Obesity

Cost-Effectiveness of Water Promotion Strategies in Schools for Preventing Childhood Obesity and Increasing Water Intake

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Objective: This study aimed to estimate the cost-effectiveness and impact on childhood obesity of installation of chilled water dispensers ("water jets") on school lunch lines and to compare water jets' cost, reach, and impact on water consumption with three additional strategies.
Methods: The Childhood Obesity Intervention Cost Effectiveness Study (CHOICES) microsimulation model estimated the cost-effectiveness of water jets on US childhood obesity cases prevented in 2025. Also estimated were the cost, number of children reached, and impact on water consumption of the installation of water jets and three other strategies.
Results: Installing water jets on school lunch lines was projected to reach 29.6 million children (95% uncertainty interval [UI]: 29.4 million-29.8 million), cost \$4.25 (95% UI: \$2.74-\$5.69) per child, prevent 179,550 cases of childhood obesity in 2025 (95% UI: 101,970-257,870), and save \$0.31 in health care costs per dollar invested (95% UI: \$0.15-\$0.55). In the secondary analysis, installing cup dispensers next to existing water fountains was the least costly but also had the lowest population reach.
Conclusions: Installating water jet dispensers on school lunch lines could also save almost half of the dollars needed for implementation via a reduction in obesity-related health care costs. School-based interventions to promote drinking water may be relatively inexpensive strategies for improving child health.

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Introduction

Reducing children's sugar-sweetened beverage (SSB) intake is critical for addressing the ongoing childhood obesity epidemic (1-3). While policies limiting SSBs in US school settings have been implemented (4,5), less attention has been paid to promoting water consumption, which would satisfy thirst without increasing energy intake. Beyond the benefit of reducing excess caloric intake, water promotion could also support improved hydration status (6), thereby improving well-being and cognitive function (7-9). Increased fluoridated water intake could also prevent dental caries (10).

Interventions promoting water consumption in schools have shown promising results for increasing water intake. In schools with existing water sources, poster campaigns (11,12), providing cups to make water more accessible (13,14), and providing updated drinking water infrastructure (12,13,15,16) have all been shown to increase water intake in schools. Improving school water access can promote healthy weight (17,18), potentially by displacing SSBs with water (14,19), thus reducing excess energy intake (20).

Despite the potential for school-based water interventions to improve student health, student water access is currently limited in school settings, and therefore there is substantial room for improvement (21). Based on the literature to date, it is unclear whether increasing efforts to improve school drinking water access would reduce childhood obesity, what the costs of such approaches would be, and what types of strategies may be the most cost-effective. Although a cost-effectiveness analysis of a school strategy promoting water consumption for obesity prevention was recently conducted by An et al. (22), that analysis failed to include several implementation costs and also projected changes in obesity in the population over an individual's lifetime, potentially underestimating the full costs of implementing such a strategy and obscuring short-term health outcomes and costs; additionally, only a single strategy was considered, and impacts on water intake itself were not considered. This paper seeks to improve our understanding of the

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potential population-wide benefits related to improved hydration and childhood obesity prevention that could result from widespread implementation of different strategies to improve tap water infrastructure in schools, using a comprehensive strategy for identifying implementation costs and a conservative 10-year time frame to better understand shorter-term outcomes and costs. We utilize a microsimulation model to evaluate the cost, number of children reached, and per capita change in water consumption that would be expected from four different strategies to promote water in schools, identified from a systematic evidence review. Additionally, for the one of the four studies with evidence for impact on children's BMI, we estimate the number of cases of obesity prevented and health care cost savings per dollar invested that would be expected.

Methods

Evidence review and identification of modeled strategies

In 2017, to identify evidence for strategies for increasing water intake during the school day, we used the Childhood Obesity Intervention Cost Effectiveness Study (CHOICES) systematic review process (23,24) to search for peer-reviewed studies of interventions focused on promoting water consumption in schools. After identifying strategies with evidence for health impact, we engaged a group of national stakeholders in the selection of intervention strategies. Consistent with the GRADE (Grading of Recommendations, Assessment, Development and Evaluation) approach used by Cochrane (25), we included evaluations using experimental designs (including randomized controlled trials and natural experiments). Our search was guided by a conceptual model that posited that a policy or programmatic change to the school drinking water environment would positively impact student water intake, which would then reduce BMI through the displacement of sugary beverage intake (Figure 1). For the analysis of the impact on water intake, we included studies that examined measured changes in water intake as a primary outcome. For the analysis estimating the impact on childhood obesity, we only included studies that examined energy intake, weight, or BMI as an outcome. We focused on studies of interventions in US public schools to ensure that the interventions could be translated easily to a US school context.

