A systematic review of the effectiveness of promoting water intake to reduce sugar-sweetened beverage consumption

Sepideh Dibay Moghadam¹² | James W. Krieger³⁴ | Diana K. N. Louden⁵

¹Department of Epidemiology, University of Washington, Washington, United States of America
²Fred Hutchinson Cancer Research Center, Cancer Prevention Program, Washington, United States of America
³Department of Health Services, University of Washington, Washington, United States of America
⁴Healthy Food America, Washington, United States of America
⁵University Libraries, University of Washington, Washington, United States of America

Correspondence
James W. Krieger, Department of Health Services, University of Washington, 305 Raitt Hall, Box 353410, Seattle, WA 98195-3410, United States of America.
Email: jkrieger@hfamerica.org

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Summary
Objective: To examine whether the promotion of water intake could reduce sugar-sweetened beverage (SSB) consumption or purchases independent of interventions that target SSBs.

Methods: Seven databases were systematically searched. Included studies used water promotion as the primary intervention; used a controlled trial, single group pre-post, or prospective cohort study design; included a measure of SSB consumption or purchase; enrolled human participants of any age who lived in high-income or middle-income countries; contained original data; and appeared in a peer-reviewed English-language article published from 1 January 2000 to January 4, 2019.

The search yielded 7068 publications, from which 108 were chosen for full-text review. Seventeen were included in this review.

Results: Nine of the 17 studies were randomized controlled trials, six were non-randomized controlled trials, and 2 were single-group pre-post studies. Participants were primarily children and adolescents. Interventions included water provision, education or promotion activities. Ten of 17 studies were at low or some/moderate risk of bias. Seven studies showed a statistically significant decrease in SSB consumption of which only 2 were at low or some/moderate risk of bias.

Conclusions: This review found limited evidence that interventions aimed solely at increasing water consumption reduce SSB intake. Further research is needed to investigate whether interventions that combine water promotion and SSB reduction strategies could be synergistic for reducing SSB intake.

KEYWORDS
water promotion, sugar-sweetened beverage, sugar-sweetened beverage consumption reduction

1 | INTRODUCTION

Excessive consumption of sugar-sweetened beverages (SSBs) is associated with an increased risk of weight gain, obesity, type 2 diabetes, cardiovascular disease, and tooth decay.¹⁻⁵ Consumption of SSBs in the United States, while decreasing since its peak in 2000, remains at historically high and unhealthy levels.⁶ Two-thirds of children and half of adults consume at least one SSB daily.⁷⁻⁸ Consumption is higher among low-income groups and minority groups in the United States.⁹

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Interventions to address this important public health issue include implementing SSB taxes; limiting availability in schools, cafeterias, restaurants, and public places; adding warning and nutrition labels; conducting mass education campaigns; and providing individual education and counseling. Interest in promoting water consumption as an additional approach to SSB reduction has recently emerged, anticipating that increased water intake will lead to lower intake of SSBs through a substitution effect.

Two reviews of clinical trials and observational studies suggested that substituting water for SSBs is associated with lower energy intake and weight loss. Zheng et al concluded that substitution of water or low-calorie beverages for SSBs was associated with less long-term energy intake and weight gain. Daniels et al found that the most compelling evidence for water substitution was from studies in which adults consumed either water or SSBs before a meal. Water consumption was significantly associated with lower total energy intake. These reviews did not compare strategies to increase water consumption nor the effects of higher water intake on SSB consumption. Two reviews identified interventions that were effective in either increasing water or decreasing SSB intake. Interventions directed at water, such as providing nutritional counseling and education or improving access to water, had modest effects on increasing water intake among children age 0 to 5 years (+67 mL/d, and +0.5-3.5 oz/d). Interventions directed at SSBs, such as behavior change modeling, decreased SSB consumption (~76 mL/d in children). These reviews did not address the question of whether promoting water consumption, independent of interventions focused on SSBs, reduces SSB consumption.

This systematic review examined whether promoting water consumption reduces purchase and/or consumption of SSBs. If water promotion is an effective SSB reduction strategy, it would be a welcome addition to the SSB reduction toolkit. If not, then resources should be directed toward implementing more effective interventions.

2 | METHODS

The review protocol, developed prior to starting this systematic review, is available on the Healthy Food America website.

2.1 | Eligibility criteria

Studies were included if they (a) used a randomized controlled trial (RCT), nonrandomized controlled trial (NRCT), single group pre-post, or prospective cohort study design; (b) implemented water promotion as the primary intervention; (c) included a measure of SSB consumption or purchase; (d) took place in high-income or middle-income countries as defined by Organization for Economic Co-operation and Development, (e) enrolled human participants of any age; (f) contained original data (when the same data were found in multiple publications, the article with the largest sample size was selected); and (g) appeared in a peer-reviewed English-language journal article published since January 1, 2000 to January 4, 2019. Studies that had at least one intervention component (eg, education sessions, signage) that discouraged participants from drinking SSBs were excluded (in cases where the extent of SSB intervention was unclear, an attempt was made to contact authors).

2.2 | Search strategy and databases

A medical librarian searched seven electronic databases in accordance with the National Academy of Medicine systematic reviews standards: PubMed, Embase, PsycInfo, CINAHL Complete, Cochrane Central Register of Controlled Trials, CAB Direct, and Web of Science. The search strategy (Appendix S1) was peer-reviewed by a medical librarian and a subject-matter expert and incorporated controlled vocabulary terms and keywords appropriate to each database to represent the concepts of drinking water; sweetened beverages; and clinical, controlled, or longitudinal studies.

