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Association Between Plain-Water Intake Frequency and Self-Reported Grades Among High School Students Participating in the 2023 National Youth Risk Behavior Survey: A Cross-Sectional Analysis

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Abstract

Background

Hydration has been associated with cognitive processes relevant to learning, but evidence linking plain-water intake frequency with academic performance in adolescents remains limited. We examined this association among participants in the 2023 National Youth Risk Behavior Survey (YRBS) with available study data.

Methods

We conducted a survey-weighted, cross-sectional complete-case analysis of 10,199 students. The primary analysis compared plain-water intake three or more versus less than three times/day in relation to self-reported mostly A/B grades. A secondary analysis used four intake categories: less than one, one to two, three, and more than four times/day. Models adjusted for age, sex, race/ethnicity, regular soda intake, physical activity, fruit/100% fruit juice intake, and vegetable intake and accounted for YRBS weights, strata, and primary sampling units.

Results

The survey-weighted prevalence of mostly A/B grades was 75.6% among students reporting intake three or more times/day and 70.8% among those reporting less than three times/day, an absolute difference of 4.86 percentage points (95% confidence interval (CI), 2.34-7.38). After adjustment, intake three or more times/day was associated with higher odds of mostly A/B grades (adjusted odds ratio (aOR), 1.16; 95% CI, 1.01-1.32). Compared with intake less than one time/day, aORs were 1.53 (95% CI, 1.26-1.87) for one to two times/day, 1.42 (95% CI, 1.08-1.86) for three times/day, and 1.45 (95% CI, 1.23-1.71) for four or more times/day.

Conclusion

In this complete-case analytic sample from the 2023 YRBS, students reporting plain-water intake three or more times/day had higher adjusted odds of reporting mostly A/B grades than those reporting intake less than three times/day. In the categorical analysis, each of the three higher-frequency groups had higher adjusted odds of reporting mostly A/B grades than the less than one time/day group, but the point estimates were similar in magnitude and did not increase monotonically across successive categories. The cross-sectional design precludes causal inference; water-drinking frequency and grades were self-reported; frequency did not measure water volume or physiological hydration status; residual confounding remains possible; and 14 of 89 primary sampling units (PSUs) contributed no complete cases, which may limit national representativeness. Longitudinal and experimental studies using objective hydration measures and independently recorded academic outcomes could further clarify this association.

Categories: Nutrition, Pediatrics, Epidemiology/Public Health
Keywords: academic performance, adolescent health, complex survey analysis, cross-sectional study, high school students, hydration, plain water intake, school health, survey-weighted analysis, youth risk behavior survey

Introduction

Water is an essential nutrient, and maintaining adequate fluid balance is fundamental to normal physiological function [1]. Children differ from adults in body water content, thermoregulation, and thirst responses, and these differences may increase vulnerability to dehydration under some conditions [2].

Whether plain-water intake frequency is associated with academic performance among adolescents, however, remains uncertain.

Research on hydration and cognition provides a plausible reason to examine this question, but the evidence is not uniform. Some studies have linked dehydration to changes in selected cognitive functions, including attention, psychomotor performance, and immediate memory, while reviews have emphasized substantial variation by hydration status, study design, and the cognitive domain assessed [2-4]. Pediatric intervention studies have likewise produced selective rather than uniform findings. Edmonds and Burford reported improvements in selected visual-attention and visual-memory tasks after supplemental water [5], while Fadda et al. observed associations involving hydration and short-term memory measures [6]. Perry et al. found that cognitive responses to water depended partly on baseline hydration status and renal response [7], and Khan et al. reported improved hydration markers and selective benefits in cognitive flexibility during a four-day water-intake intervention, while other cognitive outcomes did not significantly improve [8]. In the school-based CogniDROP trial, Drozdowska et al. reported nonlinear associations between measured morning water consumption and executive performance, with selected memory outcomes showing better performance at intake levels up to approximately 1000 mL; however, cognitive performance did not differ significantly between the randomized intervention and control groups [9]. Taken together, these studies suggest that water intake and hydration may be related to selected cognitive outcomes, although findings vary across cognitive domains, hydration states, and intake levels.

Evidence also shows that infrequent plain-water intake is common among U.S. high school students. Using the 2017 National Youth Risk Behavior Survey (YRBS), Park et al. reported that 48.7% of students drank plain water fewer than three times per day and 24.6% drank it less than once per day [10]. Academic grades were among the characteristics compared for association with water intake: students reporting mostly D/F grades had higher adjusted odds of infrequent plain-water intake than students reporting mostly A grades (adjusted odds ratio (aOR), 1.37; 95% confidence interval (CI), 1.07-1.77) [10]. In that study, however, infrequent water intake was the outcome, and grades were examined as one of several demographic and behavioral correlates. Few studies have examined academic performance as the outcome. In an observational study of university students, Pawson et al. found that bringing water into examinations was associated with higher examination performance in two of three cohorts after adjustment for prior coursework performance; however, they did not directly measure actual water consumption or hydration status [11]. U.S. evidence focused specifically on plain-water intake frequency and academic performance among high school students therefore remains limited.

The national YRBS provides an opportunity to examine this relationship in a large school-based adolescent population. The survey uses a three-stage cluster sampling design to produce national estimates for students in grades 9-12 attending public and private schools in the United States. The YRBS also collects standardized information on plain-water intake, academic grades, demographic characteristics, and several health behaviors within the same survey. An important measurement distinction remains: the YRBS assesses how often students drink plain water, not the volume consumed or their physiological hydration status [12].