From the initial search, 2,027 nonduplicate references were retrieved; of these, 111 article abstracts were reviewed for relevance, 11 papers were reviewed in full, and 4 studies were identified that estimated the effectiveness of potential policy strategies (Figure 2). One study conducted in the US utilized BMI as an outcome (the "water jets" study) (18), which was used to model impacts on childhood obesity. The other two studies, describing three strategies between them (13,14), did not measure impacts on energy intake, weight, or BMI (and thus could not be modeled for obesity impact) but did demonstrate impacts on water intake. These studies were used in the analysis of water intake, costs, and population reach comparisons only.

Interventions

All four drinking water interventions examined in this study were modeled as nationally implemented water promotion strategies to supplement the Healthy Hunger Free Kids Act (HHFKA) drinking water requirements, which specify that schools participating in the National School Lunch Program (NSLP) must provide free, potable water sources in places where meals are served. We estimated the impact of the interventions among students in kindergarten through eighth grade (K-8) attending schools that participate in the NSLP (about 64,956 schools) and thus would be subject to the HHFKA drinking water requirements. Based on an estimate that 7% of public schools do not have access to safe, potable tap water (26), we assumed that 93% of NSLP-participating schools (approximately 60,409 schools) would have viable plumbing allowing safe access to drinking water and would be eligible to implement the interventions. Table 1 provides detailed parameter inputs on cost, reach, and effects.

Interventions for analysis of cost-effectiveness and impact on water intake only

- **Grab a Cup, Fill it Up:** This strategy, evaluated in Boston Public Schools, involves the placement of promotional signage and permanent cup dispensers stocked with recyclable, disposable cups next to existing cafeteria drinking fountains (14). We assumed that, among the 93% of NSLP-participating schools with viable access to safe tap water (26), 45.7% (about 27,607 schools) would have existing tap water sources inside the school cafeteria (27). We accounted for the costs of training food service directors, installation and maintenance of cup dispensers and signs, increased tap water and disposable cup usage, and ongoing lead testing and remediation. We assumed that 100% of eligible K-8 schools would implement the intervention.

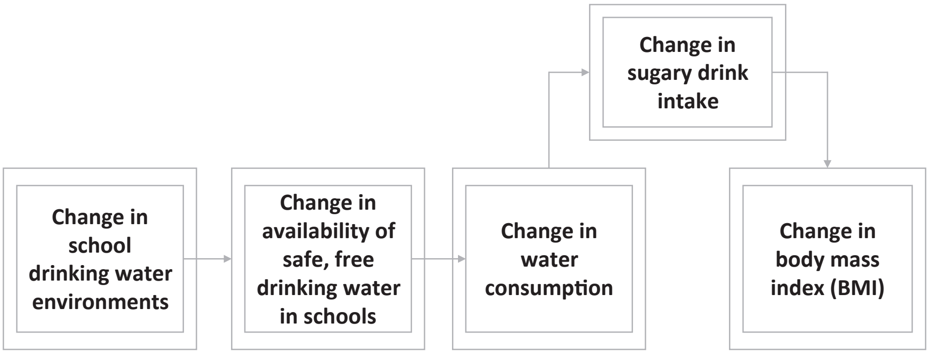

Figure 1 Conceptual model of pathways from school drinking water policies to childhood obesity.

