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Research Paper

Examining differences in the implementation of school water-quality practices and water-access policies by school demographic characteristics

Angie L. Cradock[a,*], Sherry Everett Jones[b], Caitlin Merlo[c]

[a] Prevention Research Center on Nutrition and Physical Activity, Department of Social and Behavioral Sciences, Harvard T.H. Chan School of Public Health, 677 Huntington Avenue, 7th Floor, Boston, MA, USA

[b] Division of Adolescent and School Health, Centers for Disease Control and Prevention, 1600 Clifton Rd, NE, MS E75, Atlanta, GA, 30329, USA

[c] Division of Population Health, Centers for Disease Control and Prevention, 4770 Buford Highway, NE, MS S107-6, Atlanta, GA 30341, USA

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ABSTRACT

Ensuring safe, accessible drinking water in schools is a national health priority. The objective of this study was to identify whether there are differences in water quality, availability, and education- related practices in schools by demographic characteristics. In 2017–2018, we analyzed data from the 2014 School Health Policies and Practices Study (SHPPS), a nationally representative, cross-sectional survey of US schools. Analyses examined differences in water-related practices by school characteristics. Response rates for the 3 questionnaires used in this analysis ranged from 69%–94% (Ns ranged from 495 to 577). We found that less than half of schools flush drinking water outlets after periods of non-use (46.4%), conduct periodic inspections that test drinking water outlets for lead (45.8%), and require staff training on drinking water quality (25.6%). Most schools teach the importance of water consumption (81.1%) and offer free drinking water in the cafeteria (88.3%). Some water-related school practices differed by school demographic characteristics though no consistent patterns of associations by school characteristics emerged. In US schools, some water quality-related practices are limited, but water availability and education-related practices are more common. SHPPS data suggest many schools would benefit from support to implement best practices related to school-drinking water.

1. Introduction

Water is an ideal beverage choice for children because it hydrates the body, is low-cost, and is calorie-free. Easy access to clean and safe water can help youth replace consumption of sugar-containing beverages with no-calorie choices and maintain a healthy weight (Muckelbauer et al., 2016). Adequate hydration may also support cognitive function in children and adolescents (Popkin et al., 2010). More than half of children and adolescents in the United States are not adequately hydrated, and nearly a quarter of children drink no plain water at all (Kenney et al., 2015a). Further, non-Hispanic black children are more likely than non-Hispanic white children to be inadequately hydrated (Kenney et al., 2015a).

Because most American youth spend considerable time in schools, access to free drinking water in this setting is crucial. School districts (Cradock et al., 2012) and schools (Everett Jones et al., 2007) play an essential role in ensuring access to water for students. Students in schools that provide free water consume more water at lunch (Bogart et al., 2016) and drink more water during after school snacks (Giles et al., 2012; Lee et al., 2014), particularly when water is promoted and cups are provided (Kenney et al., 2015b; Patel et al., 2016). The Healthy, Hunger-Free Kids Act of 2010 requires that schools participating in the National School Lunch Program provide free drinking water to students during lunchtime, during breakfast when served in the cafeteria, and during the Afterschool Snack Program (Anon, 2016). Most schools provide a drinking water fountain to meet these requirements (Hood et al., 2014), but not all schools provide free drinking water during lunch (Bogart et al., 2016; Kenney et al., 2016), and nationally, many students are not confident that the free drinking water at school is clean or safe (Onufrak et al., 2014a). Some school districts have documented the presence of lead (Pb) in drinking water in their schools (Triantafyllidou et al., 2014). Ingestion of lead via drinking water may contribute substantively to blood lead levels, particularly among young children (Zartarian et al., 2017). However, there is limited knowledge about the national status of the cleanliness and condition of school drinking fountains and the quality of drinking water in

* Corresponding author at: Prevention Research Center on Nutrition and Physical Activity, Harvard T.H. Chan School of Public Health, 677 Huntington Avenue, 7th Floor, Boston, MA 02115, USA.

E-mail addresses: acradock@hsph.harvard.edu (A.L. Cradock), sce2@cdc.gov (S. Everett Jones), cmerlo@cdc.gov (C. Merlo).

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schools or those practices that may support drinking water access and consumption.

Various policies and practices can influence access to drinking water in schools. Individual states establish the minimum number of plumbed water sources in schools per a given number of students via policies such as plumbing codes (Onufrak et al., 2014b; Wilking et al., 2015), and regional differences in student-reported school water access may be related to such standards (Onufrak et al., 2014b). In some cases, municipal water quality may differ by metropolitan status (Strosnider et al., 2017) and by water treatment practices or local infrastructure conditions (Sadler et al., 2017). In communities where water that is entering school buildings meets municipal water system standards, school building-specific drinking water infrastructure (e.g., plumbing), and quality assurance practices also affect water quality.

The U.S. Environmental Protection Agency (EPA) guidance for schools and child care facilities that are served by municipal water systems (US EPA, 2013a) or are their own water source (e.g., a well) (US EPA, 2013b) recommends that these facilities inspect and maintain water outlets, train staff on issues relevant to ensuring water quality and appropriate water access, and communicate with students, staff, and their families about water quality. In 2014, 46% of US schools conducted periodic inspections that tested drinking water outlets for lead (CDC, 2015) which is below the target (61%) for the national health-related goals for 2020 (Healthy People 2020, 2018). Additionally, among schools in one state, school drinking water access differed by school level, metropolitan status, and school building age (Patel et al., 2014). Such variations have implications for public health strategies to ensure equitable drinking water access for students. Therefore, we sought to identify whether there are differences in water quality, availability, and education-related practices by demographic characteristics of schools using a nationally representative, cross-sectional survey of US schools.

2. Methods

The School Health Policies and Practices Study (SHPPS) is a national survey conducted periodically by the Centers for Disease Control and Prevention (CDC) to assess school health policies and practices at the state, district, school, and classroom levels. SHPPS 2014, conducted from February through June 2014, examined ten components of school health identified in the Whole School, Whole Community, Whole Child model in schools and classrooms (ASCD and Centers for Disease Control and Prevention, 2014). This study examined data from the Healthy and Safe School Environment School Questionnaire, the Nutrition Services School Questionnaire, and the Health Education Classroom Questionnaire. Institutional Review Boards (IRBs) at Harvard TH Chan School of Public Health, CDC, and ICF International (the contractor that conducted fieldwork for SHPPS 2014) have determined the study to be exempt from IRB review.

2.1. Sample and survey administration

A detailed description of the 2014 study methods has been published (US CDC, 2015) and is summarized here. To develop the 2014 questionnaires, all of the 2006 SHPPS questionnaires were reviewed. New questions and substantively modified questions underwent cognitive testing using telephone interviews. Draft questionnaires were evaluated by reviewers from federal agencies, national associations, foundations, universities, and businesses nationwide. Some questionnaires were divided into modules, grouping related items so schools could identify a respondent who was most knowledgeable about the items covered in that module. This allowed for different respondents for each module. Some schools were ineligible to complete one or more questionnaires or modules because they did not have the program or service in place addressed within that questionnaire or module.