We therefore examined the association between plain-water intake frequency and self-reported academic performance among U.S. high school students participating in the 2023 National YRBS. The primary analysis compared students reporting plain-water intake at least three times per day with those reporting intake less than three times per day. A secondary analysis examined four water-intake frequency categories. The adjusted models examined whether plain-water intake frequency was associated with reporting mostly A/B grades after adjustment for prespecified demographic and health-behavior covariates. Given the cross-sectional design, these analyses were intended to characterize associations and cannot establish causality.

Materials And Methods

Study design and data source

We conducted a cross-sectional analysis of public-use data from the 2023 National Youth Risk Behavior Survey (YRBS). The YRBS is a biennial, school-based survey administered by the Centers for Disease Control and Prevention (CDC) to monitor health-related behaviors among U.S. students in grades 9-12. The national YRBS uses a three-stage clustered sampling design to produce national estimates for students in grades 9-12 attending public and private schools in the United States. After CDC data editing, the 2023 public-use dataset contained 20,103 usable questionnaires. We obtained the 2023 National YRBS public-use dataset from the CDC YRBS data and documentation repository [13].

The 2023 YRBS was administered from January through June 2023; participation was anonymous and voluntary, and local parental permission procedures were followed before survey administration. In 2023, the national YRBS had a school response rate of 49.8%, a student response rate of 71.0%, and an overall response rate of 35.4%. CDC conducted nonresponse-bias analyses and applied weighting adjustments for school and student nonresponse as part of the national survey methodology [14].

Because the YRBS uses a complex survey design, we incorporated CDC-provided sampling weights, strata, and primary sampling unit (PSU) variables into all survey-weighted estimates and inferential analyses. The

sampling weights account for unequal selection probabilities, school and student nonresponse, and oversampling. We first specified the survey design using the full dataset of 20,103 respondents and then defined the complete-case analytic sample within that design as a survey domain. The original CDC sampling weights were retained and were not recalibrated for study-specific PSU-level nonavailability of study variables. This approach retained the full survey design information when we estimated confidence intervals for the analytic sample.

Study population and analytic sample

The derivation of the analytic sample is shown in Figure *1*. We began with all 20,103 usable records in the 2023 National YRBS. Study-variable availability was substantially clustered at the PSU level. Thirteen of the 89 PSU clusters had no observed responses to the plain-water item (Q96) or its CDC-derived variable QNWATER3. Fourteen PSUs contributed no respondents to the complete-case analytic sample. In the additional PSU beyond those 13, water and grade data were observed, but regular soda, fruit/100% fruit juice, and vegetable-intake covariates had no observed values. Respondents in the 14 PSUs that contributed no complete cases accounted for 21.5% of the total survey weight. PSU-level study-variable availability among the 14 PSUs contributing no complete cases is detailed in Appendix A.

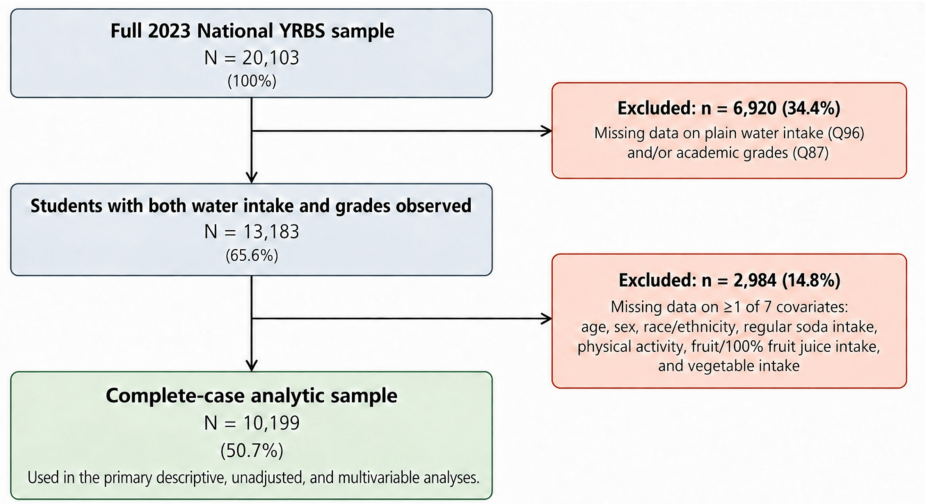


FIGURE 1: Derivation of the complete-case analytic sample, 2023 National YRBS

Note: Percentages are calculated relative to the full 2023 National YRBS sample (N=20,103).

At the respondent level, 6,920 records had missing plain-water intake (Q96), academic-grade information (Q87), or both, leaving 13,183 respondents with observed values for both the primary exposure and outcome. An additional 2,984 respondents were missing at least one of the seven prespecified covariates. The final complete-case analytic sample comprised 10,199 students. Thus, exclusion from the complete-case analysis reflected both PSU-level nonavailability of study variables and respondent-level missing data within contributing PSUs.

Because study-variable availability was clustered by PSU, we evaluated the stability of the unadjusted water-grades prevalence difference across sequential analytic restrictions. We first examined respondents with observed water-intake and grade data across all 76 PSUs contributing both variables (N=13,183). We then restricted this exposure-outcome sample to the 75 PSUs that contributed at least one complete case (N=11,624) and finally to respondents with complete exposure, outcome, and covariate data within those PSUs (N=10,199). These comparisons assessed stability across observed-data restrictions but could not recover information from PSUs in which water intake was entirely unobserved or eliminate selection bias.