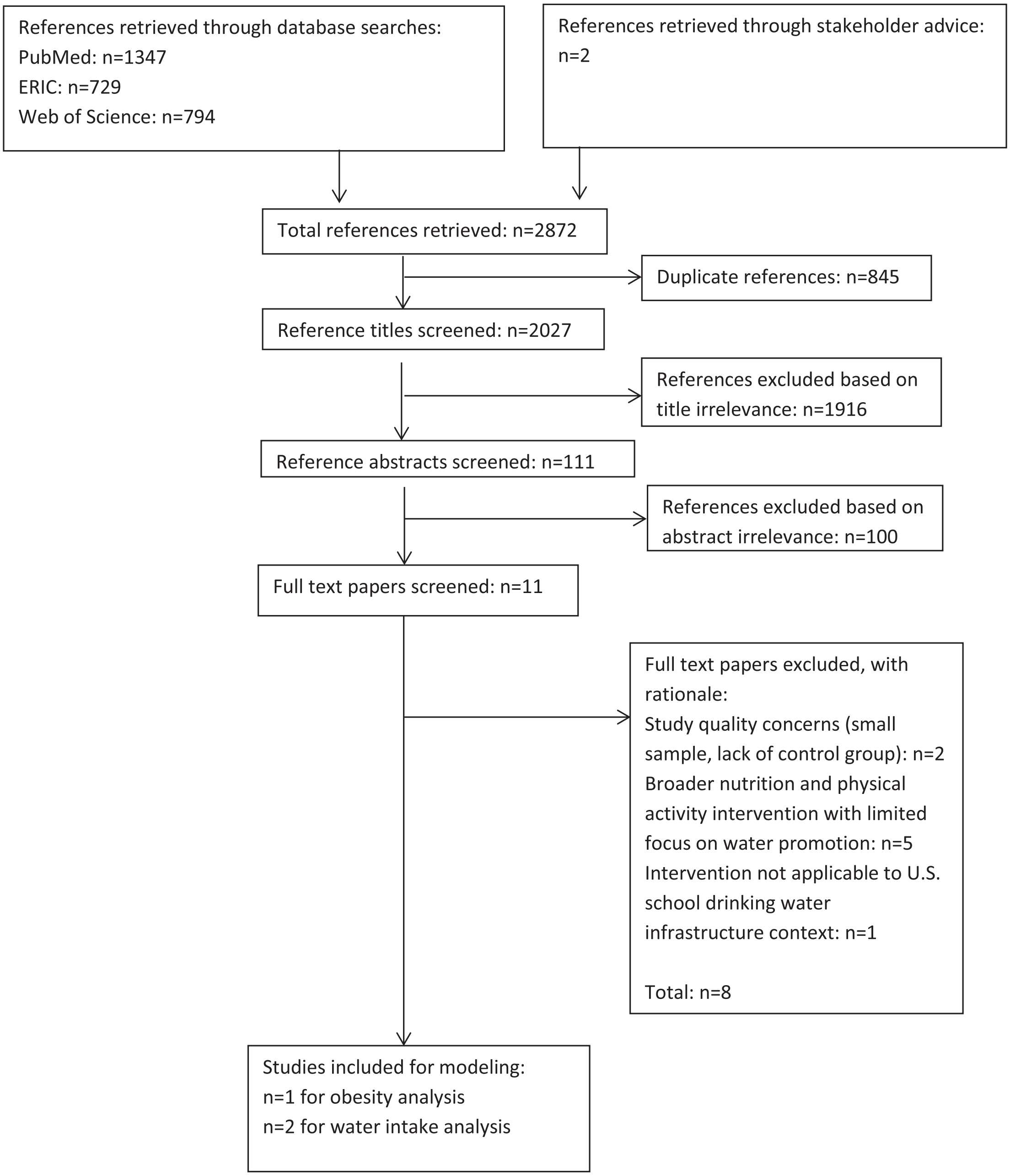

Figure 2 Summary of search for evidence and selection of papers for review.

- **Portable water dispensers:** This strategy, evaluated in the San Francisco Bay Area, involves setting up portable tap water dispensers in school cafeterias (i.e., plastic jugs with spigots), providing free disposable cups, and implementing at least 6 weeks of promotional activities that encourage students to drink water at school (13). We accounted for costs of training food service directors, purchase and maintenance of portable dispensers and cups, increased tap water and electricity usage, promotional campaign material and time, and ongoing lead testing and remediation. We assumed that 100% of eligible K-8 schools would implement the intervention.
- **Bottle-less water coolers:** This strategy, which also was evaluated in the trial of portable dispensers, involves placing Culligan (Rosemont, Illinois, USA) "bottle-less" water coolers in school cafeterias (i.e., filtered tap water dispensers, hooked up to a tap water source, that distributed chilled tap water), as well as disposable cups and the same promotional campaign as distributed with the portable water dispensers (13). We accounted for costs of training food service directors, purchase and maintenance of bottle-less cooler units and cups, increased tap water and electricity usage, and ongoing lead testing and remediation. We assumed that 100% of eligible K-8 schools would implement the intervention.

