Review Article

Does Much Hyped Alkaline Electrolyzed Water Provide Health Benefits? A Systematic Review and Narrative Synthesis

Tejus Anantharamu, R. Vishnuprasad[1], Sharmila Sinha[2], D. Santhanalakshmi[3], Sapna Pradhan[4], Fadil Salmani[4]

Regional Centre, ECHS Ranchi, [1]Station Health Organisation, Jodhpur, [2]Department of Pharmacology, Armed Forces Medical College, Pune, Maharashtra, [3]Department of Physiology, Sri Venkateswaraa Medical College Hospital and Research Institute, Chennai, [4]Department of Pharmacology, Army College of Medical Sciences, Delhi Cantt, India

Abstract

Alkaline electrolyzed water (AEW) usually has a pH value ranging from of 8 to 10, and is postulated to produce many health benefits. Alkaline water consumption still invites a lot of controversy among health professionals and researchers. There were no comprehensive large-scale studies till date that compared the effects of AEW across various disease states targeting multiple system changes as outcomes. The present literature review was carried out to collate all the available clinical research works on Alkaline Water or AEW in improving disease state or promoting health. Search in various databases and search engines brought out 19 articles, of which nine met the eligibility criteria and were included for the analysis in the present study. The risk of bias and quality for every study included in the study were assessed. For all the randomized trials included in the study bias assessment was carried out using the Cochrane Risk-of-bias tool, and nonrandomized trials were assessed using nonrandomized studies of interventions tool. Reviewed studies have reported effects of AEW on oxidative stress, gastric cancer, blood sugar levels, exercise performance, blood viscosity, and gastrointestinal symptoms. AEW has shown considerable positive health effects in small-scale clinical studies. However, presently available evidence from the research works are not sufficient enough for recommendation to the mass in general or for use as a therapeutic intervention. Research works with larger study samples and among population of different demography are required.

Keywords: Alkaline electrolyzed water, anti-oxidant, drinking water, health effects, pH

Introduction

Water is a vital need for maintaining cellular homeostasis as it constitutes almost 75% of body weight in infants and up to 55% in the elderly. Variation in water intake has been linked to human health, and performance.[1] Chemicals present in polluted water on consumption are known to induce oxidative stress.[2] It is suggested that advancing age and diet, induces chronic low-grade metabolic acidosis that can bring about a small decrease in pH and bicarbonate in plasma. To counter the same, the consumption of naturally occurring alkaline water and alkaline electrolyzed water (AEW), also known as electrochemically reduced water (ERW) that exhibits an alkaline pH (usually in the range of 8–10), rich in hydrogen molecules, has negative oxidative reduction potential and possess scavenging activity on reactive oxygen species (ROS) has been widely promoted in the recent past.[2,3] The functional water association of Japan defines functional water as the water that is activated (either by electrolysis, bubbling with gases, irradiation, ultrasonication, or treatment with magnetic field/some minerals) and produces useful functions that can be demonstrated and reproduced scientifically.[3,4] Electrolysis is performed by flowing the normal water filtered through carbon filters, into an electronic chamber containing an anode and cathode separated by a diaphragm. The water produced from cathode of the electrolytic chamber is rich in H_2 with a pH of 8–10 is called AEW or ERW and the water produced from the anode will be rich in H^+ with a pH of 4–6 is called acidic electrolyzed water or electrochemically oxidized water (EOW).[3,4] The appliances that can electrolyze drinking water have been used extensively in Japan and Taiwan for domestic purposes.[3,4] EOW is used in the food industry (especially for the processing of seafood) as a

Access this article online

Quick Response Code:

Website: www.ijehe.org

DOI: 10.4103/ijehe.ijehe_12_22

Address for correspondence: Dr. R. Vishnuprasad, No: 22, Muthu Nagar, Muthirayarpalayam, Puducherry - 605 009, India. E-mail: vishnuprasath2@gmail.com

How to cite this article: Anantharamu T, Vishnuprasad R, Sinha S, Santhanalakshmi D, Pradhan S, Salmani F. Does much hyped alkaline electrolyzed water provide health benefits? A systematic review and narrative synthesis. Int J Env Health Eng 2022;11:12.

Received: 16-03-2022, **Accepted:** 08-08-2022, **Published:** 29-11-2022

sanitizer.[5] AEW is postulated to produce many health benefits, especially in relieving gastrointestinal symptoms, reducing the incidence of cardiovascular diseases, cancer, osteoporosis, total mortality rates, and preserve insulin-producing beta cells of the pancreas by its antioxidant effects.[2-6] In Japan, these devices have been approved as medical devices as early as 1965 by the Ministry of Health, Labour and Welfare. The timeline of history, development and approval of such appliances has been presented [Figure 1]. As no universal recommendation exists for using AEW in humans, preclinical studies would play a vital role in providing guidance for future research.[7-16] Use of these appliances has been ever increasing in Europe, but are imported under the label of the European Commission but are still not approved as a medical device.[3] Although many preclinical