Academic performance

We assessed academic performance using Q87, which asked, “During the past 12 months, how would you describe your grades in school?” We used the CDC-derived variable QN87 to define a binary outcome: students reporting mostly A’s or mostly B’s were classified in the “mostly A/B grades” category, while all other nonmissing responses, including mostly C’s, mostly D’s, mostly F’s, “none of these grades,” and “not sure,” were classified in the “not mostly A/B grades” category.

The prespecified outcome was reporting mostly A/B grades versus all other nonmissing responses, rather than A/B grades versus C/D/F grades alone. We therefore retained “none of these grades” and “not sure” in

the complementary "not mostly A/B grades" category. Excluding these responses after reviewing the results would change the prespecified outcome definition and introduce a post hoc selection rule. However, the comparison category is heterogeneous and should not be interpreted as consisting exclusively of students reporting mostly C, D, or F grades.

Plain-water intake

Plain-water intake was assessed using Q96: "During the past 7 days, how many times did you drink a bottle or glass of plain water? (Count tap, bottled, and unflavored sparkling water.)" We examined plain-water intake using two prespecified exposure specifications (Figure *2*) to assess the association under different representations of water-intake frequency.

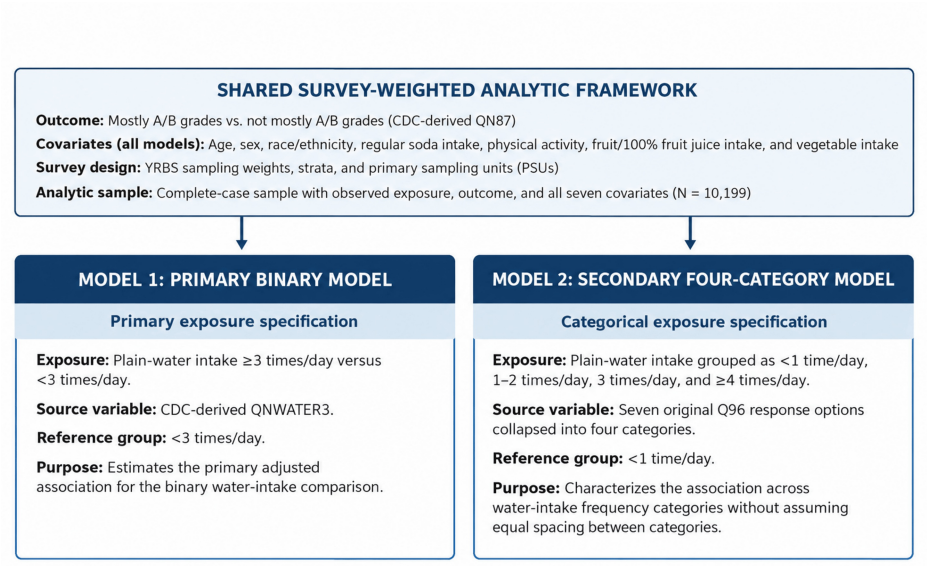


FIGURE 2: Plain-water intake specifications used in the two survey-weighted logistic regression models

Abbreviations: YRBS=Youth Risk Behavior Survey; PSU=primary sampling unit.

For the primary analysis (Model 1), we used the CDC-derived QNWATER3 variable and compared students reporting plain-water intake at least three times per day with those reporting intake less than three times per day.

For the secondary categorical analysis (Model 2), we combined the seven original Q96 response options into four categories: less than once per day, one to two times per day, three times per day, and at least four times per day, consistent with prior national YRBS research on plain-water intake [10]. We used intake of less than once per day as the reference category.

Covariates

We prespecified seven covariates as potential confounders: age, sex, race/ethnicity, regular soda intake, physical activity, fruit/100% fruit juice intake, and vegetable intake. The adjustment set was informed by prior national YRBS research, particularly Park et al. [10], and by the potential relationships of these variables with both plain-water intake and academic performance. It retained seven variables overlapping with the broader model used by Park et al. and was intended as a parsimonious common adjustment set across both water-intake specifications, rather than an exhaustive set of all possible confounders. Sleep duration and breakfast consumption were not included in the prespecified primary adjustment set.

Age was grouped as ⩽15, 16, or ⩾17 years. Sex was recorded as female or male. Using the CDC-derived race/ethnicity variable, we grouped students as White non-Hispanic, Black non-Hispanic, Hispanic/Latino, or other/multiracial non-Hispanic.

Regular soda intake was categorized as none, one to six times per week, or at least once per day. For physical activity, we used the CDC-derived variable indicating whether students reported at least 60 minutes of activity per day on five or more days per week versus fewer than five days per week. The CDC-derived

fruit/100% fruit juice variable classified intake as at least two versus fewer than two times per day, and the CDC-derived vegetable-intake variable classified intake as at least three versus fewer than three times per day.

The same seven covariates were entered simultaneously into each adjusted regression model.

Statistical analysis

Primary descriptive, unadjusted, and multivariable analyses used a survey design object defined on the full 2023 YRBS dataset (N=20,103), with the complete-case sample (N=10,199) analyzed as a survey domain. The analytic sample was described using unweighted counts and survey-weighted percentages with 95% confidence intervals (CIs).