TABLE 1 Estimates utilized for modeling effect, reach, and cost of four school-based drinking water promotion interventions

	Water jets	Cup dispensers with existing water fountains	Portable tap water dispensers plus promotion	Bottle-less water coolers plus promotion
Effect				
Average change in BMI *z* score because of intervention	Boys: −0.025 (95% CI: −0.038 to −0.011) Girls: −0.022 (95% CI: −0.035 to −0.008) (18)	NA—no direct effect of intervention on BMI	NA—no direct effect of intervention on BMI	NA—no direct effect of intervention on BMI
Reach				
Target population: Children attending K-8 public schools in the US	Derived from model			
Relevant population: Proportion attending K-8 school participating in the NSLP	0.969 (33)	0.969 (33)	0.969 (33)	0.969 (33)
Eligible population: Proportion attending a school with viable plumbing	0.93 (26)	0.93 (26)	0.93 (26)	0.93 (26)
Proportion attending a school with existing tap water source in cafeteria	NA	0.457 (27)	NA	NA
Proportion of students drinking water as a result of intervention	0.22 (16)	0.094 (14)	0.189 (13)	0.107 (13)
Costs				
Developing and implementing an online training module for food service staff	$15,000, one time (personal communication, Massachusetts Department of Public Health, 3/11/15)	$15,000, one time (personal communication, Massachusetts Department of Public Health, 3/11/15)	$15,000, one time (personal communication, Massachusetts Department of Public Health, 3/11/15)	$15,000, one time (personal communication, Massachusetts Department of Public Health, 3/11/15)
School FSD time to complete initial training	0.5 hour per school (assumption)	0.5 hour per school (assumption)	0.5 hour per school (assumption)	0.5 hour per school (assumption)
School FSD time to complete annual compliance paperwork	1 hour per school (assumption)	1 hour per school (assumption)	1 hour per school (assumption)	1 hour per school (assumption)
School FSD hourly wage	$26.75 (30)	$26.75 (30)	$26.75 (30)	$26.75 (30)
NSLP state administrator annual time to review compliance paperwork	20 minutes per school (assumption)	20 minutes per school (assumption)	20 minutes per school (assumption)	20 minutes per school (assumption)
NSLP state administrator hourly rate	$55.11 (30)	$55.11 (30)	$55.11 (30)	$55.11 (30)
School cafeteria worker time to clean new water units	Range: $333 (16) to $2,054.20 (13) annually	NA	Range: $525 (26) to $2,054.20 (13) annually	$595.70 annually (13)
Cost of water dispenser unit	$1,204.60 (includes table or cart for dispenser to rest on) (18)	NA	$204.60 (includes food cart for transporting) (13)	$345 (13)
Installation costs per water dispenser unit	$1,500 (26)	NA	NA	NA
Annual incremental electricity costs for water dispenser unit	$140 (26)	NA	Range: $0 (26) to $435.50 (13)	$1,562.10 (13)
Number of new units installed per school	1.16 (27)	NA	1.16 (27)	1.16 (27)
Cost of cup dispenser and installation (replaced annually)	NA	$173 (14)	NA	NA

TABLE 1. (continued).

	Water jets	Cup dispensers with existing water fountains	Portable tap water dispensers plus promotion	Bottle-less water coolers plus promotion
Number of cup dispensers needed per school	NA	3.5 (assumption)	NA	NA
Cost of promotion per school per year	NA	$48 ($11.99 per poster for 4 promotional posters) (14)	$155.40 (13)	$155.40 (13)
Lead testing and remediation, cost per every 5 years per school	Range: $47.60 (13) to $258 (26)	Range: $47.60 (13) to $258 (26)	Range: $47.60 (13) to $258 (26)	Range: $47.60 (13) to $258 (26)
Number of eligible schools	60,409 (26,33)	27,606 (14,26,33)	60,409 (26,33)	60,409 (26,33)
Cost per disposable cup used	$0.03 (14)	$0.03 (14)	$0.03 (14)	$0.03 (14)
Cost per ounce of tap water	$0.0001015625 (26)	$0.0001015625 (26)	$0.0001015625 (26)	$0.0001015625 (26)
Number of ounces consumed per student per day	1.43 (Harvard T.H. Chan School of Public Health Prevention Research Center and Boston Public Schools, unpublished data, 2013)	0.58 (14)	1.0 (13)	1.5 (13)

FSD, food service director; NA, not applicable; NSLP, National School Lunch Program.

