Association between water consumption and body weight outcomes: a systematic review[1–3]

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ABSTRACT

Background: Drinking water is often applied as a dietary means for weight loss and overweight/obesity prevention, but no evidence-based recommendation exists for this indication.

Objective: We summarized the existing evidence on the association between water consumption and body weight outcomes in adults of any body weight status.

Design: In a systematic review, we retrieved studies from 4 electronic databases (MEDLINE, EMBASE, CINAHL, and COCHRANE), cross-references by PubMed functions and hand-searching, and experts' recommendations. Any type of study including adults aged >18 y that reported the association between daily water consumption and any weight-related outcome, such as body weight, body mass index, or body weight classifications, was eligible.

Results: Of 4963 retrieved records, 11 original studies and 2 systematic reviews were included. In participants dieting for weight loss or maintenance, a randomized controlled trial, a nonrandomized controlled trial, and an observational longitudinal study showed that increased water consumption, in addition to a program for weight loss or maintenance, reduced body weight after 3–12 mo compared with such a program alone. In mixed-weight populations not primarily dieting for weight loss or maintenance, 2 short-term randomized trials showed no effect of water consumption on body weight; 6 cross-sectional studies showed inconsistent results.

Conclusions: Studies of individuals dieting for weight loss or maintenance suggest a weight-reducing effect of increased water consumption, whereas studies in general mixed-weight populations yielded inconsistent results. The evidence for this association is still low, mostly because of the lack of good-quality studies. This trial was registered at www.crd.york.ac.uk/Prospero as CRD42012002585. *Am J Clin Nutr* doi: 10.3945/ajcn.112.055061.

INTRODUCTION

Drinking a lot of water is publically believed to support weight-loss efforts or maintenance and has become a commonly used practice for weight control (1). Plain water is the preferred beverage to fulfill daily water needs according to a recent guidance system in the United States (2). The advice to drink plenty of water has also been proposed in several popular weight-loss diets (3), in scientific articles (4, 5), and in the lay press (6, 7). In fact, drinking plenty of water is a widespread weight-loss approach; according to NHANES data, ~30% of all adults in the United States who tried to lose weight stated that they drank a lot of water (8). In another, smaller survey, 59% of all adults applied drinking plenty of water frequently as a weight-control practice (1).

The high prevalence of overweight and obesity worldwide has prompted research into risk and protective factors (9). It has been proposed that the increasing prevalence of obesity may be connected with the shift from the consumption of water to sugar-containing beverages such as soft drinks and fruit juices (10, 11). Although the causal association is still arguable (12–15), sugar-containing beverages were proposed to be the dietary risk factor for obesity with the most consistent evidence in children (16). Thus, increasing water consumption to replace sugar-containing beverages could prevent obesity. Drinking water instead of drinking sugar-containing beverages was shown to reduce the total energy intake with the subsequent meal in adults (17, 18). Further short-term effects of water consumption include increased satiety, reduced feeling of hunger (17), and slightly increased energy expenditure as the result of a proposed water-induced thermogenic effect (19, 20).

Increasing water consumption for overweight prevention also seems promising because an interventional study in children showed that promoting the drinking of water at schools reduced the risk of overweight (21). Such evidence is missing in adults, but 2 recent systematic reviews concluded that there might be a beneficial effect of water consumption on weight control (17, 18). Both reviews had methodologic restrictions and identified few relevant studies. They did not report searching more than one or any electronic database systematically. In addition, they investigated simultaneously further research questions, such as the effect of other beverages or the short-term effect of water on energy intake. Thus, a comprehensive systematic review focusing on water consumption and body weight outcomes in adults is missing.

The objective of the present review was to systematically summarize all existing evidence of the association between dietary water consumption and weight-related outcomes in adults. Increased water consumption was evaluated in adults currently dieting for weight loss as well as in general adult populations of

mixed-weight status for the universal prevention of overweight and obesity.

METHODS

Eligibility criteria

Types of studies

We included all types of published studies describing any association between water consumption and any body weight outcome. Because of the well-recognized lack of interventional trials, studies with observational longitudinal or cross-sectional design and secondary analyses were considered. We included systematic reviews but excluded narrative, nonsystematic reviews and conference abstracts.

Types of participants

Inclusion criteria for the study population were adults aged >18 y irrespective of their body weight status (underweight, normal weight, overweight, or obese) and dieting status (currently dieting for weight loss or maintenance and not primarily dieting). We excluded studies that exclusively enrolled hospitalized patients or patients with defined diseases, such as psychotic diseases and eating disorders defined by the International Classification of Diseases code F50, or patients receiving hemodialysis or fluid-replacement therapy. Studies with only athletes or with participants performing extreme exercise were also excluded.

Types of measures

We included studies that reported the consumption of water as a beverage with a measured or estimated intake period of ≥1 d. Thus, we excluded studies that investigated only the total fluid intake or the energy density of food and beverages and experimental studies in which varying amounts of water were added to food. Any weight-related outcomes, such as body weight, BMI, body circumferences, classification of weight status (eg, overweight and obesity), and measures of body fat or lean mass, were considered.

Search strategy

The 4 electronic databases MEDLINE (http://www.nlm.nih.gov, via Ovid), EMBASE (http://www.elsevier.com/online-tools/embase, via Ovid), CINAHL (www.cinahl.com, via EBSCOhost), and COCHRANE (http://www.thecochranelibrary.com) were searched for citations on 16 September 2011, with a complete update on 19 April 2012, and there were no restrictions on publication date. The search strategy for MEDLINE is presented in **Table 1**. The search strategies for EMBASE, CINAHL, and COCHRANE are available elsewhere (*see* Supplemental Material 1 under "Supplemental data" in the online issue). In short, the search strategy in MEDLINE included the following major text words and their synonyms, closely related words, and index terms: "beverages," "water consumption," "drinking behavior," "body weight and measures," "overweight,, and "obesity." The search was limited to humans and adults by applying a highly sensitive filtering method and to publications in English, German, Spanish, or French. No limit to the study or publication type was set. The search strategies for each of the other 3 databases were

TABLE 1
Search strategy for MEDLINE via Ovid[1]

	Search terms
1	beverages/
2	exp drinking/
3	drinking behavior/
4	(1 or 2 or 3) not alcohol*.ti.
5	mineral waters/ or carbonated beverages/
6	beverag*.tw.
7	(fluid* adj1 (consum* or intake or drink* or drank)).tw.
8	(liquid* adj1 (consum* or intake or drink* or drank)).tw.
9	(water* adj1 (consum* or intake or drink* or drank)).tw.
10	mineral water*.tw.
11	or/4–10
12	body weight/ or exp body weight changes/
13	obesity/ or obesity, abdominal/ or obesity, morbid/ or thinness/
14	exp overweight/
15	"body weights and measures"/ or exp body fat distribution/ or body mass index/ or exp body size/ or skinfold thickness/ or waist-hip ratio/
16	exp adipose tissue, white/
17	body mass inde*.tw.
18	quetelet inde*.tw.
19	body size.tw.
20	bmi.tw.
21	hip circumference.tw.
22	obesity.tw.
23	body weight.tw.
24	body weight.tw.
25	body size.tw.
26	waist.tw.
27	adipos*.tw.
28	obes*.tw.
29	or/12–28
30	11 and 29
31	30 not (exp exercise test/ or exercise/ae, de, px or exp running/ or swimming/ or (marathon* or ultramarathon* or triathlon* or athlet*).tw.)
32	31 not case reports/
33	32 and humans/
34	32 and animals/
35	34 not 33
36	32 not 35
37	36 not (mice or mouse or rat? or animal? or rodent?).tw.
38	37 and (exp adolescent/ or exp child/ or exp infant/)
39	37 and exp adult/
40	38 not 39
41	37 not 40
42	limit 41 to (english or french or german or spanish)
43	remove duplicates from 42

[1] MEDLINE, http://www.nlm.nih.gov.

adapted from the search in MEDLINE by using the indexing system for subject headings specific to the databases.