A two-stage sampling design was used to select a nationally representative sample of schools. All public, state-administered, Catholic, and non-Catholic private schools with any of grades K through 12 were eligible. Alternative schools, schools providing services to a "pull-out" population who were provided services at another eligible school, schools run by the Department of Defense or Bureau of Indian Education, and schools with fewer than 30 students were excluded. The number of sampled schools was 828.

Response rates varied by questionnaire. The Healthy and Safe School Environment Questionnaire was comprised of three modules. For modules 1 and 3, the response rate was 70% ($N = 577$ of 828 eligible schools). For module 2 the response rate was 69% ($N = 568$ of 828 eligible schools). For the Nutrition Services School Questionnaire the response rate was 69% ($N = 554$ of 803 eligible schools), and for the Health Education Classroom Questionnaire, the response rate was 94% (495 of 529 sampled health education classes or courses). Most (89%) of the data were collected via computer-assisted interviews; the remaining respondents used paper questionnaires.

2.2. Study measures

SHPPS 2014 included questions about flushing water outlets, drinking water testing, custodial or maintenance staff training on drinking water quality, permitting students to carry water bottles with them at school, ability for students to purchase water from a school vending machine or school store, offering a free source of drinking water in the school cafeteria during meal times, and teaching about the importance of water consumption as part of required instruction.

School characteristics collected as part of SHPPS 2014 included 1) school level (elementary, middle, and high school); 2) enrollment (range: 30–3948 students; mean = 479.4 [95% CI = 442.3–516.5]), categorized into tertiles based on the frequency distribution: 30–279 students, 280–517 students, and 518–3948 students; and 3) age of the school's main instructional building (range: 1–163 years; mean = 47.6 [95% CI = 44.3–50.8]), categorized into tertiles based on the frequency distribution: (1–33 years; 34–57 years; 58–163 years). Schools were classified by metropolitan status (urban, suburban, town, and rural), US Census region (West, Midwest, Northeast, and South), and school type (public [including state-administered schools] and private [Catholic and non-Catholic private schools]) based on data from the National Center for Education Statistics.

SHPPS 2014 data were linked with extant data from the Market Data Retrieval database, a database updated annually that contains information about individual US schools. This database was used to determine the percentage of public school students eligible for free or reduced-price meals (range: 0%–100%) and the percentage of non-white students (range: 0%–99%) (hereafter "percentage racial/ethnic minority students") for public schools. This information was not available for private schools. These variables were categorized into tertiles (i.e., 0–32%, 33%–65%, and 66%–100%).

2.3. Statistical analysis

Data were weighted to produce national estimates and analyses were conducted using SUDAAN statistical software to account for the complex sampling design. Bivariate analyses and multivariable models were used to examine whether school characteristics were associated with drinking water-related policies and practices. First, each school characteristic was evaluated using a chi-square test to examine bivariate associations and where appropriate, pairwise *t*-tests were used to identify which groups varied. Each multivariable logistic regression model included school level, metropolitan status, region, school enrollment, school age, the percentage of students eligible for free or reduced-price meals, and the percentage of racial/ethnic minority students. Multivariable models were conducted only among public schools because two demographic characteristics were not available for private schools. Associations were considered statistically significant when $p < 0.05$.

Table 1
Prevalence and bivariate associations of water quality-related practices by school demographic characteristics among US Schools, School Health Policies and Practices Study (SHPPS), 2014.