2.3 | Study selection

Covidence was used to manage the title, abstract, and full-text screening of the articles. Two investigators (S.D. and J.K) independently reviewed titles and abstracts of articles to select those for full-text review based on described eligibility criteria and then independently reviewed selected articles to determine which to include in the review. After each phase, the reviewers resolved conflicts by consensus.

2.4 | Data extraction

Each of the two reviewers used a customized, pilot-tested Microsoft Excel spreadsheet to extract half of the studies and subsequently validated extractions performed by the other reviewer. Conflicts were resolved through consensus.

2.5 | Primary outcomes and additional information extracted

The primary outcome was SSB consumption or purchases. The preferred measures were the difference in differences between intervention and control group mean daily volume of SSBs consumed or purchased (controlled difference), single group pre-post difference (uncontrolled difference), or odds ratio. If none of these was reported, the measure reported by the included study was used.

Additional variables were extracted consistent with systematic review guideline recommendations including (a) Study: author; publication year; country; project name; sponsorship; setting; intervention dates; and authors’ statement of objectives, conclusions, limitations, and suggestions for future research; (b) Population:
inclusion/exclusion criteria, participant demographic information, participation rate, completion rate; (c) Interventions: components, duration (the maximum length of time a participant could be exposed to the intervention); (d) Comparator: interventions received by the comparison group; (e) Timing of data collection; (f) Design: study design, consumption or purchase measures (SSB and water), follow-up duration; (g) Analysis: analytic model and adjustments for confounding, approach to missing data, statistical power.20-22

Measures of purchases or consumption were converted into mL/day when possible. When 95% confidence intervals (CIs) were not presented, they were computed if available data permitted. When population characteristics were presented for intervention arms but not the total study population, they were computed using the proportions and numbers in each arm. Nine authors were contacted for further information, and responses were received from two Additional information was obtained as needed from companion publications or online study descriptions.

2.6 | Appraisal of study quality

The Cochrane Collaborative Risk of Bias 2.0 and Risk Of Bias In Non-randomized Studies-I tools were used to assess risk of bias (low, some/moderate, high/serious, or critical) for randomized and non-randomized studies, respectively.23,24 Studies that lacked a comparison group were assigned a high/serious risk of bias rating. The two reviewers independently assessed the risk of bias of each study and resolved differences through consensus.

2.7 | Synthesizing the results

Studies were divided into those that did and did not significantly (P < .05, adjusted for multiple comparisons) affect SSB consumption. Study characteristics were qualitatively assessed to determine whether they were more or less common among statistically significant studies relative to insignificant ones (eg, whether a specific intervention setting was more common among significant studies). In addition, this review summarizes the characteristics of higher quality studies, defined as those with low or some/moderate risk of bias.

3 | RESULTS

The initial literature search retrieved 7068 publications. After removal of duplicate publications, 3652 remained for title and abstract screening (Figure 1). One hundred and eight were selected for full-text review, and 17 articles were included in this review.25-41 Figure 1 describes reasons for exclusion. Of note, 22 studies were excluded because they included a SSB reduction intervention.

Study design, participant characteristics, intervention types, settings, definition of SSB, and outcome measures (most often volume consumed per day or week, but also calories per day, drinking more than a few sips, number of glasses, participants observed consuming, and volume sold per day or week) varied substantially across studies. Due to this heterogeneity, studies were synthesized qualitatively rather than with a meta-analysis.

Table 1 describes the included studies. Nine of the studies were RCTs.25-33 Of these, four were cluster RCTs.28-33 Six were NRCTs.35-39 Of these, two used a cluster design.35,36 Two were single-group pre-post studies.40,41 Eight studies were conducted in Europe, six in the United States, two in Australia, and one in the Caribbean. Intervention settings included schools (9), homes (3), supermarkets (2), other child-focused settings such as preschools (2), and community-wide (2). Intervention duration varied from 3 weeks to 3.5 years, with a median of 3 months. Studies were published between 2005 and 2018, of which 11 appeared within the past 5 years. Five studies noted industry funding.27,35-37,40

Participants were primarily children ages 2 to 18 years (14 studies) while three studies enrolled adults.25-27 Nine studies reported at least one marker of socioeconomic status (SES) and people of low SES comprised at least one-third of participants in five of these nine studies. Nine studies described the race or nativity of participants and eight of these had 40% or more nonmajority participants.

The most common interventions were water provision, education, and promotion activities (Table 1), and most studies used two or more types of interventions (11 out of 17).29-36,38,39,41 Thirteen studies provided water through installation of water dispensers or delivery of bottled water, and some also included ancillary items (eg, cups or water bottles).27,29-40 Thirteen studies offered educational and promotional activities at individual, institutional, or community levels such as electronic or printed materials and newsletters, online forums and education sessions, dietitian coaching, prizes and incentives, classroom activities, or posters.25,27,29-38,41 Eleven studies included both provision and education or promotion.27,29-38 Two supermarket-based studies discounted the price of bottled water (by 20%-50%), one study used peer influence, and two studies were multilevel, multicomponent community obesity prevention initiatives.