Intervention for analysis of cost-effectiveness, impact on childhood obesity, and impact on water intake

- **Installation of water jet dispensers on school cafeteria lunch lines.** This strategy, implemented by New York City Schools, involves the installation of water jet dispensers (chilled, easy-to-use water dispensers that can be used to fill cups or bottles) on school cafeteria lunch lines (16,18). We modeled the installation of water jets in school cafeterias nationwide at schools with viable plumbing participating in the NLSP serving K-8 students. We accounted for the costs of training school food service directors; purchasing, installing, cleaning, and maintaining dispensers; increased tap water, electricity, and disposable cup usage; and ongoing lead testing and remediation. We used sex-stratified estimates of the water jets installation's impact on BMI z score from a natural experiment among K-8 students in New York City, which found that girls' BMI z scores decreased, on average, by −0.022 units (95% CI: −0.035 to −0.008), while boys' decreased by −0.025 units (95% CI: −0.038 to −0.011) as a result of the intervention (18). In a sensitivity analysis, we also modeled a scenario in which only 39.3% of eligible schools participated, based on the original water jets participation rate in New York City. We also explored whether the model results would change if we utilized a secondary, more conservative model of effect presented in the original water jets evaluation.

Microsimulation modeling development

We used the CHOICES microsimulation model (23,28) to estimate costs, population reach, and water intake for the four strategies for the US population from 2015 to 2025. Additionally, for the analysis of obesity outcomes for the water jets intervention, we used the model to estimate health outcomes and health care cost savings related to childhood obesity for the same population and time frame. The model simulated the experiences of individuals in the US population related to weight gain, BMI, health, and health care costs from 2015 to 2025, accounting for projected population growth. Effect sizes for the impact of various interventions on body composition or energy balance were identified from the literature and applied to the model's simulated population in order to project how children's individual growth trajectories would shift as a result of experiencing such an impact. The growth of each simulated individual was projected for a 10-year period, and then the total costs, population reach, and impact on childhood obesity were estimated across that 10-year period. A 10-year time period was chosen both because of uncertainty about the long-term stability of intervention effects on childhood obesity and because a shorter time period tends to be more relevant for policy makers, particularly elected officials. Uncertainty in the original effect size was taken into account, as were variations in individuals' baseline body composition and likelihood of experiencing different growth trajectories. To estimate the likely growth trajectories for each simulated individual (under both the no-intervention and intervention scenarios), the model utilized data on demographic characteristics, growth, health behaviors, and obesity risk from multiple national data sets, including the US Census, the American Community Survey, the National Survey of Children's Health, the National Health and Nutrition Examination Survey, the Early Childhood Longitudinal Study-kindergarten cohort, and the Behavioral Risk Factor Surveillance System; more details on the trajectory development have been published elsewhere (28). To account for uncertainty in model inputs, we calculated the 95% uncertainty interval (UI), using 1,000 Monte Carlo iterations for a simulated population of 1 million individuals representative of the national population. A visual representation of the model is presented in Figure 3.

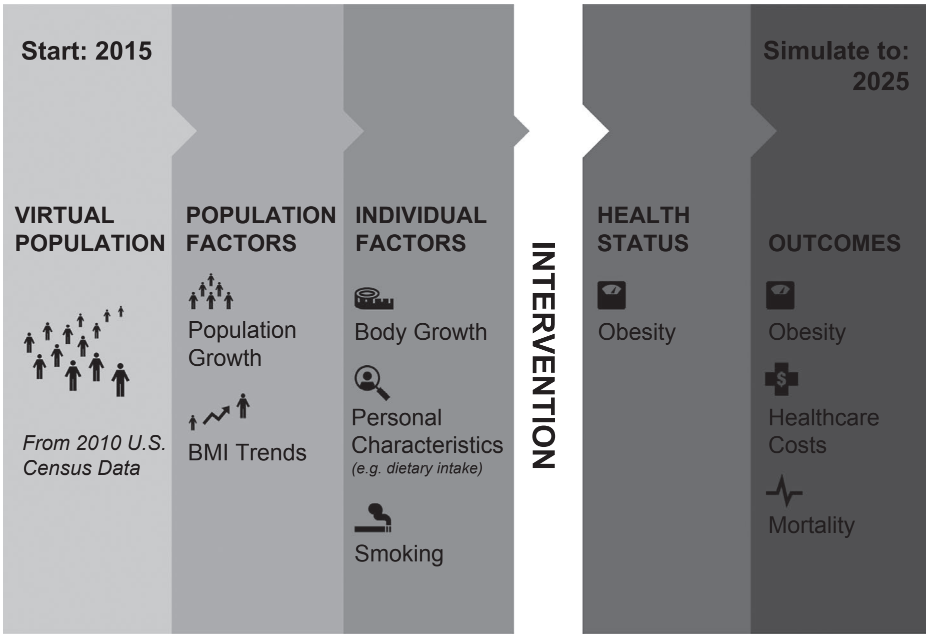

Figure 3 Visual representation of CHOICES microsimulation modeling approach.