Figure 1: History of development of electrolyzed alkaline drinking water

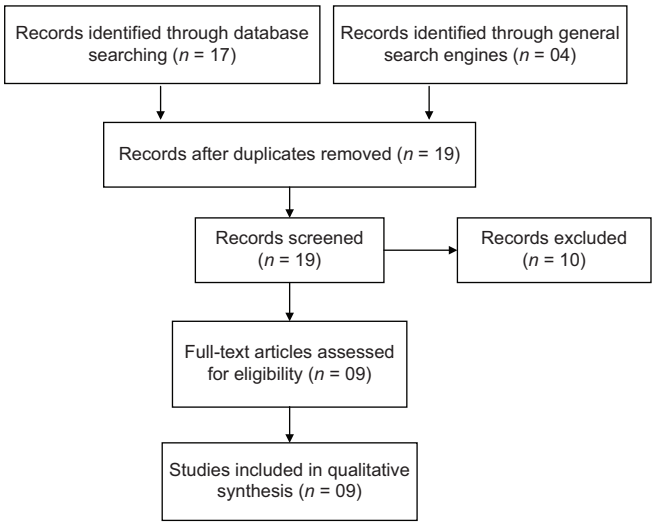

Figure 2: Flow chart of identification of studies, their inclusion and exclusion

studies and some clinical studies have been reported, but till date, no systematic review has been conducted to evaluate the overall health benefits of AEW. Health benefit is a positive effect on a person's health gained from food, treatment, or an activity, in this case, AEW. Since the studies available did not have common objective or a specific health benefit as an outcome of interest, the present study was planned as a narrative review. The purpose of this narrative review is to conduct an elaborate search on all the existing literature to determine the strength of evidence available for using AEW to gain health benefits and summarize the evidence, to make recommendations on the use of AEW.

Methods

The review follows Preferred Reporting Items for Systematic Review and Meta-analysis guidelines. A comprehensive search for all the eligible studies published in English language on the use of AEW/EAW and health benefits was conducted on PubMed, Cochrane library, Scopus, Elsevier, OVID Medline, EBSCO, and Clinical trials. Gov and Google scholar databases until October 31, 2020, using "([Alkaline electrolyzed drinking water] OR [Electrochemically reduced drinking water] OR [Alkaline drinking water] OR [Alkaline reduced water] AND [Human health] OR [Health benefits] OR [Disease])" as key words. Any timeline could not be set as the first approved apparatus producing AEW dates back to 1965. The references of the eligible studies were searched manually for any studies that might have missed our search strategy. For the identification and inclusion of studies, we defined participants, exposure, comparator, outcome (s), and type of study.

Two authors (TA and VR) reviewed the abstracts of all the results obtained from all search engines. All studies conducted in adults aged more than 17 years and older (Population of interest) utilizing AEW/EAW (exposure) obtained from an ionizer apparatus for consumption to demonstrate health benefit (outcome) in comparison to normal water (comparator), with a prospective study design (study design) were selected for review. All those studies not concerned or related to the subject of interest (includes those studies conducted using acidic electrolyzed water, and neutral electrolyzed water), those studies demonstrating benefit in food and agricultural field (without intervention on humans) and all preclinical studies were excluded as schematically depicted in Figure 2. The selected research works were studied separately by the authors TA and VR and all those studies with the availability of full texts were selected. In case of any ambiguity third and fourth authors (SS and PM) were consulted, and finally, a consensus decision was taken. Those articles without full manuscripts and duplicates from various search engines were excluded. All the selected studies were forwarded for data extraction.

One author (TA) extracted data from all the selected studies by using data extraction forms that were prespecified. Data extracted included country of study, year of publication, objective (s), methods (including study population, mean age in years, sex in terms of male-to-female ratio, exposure, comparator, and design of the study), outcome (s), results, risk of bias, and quality assessment. The second author (VR) assessed the correctness and completeness of the data extracted from the selected studies. The third and fourth authors (SS and PM) again reviewed the correctness of the data extracted from selected studies. Any discrepancies were settled by discussions among all.

Two authors (TA and VR) independently assessed the risk of bias and quality for every study included in the study. For all the randomized trials included in the study, bias assessment was carried out using Cochrane risk-of-bias tool and nonrandomized trials were assessed using the nonrandomized studies-of interventions tool.[17-20] The quality of evidence for each outcome in included studies was assessed using the Grading of Recommendations Assessment, and Development of Evaluation approach.[20] Any difference in the assessment of risk or quality of evidence between two assessors was discussed with the third and fourth authors (SS and SD), and a consensus was reached.

Results

Extensive literature search in various different databases and search engines brought out nine research publications that are eligible for review as per the predefined eligibility criteria. Majority of the articles focused their area of exploration in gastrointestinal (GI) effects of the healthy and diseased population (four studies), followed by its effects on Type II Diabetes Mellitus (T2DM), while others focused on its effects on high-intensity exercise or sports. The quality of evidence from these studies was graded low considering the relatively lesser sample size studied in these research works and the study design/methods employed. The reviewed studies are outlined in Table 1.