Additional citations were identified by hand-searching reference lists of all included reviews and selected articles. In addition, we contacted 13 experts in this field via e-mail asking for any relevant studies known to them. We also considered citations that were related to the included studies or that cited an included study by using the online functions of PubMed "Related citations" and "Cited by PubMed Central articles," respectively. We retrieved the first 10 records from the list of related citations, ranked by relevance, and all of the records that cited the included studies.

Citations were stored and managed with the reference software EndNote ×5.

All citations retrieved from the electronic search were reviewed independently by 2 reviewers, 1 of whom was an expert in the research field and 1 of whom—a research assistant—was not (RM and AG). On the basis of the titles, abstracts, or keywords of the citations, the reviewers included all citations that were possibly relevant for further investigation. In the next step, the full-text articles of the citations were retrieved. Each of the reviewers screened the full text of the citations selected in the first screening by applying all inclusion and exclusion criteria. The reviewers were not blinded to the journal and author names. Citations and full text identified by methods other than the electronic search were reviewed by one expert reviewer (RM). Articles in Spanish and French were reviewed by Flavia Barbieri as the second reviewer. The level of agreement between the 2 reviewers in selecting the studies for inclusion was assessed by the simple κ coefficient calculated with the software package SAS V9.2 (SAS Institute). Of 4439 records from the electronic databases, each of the 2 reviewers included, after the screening process, 18 full-text articles, of which 13 articles were selected by both reviewers. This resulted in a κ coefficient of 0.74, which represents a substantial level of agreement (22). Disagreements in study inclusion by the 2 reviewers were resolved by discussion in an expert round of 3 study authors (RM, GS, and JM-N).

Data collection

Data from the included full-text articles were extracted by one reviewer (RM) by using a standardized extraction form and checked by another reviewer (GS). The extraction sheet was based on the recommendations of the Centre for Reviews and Dissemination (23) and modified to meet the requirements of all study designs. Extracted data included descriptions of the participants; the type, methods, and primary aims of the study; the type and assessment of the water consumption and weight-related outcomes; the measures of association; the applied statistics; and the sources of funding. If possible, data were taken directly from studies. If the outcomes were not reported or not completely reported, the first or last author of the article was contacted by e-mail. If the authors provided data, we performed descriptive and statistical analyses ourselves with the permission of the authors.

The primary outcome of our review was any difference in body weight outcome (in means or percentage) by higher water consumption compared with lower consumption. If groups with different body weight statuses were compared regarding their beverage consumption or vice versa, group means including SDs were noted. If correlation or regression analyses were applied to estimate the change in water consumption associated with a change in body weight outcome, the statistical parameters were collected. The funding sources of the studies were categorized into governmental, industrial, or other grants.

Study quality and risk of bias

The quality of the included studies was evaluated by using assessment tools specific for each study type. To evaluate the different study types in a comparable way, we used the tools of the Critical Appraisal Skills Programme, which provides critical appraisal checklists for systematic reviews (24), randomized controlled trials (RCTs) (25), and cohort studies (26). All interventional studies, including RCTs and nonrandomized studies, were evaluated with the tool for RCTs. All observational studies were evaluated with the tool for cohort studies, with omission of the checklist points regarding follow-up when cross-sectional studies were assessed. The possible answer categories for each question of the appraisal checklists were "yes," "no," and "unclear."

Synthesis of results

The study type, details, limitations, and potential sources of bias of the included studies as well as research findings are summarized and synthesized in the Results section. Studies were categorized into longitudinal studies, cross-sectional studies, and systematic reviews. Longitudinal studies are reported stratified by their follow-up period into short-term studies with a follow-up <12 wk and longer-term studies of ≥12 wk. Descriptive data and estimates were rounded to one or no decimal place for better readability where appropriate. Indicators of measurement error or uncertainty, such as SDs or SEs, were presented if reported in the study articles. Study results with P values <0.05 were reported as significant unless otherwise stated.

Level of evidence

The level of scientific evidence for the association between water consumption and body weight outcomes using all existing studies was assessed by the system of the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) group (27). Assessment and table generation were performed for each weight-related outcome stratified according to population subgroup and study type by using GRADEpro software version 3.6.

RESULTS

The flow of the studies throughout the selection process is shown in **Figure 1** (28). From the 4963 citations identified from 4 electronic databases and the other searches, 13 articles—including 11 original studies and 2 systematic reviews—fulfilled all inclusion criteria. Of the original studies, there were 3 RCTs (29–31), 1 nonrandomized interventional study (32), 1 observational longitudinal study (3), and 6 cross-sectional studies (33–38). The characteristics and outcomes of the included studies are presented in **Table 2**, categorized by study type and duration of the follow-up period and sorted by the year of publication and first author's name. The studies excluded in a final step of the selection process and the reasons for their exclusion are listed in **Table 3** (1, 39–45).

The included studies were heterogeneous in study design, sample, method, body weight outcome, and primary aim of the study. Only 4 of the 11 original studies defined the reported association between water consumption and body weight outcomes specifically as the primary research aim of the study (3, 31, 32, 38). Water consumption was assessed by 3- to 7-d records in 4 studies (31, 32, 37, 38), by 1- to 3-d 24-h dietary recalls with or without additional questions on water in 4 studies (3, 34–36), and by a food-frequency questionnaire in one study (33). In 2 RCTs, the consumption of a defined volume of water was part of the intervention and thus was not further assessed (29, 30). The follow-up period of the 5 longitudinal studies ranged from 3 d to 12 mo. In 5 studies, estimates or P values of the association
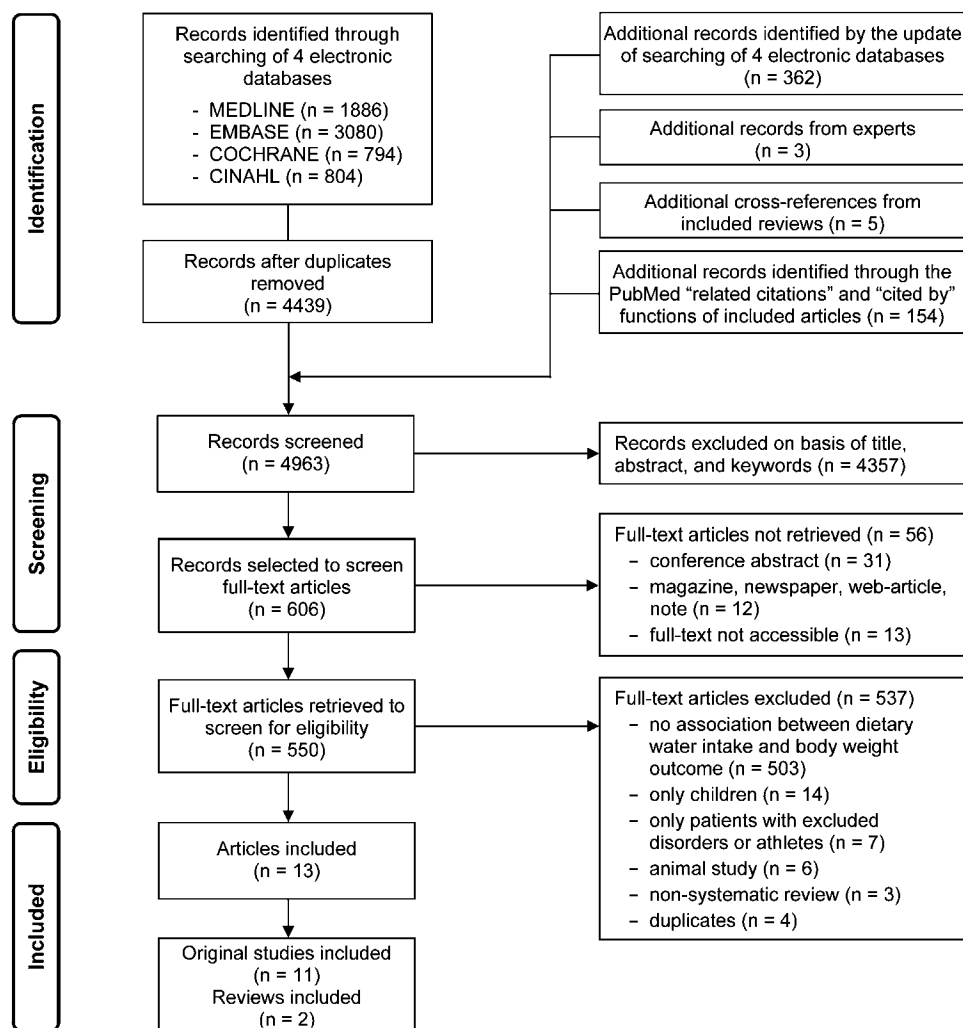
FIGURE 1. Search and screening process from the identification to the inclusion of studies, based on the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) statement (28).

