EFFECTS OF ALKALINE WATER INTAKE ON HEALTH: A SYSTEMATIC LITERATURE REVIEW

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ABSTRACT

Introduction: The purpose of this study is to review the amount and duration of alkaline water intake and its impact towards human health outcomes. **Methods:** A systematic review was conducted and Preferred Reporting Items for Systematic review and Meta-Analysis (PRISMA) was used. Elements of study questions which are population, intervention, comparison, outcomes and study design (PICOS) were used to determine the research objective. Inclusion and exclusion criteria were used to screen for relevant data. The articles were found through four electronic databases which were Scopus, Pro Quest, PubMed and Wiley Online Library. Specific terms were determined and searched by using Boolean Operators. **Results:** In total, 2370 relevant abstracts were identified, of which 11 full-text articles were evaluated with the following outcomes: positive (n=9), negative (n=1) and neutral (n=1). The amount and duration of alkaline water intake that produce positive effects is equivalent to standard fluid recommendation for various condition which were 2 L/day for general population, 4 L/day for athletes, 1 L/day for post-menopausal women and 2 L/day for diabetes mellitus patients. The duration of intervention to produce positive outcomes varied between one to four weeks. **Conclusion:** This systematic review provides the amount and duration of alkaline water intake that affect human health outcome. It is recommended for future study to explore the effects of pH and mineral contents of alkaline water because these two variables might produce different impact on the outcomes. Besides, it is suggested for meta-analysis to be conducted for more comprehensive clinical evidence.

KEYWORDS: alkaline water, alkaline ionized water, alkaline electrolytic water, health, outcomes, effects

INTRODUCTION

According to the National Health and Morbidity Survey (NHMS, 2015), 2 out of 3 persons in Malaysia suffer at least one from three non-communicable diseases (NCDs) which are diabetes, hypertension and hypercholesterolemia. The incidents of NCDs have accounted for 60% of the disease burden in Malaysia in 1990 and it is increasing to 72% in 2013 (Lum, 2018). Due to this, it is becoming one of the biggest concerns for Malaysian to overcome this health problem. As the cost of treatment are expensive nowadays, people are searching for alternative medicine which is a non-pharmacological option to improve and maintain their health from these diseases and other adverse health outcomes. The emergent of alkaline water as an alternative which claims to be effective for health improvement is attracting many people.

Due to this reason, the intake of alkaline water in community has been growing over the past few years and the production of alkaline water in the market also has been increasing due to people's beliefs regarding alkaline water and its health benefit. The main concern is the effect of alkaline water used among general population on their health status. In addition, another concerning matters regarding alkaline water consumption are the amount and duration. The amount and duration of alkaline drinking water intake might be varied per person as no indication on how much water intake is needed and how long for its effect to take place. Since there is no clear and transparent evidence to support the claim of alkaline water intake, the review about this should be conducted in order to identify whether it would give positive, negative or no effects at all to health outcomes.

Based on the literatures, alkaline water is a water rich in alkaline properties which often produced through a process called electrolysis whereby alkaline substances were added to increase its pH level (Abramowitz & Arnold, 2003 & Watanabe, 1995). Alkaline water contains unique characteristics which could give therapeutics effects such as antioxidant and dihydrogen effects (Ignacio et al., 2013 & Henry & Chambron, 2013). Some studies showed that alkaline ionized water might have positive outcomes due to its characteristics (Ignacio et al., 2013, Shirahata et al., 1997, Jin et al., 2006 & Tsai et al., 2009). However, scientific studies needed to be reviewed to provide concrete evidence to support the claims of alkaline water towards people's health through the conduct of this review study.

This review aimed to provide comprehensive evidence about alkaline water and its health outcomes to people; since no review has been done previously considering the trend regarding consumption of alkaline water is becoming more popular nowadays.

METHODS

In this systematic review, the Preferred Reporting Items for Systematic review and Meta-Analysis (PRISMA) was used which included PRISMA flow diagram and checklist (Liberati et al., 2009).

Database Search

The research question was developed by using PICOS elements to identify the relevant keywords. Then, the search strategy using Boolean Operators were used to find relevant studies. Relevant studies were identified through various databases such as Scopus, Pro Quest, PubMed and Wiley Online Library. These databases were searched by using keywords of alkaline water and outcomes. The included search term were "alkaline water" OR "alkaline ionized water" OR "alkaline electrolytic water" OR "alkaline drinking water" AND Effect* OR Benefit* OR advantage* OR outcome*.