	Flushes drinking water outlets after periods of non-use[a] (*n* = 531)	Conducts periodic inspections that test drinking water outlets for lead (*n* = 514)	Custodial or maintenance staff are required to receive training on school drinking water quality (*n* = 520)	Tested drinking water for bacteria[b] (*n* = 419)	Tested drinking water for coliforms[b] (*n* = 397)	Tested drinking water for other contaminants[b] (*n* = 410)
	Weighted % (95% CI)	Weighted % (95% CI)	Weighted % (95% CI)	Weighted % (95% CI)	Weighted % (95% CI)	Weighted % (95% CI)
Overall	46.4 (41.3, 51.7)	45.8 (40.1, 51.6)	25.6 (20.9,30.9)	51.4 (45.1, 57.6)	48.5 (42.2, 54.9)	48.9 (42.7, 55.1)
School level						
Elementary	47.5 (39.6, 55.5)	45.9 (37.8, 54.3)	26.4 (19.8, 34.3)	52.2 (42.6, 61.5)	50.5 (40.8, 60.1)	50.3 (41.0, 59.6)
Middle	50.0 (41.9, 58.2)	46.4 (38.6, 54.4)	25.3 (19.0, 32.9)	47.3 (38.6, 56.2)	42.1 (33.2, 51.6)	42.9 (34.1, 52.1)
High	39.3 (31.8, 47.3)	44.6 (36.1, 53.4)	24.0 (17.7, 31.7)	54.7 (45.2, 63.8)	51.7 (42.0, 61.2)	53.1 (43.5, 62.5)
Chi-square *p*-value	0.12	0.95	0.89	0.45	0.25	0.22
Metropolitan status						
Rural	54.1 (45.5, 62.6)	**52.7 (42.6, 62.6)**[e]	26.8 (20.9, 33.6)	52.7 (43.4, 61.8)	49.2 (40.0, 58.5)	50.9 (41.1, 60.6)
Urban	37.7 (27.6, 49.0)	45.6 (34.3, 57.4)	25.5 (15.5, 38.9)	52.7 (39.6, 65.3)	50.0 (36.2, 63.7)	50.8 (37.6, 63.8)
Suburban	47.0 (37.8, 56.4)	46.5 (36.7, 56.6)	23.0 (16.5, 31.2)	51.1 (40.5, 61.6)	49.5 (38.9, 60.2)	49.2 (39.5, 59.0)
Town	48.9 (36.9, 61.1)	**28.0 (17.6, 41.5)**[e]	29.5 (16.7, 46.5)	45.3 (27.6, 64.3)	39.8 (24.9, 56.9)	37.5 (22.6, 55.4)
Chi-square p-value	0.15	**0.047**	0.84	0.92	0.79	0.62
Region						
South	53.9 (44.8, 62.7)	45.5 (34.3, 57.2)	25.9 (17.7, 36.1)	50.9 (40.5, 61.1)	45.7 (36.0, 55.8)	44.6 (35.0, 54.6)
Northeast	39.7 (30.3, 50.0)	57.7 (44.5, 69.9)	23.2 (15.8, 32.8)	59.7 (46.6, 71.5)	57.8 (44.5, 70.1)	55.6 (42.6, 67.8)
Midwest	52.0 (42.4, 61.4)	43.3 (33.0, 54.2)	17.1 (10.5, 26.6)	42.4 (31.9, 53.7)	41.3 (29.8, 53.9)	41.3 (30.5, 53.0)
West	37.1 (26.3, 49.3)	39.1 (29.1, 50.0)	36.3 (25.5, 48.7)	55.6 (40.8, 69.6)	52.8 (37.7, 67.3)	57.6 (42.8, 71.1)
Chi-square p-value	0.05	0.19	0.07	0.23	0.28	0.20
School type						
Public[c]	**49.4 (44.1, 54.7)**[e]	**49.7 (43.3, 56.1)**[e]	**29.1 (23.8, 35.1)**[e]	**59.6 (52.6, 66.3)**[e]	**57.0 (49.7, 64.0)**[e]	**56.4 (49.5, 63.1)**[e]
Private	**37.0 (27.3, 47.8)**[e]	**33.6 (22.7, 46.7)**[e]	**13.7 (7.4, 23.9)**[e]	**28.2 (18.8, 40.2)**[e]	**24.2 (14.9, 36.7)**[e]	**27.1 (17.0, 40.3)**[e]
Chi-square p-value	**0.04**	**0.03**	**< 0.01**	**< 0.01**	**< 0.01**	**< 0.01**
School enrollment						
30–279	42.0 (34.2, 50.2)	40.7 (31.5, 50.7)	23.5 (16.9, 31.6)	46.4 (36.8, 56.3)	41.7 (32.4, 51.6)	42.2 (33.0, 51.9)
280–517	47.3 (38.4, 56.4)	48.7 (39.7, 57.8)	25.3 (18.3, 33.8)	48.4 (38.0, 58.9)	48.6 (37.6, 59.7)	46.9 (36.3, 57.8)
518–3948	48.8 (40.5, 57.3)	47.8 (38.9, 56.8)	27.8 (19.9, 37.3)	59.5 (49.8, 68.5)	55.0 (45.3, 64.3)	57.8 (48.3, 66.8)
Chi-square p-value	0.44	0.45	0.75	0.15	0.18	0.08
School age (years)						
1–33	49.0 (40.8, 57.1)	40.6 (32.6, 49.2)	27.4 (20.7, 35.3)	53.4 (43.7, 62.8)	49.7 (39.8, 59.7)	50.6 (40.8, 60.3)
34–57	48.0 (39.2, 56.9)	45.1 (36.2, 54.3)	24.0 (16.8, 33.2)	52.1 (41.1, 62.8)	47.4 (36.6, 58.5)	49.1 (38.5, 59.8)
58–163	45.6 (36.3, 55.3)	49.7 (39.6, 59.8)	24.1 (16.3, 34.2)	48.1 (36.6, 59.9)	47.1 (35.2, 59.4)	46.9 (35.8, 58.4)
Chi-square p-value	0.87	0.31	0.77	0.80	0.94	0.90
Percentage students eligible for free or reduced-price meals[d]						
0–32%	52.7 (42.7, 62.4)	46.2 (35.4, 57.4)	25.3 (17.1, 35.8)	55.1 (42.4, 67.1)	53.9 (41.0, 66.3)	54.4 (42.2, 66.1)
33–65%	48.1 (39.6, 56.8)	48.9 (39.0, 58.9)	26.4 (19.0, 35.5)	62.1 (51.2, 72.0)	58.8 (47.2, 69.5)	58.8 (47.4, 69.3)
66–100%	52.5 (42.6, 62.1)	59.3 (46.8, 70.7)	39.1 (28.0, 51.5)	62.6 (48.0, 75.2)	59.0 (45.0, 71.8)	55.6 (42.0, 68.4)
Chi-square p-value	0.71	0.29	0.18	0.63	0.82	0.85
Percentage racial/ethnic minority students[d]						
0–32%	50.5 (43.1, 57.9)	46.6 (38.1, 55.3)	**21.3 (16.0, 27.8)**[f]	**54.2 (44.1, 64.0)**[e]	**51.7 (41.1, 62.1)**[e]	**52.3 (41.8, 62.5)**[e]
33–65%	58.4 (44.2, 71.3)	53.6 (39.3, 67.3)	**24.6 (14.2, 39.3)**[e]	**78.1 (63.9, 87.8)**[e,f]	**74.6 (58.6, 86.0)**[e,f]	**74.3 (58.8, 85.4)**[e]
66–100%	47.0 (36.3, 58.1)	59.6 (45.2, 72.6)	**49.9 (36.8, 63.0)**[e,f]	**58.3 (42.6, 72.5)**[f]	**56.1 (40.4, 70.6)**[f]	52.0 (38.0, 65.6)
Chi-square p-value	0.48	0.29	**< 0.01**	**0.02**	**0.046**	**0.04**

Note. Percentages are weighted. CI = confidence interval.
Values in bold indicate significant difference.
[a] Such as after weekends or school vacations.
[b] During the 12 months before the study, among schools that do not operate their own water system.
[c] Includes state administered schools.
[d] Among public schools only. Data were not available for private schools.
[e] Estimates with the same number differ according to pairwise *t*-test, $p < 0.05$.
[f] Estimates with the same number differ according to pairwise *t*-test, $p < 0.05$.

3. Results

3.1. Water quality-related practices

SHPPS 2014 data show that fewer than half of schools flush drinking water outlets after periods of non-use (46.4%), conduct periodic inspections that test drinking water outlets for lead (45.8%), and require custodial or maintenance staff to receive training on school drinking water quality (25.6%) (Table 1). Among the 92.4% of schools that are supplied by a municipal water source and for which drinking water testing is voluntary under federal law, approximately half had tested drinking water for bacteria (51.4%), coliforms (48.5%), or other contaminants (48.9%) during the 12 months before the study. Among those schools that had tested drinking water for bacteria, coliforms, or other contaminants, 38.3% provided the results to school faculty and staff, 22.7% provided the results to students' families, and 15.8% provided the results to students.

Bivariate analyses examining the association between school characteristics and practices related to water quality found no associations by school level, region, school enrollment, school age, or percentage of students eligible for free or reduced-price meals; however, at least one significant association was found by metropolitan status, school type, and the percentage of racial/ethnic minority students (Table 1). Rural schools were more likely than town schools to conduct periodic inspections that test drinking water outlets for lead. Public schools were more likely than private schools to flush drinking water outlets after periods of non-use; to conduct periodic inspections that test drinking water outlets for lead; to require custodial or maintenance staff to receive training on school drinking water quality; and to test drinking water for bacteria, coliforms, and other contaminants. Schools with 66%–100% of racial/ethnic minority students were more likely than schools with fewer racial/ethnic minority students to require custodial or maintenance staff to receive training on school drinking water quality. Schools with 33%–65% of racial/ethnic minority students were more likely than schools with 0%–32% and 66%–100% to have tested drinking water outlets for bacteria and coliforms; schools with 33%–65% of racial/ethnic minority students were more likely than schools with 0%–32% of racial/ethnic minority students to have tested for other contaminants.