Intervention cost calculation

We identified each potential cost associated with implementation using a costing protocol following standard guidelines for resource identification, measurement, and valuation (29), using cost estimates from peer-reviewed evaluations of the interventions when possible (Table 1) (13,14,16,18). We used a modified societal perspective to account for all implementation costs (including opportunity costs) regardless of payer, except for the time for each child to engage in the intervention. All costs were calculated in 2015 dollars, and future costs were discounted at 3% annually. Labor costs were estimated using the Bureau of Labor Statistics; we assumed a fringe rate of 45.56% (30).

Outcomes

For all four strategies, we estimated the annual intervention cost per person, the total number of individuals reached by the intervention, the total costs of the intervention over the 10-year modeling period, and the cost per increased ounce of water consumed. For the analysis of the impact of water jets on childhood obesity, we used the microsimulation model to estimate the expected reductions in BMI because of implementing the water jets strategy and the number of cases of childhood obesity prevented in the year 2025. We also estimated annual health care cost savings based on published estimates of the health care cost associated with obesity among children and adults (23,31). All analyses were conducted from 2017 to 2018.

Results

Comparing cost, reach, and cost per ounce of water consumed with four water promotion strategies

Because we conceptualized the water jets, portable dispenser, and bottle-less water cooler strategies as reaching students in all K-8 school buildings with viable plumbing, all three were estimated to reach far more children (29.6 million in the first year; 95% UI: 29.4 million-29.7 million) than the Grab a Cup, Fill it Up strategy (13.5 million in the first year; 95% UI: 13.4 million-13.6 million), which is applicable only in school buildings with existing tap water sources inside the cafeteria, estimated to be less than 50% of schools (Table 2).

Over 10 years, the water jets intervention would cost \$1.255 billion (95% UI: \$809.9 million-\$1.683 billion) compared with \$121.9 million (\$93.4 million-\$149.4 million) to implement Grab a Cup, Fill it Up; \$1.223 billion (95% UI: \$802.2 million-\$1.638 billion) to implement portable tap water dispensers nationwide; and \$1.465 billion (95% UI: \$1.453 billion-\$1.477 billion) to install bottle-less water coolers. Although the lower total implementation cost for Grab a Cup, Fill it Up was partially due to its lower total population reach, the intervention was also found to be less costly per child reached (Table 2), in part because it required minimal labor for maintenance and also required no investment in new water infrastructure. Similarly, although Grab a Cup, Fill it Up was estimated to have the lowest impact on water consumption, with an increase of 0.58 oz water consumed per child per day, it was also estimated to cost the least per ounce of water increased, at \$0.005 per ounce per child per day (95% UI: \$0.003-\$0.01). The three remaining water strategies, all involving the purchasing of new types of water dispensers, were estimated to have similar costs per ounce of increased water consumption (Table 2).

Effect on childhood obesity and cost-effectiveness with water jets

We estimated that the water jets strategy would prevent 179,550 cases of childhood obesity (95% UI: 101,970-257,870) in 2025 in the primary scenario of 100% participation by eligible schools compared with no intervention implementation (Table 3); in the secondary scenario of a 39.3% reach, we estimated that 70,427 cases would be

TABLE 2 Comparing short-term and 10-year costs, population reach, cost per child, and cost per increased ounce of water consumed with four school cafeteria-based water promotion strategies (mean [95% UI])