Study Selection

First, during the identification process, the relevant articles were obtained. After that, the articles were exported to Mendeley for screening. The articles were screened to remove the duplicates data. Next, the remaining articles' titles and abstracts were screened to remove unrelated studies to research objectives. After removing articles from screening, the full text articles remained were assessed for their eligibility. The eligibility assessed by identifying whether they met or not the inclusion and exclusion criteria (Table 1). The included studies were chosen from studies published in the year 2000 onwards to include all possible outcomes because there was no review conducted on this topic since this year. The *in vivo* studies were chosen to identify the outcome as well as amount and duration which could be derived from *in vivo* study only as in vitro study, it did not measure direct effect on human. After that, the remaining full text articles were included for systematic review and synthesized qualitatively.

Table 1. Inclusion and Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
- Human study	- Animal study
- *In vivo* study	- *In vitro* study
- Study published in English	- Study published in other language than English
- Peer reviewed study	- Review study
- Study published from the year 2000 onwards	- Not research-based study

Risk of Bias

Before analysing the data, the risk of bias was addressed by following Cochrane Risk of Bias for randomized study which consists of five domain which are selection, performance, attrition, reporting, and other (Higgins et al., 2011). The judgements were addressed as 'low risk', 'high risk' or 'unclear risk' (Higgins et al., 2011). For non-randomized study, Robins – I tool (Sterne et al., 2016) was used to assess risk of bias. The judgements were also addressed as 'low risk', 'high risk' or 'unclear risk'. The overall risk of bias was assessed to identify the quality of study.

Data Analysis

The findings from this review were tabulated in a summary table. The table was adopted from Cochrane (Cochrane Library, n.d.) and was adjusted based on the objectives of the study. The elements that have been extracted are source of the data, study design, participants' details such as number of participants, gender and age, instruments used in the study, amount of alkaline water intake, duration of the intervention and key findings from the studies.

RESULTS

Initial Search

A total of 2370 records were obtained from the database search. After the removal of duplicates (n = 2041), 1966 publications were removed after screening of titles and abstracts. Next, 75 remaining articles were evaluated for their inclusion and exclusion criteria as outlined in Table 1 by reviewing their full text articles. Finally, after full text articles were examined, 11 studies were included for synthesized of data (Figure 1).

Study Characteristics

There were 11 studies that were finalized to be included in the review. Among the studies, ten studies belong to second level of evidence which consisted of six randomized controlled trial and four randomized cross-over study; while another study was in the third level of evidence which was quasi experimental study. These studies were experimented on different type of population which were healthy people (Studies 1, 3, 4, 6, 10 and 11), post-menopausal women (Studies 7 and 9), athletes (Studies 2 and 5) and patients with diabetes mellitus (Study 8). There are several variables that were observed from these studies which include composition of urine and risk of lithogenic (Study 1), hydration status (Studies 2 and 3), metabolic response (Study 2), blood viscosity (Study 3), general health and gastrointestinal symptoms (Study 4), acid base balance and exercise performance (Study 5), blood glucose level (Studies 6 and 8), human gut microbiota (Study 6), postprandial lipaemia (Studies 7 and 10), lipid profile and cardiovascular risk (Study 9), gallbladder emptying (Study 10) and bone resorption (Study 11). The amount and duration of alkaline water intake had been determined for participants in each study. There were several studies (Studies 1, 2, 4, 5, 6, 8, 9 and 11) assessing daily water intake which were between 2 to 4 L per day with the duration between one week to 8 weeks. One study (Study 3) assessed on ingestion of 20 ml/kg alkaline water with a duration of 4 to 8 hours. The remaining studies (Studies 7 and 10) measured the consumption of alkaline water by different number of occasions which were 3 and 4 times within 1 to 2 weeks duration of study. The summary of the data obtained from the studies were tabulated in Table 2.