For the unadjusted analysis, we calculated the survey-weighted prevalence of mostly A/B grades in each water-intake group (three or more versus less than three times/day) and the absolute prevalence difference between groups. The association between water-intake group and academic-grade category was evaluated using a Rao-Scott design-adjusted chi-square test with an F approximation.

We then fit survey-weighted multivariable logistic regression models using svyglm with a quasibinomial family. Results were reported as adjusted odds ratios (aORs) with 95% CIs.

Model 1 used the primary binary water variable, comparing intake three or more with less than three times/day. Model 2 used the four-category water variable, with intake less than one time/day as the reference category. The overall contribution of the four-category water-intake variable was evaluated using a global Wald F test. Both models included the same seven prespecified covariates and accounted for the YRBS sampling weights, strata, and PSUs.

Because study-variable availability was clustered by PSU, we evaluated the stability of the unadjusted water-grades prevalence difference across sequential analytic restrictions. We first estimated the difference among respondents with observed water-intake and grade data across all 76 PSUs contributing both variables (N=13,183). We then restricted this exposure-outcome sample to the 75 PSUs that contributed at least one complete case (N=11,624) and finally to respondents with complete exposure, outcome, and covariate data within those PSUs (N=10,199). These comparisons assessed the stability of the unadjusted association across observed-data restrictions but could not recover information from PSUs in which water intake was entirely unobserved or eliminate selection bias.

All statistical tests were two-sided, with α=.05. Analyses were conducted in R version 4.6.1 (R Foundation for Statistical Computing, Vienna, Austria) using the survey package, version 4.5, through the Rj Editor in jamovi (open source statistical software).

Ethical approval

The 2023 national Youth Risk Behavior Survey was conducted under protocols approved by institutional review boards at the CDC and ICF, the survey contractor [14]. The present study was a secondary analysis of publicly available, de-identified YRBS data and involved no interaction with participants or access to identifiable private information; therefore, additional institutional review board approval for this secondary analysis was not required.

Results

Participant flow

The 2023 National YRBS public-use dataset included 20,103 respondents. Of these, 6,920 respondents with missing plain-water intake (Q96), academic-grade data (Q87), or both were excluded, leaving 13,183 with observed values for both the primary exposure and outcome. An additional 2,984 respondents were excluded because of missing data on at least one of the seven prespecified covariates. The final complete-case analytic sample comprised 10,199 students (50.7% of the full dataset) and was used for the primary descriptive, unadjusted, and multivariable analyses (Figure *1*).

Sample characteristics

The characteristics of the 10,199 students in the complete-case analytic sample are presented in Table *1*. Counts are unweighted, while percentages and 95% CIs account for the YRBS complex survey design.

Characteristic	Unweighted n	Survey-weighted % (95% CI)
Academic grades		
Mostly A/B grades	7,176	73.4 (70.4-76.4)

Not mostly A/B grades [a]	3,023	26.6 (23.6-29.6)
Plain-water intake: primary binary exposure		
≥3 times/day	5,299	54.0 (51.9-56.1)
<3 times/day	4,900	46.0 (43.9-48.1)
Plain-water intake: four-category exposure		
<1 time/day	2,499	21.7 (19.3-24.0)
1-2 times/day	2,401	24.4 (22.7-26.1)
3 times/day	1,633	16.6 (15.4-17.9)
≥4 times/day	3,666	37.4 (35.9-38.8)
Age		
≤15 years	3,619	36.6 (34.7-38.5)
16 years	2,673	25.6 (24.0-27.1)
≥17 years	3,907	37.8 (35.7-39.9)
Sex		
Female	5,056	47.5 (44.5-50.5)
Male	5,143	52.5 (49.5-55.5)
Race/ethnicity		
White, non-Hispanic	4,571	48.4 (41.0-55.7)
Black, non-Hispanic	1,179	13.8 (7.7-19.8)
Hispanic/Latino	2,188	28.1 (21.9-34.4)
Other/multiracial, non-Hispanic	2,261	9.8 (7.3-12.2)
Regular soda intake		
None	2,712	29.8 (27.3-32.2)
1-6 times/week	5,592	55.2 (53.4-57.0)
≥1 time/day	1,895	15.1 (13.2-16.9)
Physical activity		
≥60 min/day on ≥5 days/week	5,007	48.8 (45.0-52.5)
<5 days/week	5,192	51.3 (47.5-55.0)
Fruit or 100% fruit juice intake		
≥2 times/day	2,578	26.9 (25.2-28.5)
<2 times/day	7,621	73.1 (71.5-74.8)
Vegetable intake		
≥3 times/day	1,271	12.7 (11.2-14.1)
<3 times/day	8,928	87.3 (85.9-88.8)

TABLE 1: Survey-weighted characteristics of the complete-case analytic sample, 2023 National YRBS (N=10,199)

Notes: Values of n are unweighted. Percentages and 95% CIs incorporate YRBS sampling weights, strata, and primary sampling units and describe the complete-case analytic sample.

[a]The YRBS-derived grade variable classified responses other than mostly A/B - including other grade categories and “not sure” - as not mostly A/B.