In patients with irritable bowel syndrome, improvement in symptoms and quality of life (QoL) were noted among the study

Table 1: Description of reviewed studies

Author, Country and Publication year	Objective(s)	Study design	Methods (including study population, exposure, comparator)	Outcome(s) and results	Risk of bias	Quality of evidence
Shin *et al*., 2018[21] Korea	To investigate whether ingestion of ARW helps improving symptoms of diarrhoea predominant IBS	Randomized double-blind placebo-controlled trial	Population Age: 18-75 years Diagnosed with diarrhea predominant IBS using Rome III criteria Exclusion criteria: History of psychiatric illness, untreated malignancy, severe liver/kidney disease, severe heart failure, acute GIT infections over last 3 months Randomization 1:1, experimental and control group with computerized block randomization with random code (by research coordinator) Patients and investigators were blinded Design Screening (at 3 weeks before randomization) Randomization (day 0, baseline questionnaire - Quality of life, abdominal pain/discomfort, number of bowel movements, stool frequency and form) Experimental group (n=13): (male: female=3:10) ARW (pH of 8.5-10) from an ionizer (KYK33000) ingested (>2 L/day) for 8 weeks Control group (n=14): (male: female=4:10) placebo water from sham device >2 L/day for 8 weeks Every 2 weeks participants visited hospital, filled questionnaire (+ questions on compliance, adverse events and amount ingested)	Primary outcome: Responders (improvement in symptom) and nonresponders. 61.5% showed improvement in symptoms in experimental group versus 42.9% in placebo group (statistically nonsignificant, P=0.449) Secondary outcomes Improvement in IBS quality of life score (P=0.029) Decrease in abdominal pain score (P=0.232) Improvement in abdominal discomfort, stool form and frequency Adverse effects: No specific adverse effect (one participant from control group had abdominal pain and vomiting, visited emergency department, treated conservatively)	Unclear	Low
Chaves *et al*., 2020[22] Brazil	To evaluate the expression of miRNAs in the gastric tissue of patients with gastritis before and after the consumption of alkaline water	Prospective observational study	Population: 50 individuals aged >35 years, median age of 44.5 years (*H. pylori* positive/negative) from state of Para in northern Brazil (where gastric cancer is a public health problem). They often used water with low pH for routine use and sold commercially (pH: 3-5) Inclusion criteria: Gastritis diagnosed by EGD Exclusion criteria: Prior history/family history of gastric cancer, those using alkaline water/antacids, those having gastric lymphoma or atrophic gastritis, those needing immediate *H. Pylori* eradication Design Subjects were asked to use alkaline water (pH: 8.5-10) obtained from ionizer for 5 months After 5 months expression of mi-RNA was evaluated again and histological analysis was done for identifying *H. Pylori* using real time PCR	Expression of various mi-RNA (↓ expression of miR-29c in gastric carcinoma tissues and Expression of miR-135b more in gastric carcinoma <gastritis <normal tissues) Statistically significant increase in expression of miR-29c (P=0.039) and miR-135b (P=0.039) Classification of gastritis using Sydney classification after EGD After consumption of alkaline water 43% (n=12) with prior moderate gastritis were categorised as mild gastritis (P=0.024)	High	Low

Contd...

Table 1: Contd...

Author, Country and Publication year	Objective(s)	Study design	Methods (including study population, exposure, comparator)	Outcome(s) and results	Risk of bias	Quality of evidence
Tanaka *et al*., 2018[23] Japan	To evaluate the effect of ingestion of AEW daily on health including GI symptoms in individuals without indefinite abdominal complaint	Double blind randomized controlled trial	Population: Healthy individuals aged 20–60 years from Osaka citizen health development consultation center Design Two groups Purified tap water group (n=30) ingested >500 ml/day (with 200 ml at awakening +300 ml throughout day), pH of 7.6 ±0.2 AEW group (n=30), issued ionizer and ingested >500 ml/day of AEW (pH: 9.2 ±0.2) Baseline evaluation Routine blood tests (RBC, WBC, Hb, hematocrit, platelet count) Biochemistry - Total protein, albumin, GOT, GPT, total cholesterol, LDL, uric acid, creatinine and blood sugar Urine analysis: Sugar, protein, occult blood and urine pH Physical measurements (grip, muscle strength, vertical jump, whole body reaction time, resting BP) Questionnaire to assess GI symptoms, urinary frequency, stool condition and physical condition - sleep After 4 r weeks of ingestion (AEW/ tap water) reassess all parameters	No significant difference amongst haematological parameters No significant change in forward bend, vertical jump, right/left grip strength, standing time and sit-up Statistically significant difference (P <0.05) for whole body reaction time in users of AEW Significant difference in quality of sleep (P <0.01) in AEW group No clear benefit in GI symptoms Increased urinary frequency in both groups Bowel movements: Significant improvement in stool consistency changed from soft to normal (P <0.01)		
Hansen *et al*., 2018[24] Denmark	To investigate possible compositional changes in the gut microbial community andglucose regulation of young healthy adults following intake of alkaline versus neutral drinking water	Nonblinded, randomized cross-over study	Population: 30 healthy, nonsmoking men, aged 18-35 years, with a body mass index between 20.0 and 27.0 kg/m^2 2 weeks intervention periods with an interposed washout period of at least 3 weeks Twenty-nine participants completed the first intervention period, and 24 completed both periods	Primary outcome; No effect of changing drinking water pH on overall diversity as represented by Shannon's index was observed No effect was observed for OTU based richness, estimated richness (Chao1) or Simpson's reciprocal index when comparing the alkaline and neutral water interventions OGTT, did not show a significant difference between interventions in neither plasma glucose nor serum insulin concentration after the two interventions No difference in frequency of bowel movements, nor in severity of gastro-intestinal symptoms	Low	Low