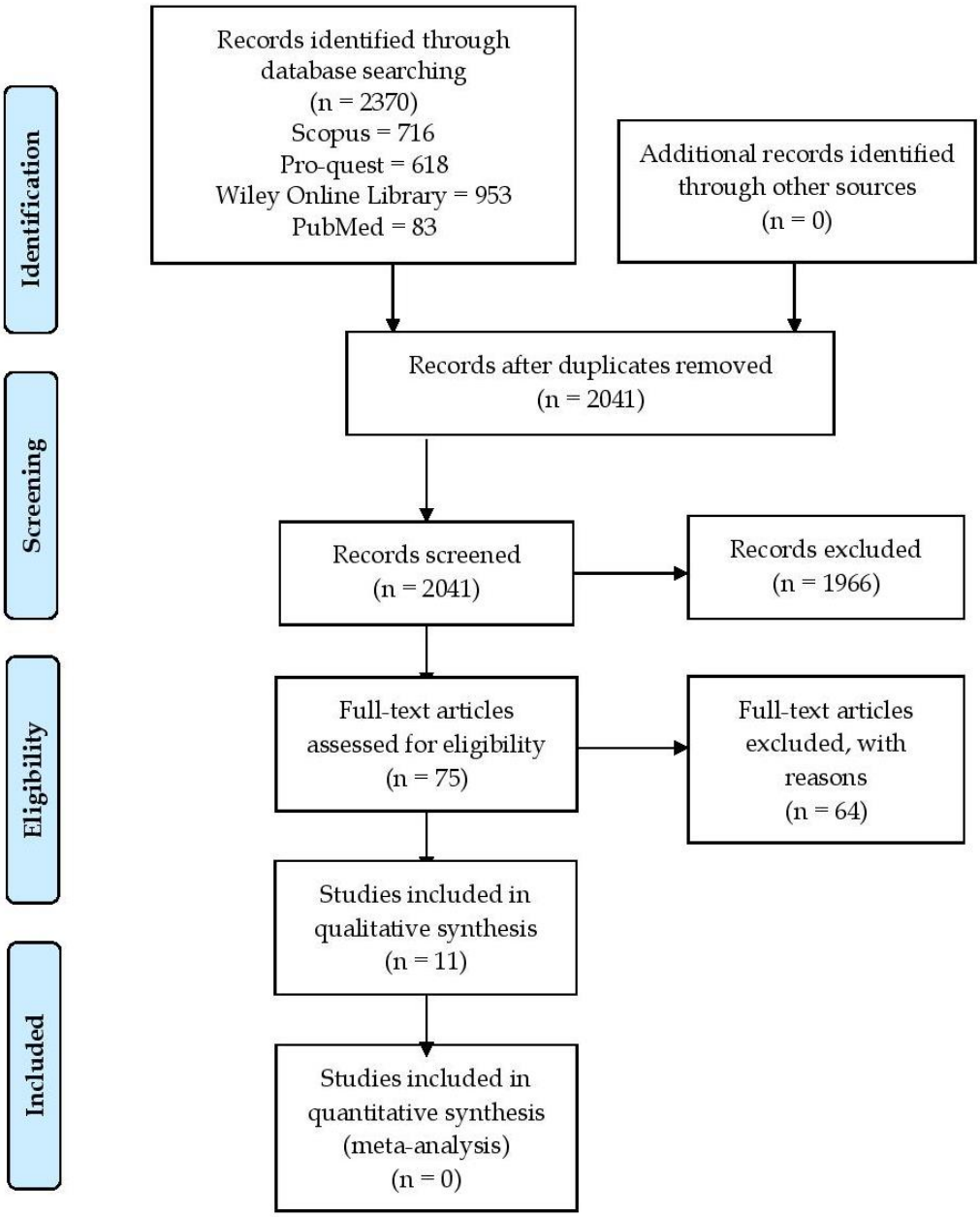

Figure 1: PRISMA 2009 Flow Diagram: Number of Studies Included

Table 2: Summary of data obtained from the included studies

Authors/ years	Study Design	Participants (n, gender, age)	Instruments	Amount and Duration	Key Findings
STUDY 1 Coen et. al (2001)	LOE: 2 Randomized controlled trial A: Oligo mineral water B: Bicarbonate-alkaline water	Healthy volunteers Males (n=11), Females (n= 10) Mean Age: A = 36 ± 4 years B = 39.5 ± 2.5 years	Creatinine, calcium, phosphate, sodium, magnesium, oxalate, citrate and osmolality	Amount 2 L/day Duration 2 weeks	• Urine calcium increases significantly in group B ($p < 0.0015$). • A significant increment in urine citrate excretion in group B (p = n.s). • Osmolar concentration of 24-hour urine was decreased in group A ($p < 0.0001$). • Urine volume standardized index(s) increases more markedly in group B. • A significant decrease in AP(CaP) index 1 in group A ($p < 0.04$).
STUDY 2 Chycki et. al (2017)	LOE: 2 Randomized Controlled Trial A: Highly mineralized water B: Low mineralized High alkaline water C: Table water (control)	Well-trained soccer players Male (n = 36) Mean age = 21.3 ± 1.8 years	Body composition, urinalysis and lactate concentration, total body water and its active transport	Amount 4 L/day Duration 7 days	• A significant decrease of specific urine gravity in group A and B ($p < 0.05$). • A significant increase of pH and lactate utilization rate in group B ($p < 0.05$).
STUDY 3 Weidman et. al (2016)	LOE: 2 Randomized Controlled Trial A: Standard bottled water (control) B: High pH alkaline water	Healthy volunteers Males (n= 50), Females (n= 50) Mean age = 31 ± 6 years	Blood viscosity at high and low shear rates, plasma osmolality, bio impedance, body mass, and vital signs	Amount 20 ml/kg Duration 4-8 hours	• A reduced in high-shear blood viscosity in group B ($p = 0.03$)