between water consumption and body weight outcomes were not reported (30, 33, 35, 36, 38). On our request, the authors of 4 studies provided statistical estimates, P values, or raw data for presentation in our systematic review (30, 35, 36, 38). With regard to funding, one study was fully funded and 3 studies were partly funded by industrial sponsors (Table 2). Other funding sources were nongovernmental organizations, foundations, or consulting firms. Three of the 4 industrial sponsors were from the beverage industry (3, 18, 29). One sponsor categorized as "other" was a foundation that received grants from the beverage industry (31). All studies were written in the English language, except for one study in French (37). Details on the study sample, methods, funding source, and weight-related outcomes of the included studies are presented in Table 2.

Longitudinal studies with a follow-up ≥12 wk

Dennis et al, 2010

This weight-loss RCT by Dennis et al (31) tested the effect of increased premeal water consumption in addition to a hypocaloric diet. The overweight and obese participants received instructions by a dietitian on a hypocaloric diet. In addition, they were provided weekly with bottled water and a few other select food items and were instructed to maintain their current level of physical activity. In the intervention group, participants were additionally advised to drink 0.5 L water before each of the 3 daily meals. After 12 wk of intervention, the primary outcome body weight loss was ∼2 kg greater in the intervention group than in the control group. Daily water consumption increased in the intervention group to ∼1.3 L, whereas the control group drank 0.3 L. The authors also showed that a reduction in body weight correlated with an increase in water consumption ($r = 0.35$, $P = 0.03$).

A methodologic limitation of the well-conducted study was the incomplete analysis of the sample including 41 out of the 48 randomized participants. Participants were not blinded to the type of intervention, but they were blinded to the specific purpose of the study. Despite the limited sample size, this RCT contributed much evidence to our systematic review because it was designed to answer our specific research question and was of good methodologic quality.

Akers et al, 2012

In this nonrandomized interventional study on weight-loss maintenance by Akers et al (32), the participants who completed the above-described weight-loss RCT by Dennis et al (31) were

TABLE 2
Characteristics and outcomes of the included studies, sorted by the publication year within the different categories of study design and follow-up duration[1]

Study (first author, pub year)	Study type, follow-up	Sample characteristics: no. (no. analyzed), sex, age, study country	Dieting and body weight status of the sample	Primary aim of the study	Methods and statistical analysis	Body weight–related outcomes[2]	Funding
Longitudinal studies with a follow-up ≥12 wk							
Dennis, 2010 (31)	RCT, 12 wk	48 (41) adults, M/F, 55–75 y, USA	Dieting for weight loss, overweight/ obese (BMI: 25–40)	Intervention effect of premeal water consumption on weight loss in dieting adults	Intervention: additional water consumption (1.5 L/d) provided in bottles (0.5 L each) consumed before each of the 3 main meals in addition to a hypocaloric diet Control group: hypocaloric diet alone; study aim blinded to participants Statistics: mixed model including all of the 12 weekly measurements	Significant intervention effect: mean decrease in body weight (in kg) over 12 wk was 44% greater ($\beta = -0.27$, $P < 0.01$; estimates approved by the authors) in the intervention group ($\beta = -0.87$) than in the control group ($\beta = -0.60$); mean decrease in total fat mass $\pm$ SE was greater in the intervention group (-5.4 ± 0.6 kg) than in the control group (-3.3 ± 0.5 kg; $P = 0.01$) No significant intervention effect: no difference in percentage of initial body weight loss, percentage body fat, BMI, and waist circumference between intervention and control groups ($P = 0.17$, $P = 0.08$, $P \geq 0.05$, and $P \geq 0.05$, respectively)	O

(Continued)

TABLE 2 (*Continued*)

Study (first author, pub year)	Study type, follow-up	Sample characteristics: no. (no. analyzed), sex, age, study country	Dieting and body weight status of the sample	Primary aim of the study	Methods and statistical analysis	Body weight–related outcomes[2]	Funding
Akers, 2012 (32)	Nonrandomized parallel group intervention, 12 mo	40 (39) adults, M/F, 63 y (mean), USA	Dieting for weight loss maintenance, participants in a previous weight-loss trial (mean BMI: 29)	Intervention effect of increased premeal water consumption on maintaining body weight after weight loss compared with self-monitoring of weight, physical activity, and fruit and vegetable consumption alone	Participants from a previous weight-loss RCT (Akers et al, 2012), allocation into study groups: participants in the RCT intervention group remained in the intervention group and in the control remained in the control group Intervention: additional water consumption ($\sim$1.4 L/d) consumed in servings [16 fl oz ($\sim$0.5 L)] before each of the 3 main meals in addition to a self-monitoring program to achieve health behavior goals (daily record of water consumption, weight, step count, and fruit and vegetable consumption by tracking sheets) Control group: self-monitoring program alone Statistics: multilevel, quadratic growth curve model for intervention effect on self-reported (daily for 365 d) and laboratory-measured body weight (monthly for 12 mo)	Significant intervention effect: mean decrease in daily self-reported body weight over 12 mo was 87% greater ($\beta = -0.01$, $P < 0.01$) in the intervention group ($\beta = -0.013$, Δweight = -0.67 kg) than in the control group ($\beta = -0.002$, Δweight = 1.00 kg), adjusted for body fat, blood pressure, resting metabolic rate, food weight, total beverage consumption, and water consumption (β estimates partly not published but provided by the authors) No significant intervention effect: no difference between intervention and control group after 12 mo in monthly laboratory-measured body weight ($\beta = -0.23$, $P = 0.08$), BMI, waist circumference, percentage body fat, and total fat mass ($P \geq 0.05$)	G, O

(*Continued*)

TABLE 2 (*Continued*)