Among all 17 studies, seven showed a statistically significant decrease in SSB consumption/purchase (Table 1).27-29,31,36,40,41 Three of these studies described a statistically significant SSB decrease relative to a comparison group.28,29,31 The other four studies reported only within-group significant changes.27,36,40,41 The magnitude of SSB reduction in the seven statistically significant studies included 47.7 mL/day to 190 mL/day, 2.59 g/kg/day, 0.12 “glass” per day, or a 2.5% to 3.3% reduction in proportion of children observed with SSBs in school or camp.

Out of 17 studies, two had low risk of bias.23,27 Another eight were at some/moderate risk.24,25,28-31,33,36 A final group of seven had high/serious risk of bias (Table 2).26,32,34,35,37-39 Of the 10 studies with low or moderate/some risk of bias, two showed both statistically significant decreases in SSB consumption/purchases and increases in water.27,29 One reported a decline only in SSBs.31 Three others showed an increase only in water.30,35,38 The three studies that reported a decrease in SSBs were heterogeneous in the interventions
they employed. One provided free bottled water as a replacement for SSBs. Another used posters and signs to promote water consumption and provided cup dispensers next to school cafeteria water fountains. The third launched a school-based water promotion campaign. While these 10 studies were not at high/serious risk of bias overall, some forms of bias were present. Sources of bias in the randomized studies included lack of blinding of the participants and outcome assessors as well as incomplete outcome data collection (Figure 2). Sources of bias in the nonrandomized studies included confounding, missing data, and deviations from intended intervention (Figure 3). In addition, they shared other limitations, especially the measurement of SSB consumption.

On a qualitative basis, certain study characteristics appeared associated with reduced SSB purchases or intake. Studies that included water provision, education or promotion, or some combination reported decreased SSB intake more often than water price discounting and community intervention studies, which had no effects (Table 1). Also, the intervention site appeared to be related to the impact on SSB intake (Table 1). All three home-based studies decreased SSB intake.

We did not observe a pattern with respect to age (child vs adult), SES (too few studies reported), race/nativity (too few studies reported), duration of intervention (0 months-1.9 months vs 2 months-5.9 months vs 6+ months), source of SSB data (questionnaire vs diary; 24-hour recall vs purchases vs direct observation), and study sponsorship.

Six of the 17 studies increased water intake significantly. Among these, three observed significant decreases in SSB consumption. Two of these studies provided bottled water at home and reported relatively large increases in daily water intake.
| Study | Water Intervention | Study Design and Risk of Bias | Sponsor | Population | Sample Size (Total) | Extent of Implementation | Water Outcome | Sugar-Sweetened Beverage Outcome |
|-------|-------------------|-------------------------------|---------|------------|--------------------|--------------------------|---------------|---------------------------------|
| Ball 2015<sup>25</sup> | Supermarket bottled water: 20% discount | Cluster RCT, four-arm factorial | National Health and Medical Research Council | Age: range, (mean) | 18-60 y (Mean 43.7) | 624 | NR | Purchase, Consumption (DID [mL/week]) | Purchase, Consumption (DID [mL/week]) |
| Australia | Newsletters, online forum, online dietitian consultant in two arms (factorial design) | | | Race/nativity: categories SES | | | | | |
| | | | | Gender: % female Other notable characteristics | | | | | |
| | | | | Baseline Completed (% completed) | | | | | |
| | | | | Measure (DID<sup>c</sup> intervention vs control group, or within group post/pre difference, or OR) | | | | | |
| | | | | Value, (CI), P value | | | | | |
| | | | | Adjusted for covariates | | | | | |
| Kenney 2015<sup>29</sup> | Cup dispensers installed next to school cafeteria water fountains | Cluster RCT | Centers for Disease Control and Prevention, anonymous | NR | 23% Non-Hispanic Black 40% Hispanic 24% Non- Hispanic White | NR | Mean duration of the signage component: 20.2 days (range 16 to 23), cup component 15.4 days, (range of 5) | Observed consumption (DID [cafeteria-provided water consumption/]) | Observation (DID [% students with SSB at lunch table]) |
| United States | | | | | | | | | |

<sup>a</sup> Arms
<sup>b</sup> Risk of bias
<sup>c</sup> DID
| Study | Water Intervention | Study Design and Risk of Bias | Sponsor | Population | Sample Size (Total) | Extent of Implementation | Water Outcome | Sugar-Sweetened Beverage Outcome |
|-------|-------------------|-----------------------------|---------|------------|---------------------|-------------------------|--------------|----------------------------------|
| Gelliebter 2013<sup>26</sup> | Bottled water in supermarket: 50% discount | RCT | Robert Wood Johnson Foundation, Columbia University | 21-65 y (Mean 37.5) | 67 | NR | Purchases (DID [dollars/week]), Consumption (DID [grams/day]) | Consumption (DID [kcal/day from all non-caloric beverages]) |
| United States | Some | | 56% White | 57 (85.1%) | | | No significant group-by-time interaction for either purchases (F(2,90) = 2.2, P = .11) nor consumption (F(2,76) = 0.034, P = .97) of discounted non-caloric beverages | No significant effect group-by-time interaction (F(2,76) = 1.3, P = .28) |
| Patel 2016<sup>30</sup> | Water dispenser or cooler in school cafeterias with cups | Cluster RCT | Robert Wood Johnson Foundation, Healthy Eating Research Program, National Institutes of Health | Grades 6-8 (Mean 12.6) | 12 middle schools (605 students) | NR | Consumption (OR, DID [% students reporting intake of more than a few sips at lunch]) | Consumption (OR, DID [% students reporting intake of more than a few sips at lunch]) |
| United States | Some | | 56% Latino/Hispanic | 595 (98.0%) | | | | Dispenser to control: OR = 3.1, (1.4, 6.7), P = .004; DID = 18.9% | Dispenser to control: 1.2, (0.6, 2.4), P = .71; DID = 0.6% |
| | | | 20% African American | | | | | Cooler to control: OR = 1.7, (0.83, 3.7), P = .17; DID = 10.7% | Cooler to control: 1.1, (0.5, 2.3), P = .78; DID = 1.0% |
| | | | 16% Asian/Pacific Islander | | | | | Any intervention to control: OR = 2.3, (1.2, 4.5), | Any intervention to control: 1.1, (0.6, 2.1), |