Contd...

Table 1: Contd...

Author, Country and Publication year	Objective(s)	Study design	Methods (including study population, exposure, comparator)	Outcome(s) and results	Risk of bias	Quality of evidence
Rias *et al*., 2020[25] Taiwan	To evaluate the effects of drinking AEW and walking on oxidative stress, inflammatory markers and quality of life amongst patients of T2DM	Randomized control trial	Population Out of 150 individuals screened, 81 individuals with T2DM recruited from two community clinics in east Java, Indonesia Inclusion criteria: Nationals of Indonesia aged 17–80 years, diagnosed with T2DM 6 months before, no history of stroke/MI/Coronary artery disease, whose T2DM confirmed with 2 h blood glucose test result and stabilized on oral hypoglycemic agents (metformin±glibenclamide) Exclusion criteria: Those with experience of drinking AEW, score of ≤ 24 on mini-mental state examination, unable to walk/amputated limb, pregnancy, history of using antidepressants, auditory deficiencies, treatment with insulin Randomization 1: 1, assignment into groups was done using computer generated sequences Participants not blinded Design Four parallel intervention groups Group A (AEW, *n*=20): 2 L/day of AEW (pH: 9.5, ORP of - 400.1 ±13.3 mV) produced by electrolyzer Kangen water type SD 501 platinum machine for 8 weeks Group B (regular walking, *n*=20): Walk for a total of 150 min/week (30 min, 5 times/week) without the measurement of speed/distance for 8 weeks Group C (AEW + regular walking, *n*=20): 2 L/day of AEW + 150 min/week walk for 8 weeks Group D (Control, *n*=21): Normal diet and activity (advised against using AEW/additional physical activity), one participant was lost to follow up at 8 weeks	No statistically difference between groups at baseline Group A: Age - 57.50±5.48 years; male: female - 9:11; duration of DM - 4.30±1.87 years Group B: Age - 54.70±4.87; male: female - 7:13; duration of DM - 4.25±1.62 years Group C: Age -56.15±4.96; male: female -7:13; duration of DM -4.20±1.51 years Group D: Age - 55.71±4.97 years; male: female - 8:13; duration of DM - 4.19±1.54 years Outcome measures Measurement of oxidative stress and inflammatory markers Concentration of AGEs products, AOPPs and MDA measured by ELISA → highly significant (P <0.001) reductions in Groups A, B and C in comparison to control WBCs count and NLR from fasting blood sample → highly significant (P <0.001) reductions in Groups A, B and C Blood glucose: No significant changes in all groups QoL (using 36 item short form survey, includes total QoL, mental component score and physical component score) AEW group: At 8 weeks highly significant changes in total QoL and physical component score (no changes in mental component score) Walking group: Significant changes in all three scores AEW and walking group: Significant changes in all three scores Control: No significant changes in any of the scores	Low	Low

Contd...

Table 1: Contd...

