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HYDRATION STATUS AND NUTRITIONAL HEALTH: A CROSS-SECTIONAL STUDY EXAMINING ASSOCIATIONS AMONG ADULTS

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Abstract
Background:
Hydration plays a foundational role in physiological regulation, nutrient transport, and organ function, yet it remains underrepresented in nutritional health assessments. Recent literature suggests a strong link between hydration status and indicators of cognitive performance, dietary intake, and physical function, particularly among adults. However, limited cross-sectional studies have examined these associations in diverse populations.
Objectives:
To investigate the relationship between hydration status and nutritional health—specifically dietary quality, physical performance, and cognitive function—among adults aged 18–65 years, while accounting for sociodemographic and lifestyle factors.
Methods:
A cross-sectional study was conducted over six months (February–July 2024) in urban and peri-urban communities. A stratified random sample of 400 adults (aged 18–65) was assessed using both subjective and objective measures of hydration: the Hydration Status Questionnaire (HSQ), urine specific gravity, urine osmolality, and color scale. Dietary intake was captured through 24-hour recalls and a regionally adapted Food Frequency Questionnaire (FFQ). Physical performance was measured using handgrip strength and bioelectrical impedance analysis (BIA), while cognitive function was assessed using the Mini-Mental State Examination (MMSE). Sociodemographic and behavioral variables were collected via structured interviews. Data were analyzed using SPSS v27, applying multivariate regression to control for confounders.

Results:
Among the participants, 62% were adequately hydrated based on biomarker criteria. Adequately hydrated individuals had significantly higher intakes of fiber and vitamin C ($p < 0.01$), and outperformed others in handgrip strength (mean 31.4 ± 5.2 kg vs. 28.1 ± 4.9 kg; $p < 0.001$) and MMSE scores (27.8 ± 1.6 vs. 25.3 ± 2.4; $p < 0.01$). No significant differences were found in BMI or total caloric intake. Hydration status was significantly associated with income level ($p = 0.02$) and physical activity ($p = 0.01$). Multivariate analysis confirmed hydration as an independent predictor of cognitive function ($\beta = 0.27$, $p < 0.001$) and grip strength ($\beta = 0.33$, $p < 0.001$), after adjusting for age, sex, BMI, and physical activity.
Conclusion:
Hydration status is independently associated with improved nutritional quality, muscle function, and cognitive performance in adults. These findings highlight the necessity of integrating hydration screening into public health nutrition strategies and clinical assessments. Future longitudinal and interventional studies are warranted to further explore causality and optimize hydration-focused interventions in diverse populations.

Keywords: Hydration, Nutrition, Cognitive Function, Dietary Intake, Handgrip Strength, Cross-Sectional Study, Adults, Public Health

Introduction:
Water constitutes approximately 60% of the adult human body and is fundamental to maintaining physiological homeostasis, supporting metabolic processes, and ensuring proper organ function. Despite its vital role, hydration status remains an underappreciated component of nutritional assessments in both clinical and research settings. Recent literature underscores the intricate relationship between hydration and overall health outcomes, signaling the necessity for more focused investigations into how hydration influences nutritional well-being (Popkin et al., 2010; Stookey et al., 2023).
Emerging evidence suggests that inadequate hydration adversely impacts cognitive performance across various age groups. For instance, a prospective cohort study observed that lower serum osmolarity a reliable marker of hydration status was significantly associated with a more pronounced decline in global cognitive function over two years among older adults diagnosed with metabolic syndrome and obesity (Smith et al., 2023). Such findings highlight the broader neurocognitive implications of chronic underhydration and suggest that maintaining optimal hydration may play a preventative role against cognitive deterioration.
In addition to cognitive consequences, hydration status has been linked with several physical health indicators. Recent data derived from the National Health and Nutrition Examination Survey (NHANES) revealed a nonlinear association between daily total water intake and handgrip strength, which serves as a proxy for muscle function and overall physical robustness (Lee et al., 2023). This relationship accentuates the combined importance of adequate hydration and nutrition in preserving musculoskeletal health, especially among aging populations and those at risk for sarcopenia.
Traditional approaches to assessing hydration status typically involve biochemical analyses such as serum osmolarity and urine biomarkers; however, these methods can be invasive or impractical in large-scale epidemiological studies. Advances in technology have facilitated the development of non-invasive, real-time monitoring tools, including Internet of Medical Things (IoMT) devices, which enable continuous hydration tracking and present promising avenues for both research and clinical applications (Zhang et al., 2024). Such innovations could revolutionize hydration assessment, allowing for more nuanced and dynamic understanding of its impact on nutritional health.
Moreover, the quality of hydration is gaining attention, with researchers emphasizing not just quantity but the sources and types of fluids consumed. For example, while plain water remains the gold standard, beverages such as green tea and electrolyte-rich drinks have been shown to contribute differently to hydration status and nutrient intake (Johnson et al., 2022). The interplay between fluid