Among complete-case respondents, 73.4% (95% CI 70.4-76.4) reported mostly A/B grades, and 54.0% (95% CI 51.9-56.1) reported drinking plain water three or more times/day (Table 1). In the four-category water measure, 21.7% reported intake less than one time/day, 24.4% reported one to two times/day, 16.6% reported three times/day, and 37.4% reported four or more times/day. The weighted analytic sample was 47.5% girls and 52.5% boys. Nearly half of students (48.8%) met the physical-activity criterion of ⩾60 minutes/day on at least five days/week. Additional demographic and behavioral characteristics are shown in Table 1.

Unadjusted association

Students reporting plain-water intake three or more times/day had a higher survey-weighted prevalence of mostly A/B grades than those reporting intake less than three times/day (75.6% vs 70.8%), corresponding to an absolute prevalence difference of 4.86 percentage points (95% CI, 2.34-7.38). The association was statistically significant in the survey-adjusted Rao-Scott test (F(1,59)=14.03, p<.001; Table 2).

Plain-water intake	Unweighted n	Survey-weighted prevalence of mostly A/B grades, % (95% CI)
≥3 times/day	5,299	75.6 (72.4-78.8)
<3 times/day	4,900	70.8 (67.5-74.0)

TABLE 2: Unadjusted association between plain-water intake and reporting mostly A/B grades, 2023 National YRBS complete-case analytic sample (N=10,199)

Absolute prevalence difference: +4.86 percentage points (95% CI, 2.34-7.38) for ≥3 versus <3 times/day.

Rao-Scott survey-adjusted test: F(1,59)=14.03, p<.001.

Notes. Counts are unweighted. Percentages and confidence intervals account for YRBS sampling weights, strata, and primary sampling units. The prevalence difference was calculated from the unrounded survey-weighted estimates.

CI: Confidence interval.

Multivariable models

In the primary survey-weighted logistic regression model (Model 1), plain-water intake three or more times/day was associated with higher adjusted odds of reporting mostly A/B grades compared with intake less than three times/day (aOR 1.16, 95% CI 1.01-1.32, p=.032), after simultaneous adjustment for age, sex, race/ethnicity, regular soda intake, physical activity, fruit/100% fruit juice intake, and vegetable intake.

In the secondary four-category analysis (Model 2), each of the three higher intake categories showed greater adjusted odds of mostly A/B grades relative to the less than one time/day reference category: one to two times/day (aOR 1.53, 95% CI 1.26-1.87, p<.001), three times/day (aOR 1.42, 95% CI 1.08-1.86, p=.014), and four or more times/day (aOR 1.45, 95% CI 1.23-1.71, p<.001). The overall water-frequency term was statistically significant in the global Wald test (F(3,45)=9.41, p<.001). The point estimates across the three higher-frequency groups were similar in magnitude rather than increasing in sequence, and the category-specific estimates were nonmonotonic (Table 3).

Model	Plain-water exposure specification	aOR (95% CI)	p-value
Model 1: Primary binary model	<3 times/day	Reference	-
	≥3 times/day	1.16 (1.01-1.32)	.032
Model 2: Four-category model	<1 time/day	Reference	-
	1-2 times/day	1.53 (1.26-1.87)	< .001
	3 times/day	1.42 (1.08-1.86)	.014
	≥4 times/day	1.45 (1.23-1.71)	< .001

TABLE 3: Survey-Weighted Multivariable Associations Between Plain-Water Intake Frequency and Reporting Mostly A/B Grades, 2023 National YRBS (N=10,199)

Both models estimated the odds of reporting mostly A/B grades, adjusted for the same seven prespecified covariates, and accounted for YRBS sampling weights, strata, and PSUs.

Full survey-weighted multivariable estimates for all predictors in Models 1 and 2 are presented in Table *4*.

Predictor	Model 1 aOR (95% CI)	p	Model 2 aOR (95% CI)	p
Plain-water intake				
≥3/day vs <3/day	1.156 (1.013–1.319)	0.032	-	-
1-2/day vs <1/day	-	-	1.534 (1.262-1.865)	< .001
3/day vs <1/day	-	-	1.417 (1.078-1.863)	0.014
≥4/day vs <1/day	-	-	1.448 (1.227-1.709)	< .001
Age				
≤15 years	Reference	-	Reference	-
16 years	0.844 (0.682-1.044)	0.116	0.841 (0.680-1.040)	0.107
≥17 years	1.058 (0.838-1.336)	0.627	1.059 (0.840-1.336)	0.62
Sex				
Female	Reference	-	Reference	-
Male	0.614 (0.531-0.710)	< .001	0.614 (0.533-0.709)	< .001
Race/ethnicity				
White, non-Hispanic	Reference	-	Reference	-
Black, non-Hispanic	0.608 (0.467-0.791)	< .001	0.632 (0.485-0.824)	0.001
Hispanic/Latino	0.467 (0.379-0.576)	< .001	0.472 (0.383–0.580)	< .001
Other/multiracial, non-Hispanic	0.923 (0.643-1.327)	0.66	0.927 (0.646-1.331)	0.676
Regular soda intake				
None	Reference	-	Reference	-
1-6 times/week	0.750 (0.664–0.846)	< .001	0.751 (0.660-0.854)	< .001
≥1 time/day	0.483 (0.389-0.599)	< .001	0.482 (0.386-0.601)	< .001
Physical activity				
<5 days/week	Reference	-	Reference	-
≥60 min/day on ≥5 days/week	1.718 (1.473-2.004)	< .001	1.687 (1.438-1.979)	< .001
Fruit/100% fruit juice intake				
<2 times/day	Reference	-	Reference	-
≥2 times/day	1.047 (0.859-1.277)	0.643	1.026 (0.841-1.252)	0.794
Vegetable intake				
<3 times/day	Reference	-	Reference	-
≥3 times/day	0.894 (0.659-1.213)	0.463	0.901 (0.665-1.220)	0.491