Study (first author, pub year)	Study type, follow-up	Sample characteristics: no. (no. analyzed), sex, age, study country	Dieting and body weight status of the sample	Primary aim of the study	Methods and statistical analysis	Body weight–related outcomes[2]	Funding
Stookey, 2008 (3)	Observational longitudinal study, 12 mo	173 adults, F, 25–50 y, water consumption <1 L/d, USA	Dieting for weight loss, overweight/obese (BMI range: 27–40)	Association of increased consumption of drinking water with weight loss over 12 mo in women assigned to 4 popular weight-loss diets	Secondary analysis of data from an RCT (Stanford A TO Z weight-loss intervention trial, which compared 4 popular weight-loss diets, differing in macronutrient profile) Participants: low baseline consumption of water (<1 L/d) Statistics: mixed models to estimate the effects of an increase in drinking water on change in body weight, waist circumference, and percentage body fat over 12 mo, including data from baseline and 2, 6, and 12 mo of follow-up	Significant association between increase in water consumption (from <1 to ≥1 L/d) and body weight outcomes: average change ± SE in body weight, waist circumference, and percentage body fat associated with drinking ≥1 L water/d: -2.3 ± 0.4 kg ($P < 0.05$), -2.3 ± 0.3 cm ($P < 0.05$), and -1.1 ± 0.2 percentage units ($P < 0.05$) Significant relative increase: each one percentage unit of sweetened caloric beverages replaced with drinking water was associated with an average ± SE weight loss of 0.030 ± 0.011 kg ($P < 0.05$), a decrease in waist circumference of 0.034 ± 0.010 cm ($P < 0.05$), and a decrease in percentage body fat of 0.019 ± 0.007 units ($P < 0.05$) Estimates were adjusted for age, race-ethnicity, baseline status, diet treatment group, energy expenditure, energy intake from food, and food macronutrient and water composition	1

(*Continued*)

TABLE 2 (*Continued*)

Study (first author, pub year)	Study type, follow-up	Sample characteristics: no. (no. analyzed), sex, age, study country	Dieting and body weight status of the sample	Primary aim of the study	Methods and statistical analysis	Body weight–related outcomes[2]	Funding
Longitudinal studies with a follow-up <12 wk							
Grandjean, 2003 (29)	Crossover RCT, 3 d (each phase)	32 (27) adults, M, 19–38 y, USA	Not primarily dieting for weight loss, but consuming a diet with the estimated daily energy requirement, normal weight (mean BMI: 23.7)	Intervention effect of drinking water as a beverage compared with a caffeine-free diet cola on hydration	Intervention: additional water consumption (one-third of individual recommended fluid intake by beverages, on average 685 mL) in addition to a standardized diet Control phase: water as beverage replaced by noncaloric caffeinated cola in addition to the standardized diet Setting: laboratory Statistics: paired *t* test to compare intervention and control phase within subjects	No significant intervention effect on body weight: mean change of −0.5 kg after intervention phase and −0.6 kg after control phase (*P* = 0.146)	I, G
Jormeus, 2010 (30)	Crossover RCT, 2 wk (each phase)	20 (20) adults, M/F, 23 y (mean), Sweden	Not primarily dieting for weight loss, mixed-weight status (mean weight: 71 kg)	Intervention effect of increased water consumption on ambulatory blood pressure in healthy subjects	Intervention: additional consumption of tap water (daily amount: 30 mL/kg body weight; mean volume: 2.1 L) provided with bottles consumed over the day Control phase: no intervention	No significant intervention effect on mean body weight: mean difference ± SD between intervention and control phase: 0.18 ± 1.5 kg (*P* = 0.613; estimate and *P* value not published, *t* test performed by the study authors using raw data provided by the study authors)	I, G, O
Cross-sectional studies							
Fulgoni, 2007 (33)	Cross-sectional	8798 adults, M/F, >18 y, USA	Not primarily dieting for weight loss, mixed-weight status	To explore sources of variation in total water intake from food and beverages and from plain water	Survey: NHANES, nationally representative, survey period from 1999 to 2002 Statistics: multiple-regression models	Significant difference in water consumption by body weight status (categories derived from the BMI, definitions not reported): normal-weight adults consumed less plain water than did obese adults, adjusted for sex, race-ethnicity, and age (estimate and *P* value not published)	O

(Continued)

TABLE 2 (Continued)

Study (first author, pub year)	Study type, follow-up	Sample characteristics: no. (no. analyzed), sex, age, study country	Dieting and body weight status of the sample	Primary aim of the study	Methods and statistical analysis	Body weight–related outcomes[2]	Funding
Kant, 2009 (34)	Cross-sectional	10,921 (survey 1999–2004)/ 3878 (survey 2005–2006) adults, M/F; ≥20 y, USA	Not primarily dieting for weight loss, mixedweight status	To investigate the association of water intake via plain water, beverages, and foods and total water with sociodemographic factors, dietary characteristics, and meal patterns	Survey: NHANES, nationally representative, survey waves (1999–2004 and 2005–2006) Statistics: multiple-regression models	Survey 1999–2004: significant difference in daily plain water consumption by body weight status Water consumption (adjusted means ± SE) was higher among higher BMI groups: normal weight (BMI < 25): 1160 ± 38 g; overweight (BMI 25 to < 30): 1224 ± 39 g; obese (BMI ≥ 30) 1382 ± 40 g ($P = 0.002$) Survey 2005–2006: no significant difference ($P = 0.2$) in daily plain water consumption (adjusted means ± SE) by body weight status; normal weight (989 ± 55 g), overweight (1041 ± 65 g), and obese (1152 ± 86 g) Means were adjusted for sex, age, race-ethnicity, poverty-income ratio, years of education, smoking status, day of dietary recall, leisure-time and daily physical activity, self-reported chronic diseases, survey wave, and ratio of energy intake to basal energy expenditure	G

(Continued)

TABLE 2 (Continued)

Study (first author, pub year)	Study type, follow-up	Sample characteristics: no. (no. analyzed), sex, age, study country	Dieting and body weight status of the sample	Primary aim of the study	Methods and statistical analysis	Body weight–related outcomes[2]	Funding
Kuczmarski, 2010 (35)	Cross-sectional	1987 adults, M/F, 30–64 y, USA	Not primarily dieting for weight loss, mixed-weight status	To determine the beverage consumption patterns of African American and white participants in the HANDLS study by their weight status	Cross-sectional analysis of the baseline evaluation of the longitudinal HANDLS study. Statistics: generalized linear models, Bonferroni corrected for multiple-comparisons tests	No significant difference in water consumption ($P > 0.0167$; P value and level of significance not published but provided by the authors) between normal/underweight (BMI < 25), overweight (BMI: 25 to <30), and obese (BMI ≥ 30): daily water consumption (mean ± SE) was 33.1 ± 1.5 fl oz (0.98 L) in normal-weight, 34.1 ± 1.6 fl oz (1.01 L) overweight, and 35.0 ± 1.3 fl oz (1.04 L) in obese participants	G
Langdon, 2010 (36)	Cross-sectional	218 adults, F, 18–22 y, USA	Not primarily dieting for weight loss, mixed-weight status	To investigate the use of water consumption as an appetite suppressant and the correlates of its use	Survey: name not reported. Statistics: correlation analysis	No significant association between BMI (calculated by self-reported body weight) and reported number of cups of water consumed per day: $r = -0.017$, $P = 0.81$ (results not published but provided by the authors)	G
Cross-sectional studies only on tap or mineral water							
Beaudeau, 2003 (37)	Cross-sectional	1809 adults and children, M/F, >3 y, France	Not primarily dieting for weight loss, mixed-weight status	To describe the tap water consumption in the French population and its associated factors	Survey: INCA1, nationally representative, survey period 1999. Statistics: generalized additive model	Significant direct association between plain tap water consumption per week and body weight in adults and children ($P = 0.004$), but the slope flattened from the weight of ~80 kg, as shown in a graph (adjustment unclear)	G