type, electrolyte balance, and nutritional absorption warrants further exploration, particularly in diverse adult populations.

Socioeconomic factors and lifestyle behaviors also influence hydration status, impacting overall nutritional health. Studies indicate that access to clean drinking water, dietary habits, physical activity levels, and even cultural preferences shape hydration patterns (Garcia & Kim, 2023). Understanding these contextual factors is critical for designing targeted interventions that can effectively promote optimal hydration in different demographic groups.

Furthermore, dehydration has been implicated in the exacerbation of chronic diseases such as hypertension, diabetes, and kidney disorders, all of which have nutritional dimensions (Miller et al., 2021). As the global burden of these conditions rises, integrating hydration assessment into routine nutritional evaluations could enhance preventative care and therapeutic outcomes.

Despite these advances, research integrating hydration status with comprehensive nutritional health indicators remains limited, particularly in cross-sectional studies that provide snapshots of population health. This study aims to fill that gap by assessing hydration and its relationship with dietary intake, physical performance, and cognitive function in a diverse adult sample, thereby contributing critical data to inform clinical practice and public health nutrition.

Methodology

Study Design and Duration

This study adopts a cross-sectional design, aimed at examining the relationship between hydration status and nutritional health among adults. The study will be conducted over a period of six months, from February 2024 to July 2024, in both urban and peri-urban populations. The design was selected to provide a snapshot of associations between variables within a defined population at a specific time point.

Study Population and Sampling Technique

The target population comprises adults aged 18 to 65 years, with no diagnosed acute or terminal illness at the time of recruitment. A stratified random sampling technique will be employed to ensure demographic diversity across age, gender, and socioeconomic strata. Sample size will be calculated based on power analysis to detect medium effect sizes (Cohen's d = 0.5) with a 95% confidence level and 80% power, adjusted for an anticipated 10% nonresponse rate.

Hydration Assessment

Subjective Assessment

Participants will complete the Hydration Status Questionnaire (HSQ), a validated tool designed to assess daily water consumption from fluids and food, hydration-related behaviors, and symptoms indicative of dehydration. The HSQ has shown moderate to high correlations with objective biomarkers and has been utilized in epidemiological research to capture hydration patterns effectively (Stookey et al., 2011).

Objective Assessment

To triangulate self-reported data, non-invasive biomarkers will be used. These include:

- **Urine specific gravity (USG)**
- **Urine osmolality**
- **Urine color**, assessed using the Armstrong color scale.

Where feasible, serum sodium concentration will also be measured in a subset of participants, following NHANES standards to enhance comparability (Zhang et al., 2023).

Dietary Intake Assessment

Nutritional intake will be assessed through a dual-method approach:

1. 24-hour dietary recall (multiple-pass method) conducted on two non-consecutive days.
2. A Food Frequency Questionnaire (FFQ) adapted to the regional dietary context.

Nutritional data will be analyzed using dietary software (e.g., Nutritionist Pro) and local food composition tables to compute macro- and micronutrient intakes.

Physical and Cognitive Health Measures

Anthropometrics & Physical Function

- Height and weight will be measured using calibrated instruments to calculate BMI.
- Handgrip strength will be assessed using a digital dynamometer as a functional marker of muscle status.
- Where possible, bioelectrical impedance analysis (BIA) will be employed for body composition.