	Water jets	Cup dispensers with existing water fountains	Portable tap water dispensers plus promotion	Bottle-less water coolers plus promotion
10-year costs and reach				
Total costs	$1.255 billion ($809.9 million to $1.683 billion)	$121.9 million ($93.4 million to $149.4 million)	$1.223 billion ($802.2 million to $1.638 billion)	$1.465 billion ($1.453 billion to $1.477 billion)
Website development for training FSDs	$15,000	$15,000	$15,000	$15,000
Training time for FSDs	$1,130,800	$516,800	$1,130,800	$1,130,800
Compliance paperwork review	$13,463,000	$4,614,400	$13,463,000	$13,463,000
Compliance paperwork preparation	$19,604,000	$2,239,700	$19,604,000	$19,604,000
Purchasing/installing water dispenser units	$198,195,300	$42,555,900	$52,366,800	$ 45,803,700
Electricity costs	$92,326,600	NA	$118,096,400	$831,225,400
Labor costs for maintaining units	$643,885,600	NA	$688,009,400	$316,984,200
Promotion costs	NA	$11,587,000	$82,691,500	$82,691,500
Lead testing and remediation	$17,339,000	$7,954,600	$17,339,000	$17,436,400
Cup costs	$262,670,500	$51,295,900	$225,676,800	$130,035,200
Extra water costs	$6,283,000	$1,164,300	$4,394,100	$6,591,200
Total number of children reached	56.0 million (55.5 million to 56.5 million)	25.6 million (25.3 million to 25.8 million)	56.0 million (55.5 million to 56.5 million)	56.0 million (55.5 million to 56.5 million)
First-year costs and cost-effectiveness for water consumption				
Cost per child	$4.25 ($2.74 to $5.69)	$0.90 ($0.69 to $1.11)	$4.14 ($2.72 to $5.55)	$4.96 ($4.90 to $5.01)
Estimated ounces of water increased per child per day	1.43 (0.58 to 2.27)	0.58 (0.25 to 0.88)	1.0 (–0.15 to 2.17)	1.5 (–1.74 to 4.71)
Annual cost per ounce of water increased per child per day	$1.62 ($0.72 to $3.96)	$0.90 ($0.54 to $1.80)	$1.80 (–$14.40 to $10.80)	$3.60 (–$14.40 to $19.80)

FSD, food service director; NA, not applicable.

TABLE 3 Estimated 10-year cost-effectiveness and economic outcomes for obesity prevention for the water jets school-based intervention to promote drinking water (mean [95% UI])

	Primary scenario: 100% of eligible schools adopt	Secondary scenario: 39.3% of eligible schools adopt
Children reached by the intervention	56.0 million (55.5 million-56.5 million)	22.0 million (21.7 million-22.2 million)
Implementation costs	$1.255 billion ($809.9 million-$1.683 billion)	$492.4 million ($318.2 million-$659.8 million)
Health care cost savings	$388.8 million ($217.3 million-$560.1 million)	$152.4 million ($84.2 million-$219.6 million)
Net costs	$866.2 million ($384.5 million-$1.342 billion)	$340.0 million ($149.1 million-$528.1 million)
Total cases of childhood obesity prevented in 2025	179,550 (101,980-257,870)	70,430 (39,830-101,220)
Childhood obesity percent reduction	0.24% (0.14%-0.35%)	0.10% (0.05%-0.14%)
Cost per case of childhood obesity prevented in 2025	$6,542 ($1,741-$11,918)	$6,546 ($1,733-$11,883)
Health care cost savings per dollar invested	$0.31 ($0.15-$0.55)	$0.31 ($0.15-$0.55)
Cost per BMI unit reduced	$105.29 ($58.24-$210.61)	$105.43 ($58.35-$210.95)

prevented (95% UI: 39,829-101,221). The water jets strategy would cost $6,542 per case of childhood obesity prevented in 2025 (95% UI: $1,741-$11,918) under both implementation scenarios. Installation of water jets nationwide would result in $388.8 million ($217.3 million-$560.1 million) in health care cost savings in the primary scenario and $152.4 million in the secondary scenario; both scenarios would result in a health care cost savings per dollar invested of $0.31 (95% UI: $0.15-$0.55). Utilizing the secondary, more conservative analysis of water jets effects did not appreciably change the results (results not shown).

Discussion

This study identified several intervention strategies that were effective at increasing water intake at a low cost per student. Estimates of the cost per ounce of increased daily water intake per child ranged from a fraction of a cent for the Grab a Cup, Fill it Up intervention to $0.02 for the bottle-less water coolers. The study also suggests that the installation of water jets machines on school lunch lines would be an effective public health strategy to prevent childhood obesity on a large scale if implemented nationally.

The cost-effectiveness of the water jets strategy to reduce childhood obesity compares favorably with several other proposed school-based obesity prevention strategies evaluated using the same cost-effectiveness modeling methods (23,24,32). The water jets strategy was estimated to prevent nearly 180,000 cases of childhood obesity in 2025, costing about $105.29 per BMI unit reduced. Although new school nutrition policies related to the HHFKA (specifically the Smart Snacks policy to improve the nutritional content of competitive foods in school cafeterias as well as the updates to the NSLP meal pattern) were estimated to prevent more cases of childhood obesity (345,000 and 1.8 million, respectively) at lower costs per BMI unit reduced ($6.1 and $53.2, respectively), strategies to increase moderate to vigorous physical activity in physical education, recess, and throughout the school day all are estimated to prevent far fewer cases of childhood obesity (ranging from 13,700 cases for more active physical education to 73,600 cases for a more active school day) at a higher cost (ranging from $541 to $2,825 per BMI unit reduced) (32).