Author, Country and Publication year	Objective(s)	Study design	Methods (including study population, exposure, comparator)	Outcome(s) and results	Risk of bias	Quality of evidence
Siswantoro and Purwanto 2017[28] Indonesia	To analyse the effectiveness of consuming alkaline water to decrease random blood sugar level in individuals of T2DM	Quasi experimental with pre- and post-test control group design	Population: Individuals with T2DM Design: Each group has 7 respondents (male: female: 20:8), AEW obtained from Kangen water type SD 501 platinum machine Group A (AEW pH 7.0/clean water) Group B (AEW pH 8.0) Group C (AEW pH 9.5) Group D (Combinations of AEW pH 9.0-11.5)	Random blood sugar levels: Statistically significant difference was noticed in Group C and D (P <0.001)	High/ unclear	Low
Ito *et al*., 2020[29] Japan	To assess EHW ingestion during exercise on balance of body fluid and exercise performance in a heated environment		Population Triathletes (n=12), age=20±1.3 years, height=171±6 cm, Body mass=60.6±3.9 kg, VO_{2max} Inclusion criteria: All were training for triathlons at same university 5 days a week (3 h/day) Exclusion criteria: History of inflammatory condition, musculoskeletal disorders, smokers, and those with antioxidant supplements Design First visit - Completed incremental pedaling test on cycle ergometer, measure individual VO_{2max} Second and third visit after overnight fast at least 3 days apart → exercise trial of 60 min pedaling on a cycle ergometer at 65% VO_{2max} at 15 min interval (i.e., exercise while drinking purified water/EHW) , temperature – 32°C, relative humidity 50% EHW - pH: 9.7±0.2, purified water pH - 7.4±0.1, subjects drank 2 ml/kg every 15 min during exercise	Body weight: Statistically nonsignificant reduction between two groups Tissue (skin and muscle) temperature: No significant difference Heart rate, scores of subjective feeling: No significant difference Respiratory variables: Lower VO_{2max} in EHW trial compared to control Blood variables (blood lactate concentration, and hematocrit, plasma volume): No significant changes Time to exhaustion during incremental pedaling test: No significant difference	High	Low
Chycki *et al*., 2018[26] Poland	To investigate the impact of mineral-based highly alkaline water on acid-base balance, hydration status, and anaerobic capacity in experienced combat sport athletes subjected to avery intense exercise protocol	A double blind, placebo controlled randomized study	Population: Sixteen very well-trained males, who competed in combat sports Experimental group (n=8) received highly alkaline water Anaerobic performance was evaluated by a two double 30 s Wingate test protocol	Statistically significant increases in values for limb total When baseline and postintervention values were compared, significant decreases in LA concentration at rest significant increase in postexercise LA concentration, and significant increase in blood pH at rest The other significant changes occurred in the postexercise concentration of K+ (↑), in urine pH (↑) and a decrease in the value of SG, all in the experimental group supplemented with alkaline water. The changes in the control group were not statistically significant.\	High	Low

Contd...

Table 1: Contd...

Author, Country and Publication year	Objective(s)	Study design	Methods (including study population, exposure, comparator)	Outcome(s) and results	Risk of bias	Quality of evidence
Weidman *et al*., 2016[27] USA	To assess the effect of electrolyzed AEW on blood viscosity in healthy adults	Randomised, double blind, parallel-arm controlled trial	Population: 100 volunteers aged 25-49 years, male: female=50:50 Inclusion criteria: Healthy adults, nonsmokers, BMI <29, no medication atleast 1 week prior Exclusion criteria: Pregnancy, breastfeeding, menstruating, history of OCPs consumption in the past 3 months All were advised to avoid strenuous activity, alcohol and excessive caffeine Design Baseline assessment (BMI, heart rate, body temperature, bioelectrical impedance, blood sample for whole blood viscosity and osmolality of plasma) To perform moderate aerobic exercise in warm environment (30°C, 70% relative humidity) until dehydration (target threshold of 20±0.2% body weight loss) → moved to thermo-neutral environment (21°C, 60% relative humidity) for resting 20 min → Assess parameters again → follow up after 120 min Rehydration at 20 ml/kg of body weight within 30 min after exercise Control: Standard bottled water with normal pH AEW: High pH	Study and control arm subjects did not differ significantly in baseline parameters No adverse events No clinically significant abnormality in vital signs and lab evaluations AEW drinking reduces systolic blood viscosity significantly in comparison to control	Low	Moderate

T2DM: Type 2 diabetes mellitus, EHW: Electrolyzed hydrogen water, IBS: Irritable bowel syndrome, EGD: Esophagogastroduodenoscopy, GOT: Glutamic oxaloacetic transaminases, GPT: Glutamic pyruvic transaminases, LDL: Low-density lipoprotein, VO_{2max}: Maximal oxygen uptake, AGEs: advanced glycation end, AOPPs: Advanced oxidation protein products, MDA: Malondialdehyde, WBCs: White blood cell, NLR: Neutrophil–lymphocyte ratio, QoL: Quality of life, *H. pylori: Helicobacter pylori,* GI: Gastrointestinal, AEW: Alkaline electrolyzed water, miRNAs: MicroRNAs, ARW: Alkaline-reduced water, GIT: GI tract, PCR: Polymerase chain reaction, RBC: Red blood cell, WBC: White blood cell, Hb: Hemoglobin, BP: Blood pressure, MI: Myocardial infarction, ORP: Oxidation reduction potential, BMI: Body mass index, OCPs: Oral contraceptives, OUT: Operational taxonomic units, OGTT: Oral glucose tolerance test, LA: Lactate

participants who consumed at least 2 L of ARW per day for 8 weeks in the study by Shin *et al*.[21] In another study by Chaves *et al*.,[22] 50 individuals more than 35 years of age consumed alkaline water (pH- 8.5–10) obtained from ionizer for 5 months. It was observed after intervention that there was a statistically significant increase in expression of miR-29c ($P = 0.039$) and miR-135b ($P = 0.039$) and 43% ($n = 12$) with prior moderate gastritis were categorized as mild gastritis ($P = 0.024$). A statistically significant difference ($P < 0.05$) for whole body reaction time in users of AEW and a significant difference in the quality of sleep ($P < 0.01$) in the AEW group was reported by Tanaka *et al*.[23] after an intervention period of 4 weeks. On the contrary, Hansen *et al*.,[24] who studied gut microbial community after 2 weeks of intervention with alkaline water, stated that they did not observe an effect on overall diversity as represented by Shannon's index. Furthermore, no effect was observed for OTU-based richness, estimated richness (Chao 1), or Simpson's reciprocal index when comparing the alkaline and neutral water interventions.