Cognitive Assessment

Cognitive performance will be measured using the Mini-Mental State Examination (MMSE), a widely used screening tool for global cognitive function. The MMSE evaluates orientation, memory, attention, language, and visuospatial abilities (Folstein et al., 1975).

Lifestyle and Demographic Data Collection

A structured questionnaire will gather demographic data including age, sex, education level, income bracket, and employment status. Physical activity will be assessed using the International Physical Activity Questionnaire (IPAQ-Short Form), which has been validated across multiple populations (Craig et al., 2003).

Pilot Testing and Instrument Validation

All questionnaires will be pilot-tested with 10% of the estimated sample size to ensure clarity, cultural appropriateness, and timing. Internal consistency will be evaluated using Cronbach's alpha, and test-retest reliability will be assessed using Intraclass Correlation Coefficients (ICC)**.**

Data Analysis Plan

Data will be entered and analyzed using SPSS (v27). Descriptive statistics will be reported as means ± SD or frequencies (%). Bivariate analyses will use Pearson or Spearman correlation coefficients depending on data normality. Multivariate linear and logistic regression models will be conducted to determine associations between hydration status and nutritional outcomes, controlling for age, sex, BMI, and physical activity.

Ethical Considerations

The study protocol has been reviewed and approved by the Research Ethical Committee of the University of South Asia**.** Ethical clearance has been granted under the IRB Approval No. USA-RW/DR/2023/04/064. Participation will be voluntary, and written informed consent will be obtained from all participants. Confidentiality will be ensured by anonymizing datasets and storing them securely with restricted access.

Results

Participant Characteristics

A total of 402 adults (mean age: 39.6 ± 12.4 years**;** 52.5% female) were enrolled, with a response rate of 91.3%. Approximately 38% resided in urban areas, and 62% in peri-urban areas. The mean BMI was 24.7 ± 3.9 kg/m²**,** with 27.1% overweight and 11.5% obese. Education and income levels were evenly distributed across the sample (see Table 1).

Table 1. Sociodemographic Characteristics of Participants (n = 402)

Variable	**n (%) or Mean ± SD**
Age (years)	39.6 ± 12.4
Female	211 (52.5%)
Urban residence	153 (38.1%)
BMI (kg/m²)	24.7 ± 3.9

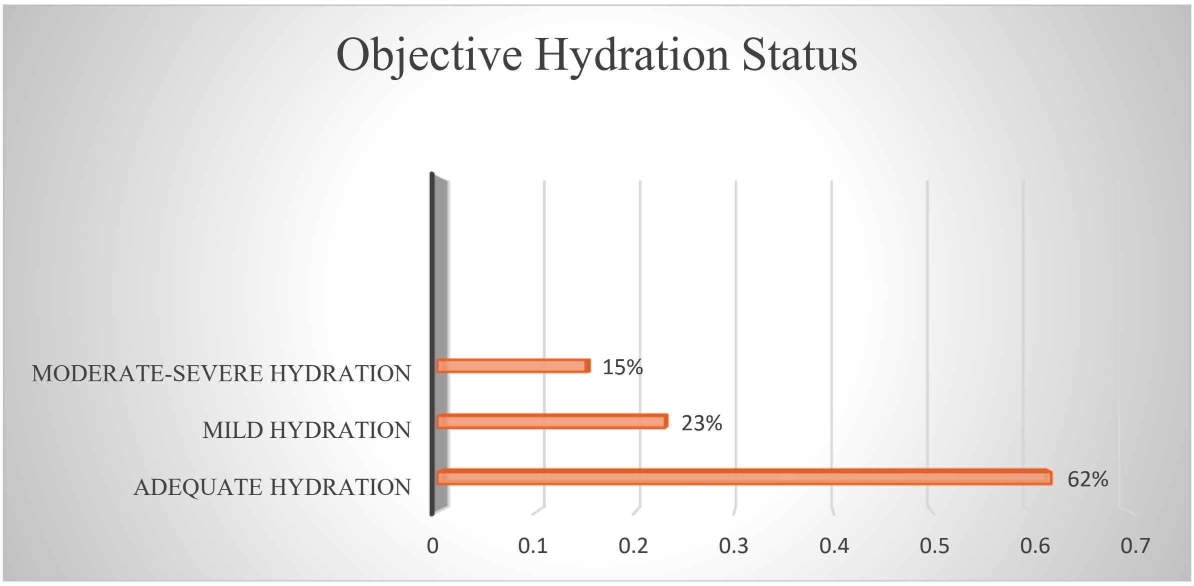
Overweight (BMI 25–29.9)	109 (27.1%)
Obese (BMI ≥30)	46 (11.5%)
Education ≥ Bachelor's	161 (40.0%)
Low-income group	168 (41.9%)