TABLE 4: Full multivariable regression estimates for Models 1 and 2, 2023 National YRBS complete-case analytic sample (N=10,199)

Notes: All estimates are survey-weighted adjusted odds ratios for reporting mostly A/B grades. Model 1 used the binary water exposure (≥3 vs <3 times/day). Model 2 modeled water as four categories with <1 time/day as the reference and had a global water-exposure Wald test of F(3,45)=9.41, p<.001. Both models adjusted simultaneously for the listed covariates and accounted for YRBS weights, strata, and PSUs.

Missing-data sensitivity analysis

Across all 76 PSUs with observed plain-water intake and academic-grade data, the unadjusted prevalence difference in mostly A/B grades between students reporting water intake three or more versus less than

three times/day was 5.11 percentage points (95% CI, 2.66-7.56; N=13,183). Restricting the exposure-outcome sample to the 75 PSUs that contributed complete cases yielded a difference of 5.15 percentage points (95% CI, 2.64-7.67; N=11,624). Further restriction to respondents with complete exposure, outcome, and covariate data yielded a difference of 4.86 percentage points (95% CI, 2.34-7.38; N=10,199; Table 5).

Analytic sample	N	≥3 times/day: weighted A/B prevalence, % (95% CI)	<3 times/day: weighted A/B prevalence, % (95% CI)	Absolute prevalence difference, PP (95% CI)
Respondents with observed water intake and grades across all 76 PSUs contributing both variables	13,183	74.49 (71.45–77.53)	69.38 (66.22–72.54)	+5.11 (2.66–7.56)
Respondents with observed water intake and grades within the 75 PSUs contributing complete cases	11,624	74.81 (71.73–77.90)	69.66 (66.42–72.89)	+5.15 (2.64–7.67)
Complete-case analytic sample within the same 75 PSUs	10,199	75.61 (72.42–78.81)	70.75 (67.48–74.02)	+4.86 (2.34–7.38)

TABLE 5: Sensitivity analyses of the unadjusted water-grades association across PSU-level and respondent-level restrictions

Notes. PP=percentage points. The first row includes respondents with observed plain-water intake and academic-grade data across the 76 of 89 PSUs that contributed both variables. The second row is restricted to respondents with observed water-intake and grade data within the 75 PSUs that contributed at least one complete case. The third row additionally requires complete information for the exposure, outcome, and all seven prespecified covariates. These comparisons assess stability across observed-data restrictions but do not recover information from PSUs with no observed water-intake data and do not rule out selection bias. Percentages, prevalence differences, and confidence intervals account for YRBS sampling weights, strata, and primary sampling units.

Discussion

Principal findings

In this analytic sample from the 2023 National YRBS, plain-water intake frequency was associated with self-reported academic performance. Students reporting plain-water intake at least three times per day had higher adjusted odds of reporting mostly A/B grades than those reporting lower intake, and the unadjusted analysis showed the same overall direction.

The four-category analysis showed that the association did not strengthen progressively as reported water-intake frequency increased. Relative to intake of less than once per day, the three higher-frequency categories had similar adjusted point estimates, and the estimates were nonmonotonic. This pattern was more consistent with a contrast between very infrequent intake and the higher-frequency categories than with progressively increasing odds across successive intake levels. However, because the study did not directly test differences and equivalence among the higher-frequency categories, the findings do not establish a threshold, plateau, or equivalence.

Comparison with prior literature

Earlier YRBS research has reported a related association. Using the 2017 National YRBS, Park et al. found that students reporting mostly D/F grades had higher adjusted odds of infrequent plain-water intake than students reporting mostly A grades (aOR 1.37, 95% CI 1.07-1.77), in a model adjusting for a similar covariate set (adjusted N=8,718) [10]. Their analysis approached the question from the opposite direction: water intake was the outcome, and grades were one of several demographic and behavioral characteristics examined as potential correlates. The present study reverses this analytic orientation, treating water intake as the exposure and academic performance as the outcome. This reversal alone is not novel, but the appearance of a related pattern across two independent national YRBS cycles, examined from different analytic directions, is noteworthy. Because both studies are cross-sectional, neither can establish that water intake affects grades or that grades affect water intake.

Research on hydration and cognition offers one possible explanation for the association, although the evidence is mixed. Experimental work in children has produced inconsistent findings. Perry et al. found that children's cognitive responses to water intake depended on baseline hydration status and renal response, with benefits observed under some but not all conditions in a relatively small experimental sample [7]. Fadda et al., studying 168 children aged nine to 11 years, found associations between hydration and selected measures of short-term memory, though results were not consistent across all cognitive tasks assessed [6].

Adan's review identified attention, psychomotor performance, and immediate memory as domains potentially sensitive to dehydration, while noting that effects vary substantially by dehydration severity and cognitive domain tested [3]. Sécher and Ritz similarly concluded that evidence linking mild dehydration to cognitive performance remains heterogeneous and methodologically difficult to synthesize, given differences in sample size, methods used to induce dehydration, and cognitive testing approaches across studies [4]. This literature provides biological plausibility for a hydration-related pathway but does not establish that experimental dehydration effects generalize to habitual water-drinking frequency or to real-world academic performance as measured in the present study.