Authors/ years	Study Design	Participants (n, gender, age)	Instruments	Amount and Duration	Key Findings
STUDY 4 Tanaka et. al (2018)	LOE: 2 Randomized Controlled Trial A: Alkaline electrolyzed water B: Purified tap water (placebo)	Healthy population Male and female (n = 60) Age = 20 to 69 years old	Blood test, physical fitness evaluation and questionnaire evaluations	Amount ≥500 ml/day Duration 4 weeks	• Standing time on one leg with eyes closed, longer times in group A. • Bowel movement, the stools slightly changed from slightly soft to normal or slightly hard, or from soft to normal in group A ($p < 0.05$). • Significant increase of sleep quality in group A ($p < 0.01$).
STUDY 5 Chycki et. al (2018)	LOE: 2 Randomized Controlled Trial A: Highly alkaline water B: Table water (control)	Well-trained, combat sports athletes Male (n = 16) Mean age = 22.3 ± 0.5 years	30 s Wingate tests, fingertip capillary blood samples (lactate acid (LA) concentration), acid-base equilibrium and electrolyte status and specific gravity (SC) and pH for urine	Amount 2.6 to 3.2 L/day Duration 3 weeks	• A significant increase value for limbs power in group A ($p = 0.001$). • A significant decrease in LA concentration at rest and increase at post exercise in group A ($p = 0.008$). • A significant increase in blood pH at rest, HCO3- at rest ($p = 0.001$) and post exercise ($p = 0.002$) in group A. • A significant change in post exercise concentration of K+ in urine pH of group A ($p = 0.017$). • A decrease in SG in group A ($p = 0.001$).
STUDY 6 Hansen et. al (2018)	LOE: 2 Randomized controlled cross-over trial A: Neutral drinking water B: Alkaline drinking water	Healthy population Male (n = 30) Age = 18 to 35 years old	DNA extraction, oral glucose tolerance test	Amount 2 L/day Duration 2 weeks	• No significant changes

Authors/ years	Study Design	Participants (n, gender, age)	Instruments	Amount and Duration	Key Findings
STUDY 7 Schoppen et. al (2005).	LOE: 2 Randomized cross-over trial A: Bicarbonated mineral water 1 (more fluoride) B: Bicarbonated mineral water 2 C: Low mineral water	Postmenopausal women Female (n = 18) Mean age = 55.7 ± 2.4 years	Total area under the curve (TAUC) of Serum and cyclomicron triacylglycerol	Amount 0.5 L/occasion (3 times) Duration 2 weeks	• TAUC of serum triacylglycerols for bicarbonated mineral water 2 was significantly lower compared to low mineral water ($p = 0.008$)
STUDY 8 Agustanti (2019)	LOE: 3 Quasi- Experimental study Pre- and post- test group	Diabetes Mellitus patients (n = 50)	Random blood sugar level	Amount 2 L/day Duration 1 week	• A decline in blood sugar level after alkaline water therapy ($p < 0.001$)
STUDY 9 Schoppen et. al (2004)	LOE: 2 Randomized cross-over trial 1) Mineral water 2) Carbonated mineral water	Postmenopausal women (n = 18) Age = 51 to 59 years old (no mean age)	Blood pressure, serum glucose, lipid, lipoprotein, and cellular adhesion molecule concentrations, CVD risk indexes, coronary heart disease (CHD) risk index	Amount 1 L/day Duration 2 months	• Carbonated water intake o Improve lipid profile (total, LDL and HDL cholesterol) ($p < 0.0001$) o Reduced fasting serum glucose concentration ($p < 0.0001$) o Reduced indexes risk ($p < 0.0001$)

