to higher mental fatigue and reduced efficiency in cognitive tasks. While these effects have been observed across different age groups, young adults are particularly vulnerable due to erratic hydration habits, reliance on stimulants, and lifestyle-related dehydration risks.[7]

Despite increasing awareness of hydration's impact on brain function, research on hydration status and cognitive efficiency in young adults remains limited. Many studies have focused on athletic performance or extreme dehydration scenarios, but few have examined the subtle effects of everyday mild dehydration on cognitive processing speed and reaction time in individuals who engage in high-level cognitive activities without physical exertion.[8] Furthermore, most hydration-related research has been conducted in older adults or pediatric populations, leaving a gap in knowledge regarding the effects of hydration on the cognitive performance of healthy young adults.

Given the increasing cognitive demands placed on young adults in academic, professional, and digital environments, understanding the role of hydration in sustaining cognitive function and neuromotor response efficiency is essential. This study aims to assess the impact of hydration status on cognitive performance and reaction time in young adults, using a controlled experimental design to compare hydrated and dehydrated participants. By evaluating attention, working memory, executive function, and reaction speed, this study seeks to determine whether mild to moderate dehydration significantly impairs cognitive efficiency and neuromotor response times.[9]

The findings of this study have potential implications for a wide range of real-world applications, including educational settings, workplace performance, and sports science, where maintaining optimal cognitive function and quick reflexes is crucial. If hydration is confirmed to be a significant modulator of cognitive and reaction-time performance, this study could support public health recommendations for improved hydration awareness among young adults, ensuring that fluid intake is prioritized to enhance mental agility, concentration, and overall cognitive health.

MATERIALS AND METHODS

This study was designed as a randomized cross-sectional trial to investigate the impact of hydration status on cognitive function and reaction time in young adults. A total of 80 healthy participants aged 18–30 years were recruited, with an equal distribution of 40 participants in the hydrated group and 40 in the dehydrated group. Participants were screened for underlying medical conditions, neurological disorders, and medication use that could influence cognitive performance. They were instructed to avoid alcohol, caffeine, and intense physical activity for 24 hours prior to testing to eliminate external confounders affecting hydration status or cognitive function.

Hydration status was assessed through urine osmolality measurements, body weight changes, and self-reported fluid intake history. Participants were categorized as hydrated (urine osmolality <700 mOsm/kg, recent fluid intake ≥ 500 mL) or dehydrated (urine osmolality ≥ 700 mOsm/kg, fluid restriction for 12 hours) before cognitive testing. The study environment was temperature-controlled to prevent dehydration due to external heat exposure.

Cognitive function was assessed using a standardized neurocognitive test battery, evaluating attention, working memory, executive function, and problem-solving ability. Tests included the Digit Span Task (short-term memory and attention), Stroop Test (cognitive flexibility and processing speed), and Trail Making Test (executive function and problem-solving ability). Reaction time was measured using computerized response-time tasks, requiring participants to respond to visual and auditory stimuli as quickly as possible. Each participant performed three trials, and the average response time was recorded.

Physiological parameters, including blood pressure, heart rate, and self-reported fatigue levels, were recorded before and after cognitive testing to determine whether dehydration induced additional systemic effects. Participants also completed a subjective questionnaire assessing their alertness, concentration difficulty, and perceived cognitive effort during testing.

Statistical analyses were performed using independent t-tests and ANOVA to compare cognitive scores, reaction times, and physiological responses between the two hydration groups. Pearson correlation analysis was conducted to examine potential relationships between hydration status, cognitive efficiency, and neuromotor response speed. A p-value of <0.05 was considered statistically significant.

The study adhered to ethical research guidelines, and informed consent was obtained from all participants. Ethical approval was granted by the institutional ethics committee, ensuring compliance with human research protocols.

RESULTS

A total of 80 young adults participated in the study, with 40 individuals in the hydrated group and 40 in the dehydrated group. The baseline characteristics, hydration markers, cognitive function, reaction times, and subjective fatigue scores were compared between the two groups to assess the impact of hydration on cognitive performance and neuromotor responses.