Rias *et al*.[25] in their research work among patients with T2DM reported that the concentration of advanced glycation end products, advanced oxidation protein products and malondialdehyde measured by ELISA showed significant ($P < 0.001$) reductions in intervention groups (AEW) as compared to control. Furthermore, white blood cell count and neutrophil–lymphocyte ratio from fasting blood samples showed significant ($P < 0.001$) reductions in intervention groups. Chycki *et al*.[26] observed a significant decrease in LA, increase in K+, urine pH and a decrease in SG, postexercise among those who were given AEW as compared to controls. Rias *et al*.'s[25] study reported that QoL (using 36-item short form survey, includes total QoL, mental component score, and physical component score) assessments depicted that the AEW group at 8 weeks highly significant changes in total QoL and physical component score (No changes in mental component score), while AEW and the walking group showed highly significant changes in all three score, whereas the control group showed no significant changes in any of the

scores. A study also reported that consumption of AEW after exercise-induced dehydration reduced high-shear viscosity; however, plasma osmolality, bioimpedance, and body mass did not change significantly.[27] Significantly higher reduction on random blood glucose values was noted among T2DM patients who consumed AEW with pH.9.0 as compared to groups who received AEW with pH 8 and 7, in the study by Siswantoro and Purwanto.[28]

Discussion

The pH level is a number that measures how acid or base, a substance is, on a scale of 0–14. The pH values of majority of the bottled waters were found to be predominantly acidic. Also, these bottled waters when tested, had a more acidic pH than the value enumerated in their water quality reports.[30] AEW usually has a pH value ranging from of 8 to 10. Alkaline water consumption still invites a lot of controversy among health professionals and researchers. There were no comprehensive large-scale studies till date that compared the effects of AEW across various disease states targeting multiple system changes as outcomes. Oxidative stress, gastric cancer, blood sugar levels, exercise performance, blood viscosity, and GI symptoms were parameters evaluated in the available studies. The present literature review was carried out to collate all the available clinical research works on Alkaline Water or AEW in improving disease state or promoting health. Search in various databases, and search engines brought out 19 articles, of which nine met the eligibility criteria and were included for the analysis in the present study. Most of the available literature on the subject are of a small sample size or without a control comparison group.

For the management of functional GI disorders, various different preclinical researches have been carried out in the past, which showed positive results.[31-33] Possible explanation for the same could be the neutralization effect of gastric acid by bicarbonate ions in alkaline water, which in turn may alter the intestinal flora, resulting in changes of the gastrointestinal activities.[34] While it is a known fact that the acidic environment of the duodenum aggravated adverse GI symptoms,[35] it is also vital that the physiological pH of the proximal duodenum is maintained. Various mineral salts and ions may stimulate GI smooth muscles to improve GI motility.[36] A state of oxidative stress is said to exist when there is excess ROS beyond neutralizing anti-oxidant capacity. Oxidative stress plays a vital role in the pathogenesis of many chronic diseases, by provoking inflammatory response to cellular damage. Reducing the ability of hydrogen ions in AEW, contribution to neutralization of ROS, can be ascribed to its beneficial effects in a state of oxidative stress.[37] It can be assumed that AEW indirectly, improves the quality of sleep and physical performance by reducing oxidative stress. These improvements ultimately result in a better QoL. Oxidative stress is believed to play an important role in the pathophysiology of diabetes mellitus as well.[38] Consumption of water rich in hydrogen has been found to improve glucose and lipid metabolism in patients with diabetes mellitus.[39] There is no evidence at present that demonstrates negative impacts or adverse effects of consumption of alkaline water of various ranges, over a long period. Although it can contended that naturally occurring alkaline water has long been consumed by humans without any potential adverse events, it is important to study the long-term effects of alkaline water consumption in population that were not naturally exposed to these environments in the past. It is also important to study the cost factor involved in making the water alkaline vis-à-vis the benefits derived. Despite the mushrooming of water alkalinizing and purifying equipment in the market, there exists no strong evidence to either support or refute the use of alkaline water for drinking.

Conclusion

AEW has shown considerable positive health effects in small-scale clinical studies. However, evidence from existing research works is not sufficient enough for recommending AEW to be used for regular consumption or for therapeutic functions. The promotion and use of alkaline water as functional water is not justified. Research works with larger study samples and among different populations are required.