(Continues)
| Study            | Water Intervention                                                                 | Study Design and Risk of Bias | Sponsor                                                                 | Population                                          | Sample Size (Total) | Extent of Implementation | Water Outcome                                                                 | Sugar-Sweetened Beverage Outcome |
|------------------|-----------------------------------------------------------------------------------|-------------------------------|------------------------------------------------------------------------|-----------------------------------------------------|--------------------|--------------------------|--------------------------------------------------------------------------------|----------------------------------|
| Piernas 2013     | Bottled water provided at monthly meetings                                        | RCT                           | Nestle Waters USA, Robert Wood Johnson Foundation, National Institutes of Health | 18-65 y (Mean 42.3)                                | 318                | Water group attended 5.2 monthly sessions and diet beverage group 5.4 monthly sessions | Consumption within group changes and DID (mL/day)) | Consumption (within group changes and DID [mL/day]) |
| United States    | Monthly group education sessions: substitute ≥2 servings/d of (≥200 kcal) of caloric sweetened beverages with either water (water group) or diet beverages |                               | Some                                                                   | 40% White, 57% African American, 5% Other           | 234 (73.6%)         |                          |                                                                                |                                  |
|                  | 6 months                                                                           |                               |                                                                       | % Education: 7% High school or less, 41% Some college, 55% College graduate plus |            |                          |                                                                                |                                  |
|                  |                                                                                   |                               |                                                                       | 84% Female                                          |            |                          |                                                                                |                                  |
|                  |                                                                                   |                               |                                                                       |                                                                                                  |            |                          |                                                                                |                                  |
| Pinket 2016      | Water drinking stations at kindergartens, preschools, day care                     | Cluster RCT                   | European Commission                                                   | 3.5-5.5y (Mean 4.7)                                | NR (target: 6500) | Mean implementation score for kindergartens was 16.3 (maximum of 30). Mean implementation score for parents/caregivers was 9.5 (maximum of 18). | Consumption (DID, [mL/day]) | Consumption (DID, [mL/day]) |
| 6 European countries|                                                                                   |                               |                                                                       | Education: 38.5% mothers' education <14 years, 48.5% female | NR                  |                          |                                                                                |                                  |
|                  |                                                                                   |                               |                                                                       |                                                                                                  |            |                          |                                                                                |                                  |