(Continued)

TABLE 2 (*Continued*)

Study (first author, pub year)	Study type, follow-up	Sample characteristics: no. (no. analyzed), sex, age, study country	Dieting and body weight status of the sample	Primary aim of the study	Methods and statistical analysis	Body weight–related outcomes[2]	Funding
Ilich, 2009 (38)	Cross-sectional	120 adults, F, 60 y (mean), Croatia	Not primarily dieting for weight loss, mixed-weight status (mean BMI: 26.5)	To investigate the association of nutrients and lifestyle modifiers with bone mineral density, body weight, and BMI	Survey: name not reported Water assessment: only mineral water Statistics: multiple-regression model	Significant inverse association between mineral water consumption and body weight outcomes: mineral water consumption in L/d was inversely related to BMI (β: −2.3, $P = 0.0033$) adjusted for age and osteoporosis status and with body weight in kg (β: −2.6, $P = 0.0029$) adjusted for age, height, and osteoporosis status (β coefficients not published but provided by the authors)	G
Systematic reviews							
Dennis, 2009 (17)	Systematic review	Adults, M/F	Dieting or weight status not defined	Effect of the consumption of different beverages on meal energy intake (short-term) and on body weight (long-term)	Search methods for identification of studies: electronic search in one database (PubMed) Limits: English language, published within the previous 15 y except 1 key reference Data synthesis: qualitative	2 references identified: 1 observational longitudinal study (3), 1 abstract of an interventional study (40) Study authors' conclusion: "Studies suggest a beneficial role for water consumption [...] in promoting weight management, yet there is insufficient data from interventional studies to make conclusive evidence-based intake recommendations for water consumption."	G
Daniels, 2010 (18)	Systematic review	Adults and children, M/F	Dieting or weight status not defined	Effects of water consumption on meal energy intake (short-term) and on body weight status (long-term)	Search methods for identification of studies: cross-references from 5 reviews on beverages and energy intake, from known studies, and eligible studies; no electronic search reported Limits: English language Data synthesis: qualitative	5 references including adults identified: 1 RCT (31), 1 observational longitudinal study (3), 1 abstract of an interventional study (40), and 2 cross-sectional studies (34, 43) Study authors' conclusion: Some adult studies supported an inverse relation of water drinking with weight status, but the literature is "strikingly sparse and this along with variation in study designs made drawing broad conclusions difficult."	I, G

[1] Data were rounded where appropriate to improve readability. BMI is reported in kg/m^{2}. G, governmental; HANDLS, Healthy Aging in Neighborhoods of Diversity across the Life Span; I, industrial; INCA1, L'enquête individuelle et nationale sur les consommations alimentaires; O, other; pub, publication; RCT, randomized controlled trial.

[2] Means, SD, estimates, and SEs are provided if reported in the articles or provided by the authors.

TABLE 3
List of selected excluded studies with study description and reason for exclusion

Study (first author, publication year)	Study aim and design	Exclusion reason
Burger, 2007 (39)	Cross-sectional study in a laboratory setting to investigate the association of participants' BMI on self-selected portion sizes from presented food	Water consumption was measured for a period shorter than 1 d
Davy, 2008 (40)	Preliminary analysis of a randomized controlled trial to investigate the effect of increased premeal water consumption on rapid weight loss in subjects on a hypocaloric diet	Publication was a conference abstract; original article was published by Dennis et al in 2010 (31)
Fowler, 1910 (41)	Nonrandomized crossover interventional study to investigate the effect of water ingestion with meals on digestive function and nitrogen metabolism in one participant	Study was a case report with one participant
Kozlowski, 1975 (42)	Randomized controlled trial with factorial design to investigate different effects of cue prominence on water consumption in obese and normal-weight subjects	Water consumption was measured for a period shorter than 1 d
Phelan, 2009 (43)	Cross-sectional study to compare the dietary strategies and use of fat- and sugar-modified foods and beverages such as water in a weight-loss maintainer group and an always normal-weight group	No eligible body weight outcome: the 2 comparison groups were weight-loss maintainers and always normal-weight subjects
Sciamanna, 2011 (1)	Cross-sectional study to compare the practices in individuals with successful short-term weight loss and individuals with long-term success who maintained their reduced weight for ≥1 y	No eligible body weight outcome: body weight development within the recent year but not the current status was reported
Tate, 2012 (44)	Randomized controlled trial to investigate the effect of 2 noncaloric beverage-replacement strategies (water and diet beverages) on body weight	No eligible measure of water consumption: the intervention consisted of the substitution of sugar-sweetened beverages with increased water consumption
Warner, 1975 (45)	Two cross-sectional studies to compare eating behavior of normal-weight and overweight subjects, measured by observation of food and beverage consumption of participants having a test meal and of students having lunch in a canteen	Water consumption was measured for a period shorter than 1 d

enrolled. Because participants remained in the study arms into which they were allocated in the previous RCT (31), the study was a nonrandomized, parallel-group interventional trial. The aim of this study was to test whether increased premeal water consumption in combination with a behavioral program would be more effective for weight-loss maintenance than the behavioral program alone. The behavioral program consisted of setting goals in health behavior, self-monitoring, and monthly dietary counseling (32). In the intervention group, participants were additionally instructed to drink ∼0.5 L water before each main meal and to self-monitor their water consumption. Analysis of daily self-reported body weight showed that weight loss was significantly greater by 87% in the intervention group than in the control group. In contrast, the intervention effect on the primary outcome monthly laboratory-measured body weights was not significant. There was also no significant group difference in waist circumference or body fat.

Thus, the results are inconclusive because the significance of the intervention effect differed by the measurement method. As an explanation, the authors stated that the power to show an intervention effect was higher when using the self-reported body weight with 365 available reports in contrast with the monthly laboratory-measured body weight.

A major limitation of the study was that the allocation of participants to the study groups was not random but was determined by participants' initial allocation to a weight-loss intervention in the previous RCT. Thus, the 2 groups differed in various baseline characteristics, such as previous weight loss, body fat, resting metabolic rate, and water consumption. The authors adjusted their analyses by including these baseline variables into the models. However, it is possible that differences in weight-loss maintenance and the reaction to the intervention were influenced by the previous weight-loss intervention.

Stookey et al, 2008

In a secondary analysis of longitudinal data from an RCT, Stookey et al (3) investigated the prospective association between increased water consumption and body weight in overweight women dieting for weight loss. In the underlying RCT (46), the effects of 4 popular weight-loss programs with different macronutrient profiles were compared. All dietary programs contained advice on beverage consumption, but they did not focus on it. In this secondary analysis, participants with a baseline water consumption <1 L/d were included. After 12 mo, the average weight loss in the total sample was 3.1 kg. Women who increased their absolute water consumption to ≥1 L water/d had, on average, a greater weight loss of 2.3 kg over 12 mo compared with women who kept on drinking <1 L/d, with control for baseline characteristics, treatment groups, and time-varying energy intake, energy expenditure, and food composition. After an additional adjustment for energy intake from beverages, the effect remained significant. This indicates that the effect of increased water consumption was independent of a change in

energy intake by beverages. Similar results were obtained for waist circumference and percentage body fat.

Regarding the limitations of the study, the character of a secondary analysis of an RCT must be mentioned; however, the analyses were controlled for diet program. In addition, only a very specific population group—overweight middle- to older-aged women willing to participate in a weight-loss trial—participated. Furthermore, only a subgroup of 173 of 311 women drinking <1 L water/d was analyzed. The transfer to other population groups may be limited, but the advanced statistical modeling with appropriate adjustments favors valid results regarding the research question of our review.