Potential explanations and context

Prior hydration-cognition research provides hypothesis-generating context only. One possible explanation, not tested in this study, is that water-drinking behavior may correlate with cognitive processes such as attention, memory, or alertness. Alternatively, reported plain-water frequency may be a marker of broader patterns involving diet, household routines, socioeconomic circumstances, or school environment that are themselves related to academic performance.

The YRBS measured how frequently students reported drinking plain water during the previous seven days. It did not measure water volume, total fluid intake, hydration biomarkers, physiological hydration status, cerebral perfusion, or cognitive function. The present analysis therefore cannot determine whether participants were hydrated or dehydrated or test a hydration-mediated mechanism. References to hydration and cognition are hypothesis-generating rather than explanations demonstrated by these data.

Strengths

This study used a large school-based analytic sample drawn from the 2023 National YRBS, which was the most recent national cycle available when the analytic plan was developed and the analyses were completed. Although CDC has since released the 2025 national data [13], that cycle does not include the academic-grade item used as the outcome in this study [15]. The 2023 cycle therefore remains the most recent national YRBS cycle that permits this specific analysis [12,15].

Survey-weighted analytic methods accounted for the YRBS sampling weights, strata, and primary sampling units [12]. The primary binary and secondary categorical specifications provided complementary views of the association while retaining the same seven prespecified covariates. The binary model provided the prespecified primary comparison, while the categorical model described the pattern across the four water-frequency categories without imposing a linear trend. Sensitivity analyses also examined the stability of the unadjusted water-grades prevalence difference across sequential PSU-level and respondent-level analytic restrictions.

Limitations

Several limitations should be considered. First, the cross-sectional design does not establish temporal ordering or causality. Plain-water intake and academic grades were self-reported and were not independently verified. The exposure and outcome also had different recall periods: water intake referred to the previous seven days, whereas grades referred to the previous 12 months. Recent water intake may not represent drinking behavior during the period in which the grades were earned and cannot be assumed to precede the reported academic performance.

Second, water intake was measured as frequency rather than volume. Students reporting the same frequency could have consumed substantially different amounts. The measure did not include fluid from other beverages or foods and did not assess physiological hydration. The findings therefore concern reported plain-water frequency, not hydration status or biological water dose.

Third, the outcome compared students reporting mostly A/B grades with all other nonmissing responses. The comparison category included students reporting mostly C, D, or F grades as well as “none of these grades” and “not sure.” This definition preserved the prespecified outcome and avoided a post hoc exclusion rule, but the comparison category is heterogeneous and should not be interpreted as equivalent to objectively verified low academic achievement.

Fourth, the parent 2023 National YRBS had an overall response rate of 35.4%, consisting of a 49.8% school response rate and a 71.0% student response rate. CDC conducted nonresponse-bias analyses and incorporated nonresponse adjustments into the survey weights, but residual nonresponse bias remains possible.

Fifth, study-variable missingness was substantially clustered at the PSU level. Thirteen of the 89 PSUs had no observed water-intake data, and one additional PSU had water and grade data but no observed regular-soda, fruit/100% fruit juice, or vegetable-intake data. The 14 PSUs contributing no complete cases accounted for 21.5% of the total survey weight. The public-use data do not identify why entire PSUs lacked particular study variables; therefore, informative cluster-level missingness cannot be ruled out. The original YRBS

weights were not recalibrated for this study-specific loss of PSU-level information, and estimates from the analytic sample should not be interpreted as fully nationally representative. The unadjusted prevalence difference was similar across the 76-PSU exposure-outcome sample, the 75-PSU exposure-outcome sample, and the complete-case sample. However, these comparisons cannot recover information from the 13 PSUs with no observed water-intake data or establish that the adjusted associations are free from selection bias.

Sixth, residual confounding remains possible despite adjustment for seven prespecified covariates. Sleep duration, breakfast consumption, socioeconomic circumstances, school engagement, and overall diet quality were not included. Because more favorable sleep, breakfast, socioeconomic, and school-engagement profiles may be associated with both more frequent water intake and higher grades, their omission would most plausibly bias the water estimate upward, away from the null, although the exact direction and magnitude cannot be determined from these data. The primary aOR was 1.16 with a 95% CI of 1.01-1.32. Because the lower confidence bound was close to the null value of 1.00, relatively small changes in model specification or analytic sample composition could cause the interval to include 1.00 and alter conventional statistical significance. The estimate is therefore vulnerable to material confounding and should not be interpreted as evidence that increasing water intake would improve grades.

Finally, the YRBS samples students attending school. These findings may not generalize to adolescents who have dropped out of school or are otherwise not enrolled.

Implications and future directions

These findings add to research examining plain-water intake frequency and self-reported academic performance in adolescents. Very infrequent plain-water intake may reflect broader behavioral or environmental patterns associated with lower odds of reporting mostly A/B grades; the present findings do not establish that increasing water intake would improve grades. Longitudinal and experimental studies incorporating objective hydration measures, water volume and total fluid intake, and independently recorded academic outcomes could help distinguish hydration-related effects from confounding by broader health behaviors and school or home environments.