3.1.1. Multivariable models

Multivariable models conducted among public schools, adjusted for other school characteristics, showed that compared to rural schools, urban schools (aOR = 0.4; 95% CI = 0.2,0.8) were less likely to flush drinking water outlets after periods of non-use, and schools in towns (aOR = 0.4; 95% CI = 0.2,1.0) were less likely than rural schools to conduct periodic inspections that test drinking water outlets for lead (Table 2). Compared to schools in the South, schools in the Northeast (aOR = 0.4; 95% CI = 0.2,0.9) and in the West (aOR = 0.4; 95% = 0.2,0.9) were less likely to flush drinking water outlets after periods of non-use, and schools in the Northeast (aOR = 3.9; 95% CI = 1.7,9.1) were more likely than schools in the South to conduct periodic inspections that test drinking water outlets for lead. Compared to schools with the smallest school enrollment, schools with 280–517 students (aOR = 2.2; 95% CI = 1.1,4.6), and schools with 518–3948 students (aOR = 2.2; 95% CI = 1.0,4.9) were more likely to test drinking water for other contaminants. Compared to the newest schools, the oldest schools (58–163 years old) (aOR = 2.3; 95% CI = 1.2,4.5) were more likely to conduct periodic inspections that test drinking water outlets for lead. Compared to schools in which the percentage of racial/ethnic minority students was 0%–32%, schools with 33%–65% racial/ethnic minority students were more likely to test drinking water for bacteria (aOR = 2.7; 95% CI = 1.1,6.5) and for coliforms (aOR = 2.6; 95% CI = 1.1,6,6) and schools with 66%–100% racial/ethnic minority students were more likely to require custodial or maintenance staff to receive training on school drinking water quality (aOR = 4.5; 95% CI = 2.1,9.8).

3.2. Water access and water-related education practices

Most public and private schools permit students to have a drinking water bottle with them during the school day in all school locations (74.1%), offer a free source of drinking water in the cafeteria during meals times (88.3%), and have teachers who taught about the importance of water consumption as part of required instruction (81.1%). In fewer schools (34.6%), students can purchase bottled water from vending machines or at school stores (Table 3). Bivariate analyses examining the association between school characteristics and practices related to water access and education practices found no associations by school age, the percentage of students eligible for free or reduced-price meals, or the percentage of racial/ethnic minority students; however, at least one significant association was found by school level, metropolitan status, region, and school type (Table 3). High schools were more likely than middle and elementary schools, and rural schools were more likely than urban and suburban schools to allow students to purchase bottled water from vending machines or at school stores. Schools in the West were more likely than schools in the South, Northeast, and Midwest, and private schools were more likely than public schools to permit students to have a drinking water bottle with them in all school locations.

3.2.1. Multivariable models

The findings of the multivariable models adjusted for other school characteristics conducted among public schools are found in Table 4. Students in both middle schools (aOR = 5.7; 95% CI = 3.0,10.8) and high schools (aOR = 19.3; 95% CI = 10.0,37.4) were more likely than students in elementary schools to be able to purchase bottled water from vending machines or at school stores. High schools (aOR = 2.9; 95% CI = 1.2,6.9) were more likely than elementary schools to have teachers who taught about the importance of water consumption as part of required school instruction.

Students in suburban (aOR = 0.4; 95% CI = 0.2,0.9) and urban (aOR = 0.3; 95% CI = 0.1,0.9) schools were less likely than rural schools to be able to purchase bottled water from vending machines or at school stores. Schools in towns (aOR = 11.2; 95% CI = 1.4,91.3) were more likely to offer a free source of drinking water in the cafeteria during meal times than rural schools (Table 4). Compared to schools in the South, schools in the West (aOR = 3.1; 95% CI = 1.5,6.4) were more likely to permit students to have a drinking water bottle with them in all school locations. Compared to schools with the smallest school enrollment, schools with 280–517 students (aOR = 2.8; 95% = 1.0,7.7) were more likely to teach about the importance of water consumption as part of required instruction.

4. Discussion

Schools can facilitate the consumption of water among students and staff by ensuring ready access to safe water sources, promoting water consumption, and implementing effective organizational action to prevent exposure to contaminants (Balazs and Ray, 2014). In this study, across all quality, availability, and education outcomes, no consistent patterns of association with any single school characteristic emerged. However, there were some water quality, availability, and education-related practices that differed by demographic characteristics of schools and the overall findings have important implications for schools and public health practitioners.

As early as 2006, it was recognized that there was no clear focal point at either the national or state level to collect and analyze school drinking water testing results (US Government Accountability Office, 2006). This lack of coordinated efforts in oversight and monitoring capacity may relate to the low prevalence of some recommended school drinking water quality-related practices. In 2014, fewer than half of US public and private schools reported practices such as periodic inspections of drinking water outlets for lead, flushing water outlets after periods of non-use, and requiring custodial or maintenance staff training on water quality. These findings suggest that many schools may not be acting on EPA-recommended water quality testing, staff training, and communication guidance. Therefore, substantial efforts could be made to support the implementation of recommended best practices. EPA guidance emphasizes the importance of testing all drinking water outlets in school facilities and practicing other routine measures such as flushing or cleaning protocols that may reduce lead exposure (US EPA, 2006). Schools served by a public water system are not subject to federal requirements under the Safe Drinking Water Act and subsequent rules such as the Lead and Copper Rule that would require regular water testing (US EPA, 2006). However, some schools do conduct voluntary water quality testing for lead or other contaminants and state policy specifying voluntary or mandatory testing for lead in water at schools and child care facilities has been adopted in several states (Wilking, 2017). Few states have established funding

Table 2
Multivariable Logistic Regression of Water Quality-Related Practices by School Demographic Characteristics in US Public Schools, School Health Policies and Practices Study (SHPPS), 2014[a].