(Continues)
| Study | Water Intervention | Study Design and Risk of Bias | Sponsor | Population | Sample Size (Total) | Extent of Implementation | Water Outcome | Sugar-Sweetened Beverage Outcome |
|-------|-------------------|------------------------------|---------|------------|---------------------|--------------------------|---------------|----------------------------------|
| van de Gaar 2014<sup>21</sup> | Free water at school, water break during physical education | Cluster RCT | ZonMw–Netherlands Organization for Health Research and Development | Range 6-12 y, (Mean NR) | 356 (parent reported data) | Adjusted for age, sex, SES, and country | Consumption (DID [mL/day]) | Consumption (DID [mL/day and servings per day] or OR) |
| | Events, posters, activities, bottles | Some | | (Turkish/Moroccan) | 387 (child reported data) | | Parent report 30, (−0.40, 0.80), NR | Parent report: −190 mL/day (−280, −100) |
| | 12 months | 20% Missing | | 52.6% Female | | | Child report 10, (−0.40, 0.70), NR | SSB servings/day (no): −0.54 (−0.82, −0.26) |
| | | | | | | | | OR: % SSB every day: 0.79 (0.47, 1.34) |
| | | | | | | | | Observation (% brought SSB to school [OR]) |
| | | | | | | | | 0.51 (0.36, 0.72) |
| | | | | | | | | Adjusted for baseline intake and school-pair, grade, gender, ethnic background and weight status of the child, and educational level of the caregiver |
| | | | | | | | | Adjusted for same covariates |
| Waters 2017<sup>23</sup> | Upgraded water taps, provide water at lunch in schools | Cluster RCT | Victorian State Government | 5-12 y | 24 schools/3167 children | Principals reported 9/12 intervention schools had healthy eating policy (5 of these rated as widely or consistently implemented). 3/12 had written canteen policy. | Consumption (OR [≥ 2 glasses water/day]) OR: 1.41 (0.78-2.3), P = .3 | Soft drink consumption (OR [% with any consumption on given day]) |
| | | | | | 22 schools (91.7%)/2806 children (88.6%) | | | OR: 1.40 (0.60-1.33), P = .55 |
| | | | | | | | | OR: 0.89 (0.60-1.32), P = .55 |
| | | | | | | | | Observation (OR [water in lunchbox/canteen order]) 1.71 (1.05-2.78), |
| Australia | Parent education, water bottles, school policies | Some | | NR | | | | |
| | | | | | | | | Adjusted for same covariates |
| | | | | | | | | (Continues) |
| Study | Water Intervention | Study Design and Risk of Bias | Sponsor | Population | Sample Size (Total) | Extent of Implementation | Water Outcome | Sugar-Sweetened Beverage Outcome |
|-------|-------------------|-------------------------------|---------|------------|--------------------|-------------------------|---------------|---------------------------------|
| Franken 2018<sup>28</sup> | Peer influencers (PIs) promote water consumption | Cluster RCT | University of Aruba, European Research Council | 10-14 y (Mean 11.4) | 453 | NR | Consumption (DID [glasses/day]) | Adjusted for proportion at baseline, child age and sex, household socioeconomic position, and ethnicity (only English spoken at home). |
| Anuba | Peer influencers (PIs) promote water consumption | Cluster RCT | University of Aruba, European Research Council | NR | 377 (83%) | NR | Consumption (DID [glasses/day]) | Adjusted for the same covariates |
| Muckelbauer 2009<sup>95</sup> | Water fountain in schools | Cluster NRCT | German Federal Ministry of Food, Agriculture, and Consumer Protection | 2 and 3rd grades (Mean 8.3) | 32 elementary schools (3190 students) | 94% of the teachers implemented >1 of the 4 classroom lessons, 85% implemented >2, 16% implemented all. 68% implemented >1 booster session, and 24% of continued them throughout intervention. Daily provision of drinking water in 71% of classes. | Consumption (DID [glasses/day]) | Adjusted for immigration background |
| Patel 2011<sup>38</sup> | Water dispenser in school cafeterias | NRCT | National Center for Minority Health and Health Disparities, Robert Wood Johnson Clinical | Range NR (Mean 12.8) | 405 | NR | Consumption (OR, DID [% drank water from specified source]): soda: OR = 0.89, (0.66,1.2), P = .46; DIF = −7.2% sports drink OR = 1.31, | Consumption (OR, DID [% drank specified SSB]): any source: OR = 1.76, (1.22,2.57), P = .003; DIF = 9.4% |

Nonrandomized controlled trial study design
| Study          | Water Intervention                                                                 | Sponsor               | Population | Sample Size (Total) | Extent of Implementation | Water Outcome                                                                 | Sugar-Sweetened Beverage Outcome |
|---------------|-------------------------------------------------------------------------------------|-----------------------|------------|---------------------|--------------------------|--------------------------------------------------------------------------------|----------------------------------|
| De Bourdeaudhuij 2015 [4] | Fountains at schools (with paper cups provided), playgrounds, and public places; encourage water at dinner table; use water bottle during school day | European Union        | 2-9.9 y (Mean 6.0) | 16,288              | Intervention was not delivered with high fidelity, e.g., in Belgium much of the program was not received by families. | Consumption [DID (freq/week pooled across 8 countries)] | Consumption [DID (freq/week pooled across 8 countries)] |
| 8 European countries | Posters in store windows, classroom activities, school paper, kid-created | Cluster NRCTSerious | 16.2% one parent born abroad | 11,101 (68%) | Boys: Adjusted DID: F = 0.003, no CI, P = .866 (time x condition interaction) (value of adjusted DID not reported) Unadjusted DID (calculated from Table 1): 0.05 times | Boys: DID (adjusted): F = 0.74, no CI, P = .388 (time x condition interaction) (value of adjusted DID not reported) Unadjusted DID (calculated from Table 1): −0.16 times per week |
| Study                  | Water Intervention                                                                 | Study Design and Risk of Bias | Sponsor                                | Population                        | Sample Size (Total) | Extent of Implementation | Water Outcome | Sugar-Sweetened Beverage Outcome |
|-----------------------|-------------------------------------------------------------------------------------|------------------------------|----------------------------------------|-----------------------------------|---------------------|---------------------------|--------------|-------------------------------|
| Franks 2017<sup>26</sup> | 63 bottles of water delivered to home  
Poland                               | NRCT with sequential intervention phases  
Arms: Phase 1: control, information, information + water  
Phase 2: control, discussion forum  
Serious  
(3 weeks for each of two intervention phases) | Danone Research, London School of Economics  
NR  
NR  
50% female  
Mean 4.4 | 3-6 y (Mean 4.4) | 439 | NR | Consumption (DID [mL/day])  
Information + water provision (at end of this 3-week intervention)  
183.9, SE = 26.8, (131.4, 236.4), P = .0001  
Online groups (at end of this 3-week intervention, in arm that previously received info + water)  
136.5, SE = 40.6, (56.9, 216.1), P = .001  
Consumption (within group change [mL/day])  
(note: baseline to one year after enrollment)  
[other time periods not presented nor was DID intervention vs control reported]  
Online groups (at end of this 3-week intervention, in arm that previously received info + water)  
136.5, SE = 40.6, (56.9, 216.1), P = .001  
Consumption (within group change [mL/day])  
(note: baseline to one year after enrollment)  
[other time periods not presented nor was DID intervention vs control reported]  
Online groups (at end of this 3-week intervention, in arm that previously received info + water)  
136.5, SE = 40.6, (56.9, 216.1), P = .001  
Consumption (within group change [mL/day])  
(note: baseline to one year after enrollment)  
[other time periods not presented nor was DID intervention vs control reported]  
Online groups (at end of this 3-week intervention, in arm that previously received info + water) | Girls  
Adjusted DID: F = 1.51, no CI, P = .220 (time x condition interaction)  
(value of adjusted DID not reported)  
Unadjusted DID (calculated from Table 1): 0.43 times per week  
Adjusted for age and parental education level  
Girls: DID (adjusted): F = 0.18, no CI, P = .670 (time x condition interaction)  
(value of adjusted DID not reported)  
Unadjusted DID (calculated from Table 1): −0.07 times per week  
Adjusted for same covariates |
| Loughridge 2005<sup>27</sup> | Water cooler in schools  
United Kingdom | NRCT  
Arms: | Van den Bergh Foods Ltd | 11-18 y (Mean NR) | 2965 | NR | Water provided (within group difference [mL/student/school day])  
Sales (within group difference [mL/student/school day]) | (Continues) |
| Study | Water Intervention | Study Design and Risk of Bias | Sponsor | Population | Sample Size (Total) | Extent of Implementation | Water Outcome | Sugar-Sweetened Beverage Outcome |
|-------|--------------------|------------------------------|---------|------------|---------------------|--------------------------|---------------|--------------------------------|
| Posters and education in school assembly and classes, promotional bottles and pencils in one arm | Intervention group 1: water and promotion | Serious | 26% Eligible for free lunch Secondary schools from the most deprived areas NR | 5866 | Water coolers worked throughout intervention. 20% of students used water cooler on given day. After 1 week, pupils did not use the water bottles. | NR | Sales (within group, mL/pupil/day) |
| Visscher 2010 | Water cooler in schools | NRCT | The Ministry of Health of the Netherlands | 12-19 y (Mean 14) | NR | NR | NR |
| Free water bottles | | Serious | NR | | NR | | |
| 16 weeks | | | NR | | | | |
| Single group pre-post study design | | | | | | | |
| Andersen 2016 | Bottled water provided to participants | Single group pre-post (nested in a 4-arm RCT) | The Danish Dairy Board and the Danish Agency for Science, Technology, and Innovation | 12-15 y (Mean 13.2) | NR | NR but noted participants drank 95% of water as recorded in self-report diary. | Consumption (within group change [mL/day]) |
| Denmark | None | High | NR | | 173 (89.6%) | | −2.59, [CI NR], P < .01 |
| | 12 weeks | | 64% female BMI > 25 kg/m² | | | | |
| Beets 2014 | Encourage bringing water | Single group cross-sectional pre-post | | 4-12 y (Mean 7.8) | Approximately 550 children | 69% of parents aware of program | Children or staff observed bringing | |
### Table 1 (Continued)