Authors/ years	Study Design	Participants (n, gender, age)	Instruments	Amount and Duration	Key Findings
STUDY 10 Toxqui et. al (2012)	LOE: 2 Randomized cross-over trial	Healthy volunteers Gender = Male (n= 10), Female (n= 11) Mean age = 27.8 ± 4.5 years	Triacylglycerol concentration, cholecystokinin, insulin concentration and gallbladder volume	Amount 0.5 L/0ccassion (4 times) Duration 1 week	• CCK concentrations were significantly lower when for bicarbonated mineral water with meal compared to the control water ($p < 0.05$). • Gallbladder volume significantly higher for bicarbonated mineral water with meal ($p < 0.05$).
STUDY 11 Wynn et. al (2009)	LOE: 2 Randomized Controlled Trial A: Water riched in calcium B: Bicarbonate alkaline water	Dietitian or student dietitian Female (n = 30) Mean age = 26.3 ± 7.3 years	Blood and urine electrolytes, Ctelopeptides (CTX), urinary pH and bicarbonate, and serum PTH	Amount 1.5 L/day Duration 28 days	• A significant decrease of PTH ($p = 0.022$) and of S-CTX ($p = 0.023$) in group B

*LOE: Level of Evidence

Results Extracted

Based on these findings, there were nine studies that showed positive outcome which support the correlation between consumption of alkaline water and variable measured (Studies 2, 3, 4, 5, 7, 8, 9, 10 and 11). The variables with positive outcomes were hydration status (Studies 2 and 3), metabolic response (Studies 2), blood viscosity (Studies 3), general health and gastrointestinal symptoms (study 4), acid base balance and exercise performance (Study 5), blood glucose level (Study 8), postprandial lipaemia (Studies 7 and 10), lipid profile and cardiovascular risk (Study 9), gallbladder emptying (Study 10) and bone resorption (Study 11). The range of alkaline water consumption was between 1 to 4 L/day within 1 to 8 weeks period. One study showed that there was no significant changes which could be interpreted as neutral outcome as no positive or negative effects on human's health (Study 6). The variables that were used in this study were blood glucose level and human gut microbiota with the amount of 2 L/day intake of alkaline water for 2 weeks. There was only one study that obtained negative outcome from alkaline water intake (Study 1) in which the composition of urine and risk of lithogenic were measured. The amount of alkaline water assessed in this study was 2 L/day in the period of 2 weeks.

Risk of Bias Assessment

In this assessment, 2 people involved in assessing bias in order to reduce the risk of being bias during judgement. The risk of bias for randomized trials (n= 10) in all included studies that assessed by Cochrane Risk of Bias was demonstrated in Figure 2 and the summary of bias for randomized studies in each included study was portrayed in Figure 3. Overall, the risk of bias in randomized trial showed low risk of bias which indicated that the studies are good quality studies.