Table 1: Baseline Characteristics of Study Participants

The baseline characteristics of both groups were analyzed, confirming that age, gender, and BMI were evenly distributed, eliminating confounding variables

Table 1: Demographic details of participants

Parameter	Hydrated Group (n=40)	Dehydrated Group (n=40)	p-value
Age (years, mean ± SD)	23.6 ± 1.9	23.9 ± 1.9	0.74
BMI (kg/m², mean ± SD)	22.5 ± 1.3	22.6 ± 1.5	0.82

Table 2: Hydration Status and Physiological Parameters

Urine osmolality, body weight change, and vital signs were assessed to confirm hydration status. Dehydrated participants exhibited significantly higher urine osmolality, greater body weight loss, and elevated heart rates compared to hydrated individuals.

Table 2: Hydration and Physiological Markers

Parameter	Hydrated Group (n=40)	Dehydrated Group (n=40)	p-value
Urine Osmolality (mOsm/kg)	503.3 ± 45.0	811.4 ± 67.7	<0.001
Body Weight Change (%)	0.48 ± 0.21	1.86 ± 0.24	<0.001
Heart Rate (bpm)	71.6 ± 3.9	81.3 ± 6.2	<0.001

Table 3: Cognitive Performance Scores Across Neurocognitive Tasks

Participants in the dehydrated group exhibited significantly lower scores in attention, working memory, and executive function tests, confirming that mild dehydration negatively affects cognitive efficiency.

Table 3: Cognitive Function Performance

Cognitive Test	Hydrated Group (n=40)	Dehydrated Group (n=40)	p-value
Digit Span Score (Memory)	12.0 ± 1.5	10.0 ± 1.5	<0.01
Stroop Test Score	85.0 ± 5.0	78.0 ± 6.0	<0.01
Trail Making Test (s)	30.0 ± 3.0	37.0 ± 4.0	<0.01

Table 4: Reaction Time Performance

Reaction times were significantly slower in the dehydrated group compared to the hydrated group, indicating that fluid deficits impair neuromotor response speed.

Table 4: Reaction Time Results

Reaction Time Task	Hydrated Group (n=40)	Dehydrated Group (n=40)	p-value
Simple Reaction Time (ms)	250.0 ± 20.0	280.0 ± 25.0	<0.01
Choice Reaction Time (ms)	420.0 ± 30.0	460.0 ± 35.0	<0.01

Table 5: Subjective Feelings of Fatigue and Cognitive Effort

Participants in the dehydrated group reported higher levels of fatigue, reduced alertness, and increased cognitive effort during testing.

Table 5: Self-Reported Cognitive Fatigue and Alertness

Parameter	Hydrated Group (n=40)	Dehydrated Group (n=40)	p-value
Fatigue Level (1-10)	3.5 ± 1.0	6.2 ± 1.2	<0.01
Alertness Rating (1-10)	8.2 ± 0.8	5.6 ± 1.1	<0.01

Table 6: Relationship Between Hydration Status and Cognitive Function (Pearson Correlation Analysis)

Correlation analysis showed that higher urine osmolality and greater body weight loss were significantly associated with poorer cognitive performance and slower reaction times.

Table 6: Correlation Between Hydration Markers and Cognitive Performance

Variable	Cognitive Function Correlation (r)	Reaction Time Correlation (r)	p-value
Urine Osmolality	-0.42	0.39	<0.05
Body Weight Change (%)	-0.44	0.41	<0.05

Table 7: Influence of Hydration on Executive Function
Participants in the hydrated group demonstrated superior performance in executive function tasks, particularly in decision-making speed and problem-solving accuracy.

Table 7: Executive Function Scores

Executive Function Task	Hydrated Group (n=40)	Dehydrated Group (n=40)	p-value
Decision-Making Accuracy (%)	90.2 ± 4.5	81.6 ± 5.3	<0.01

Table 8: Adverse Effects of Dehydration on Cognitive Processing
Dehydrated participants showed a greater number of errors in cognitive tasks, indicating reduced processing efficiency.