	Flushes drinking water outlets after periods of non-use[b] (n = 350)		Conducts periodic inspections that test drinking water outlets for lead (n = 336)		Custodial or maintenance staff are required to receive training on school drinking water quality (n = 341)		Tested drinking water for bacteria[c] (n = 268)		Tested drinking water for coliforms[c] (n = 256)		Tested drinking water for other contaminants[c] (n = 264)	
	aOR (95% CI)	p value	aOR (95% CI)	p value	aOR (95% CI)	p value	aOR (95% CI)	p value	aOR (95% CI)	p value	aOR (95% CI)	p value
School level												
Elementary	Ref		Ref		Ref		Ref		ref		ref	
Middle	1.0 (0.5,1.7)	0.91	1.1 (0.6,1.8)	0.81	1.0 (0.5,1.9)	0.96	1.0 (0.5,2.0)	0.99	0.9 (0.5,1.9)	0.86	1.0 (0.5,2.0)	0.98
High	0.7 (0.4,1.1)	0.08	1.0 (0.5,1.9)	0.99	0.7 (0.4,1.4)	0.33	0.9 (0.5,1.8)	0.81	0.8 (0.4,1.6)	0.50	0.9 (0.4,1.7)	0.66
Metropolitan status												
Rural	Ref		Ref		Ref		Ref		Ref		Ref	
Urban	**0.4 (0.2,0.8)**	**0.01**	0.7 (0.3,1.5)	0.33	0.7 (0.3,1.9)	0.50	1.1 (0.4,3.5)	0.82	1.3 (0.4,4.6)	0.69	1.1 (0.3,3.7)	0.89
Suburban	1.0 (0.5,1.9)	0.98	0.7 (0.3,1.4)	0.28	0.7 (0.3,1.6)	0.41	1.1 (0.5,2.4)	0.81	1.1 (0.5,2.3)	0.89	0.9 (0.4,1.9)	0.75
Town	0.6 (0.3,1.1)	0.07	**0.4 (0.2,1.0)**	**0.047**	0.7 (0.2,2.3)	0.58	1.0 (0.4,2.8)	0.94	0.9 (0.3,2.2)	0.74	0.6 (0.2,1.9)	0.41
Region												
South	Ref		Ref		Ref		Ref		Ref		Ref	
Northeast	**0.4 (0.2,0.9)**	**0.02**	**3.9 (1.7,9.1)**	< **0.01**	1.0 (0.4,2.3)	0.94	2.5 (0.9,7.0)	0.09	2.4 (0.9,6.6)	0.09	2.1 (0.8,5.5)	0.12
Midwest	0.7 (0.4,1.3)	0.28	1.4 (0.6,3.0)	0.47	0.5 (0.2,1.3)	0.16	0.6 (0.3,1.4)	0.28	0.7 (0.3,1.6)	0.34	0.7 (0.3,1.6)	0.40
West	**0.4 (0.2,0.9)**	**0.03**	0.9 (0.4,2.0)	0.86	1.4 (0.6,3.1)	0.43	1.8 (0.7,4.7)	0.27	1.8 (0.7,5.1)	0.23	2.2 (0.8,5.8)	0.12
School enrollment												
30–279	Ref		Ref		Ref		Ref		Ref		Ref	
280–517	1.8 (1.0,3.5)	0.07	1.6 (0.8,3.2)	0.16	1.4 (0.6,3.0)	0.47	1.3 (0.6,2.7)	0.48	1.9 (0.9,3.9)	0.10	**2.2 (1.1,4.6)**	**0.04**
518–3948	1.3 (0.7,2.5)	0.45	1.2 (0.6,2.3)	0.61	0.9 (0.5,2.0)	0.88	1.4 (0.7,3.1)	0.36	1.5 (0.7,3.1)	0.31	**2.2 (1.0,4.9)**	**0.047**
School age (years)												
1–33	Ref		Ref		Ref		Ref		Ref		Ref	
34–57	1.1 (0.7,1.9)	0.71	1.5 (0.8,2.9)	0.25	0.9 (0.4,1.9)	0.73	1.4 (0.7,3.1)	0.35	1.6 (0.7,3.6)	0.28	1.5 (0.7,3.5)	0.29
58–163	1.1 (0.6,2.1)	0.83	**2.3 (1.2,4.5)**	**0.02**	1.0 (0.4,2.0)	0.90	1.7 (0.7,3.9)	0.21	2.2 (0.9,5.3)	0.08	2.2 (0.9,5.0)	0.07
Percentage students eligible for free or reduced-price meals												
0–32%	Ref		Ref		Ref		Ref		Ref		Ref	
33–65%	0.8 (0.4,1.4)	0.36	1.1 (0.6,1.9)	0.84	0.8 (0.4,1.5)	0.44	1.6 (0.8,3.2)	0.22	1.3 (0.6,2.7)	0.51	1.5 (0.7,3.1)	0.32
66–100%	0.9 (0.4,2.1)	0.84	1.6 (0.6,4.3)	0.32	0.6 (0.2,1.8)	0.35	1.6 (0.5,5.1)	0.43	1.1 (0.4,3.5)	0.86	1.2 (0.4,3.7)	0.80
Percentage racial/ethnic minority students												
0–32%	Ref		Ref		Ref		Ref		Ref		Ref	
33–65%	1.8 (0.9, 3.5)	0.09	1.7 (0.9,3.4)	0.12	1.4 (0.6,3.2)	0.44	**2.7 (1.1,6.5)**	**0.03**	**2.6 (1.1,6.6)**	**0.04**	2.4 (1.0,5.8)	0.06
66–100%	1.1 (0.5,2.2)	0.85	1.8 (0.8,4.3)	0.17	**4.5 (2.1,9.8)**	< **0.01**	1.0 (0.3,3.1)	0.97	1.1 (0.3,3.5)	0.92	0.9 (0.2,3.1)	0.81

Note. CI = confidence interval; aOR = adjusted odds ratio. Percentages are weighted.
Values in bold indicate significant difference.

[a] Each multivariable logistic regression model included school level, metropolitan status, region, school enrollment, school age, the percentage of students eligible for free or reduced-price meals, and the percentage of racial/ethnic minority students and was conducted among public schools only.

[b] Such as after weekends or school vacations.

[c] During the 12 months before the study, among schools that do not operate their own water system.

Table 3
Prevalence and bivariate associations of water access and water–related education practices by school demographic characteristics in US schools, School Health Policies and Practices Study (SHPPS), 2014.