Longitudinal studies with a follow-up <12 wk

Grandjean et al, 2003

The aim of this randomized crossover study by Grandjean et al (29) was to measure the effect of the consumption of water compared with a noncaloric soft drink on body hydration. Thus, the body weight change was used as an indicator of hydration status. In the intervention phase, one-third of the individually recommended fluid intake from beverages was provided by drinking water. In the control phase, water was replaced by a noncaloric caffeinated soft drink. No difference in weight change between the 2 study phases lasting 3 d was detected.

A major limitation of this study with respect to our research question was that the standardized water consumption in the intervention phase was completely substituted by another noncaloric beverage. Thus, the study could not investigate the effect of additional water consumption mediated by a replacement of other caloric beverages or an overall increased fluid intake. In addition, the follow-up was only 3 d, which was likely too short to show an effect of a dietary intervention modified by increased water consumption on body weight outcomes. In this study, body weight was defined as a hydration marker and not as an indicator of body weight status, which highlighted that the research aim of the study differed from ours.

Jormeus et al, 2010

Another randomized crossover study, by Jormeus et al (30), investigated the effect of increased water consumption on ambulatory blood pressure. In the intervention but not in the control phase, participants were instructed regarding the daily additional consumption of 30 mL tap water/kg body weight. The actual increase in water consumption was, on average, 2.0 L, as indicated by urine volume. Because details of the secondary outcome body weight were not reported, the study authors provided the raw data to us to calculate descriptive and analytic statistics. No significant difference in body weight between the intervention and control phases after 2 wk was observed.

A main limitation of this study for providing evidence for our review was that the primary research question differed from ours by targeting the effect of water consumption on blood pressure. The increase in water consumption by 2.0 L was considerable, but the mean fluid intake in the control phase was also in the standard range (1.7 L), indicated by the mean urine volume. The intervention phase of 2 wk may have also been too short to observe significant effects of water consumption on body weight in participants of mixed-weight status not primarily dieting for weight loss or maintenance. In addition, our statistical analysis could not consider any possible carryover effect because we had no information on the individual treatment sequence.

Cross-sectional studies

Fulgoni, 2007

Fulgoni (33) performed a cross-sectional analysis of NHANES in the United States from the survey years 1999–2002. The aim of the study was to investigate factors that were associated with the consumption of plain water, total fluid, and fluid from food and beverages. Body weight status was categorized by BMI into normal weight, overweight, and obesity without providing the BMI cutoffs. The author reported significant differences in plain water consumption by body weight status, adjusted for age, sex, and race-ethnicity in adults. Obese adults consumed more plain water than normal-weight adults. Neither data on plain water consumption in these groups nor on the statistics and P values were presented in the article.

The data from NHANES can provide good estimates of water consumption in the US population because participants were drawn from a representative sample. Plain water consumption was estimated by using a food-frequency questionnaire for which no data on validity regarding the measurements of plain water consumption were available. The analysis was adjusted for some covariates but not for other potential confounders, such as energy intake, that may further limit the interpretation of this cross-sectional association.

Kant et al, 2009

Kant et al (34) also analyzed NHANES data aiming to assess the association of fluid intake with several sociodemographic and dietary characteristics. Two periods of the survey were analyzed separately. In the waves between 1999 and 2004, adjusted plain water consumption was higher in adults of higher BMI groups. In contrast, in the wave from 2005 to 2006, the difference in daily plain water consumption by body weight status was not significant.

A possible reason for the inconsistent association among the survey waves could be the different methods used for the assessment of water consumption. In the period from 1999 to 2004, plain and carbonated water consumption was assessed by a 24-h recall and by additional questions on water consumption asked after the recall. In the survey wave from 2005 to 2006, the data on water consumption was collected by integrated questions in a 24-h dietary recall. The authors stated that this was the reason for the stratified analyses by survey wave and suggested that this could explain why the association between water consumption and body weight status was only significant in the earlier wave period. The analysis was adjusted for several covariates, such as socioeconomic characteristics, health and smoking status, and indicators of physical activity and energy intake, that can influence the water needs and losses of the body.

Kuczmarski et al, 2010

In a cross-sectional analysis of a cohort study, Kuczmarski et al (35) investigated the beverage-consumption patterns of African American and white participants by weight status. Participants at baseline with 2 reliable dietary recalls were analyzed. The

consumption of water, which included tap, bottled, and fitness water, did not differ significantly between the normal-weight, overweight, and obese adults. The analysis of this association was not adjusted for possible confounders. Water consumption was higher among overweight and obese African Americans than among their white counterparts. Thus, the association between water and body weight status might have been hidden or confounded by ethnicity. However, data from this select sample of middle-aged adults with a lower income cannot be easily transferred to the general population. In addition, the association was not adjusted for possible confounders.

Langdon et al, 2010

Langdon et al (36) investigated the use of water consumption as an appetite suppressant in female students in a cross-sectional study. The participants self-reported their body weight, height, and dietary water consumption during the previous 48 h with the use of an online questionnaire. The association between water consumption and any weight outcome was not reported. At our request, the authors provided the results of a correlation analysis. No significant correlation was found between BMI and water consumption.

The aim of this study was to compare the characteristics of women who used water consumption as an appetite suppressant with those women who did not. Thus, the statistical association between water consumption and body weight outcomes was not part of the primary analysis. No adjustment for potential confounders, such as using water consumption as an appetite suppressant, was performed.

Cross-sectional studies with tap or mineral water only

Beaudeau et al, 2003

A 1999 nationally representative dietary survey by Boudreau et al (37) in France, called INCA1 (L'enquête individuelle et nationale sur les consommations alimentaires), was analyzed to describe water consumption and its associated factors. Several types of water, such as nonheated and heated tap water as well as bottled water, were assessed by using a 7-d protocol. Analyses showed that nonheated tap water consumption per week was directly associated with body weight in adults and children. The nonlinear graph of this association indicated that the increase of tap water consumption with body weight flattened for body weights higher than ~80 kg.

The association of total water consumption with body weight was not reported. Because the study showed that the association between tap and bottled water consumption was U-shaped rather than linear, tap water is most likely not a good predictor of total water consumption. Furthermore, in cross-sectional analyses, body weight is not an appropriate indicator of body weight status if not adjusted, eg, for age or height. The regression analyses of water consumption on body weight included adults and children without control for age or height. Because of these study limitations, no valid conclusion on the association between water consumption and weight-related outcomes as indicators of body weight status in adults can be drawn from this study.

Ilich et al, 2009

A cross-sectional study by Ilich et al (38) in Croatia investigated the association of dietary and other lifestyle factors with bone mineral density and body weight. By means of a dietary record, mineral water but not tap water was assessed. Regression analyses showed that BMI was inversely related to the consumption of mineral water. Each increase in mineral water consumption by 1 L was associated with a decrease in BMI (in kg/m^2) by 2.3, adjusted for age and osteoporosis status. Similar results were obtained for body weight. Estimates from the regression analyses were not presented in the publication, but were provided by the authors.

Because of recruitment from university staff and from women who were referred for densitometry to a hospital, the sample population cannot be regarded as representative of Croatian women. Because only 44 of 120 women drank any mineral water as reported by the authors on request, the interpretation of the observed positive association was further limited. It is important to stress that consumption of only mineral water and not of other water types, such as tap water, was assessed, most likely because of the primary research question regarding bone mineral density. Thus, conclusions on the association between total dietary water consumption and body weight outcomes cannot be drawn from this study.