Table 8: Cognitive Task Errors

Cognitive Error Type	Hydrated Group (n=40)	Dehydrated Group (n=40)	p-value
Memory Recall Errors (%)	8.5 ± 2.0	15.2 ± 2.8	<0.01
Stroop Test Errors (%)	6.2 ± 1.5	12.8 ± 2.4	<0.01

Table 9: Cognitive Performance Comparison by Gender
No significant differences were found in hydration-related cognitive performance between male and female participants, confirming that hydration affects cognitive function independently of gender.

Table 9: Gender-Based Cognitive Performance Comparison

Gender	Hydrated Group Score	Dehydrated Group Score	p-value
Male	85.4 ± 4.8	78.9 ± 5.1	0.12
Female	84.9 ± 5.1	78.5 ± 5.3	0.14

Table 10: Cumulative Impact of Hydration on Cognitive Function Over Time
Hydration significantly influenced cognitive efficiency and reaction time across different testing intervals, with greater impairment observed in dehydrated individuals over longer durations.

Table 10: Cumulative Impact of Hydration Over Time

Time Interval (Minutes)	Hydrated Group Score	Dehydrated Group Score	p-value
0-15 min	85.2 ± 4.6	78.6 ± 5.0	<0.05
15-30 min	83.8 ± 4.9	76.5 ± 5.2	<0.05
30-45 min	81.9 ± 5.1	74.3 ± 5.5	<0.01

DISCUSSION

Hydration plays a fundamental role in cognitive function, reaction time, and overall neurological performance, making it a crucial factor in daily mental efficiency and physical response accuracy. The findings of this study provide compelling evidence that mild to moderate dehydration significantly impairs cognitive abilities, reaction time, and subjective alertness in young adults. The results indicate that dehydrated individuals performed worse on cognitive tasks, exhibited slower response times, and reported higher levels of fatigue compared to hydrated individuals. These findings support the growing body of research emphasizing the importance of proper hydration in maintaining optimal brain function.[10]

One of the most significant findings was the negative impact of dehydration on memory, executive function, and attention span. The Digit Span Test, which assesses working memory and attention, showed a marked decline in performance among dehydrated participants. Similarly, the Stroop Test, which measures cognitive flexibility and processing speed, revealed slower response times and a higher rate of errors in the dehydrated group, reinforcing the idea that dehydration compromises the brain's ability to process and respond to information efficiently. The Trail Making Test, a widely used neuropsychological assessment for executive function and problem-solving, demonstrated that dehydrated individuals took significantly longer to complete tasks, indicating a slower information processing speed and reduced mental agility.[11]

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These cognitive impairments may be attributed to dehydration-induced reductions in cerebral blood flow and alterations in neurotransmitter function. Previous studies using functional MRI and EEG data have shown that even mild dehydration can lead to decreased neural activity in regions associated with attention, working memory, and decision-making, supporting our findings. The human brain is composed of nearly 75% water, and fluid imbalances can negatively affect synaptic transmission, disrupt neurochemical processes, and impair oxygen and glucose delivery to neurons. As observed in this study, these physiological alterations translate into measurable declines in cognitive efficiency and mental stamina.[12]

Another critical finding was the significant increase in reaction times among dehydrated participants. In both simple and choice reaction time tests, dehydrated individuals exhibited delayed response speeds, suggesting that neuromuscular coordination and sensory processing are adversely affected by fluid deficits. The delay in reaction time can be particularly concerning for individuals in high-performance settings, such as athletes, students, medical professionals, and individuals working in challenging environments, where quick reflexes and split-second decision-making are crucial. Given that even slight impairments in reaction time can impact safety and performance, maintaining proper hydration should be a priority in occupational and athletic settings.[13]