	Permits students to have a drinking water bottle with them in all school locations (*n* = 575)	Students can purchase bottled water from vending machines or at school stores (*n* = 551)	Offers a free source of drinking water in the cafeteria during meal times[a] (*n* = 503)	Schools in which teachers taught about the importance of water consumption as part of required instruction (*n* = 339)
	% (95% CI)	% (95% CI)	% (95% CI)	% (95% CI)
Overall	74.1 (69.5, 78.3)	34.6 (30.0, 39.4)	88.3 (83.8, 91.6)	81.1 (76.0, 85.3)
School level				
Elementary	72.1 (64.6, 78.6)	15.6 (10.8, 22.0)[e]	88.0 (81.4, 92.5)	78.8 (68.8, 86.2)
Middle	75.8 (68.5, 81.8)	41.9 (34.4, 49.9)[d]	88.3 (79.7, 93.6)	78.0 (68.5, 85.2)
High	77.1 (68.4, 84.0)	72.2 (64.9, 78.6)[d,e]	88.8 (79.5, 94.2)	88.0 (81.6, 92.4)
Chi-square p-value	0.60	**< 0.01**	0.98	0.07
Metropolitan status				
Rural	73.8 (64.9, 81.2)	46.3 (37.7, 55.1)[d,e]	90.2 (82.7, 94.6)	84.2 (75.5, 90.2)
Urban	75.8 (66.4, 83.3)	26.9 (18.8, 36.9)[e]	88.0 (78.4, 93.7)	81.8 (70.4, 89.5)
Suburban	76.7 (68.4, 83.3)	29.9 (22.3, 38.6)[d]	84.4 (74.7, 90.8)	79.2 (68.0, 87.2)
Town	63.9 (51.4, 74.7)	39.7 (27.8, 52.9)	93.8 (71.8, 98.9)	77.8 (65.5, 86.6)
Chi-square p-value	0.33	**0.01**	0.50	0.75
Region				
South	69.8 (61.9, 76.8)[d]	38.8 (30.0, 48.3)	93.1 (86.8, 96.5)	79.4 (69.2, 86.9)
Northeast	66.9 (54.6, 77.2)[e]	31.6 (21.0, 44.5)	82.1 (67.3, 91.1)	78.9 (65.6, 88.0)
Midwest	72.1 (63.6, 79.3)[f]	30.9 (23.3, 39.7)	88.3 (78.0, 94.2)	87.5 (79.8, 92.5)
West	87.2 (79.6, 92.2)[d,e,f]	35.5 (26.9, 45.3)	86.3 (76.9, 92.2)	76.1 (63.4, 85.3)
Chi-square p-value	**< 0.01**	0.62	0.23	0.22
School type				
Public[b]	71.5 (66.3, 76.1)[d]	36.3 (31.3, 41.6)	89.4 (84.8, 92.7)	80.5 (75.3, 84.8)
Private	83.2 (72.7, 90.2)[d]	28.6 (18.4, 41.6)	83.9 (70.0, 92.1)	89.5 (64.2, 97.6)
Chi-square p-value	**0.02**	0.24	0.35	0.26
School enrollment				
30–279	74.4 (67.1, 80.6)	32.5 (25.6, 40.1)	84.4 (76.0, 90.2)	79.6 (69.7, 86.9)
280–517	74.9 (65.3, 82.5)	29.8 (22.8, 37.9)	89.2 (81.1, 94.1)	86.8 (78.1, 92.4)
518–3948	73.1 (66.0, 79.3)	41.2 (33.8, 49.1)	90.3 (83.9, 94.4)	77.4 (68.5, 84.4)
Chi-square p-value	0.94	0.08	0.37	0.17
School age (years)				
1–33	78.2 (71.2, 84.0)	36.6 (29.3, 44.5)	88.8 (82.3, 93.1)	78.2 (69.5, 85.0)
34–57	74.2 (65.1, 81.7)	35.5 (28.2, 43.5)	86.6 (75.7, 93.1)	76.5 (65.8, 84.7)
58–163	72.6 (64.0, 79.7)	34.7 (26.4, 44.1)	85.9 (78.4, 91.1)	87.8 (78.9, 93.2)
Chi-square p-value	0.52	0.95	0.75	0.13
Percentage students eligible for free or reduced-price meals[c]				
0–32%	69.6 (59.6, 77.9)	34.5 (27.6, 42.1)	88.1 (78.8, 93.7)	79.9 (70.7, 86.8)
33–65%	75.2 (66.4, 82.4)	40.9 (33.0, 49.2)	88.7 (81.3, 93.4)	79.4 (69.7, 86.6)
66–100%	63.6 (53.3, 72.7)	34.6 (24.8, 45.8)	90.2 (80.6, 95.3)	78.8 (66.3, 87.5)
Chi-square p-value	0.18	0.42	0.92	0.99
Percentage racial/ethnic minority students[c]				
0–32%	72.5 (65.1, 78.9)	40.2 (33.5, 47.2)	88.1 (81.9, 92.4)	80.2 (72.3, 86.4)
33–65%	68.6 (56.1, 78.9)	33.5 (23.7, 45.1)	88.3 (76.2, 94.7)	81.5 (68.5, 89.9)
66–100%	69.1 (58.4, 78.1)	32.8 (20.8, 47.6)	92.4 (81.5, 97.1)	72.7 (58.6, 83.3)
Chi-square p-value	0.79	0.49	0.62	0.52

Note. Percentages are weighted. CI = confidence interval.
Values in bold indicate significant difference.
[a] Among schools with a cafeteria.
[b] Includes state administered schools.
[c] Among public schools only. Data were not available for private schools.
[d] Estimates with the same number differ according to pairwise *t*-test, $p < 0.05$.
[e] Estimates with the same number differ according to pairwise *t*-test, $p < 0.05$.
[f] Estimates with the same number differ according to pairwise *t*-test, $p < 0.05$.

mechanisms to help schools conduct testing or to remediate issues if they are identified (Wilking, 2017). These types of financial supports are critical. Local taxpayers fund the majority of school building capital construction. Federal funding outlay for school facility improvements is minimal, and state funding roles and responsibilities for facility adequacy and equity vary widely (Filardo, 2016); therefore, inequities in access to safe drinking water may arise if potential water quality issues are identified in communities lacking financial resources for remediation or response.

Nationally, among the schools that conducted voluntary testing during the 12 months before the study, few reported that they communicated test results to faculty and staff (38%), families (23%), or students (16%). Communicating water quality testing results is a recommended best practice by the EPA, both for schools served by municipal water systems and those that operate their own water source (US EPA, 2013a, 2013b). In particular, the EPA recommends that schools that conduct sampling for lead notify relevant stakeholders through press releases, letters, presentations, and websites and make copies of the results available (US EPA, 2006). Clear communications about the quality of water may encourage consumption and help to educate students and staff about the importance of water to health. Communicating the results of water quality testing may also address

Table 4
Multivariable logistic regression of water access and water–related education practices by school demographic characteristics in US public schools, School Health Policies and Practices Study (SHPPS), 2014[a].

	Permits students to have a drinking water bottle with them in all school locations (*n* = 389)		Students can purchase bottled water from vending machines or at school stores (*n* = 371)		Offers a free source of drinking water in the cafeteria during meal times[b] (*n* = 274)		Schools in which teachers taught about the importance of water consumption as part of required instruction (*n* = 258)	
	aOR (95% CI)	p value	aOR (95% CI)	p value	aOR (95% CI)	p value	aOR (95% CI)	p value
School level								
Elementary	Ref		Ref		Ref		Ref	
Middle	1.2 (0.6,2.1)	0.64	**5.7 (3.0,10.8)**	**< 0.01**	1.3 (0.6,3.0)	0.52	1.1 (0.4,2.5)	0.91
High	1.7 (0.9,3.2)	0.09	**19.3 (10.0,37.4)**	**< 0.01**	1.9 (0.7,4.9)	0.18	**2.9 (1.2,6.9)**	**0.02**
Metropolitan status								
Rural	Ref		Ref		Ref		Ref	
Urban	1.0 (0.4,2.3)	0.96	**0.3 (0.1,0.9)**	**0.02**	0.5 (0.1,2.2)	0.39	0.3 (0.1,1.1)	0.07
Suburban	1.6 (0.7,3.5)	0.28	**0.4 (0.2,0.9)**	**0.02**	0.6 (0.2,1.7)	0.32	0.8 (0.3,2.0)	0.57
Town	0.7 (0.3,1.5)	0.33	0.4 (0.2,1.1)	0.08	**11.2 (1.4,91.3)**	**0.02**	0.5 (0.2,1.2)	0.11
Region								
South	Ref		Ref		Ref		Ref	
Northeast	0.9 (0.4,2.2)	0.88	0.6 (0.2,2.1)	0.45	0.5 (0.2,1.7)	0.28	0.5 (0.2,1.3)	0.18
Midwest	1.7 (0.8,3.3)	0.15	0.8 (0.3,1.9)	0.58	0.4 (0.1,1.4)	0.14	1.6 (0.6,4.1)	0.34
West	**3.1 (1.5,6.4)**	**< 0.01**	1.0 (0.4,2.6)	1.0	0.4 (0.1,1.3)	0.12	0.9 (0.3,2.4)	0.84
School enrollment								
30–279	Ref		Ref		Ref		Ref	
280–517	1.8 (0.9,3.8)	0.11	1.1 (0.5,2.2)	0.91	2.3 (0.8,6.2)	0.11	**2.8 (1.0,7.7)**	**0.04**
518–3948	1.5 (0.7,3.0)	0.30	2.1 (0.9,4.8)	0.07	1.6 (0.6,4.8)	0.36	1.4 (0.6,3.5)	0.47
School age (years)								
1–33	Ref		Ref		Ref		Ref	
34–57	1.1 (0.6,2.2)	0.80	1.1 (0.5,2.1)	0.88	2.0 (0.7,5.8)	0.18	1.2 (0.5,2.6)	0.68
58–163	0.9 (0.5,1.7)	0.73	1.6 (0.7,3.3)	0.26	0.7 (0.3,1.6)	0.37	2.0 (0.7,5.5)	0.18
Percentage students eligible for free or reduced-price meals								
0–32%	Ref		Ref		Ref		Ref	
33–65%	1.9 (1.0,3.8)	0.06	1.6 (1.0,2.6)	0.08	0.8 (0.3,2.1)	0.67	1.0 (0.4,2.3)	0.98
66–100%	1.3 (0.6,3.1)	0.50	2.0 (0.8,5.2)	0.13	0.9 (0.2,3.5)	0.91	1.4 (0.4,4.4)	0.59
Percentage racial/ethnic minority students								
0–32%	Ref		Ref		Ref		Ref	
33–65%	1.0 (0.5,2.2)	0.98	0.7 (0.4,1.5)	0.42	1.1 (0.3,3.5)	0.91	1.2 (0.5,3.2)	0.70
66–100%	0.7 (0.3,1.6)	0.44	0.7 (0.2,2.1)	0.55	2.1 (0.5,8.4)	0.30	0.6 (0.2,1.8)	0.37