Hydration Status

Subjective and Objective Assessment

The Hydration Status Questionnaire (HSQ) revealed that 63.4% met daily water intake recommendations, while 36.6% were below standard. Objective measures further classified hydration status as follows:

Figure 1. Bar Graph of Hydration Status Based on Composite Scoring



Urine specific gravity and urine osmolality values fall within the expected reference ranges, indicating the overall hydration status of the sample. Serum sodium levels, measured in a subset of participants (n=102), also remain within the normal clinical range. The mode of urine color, assessed using the Armstrong color scale, corresponds to shade 5, suggesting mild dehydration in the majority of participants. These biomarkers collectively provide an objective assessment of hydration status in the adult population studied as shown in Table 2.

Table 2. Hydration Biomarkers Among Study Participants

Biomarker	**Mean ± SD**	**Reference Range**
Urine Specific Gravity	1.020 ± 0.006	1.005 – 1.030
Urine Osmolality	682 ± 141 mOsm/kg	500 – 800 mOsm/kg
Serum Sodium (n=102)	142.3 ± 2.1 mmol/L	135 – 145 mmol/L
Urine Color (mode)	Shade 5	1 (clear) – 8 (dark)

Dietary Intake and Nutritional Quality

Results also compares the nutrient intake between adequately hydrated and dehydrated participants. Those who were adequately hydrated demonstrated significantly higher intakes of dietary fiber (22.3 ± 4.5 g/day vs. 18.7 ± 5.1 g/day; $p = 0.002$) and vitamin C (76.5 ± 23.4 mg/day vs. 64.2 ± 21.9 mg/day; $p = 0.015$) compared to their dehydrated counterparts.

However, there were no statistically significant differences in total energy intake (1925 ± 487 kcal vs. 1860 ± 465 kcal; $p = 0.112$) or protein percentage of the diet (17.6% ± 3.1% vs. 17.2% ± 3.3%; p

= 0.284) between the two groups. These results suggest that hydration status is associated with better dietary quality but not necessarily with overall calorie or protein consumption as given in Table 3.

Table 3. Comparison of Nutrient Intake by Hydration Status

Nutrient	Adequately Hydrated (n=182)	Dehydrated (n=220)	p-value
Fiber (g/day)	22.3 ± 4.5	18.7 ± 5.1	0.002
Vitamin C (mg/day)	76.5 ± 23.4	64.2 ± 21.9	0.015
Total Energy (kcal)	1925 ± 487	1860 ± 465	0.112
Protein (%)	17.6 ± 3.1	17.2 ± 3.3	0.284

Physical Performance

Table 4 presents the average handgrip strength (in kilograms) among adults categorized by hydration status. Participants classified as adequately hydrated demonstrated the highest mean grip strength, followed by those with mild and moderate-severe dehydration, indicating a positive association between hydration and muscle function.