The self-reported data in this study further corroborate the cognitive and physiological impairments observed in the dehydrated group. Participants in this group reported significantly higher levels of fatigue, reduced alertness, and increased cognitive effort, reinforcing the subjective burden of dehydration on mental performance and well-being. Fatigue and cognitive strain can reduce overall productivity, leading to reduced motivation, mental burnout, and an increased likelihood of errors in demanding cognitive tasks. These subjective effects may stem from hormonal and metabolic responses to dehydration, including increased levels of cortisol (stress hormone) and reduced dopamine and serotonin activity, which could explain why dehydrated individuals not only performed worse but also felt more exhausted and mentally drained.[14]

A particularly interesting aspect of this study was the correlation analysis between hydration markers and cognitive performance. A significant inverse relationship was found between urine osmolality and cognitive efficiency, meaning that as dehydration worsened, cognitive function declined. Additionally, body weight changes due to fluid loss were correlated with slower reaction times, further validating the role of hydration in neuromuscular response regulation. These findings reinforce the physiological basis of hydration-related cognitive impairment and suggest that monitoring hydration markers may provide a valuable tool for identifying individuals at risk of cognitive decline due to dehydration.[15]

One of the notable implications of this study is its relevance to everyday life. Many individuals experience mild dehydration regularly due to insufficient water intake, consumption of diuretics (such as caffeine and alcohol), or prolonged periods of cognitive exertion without hydration breaks. The findings suggest that even mild dehydration can reduce efficiency in learning, decision-making, and motor response, highlighting the need for adequate hydration strategies in schools, workplaces, and other cognitively demanding environments. Future recommendations may include hydration awareness campaigns, workplace hydration policies, and hydration breaks integrated into high-focus activities to optimize mental and physical performance.

Although this study provides convincing evidence for the cognitive and neuromuscular consequences of dehydration, certain limitations must be acknowledged. First, the study was conducted in a controlled environment, which may not fully capture the effects of chronic dehydration in real-world scenarios. Additionally, individual variability in hydration needs, diet, and metabolic responses was not accounted for, meaning that future research should explore more personalized hydration strategies based on individual physiological differences. Furthermore, while self-reported fatigue and alertness measures were useful, future studies should incorporate objective biomarkers of cognitive fatigue, such as cortisol levels, brain imaging, and electrophysiological measurements, to provide a more comprehensive understanding of hydration-related cognitive changes.

Future Directions

Given the significant impact of hydration on cognitive function and reaction time, future studies should aim to explore:

1. Longitudinal studies examining chronic hydration habits and their long-term effects on cognitive health and aging-related cognitive decline.
2. The impact of distinct types of beverages (e.g., water vs. sports drinks vs. caffeine-containing fluids) on cognitive function and hydration balance.
3. Hydration interventions in high-performance environments, such as competitive sports, military training, and professions requiring quick decision-making (e.g., pilots, surgeons, first responders).
4. Personalized hydration strategies based on individual metabolic and genetic factors, allowing for more tailored hydration recommendations.
5. The effect of hydration status on specific cognitive domains, such as problem-solving, emotional regulation, and stress resilience.

Clinical and Practical Implications

This study underscores the critical role of proper hydration in sustaining cognitive performance, alertness, and neuromotor response times. The results suggest that individuals should prioritize adequate

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water intake, particularly before and during mentally demanding tasks. From a public health perspective, institutions such as schools, workplaces, and athletic organizations should emphasize hydration education and provide accessible drinking water to improve cognitive and physical efficiency. Given the growing reliance on mental agility and rapid decision-making in modern professional and academic settings, ensuring optimal hydration levels should be a key focus for enhancing overall cognitive wellness and productivity.

CONCLUSION

This study confirms that mild to moderate dehydration significantly impairs cognitive function, reaction time, and alertness in young adults. Dehydrated individuals exhibited slower processing speed, reduced working memory, and delayed neuromotor responses, emphasizing the importance of maintaining adequate hydration for optimal cognitive efficiency and mental performance. Given the impact of dehydration on decision-making and fatigue, hydration should be prioritized in academic, occupational, and high-performance environments to sustain mental clarity and reaction speed. Future research should explore long-term hydration effects and individualized hydration strategies to enhance cognitive resilience and overall brain health.

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