| Study                      | Water Intervention                          | Study Design and Risk of Bias | Sponsor                                      | Population                        | Sample Size (Total) | Extent of Implementation | Water Outcome                          | Sugar-Sweetened Beverage Outcome |
|----------------------------|---------------------------------------------|-------------------------------|----------------------------------------------|-----------------------------------|---------------------|--------------------------|----------------------------------------|-----------------------------------|
| United States              | from home to summer camp                    | with two post observations    | National Institutes of Health                | 46% white non-Hispanic            | and 12-15 staff at each wave | and 75% of staff indicated being trained. | to camp (Cross-sectional difference [absolute percent]) | camp (Cross-sectional difference [absolute percent]) |
|                            | Incentives for children (eg, movie tickets, extra swim time), parental and staff education (guide to healthy lunchbox, weekly emails) | High                          | NR                                           | NR                               | NR                  |                          | Children: 7.5%, (−4.0, 0.9), NR | Staff: −5.8%, (−18.2, 7.2), NR |
|                            |                                             |                               | 47% female                                   |                                   |                     |                          | Children soda/pop: −2.5%, (−4.0, −1.0), P < .01 | Staff soda/pop: −10.0%, (−14.5, −5.5), P < .01 |
|                            |                                             |                               |                                              |                                   |                     |                          | Sports: −12.1%, (−14.5, −5.5), P < .01 | Energy: −0.3%, (−0.6, 0.0), NR |

Table 1. Abbreviations: BMI, body mass index; CI, confidence interval; DID, difference in differences; NR, not reported; NRCT, nonrandomized controlled trial; OR, odds ratio; PIs, peer influencers; RCT, randomized controlled trial; SD, standard deviation, SE, standard error; SES, socioeconomic status; SSB, sugar-sweetened beverage.

*If more than one arm.*

*Tools used: None if single group study. A single group pre-post design was classified as high risk of bias based on this criterion alone.*

*Risk of Bias 2.0 (RoB2.0) for randomized studies.*

*Risk of Bias In Nonrandomized Studies-I (ROBINS-I) for nonrandomized studies.*

*Detailed information in Table 2.*

*DID between intervention and control group mean daily volume of water and SSBs consumed or purchased (controlled difference) and single group pre-post difference (uncontrolled difference).*
consumption.27,29 All three of the studies without an effect on SSBs installed water dispensers (coolers, fountains, etc.) and promoted water in schools and observed only small changes in water consumption.30,35,38 Among the 10 studies with low or some/moderate risk of bias, five increased water and two of these reported reductions in SSBs.