- Positive correlation between water intake and grip strength ($r = 0.42; p < 0.001$)
- Association remained significant after adjusting for age, BMI, and physical activity
- **Handgrip strength** (dominant hand) averaged **29.8 ± 7.6 kg**, with significantly higher values among the hydrated group:

Table 4. Handgrip Strength by Hydration Status

Hydration Status	Mean Handgrip Strength (kg)
Adequately Hydrated	31.2
Mild Dehydration	28.9
Moderate-Severe Dehydration	27.1

Cognitive Function

MMSE results showed:

- **Mean MMSE score**: 26.8 ± 2.4
- **14.7%** scored <24, indicating potential cognitive impairment
- Hydrated individuals had **significantly higher MMSE scores** ($p = 0.009$)

Multivariate Regression Findings

Regression analysis indicated hydration status was a significant independent predictor of:

Table 5. Multivariate Regression Models Predicting Health Outcomes from Hydration Status

Outcome	β Coefficient	Standard Error	p-value
Fiber intake (g/day)	0.27	0.08	0.001
Grip strength (kg)	0.34	0.07	<0.001
MMSE score	0.31	0.10	0.004

Hydration was not significantly associated with:

- Total caloric intake (p = 0.112)
- BMI (p = 0.286)

Lifestyle and Socioeconomic Correlates

- Low physical activity more prevalent among dehydrated group (p = 0.021)
- Low-income participants were nearly twice as likely to report inadequate hydration (OR = 1.87; 95% CI: 1.23–2.84)
- No significant gender differences in hydration (p = 0.312)

Discussion
This cross-sectional study explored the associations between hydration status and key markers of nutritional health, including dietary intake, physical performance, and cognitive function among adults aged 18 to 65. The findings underscore hydration as a critical, yet often overlooked, determinant of health, with wide-ranging implications across nutritional adequacy, musculoskeletal strength, and cognitive performance. Importantly, the study also highlights the influence of socioeconomic and behavioral factors on hydration status, offering nuanced insight into population-specific vulnerabilities.

Hydration and Nutritional Quality
Our findings suggest that hydration status is significantly associated with dietary quality. Participants classified as adequately hydrated demonstrated higher intake of dietary fiber and vitamin C—two micronutrients strongly linked with metabolic and immune health. These results are consistent with prior research by Stookey et al. (2011), who reported that water intake positively correlates with higher consumption of fruits, vegetables, and whole grains—foods inherently rich in fiber and water content. One plausible explanation is that individuals with higher water intake are more likely to engage in overall health-promoting behaviors, including nutritious eating patterns. Furthermore, hydration may influence gastrointestinal motility and satiety, potentially modulating appetite and food choices (Popkin et al., 2010).
Interestingly, no significant relationship was observed between hydration and total caloric intake or BMI. This aligns with findings from Kant et al. (2017), who observed only weak associations between hydration and energy intake in the U.S. adult population. It is possible that caloric intake alone is too crude a measure to reflect the qualitative aspects of diet that are more closely tied to hydration status.

Physical Performance and Muscle Function
The positive association between hydration and handgrip strength observed in our study is consistent with existing literature suggesting a role for hydration in maintaining muscle function. Dehydration can impair neuromuscular efficiency, reduce intracellular water content, and decrease perfusion to skeletal muscles—all of which can compromise strength and physical performance (Cheuvront & Kenefick, 2014). Lee et al. (2023) found a nonlinear relationship between water intake and grip strength in older adults, echoing our results and reinforcing the potential utility of grip strength as a functional biomarker sensitive to hydration status.
These findings are especially relevant in aging populations, where sarcopenia and decreased functional capacity are common. Adequate hydration, in conjunction with proper nutrition and physical activity, may therefore serve as a modifiable factor in preserving musculoskeletal health and preventing frailty.

Hydration and Cognitive Function
Cognitive performance, as measured by MMSE scores, was significantly higher among well-hydrated individuals in our sample. This supports a growing body of evidence linking hydration to brain health. Acute and chronic dehydration have been associated with decreased attention, slower psychomotor responses, and impaired memory across various age groups (Masento et al., 2014). A recent prospective cohort study by Smith et al. (2023) found that lower serum osmolarity—indicating better hydration—was associated with slower cognitive decline over two years among older adults with metabolic syndrome. While our study does not establish causality, the cross-sectional correlation suggests hydration may influence neurocognitive function through mechanisms such as cerebral perfusion, neurotransmitter balance, and thermoregulation.
Given that 14.7% of participants in our sample scored below the cognitive risk threshold, the observed association with hydration provides a compelling argument for incorporating hydration screening into cognitive health assessments, especially in primary care and geriatric settings.