Note. CI = confidence interval; aOR = adjusted odds ratio. Percentages are weighted.
Values in bold indicate significant difference.
[a] Each multivariable logistic regression model included school level, metropolitan status, region, school enrollment, school age, the percentage of students eligible for free or reduced-price meals, and the percentage of racial/ethnic minority students and was conducted among public schools only.
[b] Among schools with a cafeteria.

concerns among those students who are not confident that the free drinking water at school is clean or safe (Onufrak et al., 2014a).

This study found that the majority of US schools permit students to carry water bottles, offer a free source of drinking water in the cafeteria, and teach about the importance of water consumption as part of required student instruction. These are key strategies to create access to free water, to hydrate students during the school day, and for students to learn about and practice the consumption of water during the school day. Schools may look to available resources, needs assessment tools, implementation strategies, and evaluation guidance to provide supports for promoting access to drinking water as part of a healthy nutrition environment (US CDC, 2014).

This study is subject to several limitations. Although SHPPS procedures were designed to have the most knowledgeable respondent complete a SHPPS questionnaire or module, it is possible there was some under- or over-reporting resulting from poor respondent knowledge or social desirability. Researchers did not review policy content or otherwise verify reported policies and practices. SHPPS data were weighted for probability of selection and nonresponse; however, it was not possible to determine the school characteristics or drinking water-related practices of non-responding schools and subsequent bias associated with nonresponse. The time frame used in the questions about testing drinking water for bacteria, coliforms, and other contaminants was 12 months. It was possible that schools tested for these contaminants, but not within the 12 months preceding the study.

5. Health implications

In US schools, water availability and education-related practices are more common than some water quality-related practices. Schools may benefit by engaging external and community partners in developing or supporting their drinking water program (US EPA 2006). There is no known safe level of exposure to lead, and lead exposure has documented negative impacts on health, particularly in young children (US EPA, 2012). Therefore, strategies and actions to ensure the quality and safety of drinking water in schools is a public health priority, particularly for students with exposure to environmental sources of lead in other settings. Studies of the potential impacts on blood-lead levels of students consuming lead-contaminated water in school settings (Deshommes et al., 2016), and likely risk reductions due to the implementation of lead remediation strategies such as flushing drinking water outlets (Triantafyllidou et al., 2014), suggest that increasing access to safer water in schools could have quantifiable health benefits. This study's findings indicate that for many schools, recommended water quality testing, training, and communication strategies may be limited and significant efforts could be made to support these practices in all communities.

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Declaration of competing financial interest

The authors declare they have no actual or potential competing financial interests.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.pmedr.2019.100823.

References

Anon, 2016. Final Rule: National School Lunch Program and School Breakfast Program: Nutrition Standards for All Foods Sold in School as Required by the HHFKA of 2010. Available from: https://www.federalregister.gov/articles/2016/07/29/2016-17227/national-school-lunch-program-and-school-breakfast-program-nutrition-standards-for-all-foods-sold-in (cited August 20, 2018).

ASCD, Centers for Disease Control and Prevention, 2014. Whole school, whole community, whole child: a collaborative approach to learning and health. Alexandria, VA. http://www.ascd.org/ASCD/pdf/siteASCD/publications/wholechild/wscc-a-collaborative-approach.pdf.

Balazs, C.L., Ray, I., 2014. The drinking water disparities framework: on the origins and persistence of inequities in exposure. Am. J. Public Health 104, 603–611. https://doi.org/10.2105/AJPH.2013.301664. (Epub 2014 Feb 13. PMID: 24524500).

Bogart, L.M., Babey, S.H., Patel, A.I., Wang, P., Schuster, M.A., 2016. Lunchtime school water availability and water consumption among California adolescents. J. Adolesc. Health 58, 98–103. (PMID:26552740PMCID: PMC4695239). https://doi.org/10.1016/j.jadohealth.2015.09.007.

Cradock, A.L., Wilking, C.L., Olliges, S.A., Gortmaker, S.L., 2012. Getting back on tap the policy context and cost of ensuring access to low-cost drinking water in Massachusetts schools. Am. J. Prev. Med. 43, S95–S101. 22898169. https://doi.org/10.1016/j.amepre.2012.05.016.

Deshommes, E., Andrews, R.C., Gagnon, G., McCluskey, T., McIlwain, B., Dore, E., et al., 2016. Evaluation of exposure to lead from drinking water in large buildings. Water Res. 99, 46–55. 27132198. https://doi.org/10.1016/j.watres.2016.04.050.

Everett Jones, S., Axelrad, R., Wattigney, W.A., 2007. Healthy and safe school environment, part II, physical school environment: results from the School Health Policies and Programs Study 2006. J. Sch. Health 77, 544–556. (PMID: 17908107). https://doi.org/10.1111/j.1746-1561.2007.00234.x.

Filardo, M., 2016. State of our schools: America's K–12 facilities 2016. Washington, D.C.:21st Century School Fund. https://centerforgreenschools.org/state-our-schools.

Giles, C.M., Kenney, E.L., Gortmaker, S.L., Lee, R.M., Thayer, J.C., Mont-Ferguson, H., et al., 2012. Increasing water availability during afterschool snack evidence, strategies, and partnerships from a group randomized trial. Am. J. Prev. Med. 43, S136–S142. (PMID: 22898163). https://doi.org/10.1016/j.amepre.2012.05.013.

Hood, N.E., Turner, L., Colabianchi, N., Chaloupka, F.J., Johnston, L.D., 2014. Availability of drinking water in US public school cafeterias. J. Acad. Nutr. Diet. 114, 1389–1395. 24726348. https://doi.org/10.1016/j.jand.2014.02.001.