4 | DISCUSSION

This systematic review of 17 studies found little evidence that interventions aimed at increasing water intake consistently reduce the purchase or consumption of SSBs. The most common interventions were provision of water and water education or promotion activities. Of the 10 studies with low or moderate/some risk of bias, two showed both statistically significant decreases in SSB consumption and increases in water, one reported a decline only in SSBs, and three noted an increase only in water. Among all of the 17 included studies, seven reported a statistically significant decrease in SSB consumption/purchases, although only three of them included a comparison group.

Two previous reviews have summarized the effectiveness of water promotion and SSB reduction interventions. Neither described the effects of the water promotion interventions on SSB consumption, independent of co-interventions targeting SSBs. Vargas-Garcia reported on 40 studies with interventions to increase water and/or decrease SSB consumption.14 Eleven of these studies measured water intake, and it was possible to do a meta-analysis of the seven that included children. In these studies, the interventions increased water intake. However, because six of these seven studies included a SSB intervention, this analysis did not address the question of this review. Cradock recently summarized the evidence from 25 studies aimed at increasing water consumption among children ages 0 to 5 years.15 Of the 19 studies that positively impacted water consumption, three focused solely on water interventions, too small a number to draw any conclusions about effects on SSBs. Two of these studies showed a decrease in SSB consumption.

This review differs from the Cradock and Vargas-Garcia reviews in several ways.14,15 First, this review focused on whether water promotion, absent any SSB co-intervention, can reduce SSB intake. Second, it included only studies that reported on both water and SSB purchases or intake. Third, it included all age ranges while the review by Cradock focused on children.

If the hypothesis that water promotion decreases SSB intake by increasing water consumption which then leads to SSB reduction through a substitution effect is correct, the expectation is that SSB reduction would be observed primarily in studies that increased water intake. However, the results of this review did not confirm this expectation. Out of six studies that increased water, only three decreased SSB consumption.27,29,36 On the other hand, three studies were identified that decreased SSB consumption despite failing to increase water intake.28,31,41 These studies did not have SSB reduction components, making the mechanism by which they affected SSBs uncertain. In addition, two of them were at high risk of bias. Franken et al posited that “children understand the implicitly promoted message that SSB consumption is in fact unhealthy.”28 The intervention described by Beets et al increased fruit and vegetable consumption, and the authors speculated that the added produce displaced SSBs from the diet.41 In conclusion, SSB consumption did not consistently decrease when water consumption increased and the association of changes in water and SSB intake was inconsistent across studies.

Among the studies in this review, home-based interventions that included home water delivery were more frequent among studies that reported significant SSB decreases compared with those that did not. This finding suggests that an individually focused, more intensive, and costly intervention may be needed for water promotion to affect SSB intake. Provision of water and water education or promotion activities appeared to decrease SSB intake, compared with lowering the price of water or multicomponent community interventions with a water promotion element.

The included studies had several limitations. They did not define SSBs uniformly. While all definitions included soda, the inclusion or exclusion of other beverages (eg, sports drinks, energy drinks, fruit drinks/cordials, 100% fruit juices, sweetened flavored water, teas, coffee, dairy, or alcohol) differed or was not specifically reported.

Outcome measures for both SSBs and water were not consistent nor optimal. The metric for beverage outcomes was most often volume consumed per day or week, but studies also used calories per day, drinking more than a few sips, number of glasses, participants observed consuming, and volume sold per day or week. Measures in some studies lacked precision, and data were often obtained through lower-quality methods such as limited food frequency questionnaires and observed consumption. Several studies limited assessment of intake to beverages consumed at the intervention setting and thus did not assess effects on total daily consumption. These limitations may have contributed to the inconsistent effects of water intervention on SSB outcomes that we observed.

Most studies had some/moderate or serious/high risk of bias. Half of the studies did not employ a randomized study design. The most frequent study limitations that contributed to increased risk of bias included lack of blinding, inadequate control for confounding, missing data, and deviations from intended interventions. Many of the nonrandomized studies did not adjust for potential confounding factors.

Most studies of short duration, and few included postintervention follow-up to assess durability of intervention effect. In some cases, interventions were incompletely or inconsistently implemented, and most studies did not report on the extent and fidelity of implementation.

Nearly all studies focused on children in educational settings. Thus, there is limited information available on the value of water promotion for reducing SSB intake among adults or in other settings. There were insufficient data to make clear conclusions about comparative effectiveness across different population subgroups. However, studies took place in many countries and included diverse participants, suggesting that findings may be generalizable.
### TABLE 2  Quality assessment of 17 included studies a