Systematic reviews

Two systematic reviews (17, 18), published in 2009 and 2010, were included in our systematic review. Both reviews together identified 5 original studies of the association between water consumption and body weight outcomes. Only 3 of these 5 studies met our eligibility criteria and were included in our systematic review (3, 31, 34). In total, we identified an additional 8 original studies that were not included in the 2 previous reviews (29, 30, 32, 33, 35–38).

Dennis et al, 2009

The first systematic review by Dennis et al (17) addressed both the short-term and long-term effects of the consumption of various beverages, including water, in adults. The short-term effect was understood as the effect of premeal beverage consumption on energy intake with subsequent ad libitum meals. The longer-term effect was defined as the effect of beverage consumption on body weight. With regard to the effect of water consumption on body weight in adults, Dennis et al identified the following 2 references: an observational longitudinal study (3) and a conference abstract (40) with preliminary results of a nonrandomized interventional study that was published as an article by Akers et al (32) in 2012. Both references pointed to a beneficial effect of increased daily water consumption on individuals dieting for weight loss or maintenance. Thus, the authors concluded that, whereas encouraging water consumption may facilitate weight management, the evidence had been very limited and more interventional studies were needed. In contrast, a much greater number of studies was identified that investigated the short-term effect of water consumption on energy intake.

The authors performed a systematic electronic search in PubMed but did not title their review as "systematic." This may be a reason why there were only limited reports on the methods. No information was given about the search terms used in the electronic search, the reviewers who screened the references, or the number of identified references, screened full-text articles, and included and excluded studies. It also remained unclear

which study types were included and if cross-sectional studies were also searched to answer the research question. In fact, no cross-sectional studies were reported. In addition, the review did not focus only on water consumption and its effect on body weight but also on the short- and longer-term effects on body weight of various beverage categories, such as soft drinks, milk, and tea. Thus, only a small proportion of the review and the identified studies were relevant for the research question of our systematic review.

Daniels et al, 2010

A second systematic review by Daniels et al (18), published 1 y later in 2010, also focused on more than one research question as it investigated not only the effect of water consumption on body weight status but also the short-term effect on energy intake with the subsequent meal. With regard to studies in adults, the review identified 1 RCT (31), 1 observational longitudinal study (3), 1 abstract with preliminary results of an interventional trial (40), and 2 cross-sectional studies (34, 43). In contrast with our review, Daniels et al included the study by Phelan et al (43), which showed that weight-loss maintainers drank more water servings than did participants who always had a normal weight. We excluded this study from our review because water consumption was not compared between groups of different weight statuses but rather between weight-loss maintainers and individuals with normal weight who had not lost weight before inclusion in the study (43).

The authors summarized that, whereas it was difficult to make any conclusion because of the very sparse literature and the high variation in study design, there was some evidence from the adult studies for an inverse relation between drinking water and body weight.

A major limitation of this systematic review was that it did not report whether electronic databases were searched systematically in addition to the cross-referential search. Search terms for the electronic search, details on the screening process, the numbers of identified references and screened full-text articles, and inclusion or exclusion criteria for study types were not reported. Similarly to the review by Dennis et al (17), the primary research aim was not exclusively the effect of water consumption on body weight but also the short-term effect of water consumption on energy intake compared with other beverages. For this short-time effect, the authors identified numerous trials that were meta-analyzed.

Study quality

Because we included studies with a wide range of designs and methods, the quality was very heterogeneous and depended basically on the study type. Tables showing the quality assessments of the included studies, as determined by applying the Critical Appraisal Skills Programme criteria for interventional studies, observational studies, and systematic reviews, are presented elsewhere (*see* Supplemental Material 2, 3, and 4, respectively, under "Supplemental data" in the online issue). All studies had some methodologic limitations, and none of the included studies fulfilled all of the quality criteria. Two of the 5 longitudinal studies were short-term crossover RCTs with a follow-up period of 3 to 14 d. In the 4 interventional studies, none of the interventions could be blinded to the participants, the precision of the statistical estimates was not reported, and in

3 studies, losses to follow-up were not accounted for in the analysis. One interventional study was not randomized. In 2 of the 3 RCTs, the primary research question differed from ours. The observational longitudinal study can be regarded as of good quality with few limitations. In contrast, most of the cross-sectional studies had a lower quality level, mainly because most of them did not consider possible confounding factors. The 2 systematic reviews addressed clearly defined research questions, but both were far broader than ours. The authors of the systematic reviews looked for the appropriate types of articles, but both reviews showed limitations in the search strategy or in the reporting of the searching and review methods. None of the reviews systematically assessed the quality of the included studies using tools for quality evaluation.

Summarizing the evidence

Of the studies with populations participating in a program for weight loss or maintenance, 2 studies—1 nonrandomized interventional trial (32) and 1 observational longitudinal study (3)—showed that increased water consumption has the potential to reduce body weight. In the only RCT among this specific population group, the beneficial effect of water consumption was shown to be effective at reducing total fat mass and self-measured body weight but not laboratory-measured body weight (31). With regard to other body weight outcomes, the beneficial effect of water consumption on waist circumference and percentage body fat was only significant in the observational longitudinal study (3). However, no effect was reported on BMI, percentage of initial body weight loss, or total fat mass. The 2 interventional studies investigated the effect of increasing daily water consumption by a volume of 1.4 to 1.5 L water, consumed in servings of 0.5 L before each main meal over 3–12 mo. The observational longitudinal study tested the effect of increasing water consumption from <1 to ≥ 1 L/d over 12 mo.

In healthy adults not primarily dieting for weight loss or maintenance, 2 small crossover RCTs investigated the short-term effect of water consumption on body weight after 3–14 d (29, 30). Both trials reported the effect on body weight as a secondary outcome. Changes in body weight outcomes were intended to indicate changes in the water content of the body rather than in body fat. As a result, neither trial detected an effect on body weight after the intervention phases of 3 and 14 d, respectively. In one of these short-term studies, the effect of 2.1 L of additionally consumed water was investigated (30); in the other study, the effect of substituting ~ 0.7 L water with another noncaloric beverage was evaluated (29).

Two representative surveys, which generated 3 analyses (33, 34), and 2 cross-sectional studies (35, 36) investigating the association between the amount of daily water consumption and the body weight status of US adults yielded controversial results. Three of these analyses did not find a significant association with BMI or BMI category. In contrast, 2 analyses showed that obese individuals consumed, on average, more water than did normal-weight individuals.

Two additional cross-sectional studies assessed the consumption of only tap water (37) or only mineral water (38). Tap water consumption was directly associated with body weight, whereas mineral water consumption increased with decreasing BMI.

The overall level of evidence, assessed by using the GRADE system (27) is presented for each weight outcome in **Table 4**. The 2 studies providing only mineral or tap water consumption and the 2 reviews were excluded from the evidence assessment, which resulted in the analysis of 9 studies. In subjects dieting for weight loss or maintenance, the overall quality of evidence for the effect of increased water consumption on several body weight outcomes was "very low" when derived from interventional studies or could not be evaluated because of the availability of only one cohort study. Similarly, in general, mixed-weight populations not primarily dieting for weight loss or maintenance, the quality of evidence of an association between increased water consumption and the outcomes body weight, BMI, or body weight status was "very low," mainly because of the lack of good-quality interventional studies and the data derived from cross-sectional studies.