Our results for the water jets strategy differ considerably from another recent cost-effectiveness analysis of the strategy. An et al. (22) estimated that nationwide implementation of water jets would result in more than three times as many cases of childhood obesity and substantial cost savings, at $14.50 saved per dollar invested, compared with our own estimate of $0.31 per dollar invested. The CHOICES modeling approach differs from that of An et al. in many respects. An et al. used a lifetime analysis that assumes a sustained intervention effect on weight over several decades, whereas the CHOICES model takes a more conservative approach, estimating intervention benefits and costs over a 10-year time period only. An et al. assumed that all private and public schools would implement water jets regardless of their existing tap water infrastructure. The authors also did not include several key costs that would be required for implementation based on prior studies (13,26), including increases in electricity and water usage, costs for tables or carts for the units, costs for periodic replacement of the units, cup costs, and costs associated with periodic lead testing. Our study, which did incorporate these costs, provides a more conservative estimate of cases of obesity averted and health care cost savings, which may be particularly useful for policy makers.

Installing water jets has the potential to increase student water intake during the day and thus potentially reduce the high prevalence of inadequate hydration seen among youth (6). Because this strategy involved changes to infrastructure and required relatively minimal training and labor for upkeep, water jets also have high potential to be sustainable over time. The water jets strategy had similar implementation costs to two other strategies for increasing drinking water access through new water dispensers: portable water dispensers and bottle-less water coolers. Although the latter two strategies had lower up-front costs in infrastructure, the labor, electricity, and promotion costs of both interventions resulted in roughly equivalent long-term implementation costs. While the water jets strategy cost more both overall and per child than the Grab a Cup, Fill it Up strategy, which relied on existing tap water infrastructure and had minimal costs, the water jets strategy could reach a much larger population of children and had a demonstrated impact on childhood obesity.

Installation of water jets on school lunch lines could be a relatively low-cost strategy for meeting the NSLP's drinking water requirements while also contributing to childhood obesity prevention. However, installing the updated units would still cost some money up front.

Installing water jets in the absence of external funding would require schools to invest about $2,500 per unit as well as to train staff in maintaining and cleaning the units. In an age of limited school funding, spending resources on water jets installation may not be appealing to many school and district administrators. Schools may consider installing water jets devices as they overhaul drinking water infrastructure in order to address water quality concerns such as lead concentrations, which may minimize incremental installation costs.

This study has several limitations. Because none of the strategies has been implemented at a broad scale, the true implementation costs, cost savings, and impact are unknown. However, we used the best available data, estimating the impact of the interventions using evidence from high-quality studies (natural experimental studies and randomized controlled trials) and estimating the potential costs of the intervention using standard costing protocols. We also incorporated uncertainty about estimates into the model. An important limitation is that we assumed that the average effects observed in the original study population were generalizable to the larger US population (an assumption that is often made for cost-effectiveness or cost-benefit analyses), but the true generalizability of the results is not known. Indeed, a comparison of the sociodemographic characteristics of the three intervention study populations with the general US public school population shows that the study populations had substantially higher proportions of low-income and nonwhite children (Supporting Information Table S1). Because the original studies were conducted in large cities with a history of strong public health efforts, it is possible that the intervention effects seen in these studies would not translate to be as large for populations in suburban or rural areas. However, because the original study population did not present effect heterogeneity by different demographic characteristics, we were unable to do so here as well. Similarly, although there is likely heterogeneity in how cost-effective the intervention may be across different types of schools (e.g., smaller vs. larger, urban vs. rural), we were only able to estimate average costs across all school types. Another limitation of this study is that population health impacts and costs related to other benefits of increased drinking water (such as potentially improving dental health and improving cognitive functioning through better hydration status) were not included; only effects and costs related to childhood obesity were considered.

Conclusion

Installing water dispensers on school cafeteria lunch lines could contribute substantially to reducing childhood obesity and related health care costs while improving students' hydration status. Policy makers and schools seeking to address childhood obesity through policies in school settings should consider this strategy to promote drinking water consumption. **O**

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