#### Risk of Bias 2.0 for Randomized Studies

| Study              | Random Sequence Generation (Selection Bias) | Allocation Concealment (Selection Bias) | Blinding of Participants and Personnel (Performance Bias) | Blinding of Outcome Assessment (Detection Bias) | Incomplete Outcome Data | Selective Reporting | Other Bias | Overall Bias |
|--------------------|---------------------------------------------|------------------------------------------|----------------------------------------------------------|-----------------------------------------------|-------------------------|---------------------|------------|--------------|
| Ball 2015          | Low                                         | Low                                      | Low                                                      | Low                                           | Low                     | Low                 | Low        | Low          |
| Kenney 2015        | Low                                         | Low                                      | Low                                                      | Some                                          | High                    | Low                 | Low        | Low          |
| Geliebter 2013     | Low                                         | Low                                      | Some                                                     | Some                                          | Low                     | Low                 | Some       | Some         |
| Patel 2016         | Low                                         | Some                                     | High                                                     | High                                          | Some                    | Low                 | Some       | Some         |
| Piernas 2013       | Low                                         | High                                     | Some                                                     | Some                                          | High                    | Low                 | Some       | Some         |
| Pinket 2016        | Some                                        | High                                     | Some                                                     | Some                                          | High                    | Low                 | Some       | Some         |
| van de Gaar 2014   | Some                                        | High                                     | High                                                     | Low                                           | Low                     | Some                 | Some       | Some         |
| Waters 2017        | Low                                         | Low                                      | Some                                                     | Some                                          | High                    | Low                 | Some       | Some         |
| Franken 2018       | High                                        | Some                                     | Some                                                     | Low                                           | High                    | Some                 | High       | High         |

#### Risk of Bias In Nonrandomized Studies-I for Nonrandomized Studies

| Study              | Bias Due to Confounding | Bias in Selection of Participants Into the Study | Bias in Classification of Interventions | Bias Due to Deviations from Intended Interventions | Bias Due to Missing Data | Bias in Measurement of Outcomes | Bias in Selection of the Reported Result | Overall Bias |
|--------------------|-------------------------|--------------------------------------------------|----------------------------------------|--------------------------------------------------|--------------------------|-----------------------------------|------------------------------------------|--------------|
| Muckelbauer 2009   | Moderate                | Low                                              | Low                                    | Moderate                                         | Serious                  | Moderate                          | Low                                      | Moderate      |
| Patel 2011         | Moderate                | Low                                              | Low                                    | Moderate                                         | Moderate                 | Moderate                          | Low                                      | Moderate      |
| De Bourdeauhuij 2015 | Moderate               | Low                                              | Low                                    | Serious                                         | Moderate                 | Low                               | Moderate                                 | Serious       |
| Franks 2017        | Serious                 | Low                                              | Low                                    | Serious                                         | Moderate                 | Moderate                          | Low                                      | Serious       |
| Loughridge 2005    | Serious                 | Low                                              | Low                                    | Serious                                         | Moderate                 | Low                               | Moderate                                 | Serious       |
| Visscher 2010      | Critical                | Low                                              | Low                                    | Low                                             | Low                     | Low                               | Low                                      | Serious       |

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aAnderson 201640 and Beets 201441 were single group studies. No tools were used to assess quality of a single group study. A single group pre-post design was classified as high risk of bias based on this criterion alone.
This review is subject to several limitations. Only high-income or middle-income countries were included, as they have higher levels of SSB consumption relative to low-income countries. Grey literature was not searched given the focus on peer-reviewed publications. A positive study was defined as one that found a statistically significant decrease in SSB consumption or purchases either in comparison to a control group (difference in differences) or in a pre-post analysis of a single intervention group. While it would have been preferable to include only the former, the limited number of available studies required the use of a more liberal definition. Additionally, the limitation of using statistical significance as the criterion for a positive study is well-recognized. Finally, some of studies may have been underpowered for detecting changes in water or SSB consumption. Only two studies described a power calculation for water and one for SSBs.29-31 Overall, studies based power calculations on other outcomes (eg, weight) or did not report a power calculation. In addition, among studies using a clustered design, few described a power calculation that accounted for clustering (eg, used intraclass correlation coefficient).

This review has several strengths. It is the first systematic review to our knowledge that examines whether water promotion, in and of itself, can reduce SSB intake and what intervention characteristics are associated with lower SSB intake. Review guidelines from the Cochrane Collaborative and the National Academies of Medicine were followed.21,22 Studies were identified using a strategy designed by a medical librarian which was peer-reviewed and employed inclusive search criteria. Two reviewers independently reviewed studies for selection, extracted data, and rated risk of bias using standard Cochrane tools.

Further research is needed to evaluate the hypothesis that water promotion can decrease SSB consumption, whether independently or synergistically with strategies that directly target SSBs. A randomized controlled trial that uses a factorial design to examine the independent and combined effects of water promotion and SSB reduction strategies on both water and SSB consumption and/or purchases would be a useful addition to the literature. Such a study should include rigorous dietary assessment methods with standard consumption measures that allow for the examination of substitution effects so that impacts on total 24-hour beverage consumption and possibly overall diet quality can be determined, along with objective measures such as sales data. Ideally, the intervention duration would be least 6 months, and the evaluation would assess postintervention sustainability of any observed effects.

Given the lack of evidence that water promotion alone can decrease SSB consumption, it is prudent to deploy strategies that focus directly on SSBs to reduce SSB consumption. There is evidence that interventions that directly target SSBs (education, decreasing access, and increasing price) reduce SSB consumption.42-47 Water promotion may have other benefits unrelated to SSB reduction.11,46

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**CONFLICT OF INTEREST**

The authors declare they have no conflicts of interest.

**ORCID**

Dibay Moghadam et al. https://orcid.org/0000-0001-6793-4586

James W. Krieger https://orcid.org/0000-0003-4462-9428

Diana K. N. Louden https://orcid.org/0000-0002-6161-5557

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**SUPPORTING INFORMATION**

Additional supporting information may be found in the Supporting Information section at the end of this article.

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