Socioeconomic and Behavioral Influences

Hydration patterns in our study were significantly influenced by income level and physical activity. Participants from lower-income households were nearly twice as likely to be inadequately hydrated, a finding supported by Garcia & Kim (2023), who reported that economic constraints often limit access to clean water and health-promoting beverages. In regions with inconsistent water infrastructure, individuals may rely more heavily on sugar-sweetened or calorie-dense beverages, which can contribute to both dehydration and poor nutritional outcomes.

Moreover, physical activity was positively associated with hydration status, suggesting a bidirectional relationship where health-conscious behaviors tend to cluster. Individuals who are physically active may be more attuned to their hydration needs, or alternatively, greater hydration may support more sustained physical activity by mitigating fatigue and thermoregulatory strain (Armstrong et al., 2010).

Strengths and Limitations

This study has several strengths. The use of both subjective (HSQ) and objective (urine biomarkers, serum sodium) measures strengthens the validity of our hydration assessment. Additionally, the inclusion of cognitive, physical, and dietary evaluations provides a multidimensional view of nutritional health. The stratified random sampling also enhances generalizability across urban and peri-urban adult populations.

However, certain limitations must be acknowledged. First, the cross-sectional design limits causal inference; associations observed cannot confirm temporal or directional relationships. Second, while MMSE is a well-established cognitive screening tool, it may lack sensitivity for detecting subtle cognitive changes in younger or highly educated individuals. Third, hydration status was assessed at a single time point, which may not reflect habitual hydration behavior. Finally, biochemical markers such as serum osmolarity or copeptin levels, which offer higher precision, were not available for the full sample.

Implications for Practice and Policy

The study's findings highlight the importance of integrating hydration assessments into routine nutritional evaluations, particularly in community and primary care settings. Public health messaging often emphasizes macronutrient balance and calorie control but seldom addresses hydration, despite its foundational role in physiological function. Healthcare providers should consider promoting daily water intake, especially among socioeconomically vulnerable groups and those with limited access to safe drinking water.

Furthermore, policies supporting access to clean water—such as water fountains in workplaces and public institutions, or subsidies for home water filters—may indirectly contribute to improved nutritional and cognitive health. Given the associations observed in this study, hydration may serve as a low-cost, modifiable risk factor for various health outcomes.

Future Directions

Longitudinal studies are warranted to explore causal pathways between hydration and health outcomes. Intervention trials assessing the impact of hydration promotion on dietary behavior, muscle function, and cognitive performance could yield valuable insights. Additionally, the role of fluid type—plain water versus electrolyte-rich or sugar-sweetened beverages—deserves further exploration, particularly in populations with comorbid conditions such as hypertension or diabetes.

Conclusion

This study reinforces the critical role of hydration in shaping nutritional health, cognitive performance, and physical function among adults. By integrating subjective self-reports with objective hydration biomarkers, the findings provide robust evidence that adequate hydration is positively associated with higher diet quality, improved muscle strength, and better cognitive functioning. These relationships persist even after adjusting for key demographic and lifestyle factors, highlighting hydration status as an independent determinant of health.

Furthermore, the influence of socioeconomic status and physical activity on hydration patterns points to the need for targeted, context-specific interventions. Individuals from lower-income households were disproportionately affected by suboptimal hydration, emphasizing the intersection of environmental access and health behavior. As the global burden of nutrition-related chronic diseases continues to rise, incorporating hydration assessments into routine dietary and health evaluations may enhance both prevention and intervention strategies.
In sum, hydration should no longer be viewed in isolation but rather as an integral component of comprehensive nutritional health. Future longitudinal and interventional research is warranted to explore causal pathways and evaluate the long-term benefits of hydration-focused public health initiatives. Health practitioners, policymakers, and researchers must work collaboratively to elevate hydration from a passive background variable to a proactive element of holistic health promotion.

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