Conclusions

Among analyzed participants in the 2023 National YRBS, high school students who reported drinking plain water at least three times per day had higher adjusted odds of reporting mostly A/B grades than those reporting intake less than three times per day. In the categorical analysis, each of the three higher-frequency groups had higher adjusted odds than the less than one time/day group, but the point estimates were similar in magnitude and did not increase monotonically across successive categories. These findings add to the limited U.S. evidence examining the relationship between plain-water intake frequency and self-reported academic performance among adolescents.

Because the YRBS is cross-sectional, these results cannot show that drinking more water leads to better grades. Very infrequent plain-water intake may instead reflect broader behavioral or environmental factors that are also related to academic performance. Accordingly, these findings do not establish that interventions to increase water intake would improve academic performance. Future longitudinal and experimental studies could clarify this relationship by measuring water volume and total fluid intake, incorporating objective measures of hydration, and using repeated or objectively recorded academic outcomes. Such studies could help clarify the extent to which the observed association reflects hydration-related processes, broader patterns of health behavior, environmental factors, or some combination of these influences.

Appendices

Appendix A

Of the 89 nested PSUs in the full survey design, 13 had no observed Q96/QNWATER3 data and 14 contributed no complete cases. The 14 noncontributing PSUs included 6,784 respondents and accounted for 21.5% of the total survey weight. PSU-level study-variable availability is summarized in the table below.

Nested PSU identifier	Unweighted N	Plain-water data observed, n	Academic-grade data observed, n	Complete cases, n	Study-variable domains with zero observed values	Share of total survey weight, %
101.329556	799	0	767	0	Plain water; regular soda; vegetable intake	1.09
112.344217	256	0	0	0	Plain water; academic grades	0.71
113.343252	335	0	0	0	Plain water; academic grades	4.57
113.351366	98	0	0	0	Plain water; academic grades	0.47
201.330088	527	0	492	0	Plain water; regular soda; vegetable intake	1.57
202.214944	360	0	355	0	Plain water	2.63
211.343307	1,298	0	0	0	Plain water; academic grades	0.95
213.344677	175	0	0	0	Plain water; academic grades	1.86
214.689625	160	0	137	0	Plain water	1.99
300.30356	441	0	430	0	Plain water	0.03
300.30657	545	0	489	0	Plain water	0.15
300.472861	153	0	152	0	Plain water; regular soda; physical activity; fruit/100% fruit juice; vegetable intake	2.84
300.689625	30	0	30	0	Plain water	0.57
300.786048	1,607	1,578	1,565	0	Regular soda; fruit/100% fruit juice; vegetable intake	2.12

TABLE 6: PSU-level study-variable availability among the 14 PSUs contributing no complete cases, 2023 National YRBS

PSU identifiers are nested public-use cluster identifiers formed from the stratum and PSU variables. Plain-water data refer to Q96 and the CDC-derived QNWATER3 variable. All counts are unweighted except the survey-weight percentages. All 14 PSUs had zero complete cases. The public-use dataset identifies the study-variable availability pattern but does not identify the operational reason why variables were entirely unavailable within particular PSUs. Percentages may not sum exactly to 21.5% because of rounding.

PSU: Primary sampling unit; YRBS: National Youth Risk Behavior Survey; CDC: Centers for Disease Control and Prevention.

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

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Disclosures

Human subjects: Informed consent for treatment and open access publication was obtained or waived by all participants in this study. Centers for Disease Control and Prevention (CDC) and ICF Institutional Review Boards - approved the original 2023 National YRBS protocol issued approval Not applicable - no additional IRB review was required for our secondary analysis of publicly available, de-identified data. The present study was a secondary analysis of publicly available, de-identified data from the 2023 National Youth Risk Behavior Survey (YRBS). The authors had no interaction with participants and no access to identifiable private information; therefore, additional IRB review was not required for this secondary analysis. The original 2023 National YRBS protocol was reviewed and approved by the institutional review boards of the Centers for Disease Control and Prevention (CDC) and ICF, the survey contractor. (Please see in the uploaded CDC documentation, under the section, "Data Collection Procedures," where it states "Institutional review boards at Centers for Disease Control (CDC) and ICF, the survey contractor, approved the protocol for YRBS.) Data collection was conducted consistent with applicable Federal law and CDC policy." . **Animal subjects:** All authors have confirmed that this study did not involve animal subjects or tissue. **Conflicts of interest:** In compliance with the ICMJE uniform disclosure form, all authors declare the following: **Payment/services info:** All authors have declared that no financial support was received from any organization for the submitted work. **Financial relationships:** All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. **Other relationships:** All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

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Use of Artificial Intelligence-Assisted Tools: We conceived and designed the study, conducted the literature review, obtained and prepared the 2023 National YRBS data, determined the analytic approach and model specifications, and executed all statistical analyses ourselves in jamovi using the Rj Editor. We reviewed the R/Rj output, prepared the reported numerical results, interpreted the findings, and determined the manuscript structure and presentation. We used ChatGPT (OpenAI, San Francisco, CA, USA) to assist with R syntax, manuscript organization, language refinement, and secondary consistency checks, and used Claude (Anthropic, San Francisco, CA, USA) to a lesser extent for similar purposes. We reviewed all AI-assisted suggestions and take full responsibility for the statistical results, scientific interpretation, and final manuscript content. Data and Code Availability: The 2023 National YRBS public-use data analyzed in this study are publicly available from the Centers for Disease Control and Prevention through the YRBS datasets and documentation repository. Analytic code and study materials are available from the corresponding author upon reasonable request.

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