Acknowledgments

The authors extend their gratitude to their mentors for guidance and reviewing the research manuscript.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1. Popkin BM, D'Anci KE, Rosenberg IH. Water, hydration, and health. Nutr Rev 2010;68:439-58.
2. Mousa HA. Health effects of alkaline diet and water, reduction of digestive-tract bacterial load, and earthing. Altern Ther Health Med 2016;22 Suppl 1:24-33.
3. Henry M, Chambron J. Physico-chemical, biological and therapeutic characteristics of electrolyzed reduced alkaline water (ERAW). Water 2013;5:2094-115.
4. Shirahata S, Hamasaki T, Teruya K. Advanced research on the health benefit of reduced water. Trends Food Sci Technol 2012;23:124-31.
5. Dewi FR, Stanley R, Powell SM, Burke CM. Application of electrolysed oxidising water as a sanitiser to extend the shelf-life of seafood products: A review. J Food Sci Technol 2017;54:1321-32.
6. Franceschelli S, Gatta DM, Pesce M, Ferrone A, Patruno A, de Lutiis MA, *et al.* New approach in translational medicine: Effects of electrolyzed reduced water (ERW) on NF-κB/iNOS pathway in U937 cell line under altered redox state. Int J Mol Sci 2016;17:1461.
7. Cheng TC, Hsu YW, Lu FJ, Chen YY, Tsai NM, Chen WK, *et al.* Nephroprotective effect of electrolyzed reduced water against cisplatin-induced kidney toxicity and oxidative damage in mice. J Chin Med Assoc 2018;81:119-26.
8. Watanabe T, Kishikawa Y, Shirai W. Influence of alkaline ionized water on rat erythrocyte hexokinase activity and myocardium. J Toxicol Sci 1997;22:141-52.
9. Lee KJ, Park SK, Kim JW, Kim GY, Ryang YS, Kim GH, *et al.* Anticancer effect of alkaline reduced water (international conference on mind body science: Physical and physiological approach joint with the