DISCUSSION

To our knowledge, this was the first systematic review to focus on the association between dietary water consumption and body weight outcomes in adults. We identified 11 original studies. In individuals dieting for weight loss or maintenance, a body weight–reducing effect of increased water consumption was detected in 2 interventional and in 1 observational longitudinal study. In non-dieting participants, 2 short-term RCTs found no effect of increased water consumption on body weight. The cross-sectional studies in general, mixed-weight populations led to contradictory results. The quality of the included studies was limited mainly because of the observational character and the differing primary research questions. According to the GRADE system (27), the level of evidence for the effect of increased water consumption on different body weight outcomes was evaluated as very low.

Recently, 2 systematic reviews concluded that increased water consumption may have a beneficial role in weight management and obesity prevention (17, 18). In our review, we were able to identify 11 original studies compared with 2 and 5 studies, respectively, in these 2 reviews. A reason for this difference may be that we focused on one research question. The previous reviews simultaneously investigated the effects of a variety of beverages, such as soft drinks and coffee, or studied also the short-term effect on energy intake. Both reviews applied less comprehensive search strategies to identify relevant studies. They did not report a systematic search of an electronic database or searched only one and included only articles in the English language. In contrast, we performed an extensive literature search applying several search methods. We searched 4 electronic databases in 4 major publication languages without any limits to publication year.

TABLE 4
Level of evidence for the association between consumption of water as a beverage and body weight outcomes, separated by populations dieting for weight management and general mixed-weight population

Outcomes	Study design	No. of studies	No. of participants	Duration of follow-up	Quality of the evidence	
					GRADE level[1]	Reason for downgrade
Adults, dieting for weight loss or maintenance						
Body weight	Randomized controlled trial[2]	2	80	32 wk	Very low[2–4]	Risk of bias, inconsistency, imprecision
BMI, waist circumference, percentage body fat, and total fat mass	Randomized controlled trial[2]	2	80	32 wk	Very low[4–6]	Inconsistency, indirectness, imprecision
Body weight, waist circumference, and percentage body fat	Cohort study	1	173	52 wk	No evaluation	Only one study
Adults, general, mixed-weight population						
Body weight	Randomized controlled trial[7]	2	94	9 d	Very low[4,6,8,9]	Risk of bias, indirectness
BMI	Cross-sectional	1	2018	—	No evaluation	Only one study
Body weight status (defined by BMI)	Cross-sectional	3 (4 analyses)	25,584	—	Very low[4,5,10,11]	Risk of bias, inconsistency, indirectness, imprecision

[1] GRADE (Grading of Recommendations Assessment, Development, and Evaluation) Working Group levels of evidence: high (further research is very unlikely to change our confidence in the estimate of effect), moderate (further research is likely to have an important effect on our confidence in the estimate of effect and may change the estimate), low (further research is very likely to have an important effect on our confidence in the estimate of effect and is likely to change the estimate), and very-low (we are very uncertain about the estimate).
[2] Includes one nonrandomized trial.
[3] Self-reported weight and measured weight do not yield the same result.
[4] Sparse data.
[5] Results were contradictory.
[6] Weight-related outcome not primary outcome.
[7] Crossover design.
[8] Short follow-up of ≤2 wk.
[9] Studies were not designed and powered to detect effects on the outcome.
[10] Potential relevant confounders not considered.
[11] Outcome was often not the primary outcome.

The major limitation of our systematic review was the limited number of existing original studies, especially with longer-term follow-ups. Only 3 longitudinal studies had a follow-up period of 3 to 12 mo (3, 31, 32), which can be considered as appropriate for assessing significant changes in body weight outcomes. In contrast, the follow-up periods of 3 to 14 d in the 2 short-term RCTs (29, 30) were most likely too short to result in any measurable and relevant effect on body fat content. A further limitation was that 6 of the identified studies had a cross-sectional design. These studies can only show associations but not causal effects of increased water consumption on body weight outcomes. The cross-sectional associations of water consumption with body weight were not consistent; most studies indicated either a direct association or no association. The higher water consumption in overweight and obese than in normal-weight adults could be explained by an increased requirement of total water intake, because the individual's water requirement also depends on the diet (47, 48). Food with a higher renal solute load, which is predominantly determined by the protein and salt contents of the diet, requires more water for renal solute excretion (48). Salt intake was higher in obese than in nonobese adults, eg, in a Turkish population, but not in the US population (49, 50). Recent NHANES data also showed that the proportion of energy intake from protein was higher in obese than in normal-weight adults (51). Although the influence of dietary protein and sodium intakes on water consumption is not proven (47, 48), these potential differences in the diet by body weight status may explain the higher water consumption in obese than in normal-weight adults.

The identified studies varied widely with regard to study design and population but also in statistical analyses and adjustments. Because the association between water and body weight outcomes was often not the primary research question, the selection of adjustment sets for the control of confounders was not theory-driven. In some cross-sectional studies, only the crude association was calculated (35, 36), whereas in others the association was adjusted for several covariates (33, 34, 38). However, most of the analyses did not control for possible weight-related confounders, which were shown to be linked to water consumption, such as dietary fiber intake, physical activity, education, or consumption of caloric beverages or fast food, or total sugar intake (33, 34, 52). In addition, water consumption has been defined and measured very heterogeneously. The validity of the assessment tool regarding water consumption was usually not reported. In the NHANES, the assessment tools for water consumption differed among the survey waves, which may have accounted for the observed variation in association (34).

Some of the included studies were funded by the beverage industries, which are interested in marketing bottled water. The funding of the study should be considered when interpreting the results (53). In our systematic review, 3 of the 5 longitudinal studies and 1 systematic review were at least in part industry-sponsored. Because the studies showing a beneficial effect of water consumption had different types of sponsorships, no obvious trend for a bias by sponsorship can be derived.

Several potential mechanisms might have contributed to a beneficial effect of water on weight loss and maintenance. One postulated pathway is a short-term suppression of hunger leading to a reduced energy intake (17, 18). A meta-analysis estimated the effect of water ingested before or with a meal on energy intake during the subsequent meal based on 13 studies (18). Overall, there was no effect, but a stratified analysis by age group showed that increased water consumption reduced energy intake in older but not in younger subjects (18). A systematic review came to the same conclusion (17). In the 2 interventional studies indicating that water consumption may reduce weight, the middle- to older-aged participants were also instructed to drink ∼0.5 L water before each main meal (31, 32). Another potential mechanism of water consumption on body weight is the so-called thermogenic, energy-consuming effect of ingested water. In 2 experimental studies the consumption of 0.5 L water increased the metabolic rate and resulted in excess energy expenditure by ∼100 kJ in normal-weight adults and 95 kJ in overweight adults, including the energy needed to warm the water up to body temperature (19, 20). However, the thermogenic effect of water consumption has not been confirmed by other experimental studies and appears to be minor (54, 55).

These suggested dietary and physiologic mechanisms of increased water consumption for a beneficial effect may also apply to other noncaloric beverages, such as tea or coffee. To evaluate whether water consumed in other forms has a similar effect requires studies that consider all sources of fluid intake by noncaloric beverages.

Because tap water is widely and economically accessible, a recommendation of increased water consumption to prevent overweight and obesity may become relevant for public health. Especially in countries where drinking water from the tap is safe and palatable, tap water should be promoted as the preferred water source. In countries where tap water is still potentially contaminated, the provision of safe tap water should have priority.

This comprehensive systematic review showed that studies of individuals dieting for weight loss or maintenance suggest a weight-reducing effect of increased water consumption, whereas studies in general and in mixed-weight populations yielded inconsistent results. The evidence for this association is still sparse, mostly because of the lack of good-quality studies. Longitudinal studies with a comparator group and a large enough sample size are needed both in individuals dieting for weight loss or maintenance and in the general population for the prevention of overweight and obesity.

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