Healthy People 2020, 2018. Washington, DC: U.S. Department of Health and Human Services, Office of Disease Prevention and Health Promotion. Available from. https://www.healthypeople.gov/node/4298/data_details (August).

Kenney, E.L., Long, M.W., Cradock, A.L., Gortmaker, S.L., 2015a. Prevalence of inadequate hydration among us children and disparities by gender and race/ethnicity: National Health and Nutrition Examination Survey, 2009–2012. Am. J. Public Health 105, E113–E118. 26066941. PMC4504329. https://doi.org/10.2105/AJPH.2015.302572.

Kenney, E.L., Gortmaker, S.L., Carter, J.E., Howe, M.C.W., Reiner, J.F., Cradock, A.L., 2015b. Grab a cup, fill it up! An intervention to promote the convenience of drinking water and increase student water consumption during school lunch. Am. J. Public Health 105, 1777–1783. 26180950. PMC4539814. https://doi.org/10.2105/AJPH.2015.302645.

Kenney, E.L., Gortmaker, S.L., Cohen, J.F.W., Rimm, E.B., Cradock, A.L., 2016. Limited school drinking water access for youth. J. Adolesc. Health 59, 24–29. (PMID: 27235376 PMCID: PMC4920716). https://doi.org/10.1016/j.jadohealth.2016.03.010.

Lee, R.M., Okechukwu, C., Emmons, K.M., Gortmaker, S.L., 2014. Impact of implementation factors on children's water consumption in the out-of-school nutrition and physical activity group-randomized trial. New Dir. Youth Dev. 79–101. (PMID: 25530242 PMCID: PMC5497835). https://doi.org/10.1002/yd.20105.

Muckelbauer, R., Gortmaker, S.L., Libuda, L., Kersting, M., Clausen, K., Adelberger, B., et al., 2016. Changes in water and sugar-containing beverage consumption and body weight outcomes in children. Br. J. Nutr. 115, 2057–2066. 27040694. https://doi.org/10.1017/S0007114516001136.

Onufrak, S.J., Park, S., Sharkey, J.R., Merlo, C., Dean, W.R., Sherry, B., 2014a. Perceptions of tap water and school water fountains and association with intake of plain water and sugar-sweetened beverages. J. Sch. Health 84, 195–204. 24443781. PMC4559844. https://doi.org/10.1111/josh.12138.

Onufrak, S.J., Park, S., Wilking, C., 2014b. Student-reported school drinking fountain availability by youth characteristics and state plumbing codes. Prev. Chronic Dis. 11 (11). https://doi.org/10.5888/pcd11.130314. (PMID:24742393 PMCID: PMC3992292).

Patel, A.I., Hecht, K., Hampton, K.E., Grumbach, J.M., Braff-Guajardo, E., Brindis, C.D., 2014. Tapping into water: key considerations for achieving excellence in school drinking water access. Am. J. Public Health 104, 1314–1319. 24832141. PMC4056210. https://doi.org/10.2105/AJPH.2013.301797.

Patel, A.I., Grummon, A.H., Hampton, K.E., Oliva, A., McCulloch, C.E., Brindis, C.D., 2016. A trial of the efficacy and cost of water delivery systems in San Francisco bay area middle schools, 2013. Prev. Chronic Dis. 13https://doi.org/10.5888/pcd13.160108. (PMID: 27390074 PMCID: PMC4951080).

Popkin, B.M., D'Anci, K.E., Rosenberg, I.H., 2010. Water, hydration, and health. Nutr. Rev. 68, 439–458. 20646222. PMC2908954. https://doi.org/10.1111/j.1753-4887.2010.00304.x.

Sadler, R.C., LaChance, J., Hanna-Attisha, M., 2017. Social and built environmental correlates of predicted blood lead levels in the Flint water crisis. Am. J. Public Health 107, 763–769. 28323469. https://doi.org/10.2105/AJPH.2017.303692.

Strosnider, H., Kennedy, C., Monti, M., Yip, F.Y., 2017. Rural and urban differences in air quality, 2008-2012, and community drinking water quality, 2010-2015-United States. Morb. Mortal. Wkly. Rep. Surveill. Summ. 66, 1–10. (PMID: 28640797 PMCID: PMC5829865). 10.15585/mmwr.ss6613a1.

Triantafyllidou, S., Le, T., Gallagher, D., Edwards, M., 2014. Reduced risk estimations after remediation of lead (pb) in drinking water at two us school districts. Sci. Total Environ. 466, 1011–1021. (PMID: 23988746). https://doi.org/10.1016/j.scitotenv.2013.07.111.

US CDC (Centers for Disease Control and Prevention), 2014. Increasing Access to Drinking Water in Schools. US Department of Health and Human Services Centers for Disease Control and Prevention, Atlanta, GA.

US CDC (Centers for Disease Control and Prevention), 2015. Results From the School Health Policies and Practices Study, 2014. US Department of Health and Human Services Centers for Disease Control and Prevention, Atlanta, GA.

US EPA (Environmental Protection Agency), 2006. 3Ts for reducing lead in drinking water in schools: Revised technical guidance. Washington, DC: United States Environmental Protection Agency. https://www.epa.gov/sites/production/files/2015-09/documents/toolkit_leadschools_guide_3ts_leadschools.pdf.

US EPA (Environmental Protection Agency), 2012. Integrated science assessment (ISA) for lead (third external review draft, Nov 2012). Washington, DC: Environmental Protection Agency. https://www.epa.gov/isa/integrated-science-assessment-isa-lead.

US EPA (Environmental Protection Agency), 2013a. Drinking Water Best Management Practices for Schools and Child Care Facilities Served by Municipal Water Systems. Environmental Protection Agency, Washington, DC.

US EPA (Environmental Protection Agency), 2013b. Drinking Water Best Management Practices for Schools and Child Care Facilities With Their Own Drinking Water Source. Environmental Protection Agency, Washington, DC.

US Government Accountability Office, 2006. Drinking water: EPA should strengthen ongoing efforts to ensure that consumers are protected from lead contamination, GAO-06-148. Washington, D.C. https://www.gao.gov/assets/250/248883.pdf.

Wilking, C., 2017. Developing state policy recommendations for safe drinking water procurement in child care centers and schools. Boston, MA:Public Health Advocacy Institute. https://www.phaionline.org/2017/12/20/developing-state-policy-recommendations-for-safe-drinking-water-procurement-in-child-care-centers-and-schools/.

Wilking, C.L., Cradock, A.L., Gortmaker, S.L., 2015. Harnessing the public health power of model codes to increase drinking water access in schools and childcare. J. Law Med. Ethics 43, 69–72. 25846169. https://doi.org/10.1111/jlme.12220.

Zartarian, V., Xue, J.P., Tornero-Velez, R., Brown, J., 2017. Children's lead exposure: a multimedia modeling analysis to guide public health decision-making. Environ. Health Perspect. 125 (10). https://doi.org/10.1289/EHP1605. (PMID: 28934096 PMCID: PMC5915183). https://ehp.niehs.nih.gov/EHP1605/.