eighteenth symposium on life information science). J Int Soc Life Inf Sci 2004;22:302-5.
10. Naito Y, Takagi T, Uchiyama K, Tomatsuri N, Matsuyama K, Fujii T, *et al.* Chronic administration with electrolyzed alkaline water inhibits aspirin-induced gastric mucosal injury in rats through the inhibition of tumor necrosis factor-α expression. J Clin Biochem Nutr 2002;32:69-81.
11. Ignacio RM, Kang TY, Kim CS, Kim SK, Yang YC, Sohn JH, *et al.* Anti-obesity effect of alkaline reduced water in high fat-fed obese mice. Biol Pharm Bull 2013;36:1052-9.
12. Magro M, Corain L, Ferro S, Baratella D, Bonaiuto E, Terzo M, *et al.* Alkaline water and longevity: A murine study. Evid Based Complement Alternat Med 2016;2016:3084126.
13. Jin D, Ryu SH, Kim HW, Yang EJ, Lim SJ, Ryang YS, *et al.* Anti-diabetic effect of alkaline-reduced water on OLETF rats. Biosci Biotechnol Biochem 2006;70:31-7.
14. Elsaid A, Faheem N. Alkaline ionized water ameliorates the structural and ultrastructural changes induced by hyperlipidemia on the renal cortex of the adult albino rats. Egypt J Anat 2017;40:189-202.
15. Bordoni L, Gabbianelli R, Fedeli D, Fiorini D, Bergheim I, Jin CJ, *et al.* Positive effect of an electrolyzed reduced water on gut permeability, fecal microbiota and liver in an animal model of Parkinson's disease. PLoS One 2019;14:e0223238.
16. Jackson K, Dressler N, Ben-Shushan RS, Meerson A, LeBaron TW, Tamir S. Effects of alkaline-electrolyzed and hydrogen-rich water, in a high-fat-diet nonalcoholic fatty liver disease mouse model. World J Gastroenterol 2018;24:5095-108.
17. Sterne JA, Savović J, Page MJ, Elbers RG, Blencowe NS, Boutron I, *et al.* RoB 2: A revised tool for assessing risk of bias in randomised trials. BMJ 2019;366:l4898.
18. Sterne JA, Hernán MA, Reeves BC, Savović J, Berkman ND, Viswanathan M, *et al.* ROBINS-I: A tool for assessing risk of bias in non-randomised studies of interventions. BMJ 2016;355:i4919.
19. Balshem H, Helfand M, Schünemann HJ, Oxman AD, Kunz R, Brozek J, *et al.* GRADE guidelines: 3. Rating the quality of evidence. J Clin Epidemiol 2011;64:401-6.
20. Tan E, Braithwaite I, McKinlay CJ, Dalziel SR. Comparison of acetaminophen (Paracetamol) with ibuprofen for treatment of fever or pain in children younger than 2 years: A systematic review and meta-analysis. JAMA Netw Open 2020;3:e2022398.
21. Shin DW, Yoon H, Kim HS, Choi YJ, Shin CM, Park YS, *et al.* Effects of alkaline-reduced drinking water on irritable bowel syndrome with diarrhea: A randomized double-blind, placebo-controlled pilot study. Evid Based Complement Alternat Med 2018;2018:9147914.
22. Chaves JR, de Souza CR, Modesto AA, Moreira FC, Teixeira EB, Sarraf JS, *et al.* Effects of alkaline water intake on gastritis and miRNA expression (miR-7, miR-155, miR-135b and miR-29c). Am J Transl Res 2020;12:4043-50.
23. Tanaka Y, Saihara Y, Izumotani K, Nakamura H. Daily ingestion of alkaline electrolyzed water containing hydrogen influences human health, including gastrointestinal symptoms. Med Gas Res 2018;8:160-6.
24. Hansen TH, Thomassen MT, Madsen ML, Kern T, Bak EG, Kashani A, *et al.* The effect of drinking water pH on the human gut microbiota and glucose regulation: results of a randomized controlled cross-over intervention. Sci Rep 2018;8:16626.
25. Rias YA, Kurniawan AL, Chang CW, Gordon CJ, Tsai HT. Synergistic effects of regular walking and alkaline electrolyzed water on decreasing inflammation and oxidative stress, and increasing quality of life in individuals with type 2 diabetes: A community based randomized controlled trial. Antioxidants (Basel) 2020;9:946.
26. Chycki J, Kurylas A, Maszczyk A, Golas A, Zajac A. Alkaline water improves exercise-induced metabolic acidosis and enhances anaerobic exercise performance in combat sport athletes. PLoS One 2018;13:e0205708.
27. Weidman J, Holsworth RE Jr., Brossman B, Cho DJ, St. Cyr J, Fridman G. Effect of electrolyzed high-pH alkaline water on blood viscosity in healthy adults. J Int Soc Sports Nutr 2016;13:45.
28. Siswantoro E, Purwanto NH. Effectiveness of Alkali water consumption to reduce blood sugar levels in diabetes mellitus type 2. J Diabetes Mellitus 2017;7:249.
29. Ito H, Kabayma S, Goto K. Effects of electrolyzed hydrogen water ingestion during endurance exercise in a heated environment on body fluid balance and exercise performance. Temperature (Austin) 2020;7:290-9.
30. Wright KF. Is your drinking water acidic? A comparison of the varied pH of popular bottled waters. J Dent Hyg 2015;89 Suppl 2:6-12.
31. Koufman JA, Johnston N. Potential benefits of pH 8.8 alkaline drinking water as an adjunct in the treatment of reflux disease. Ann Otol Rhinol Laryngol 2012;121:431-4.
32. Nassini R, Andrè E, Gazzieri D, De Siena G, Zanasi A, Geppetti P, *et al*. A bicarbonate-alkaline mineral water protects from ethanol-induced hemorrhagic gastric lesions in mice. Biol Pharm Bull 2010;33:1319-23.
33. Bertoni M, Olivieri F, manghetti M, Boccolini E, Bellomini MG, Blandizzi C, *et al.* Effects of a bicarbonate-alkaline mineral water on gastric functions and functional dyspepsia: A preclinical and clinical study. Pharmacol Res 2002;46:525-31.
34. Zheng W, Ji X, Zhang Q, Yao W. Intestinal microbiota ecological response to oral administrations of hydrogen-rich water and lactulose in female piglets fed a *Fusarium* toxin-contaminated diet. Toxins (Basel) 2018;10:246.
35. Ishii M, Kusunoki H, Manabe N, Kamada T, Sato M, Imamura H, *et al.* Duodenal hypersensitivity to acid in patients with functional dyspepsia-pathogenesis and evaluation. J Smooth Muscle Res 2010;46:1-8.
36. Anti M, Lippi ME, Santarelli L, Gabrielli M, Gasbarrini A, Gasbarrini G. Effects of mineral-water supplementation on gastric emptying of solids in patients with functional dyspepsia assessed with the 13C-octanoic-acid breath test. Hepatogastroenterology 2004;51:1856-9.
37. Ogawa S, Ohsaki Y, Shimizu M, Nako K, Okamura M, Kabayama S, *et al*. Electrolyzed hydrogen-rich water for oxidative stress suppression and improvement of insulin resistance: a multicenter prospective double-blind randomized control trial. Diabetol Int. 2021;13:209-19.
38. Asmat U, Abad K, Ismail K. Diabetes mellitus and oxidative stress – A concise review. Saudi Pharm J 2016;24:547-53.
39. Kajiyama S, Hasegawa G, Asano M, Hosoda H, Fukui M, Nakamura N, *et al.* Supplementation of hydrogen-rich water improves lipid and glucose metabolism in patients with type 2 diabetes or impaired glucose tolerance. Nutr Res 2008;28:137-43.