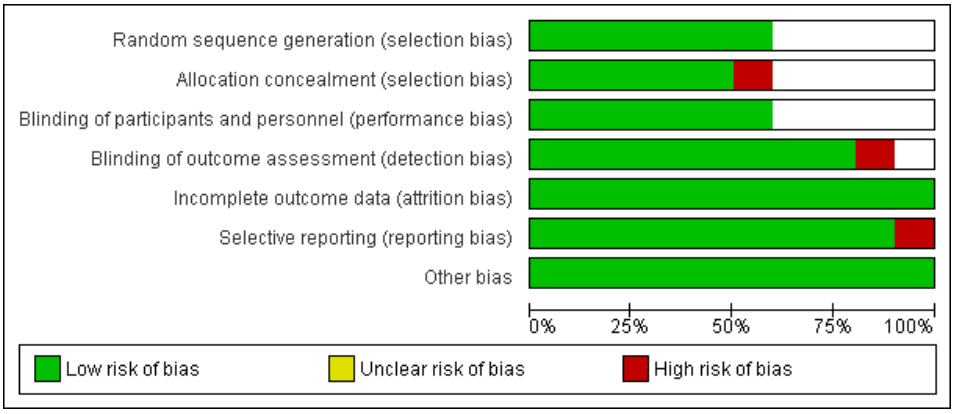

Figure 2. Risk of Bias Graph of Randomized Control Trials

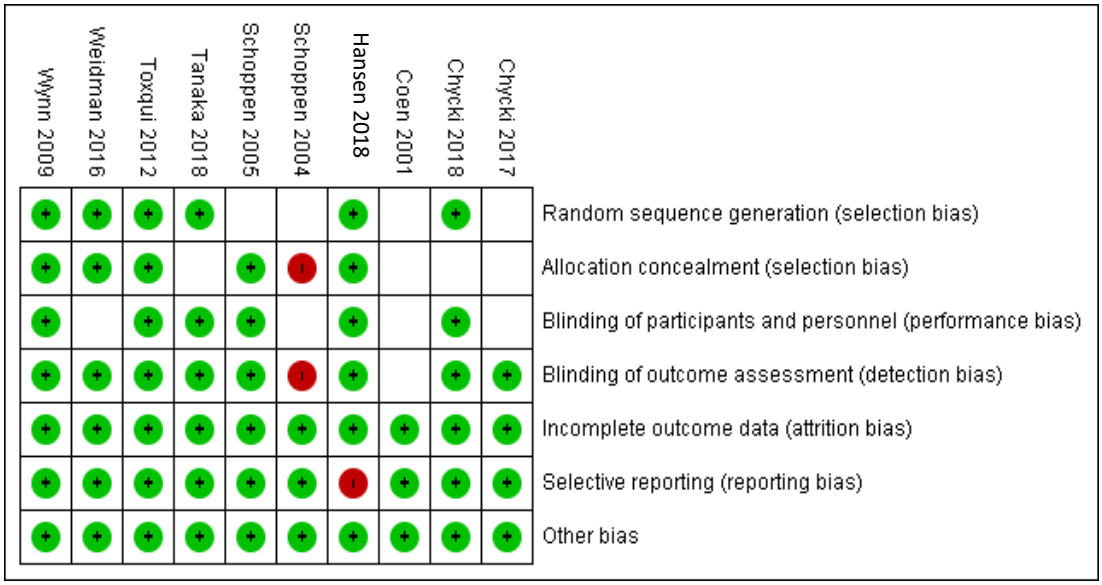

Figure 3. Summary of Risk of Bias

Then, the risk of bias for only one non-randomized trial (n= 1) that used quasi-experimental design (study 8) was assessed by using Robins-I tool; which was shown in Table 3. To summarize, the risk of bias for overall is low. Hence, this showed that the study had a good quality.

Table 3. Robins - I Tool Risk of Bias Assessment

Domains	Assessment
	Study 8
Bias due to confounding	Unclear
Bias in selection of participants into study	Low
Bias in measurement of interventions	Low
Bias due to departures from intended interventions	Low
Bias due to missing data	Low
Bias in measurement of outcomes	Low
Bias in selection of reported result	Low
Overall	Low

DISCUSSION

Based on the studies reviewed, there are 9 articles (Chycki, 2017, Weidman, 2016, Tanaka, 2018, Chycki, 2018, Schoppen 2005, Agustanti, 2019, Schoppen 2004, Toxqui, 2012 and Wynn, 2009) that showed positive results of alkaline water intake in human's health. One study (Hansen, 2018) with neutral outcome and also one study (Coen, 2001) with negative outcome.

A contrary between two studies that used blood profile to monitor blood glucose showed a positive and neutral outcome. The study with neutral outcome (Hansen, 2018) used healthy population as participants; while another study with positive outcome (Agustanti, 2019) recruited patients with diabetes mellitus that associated more with the biomarker used for assessment. Other than that, the intervention done within the study might affect the result

of trials where Hansen (2018) used cross-over controlled-trial to observe the changes while Agustanti (2019) used quasi-experimental study where they compared the pre and post intervention. Based on the level of evidence, Hansen (2018) has higher quality of evidence compared to Agustanti (2019).

Besides, negative outcome from Coen (2001) showed a significant change that lead to negative health outcome which increase the risk of renal lithogenesis. In this study, the alkaline water used was rich in calcium which subsequently resulting in the recurrence of stone in the kidney. As the amount of calcium is too much, it could exhibit undesirable health condition. Hence, it is important to consider the mineral content percentage in alkaline water since it might bring negative health effects.

The findings related to amount and duration of ionized alkaline water could be divided into four categories: general healthy population, athletes, post-menopausal women and diabetes mellitus patients. All of the outcome showed a variation of amount and duration.

Healthy Population

For general healthy population, the results were extracted from 4 articles reporting positive outcome (Weidman, 2016, Tanaka, 2018, Toxqui, 2012 & Wynn, 2009). The amount of alkaline water consumed in the studies was between 1.5 to 2.0 L/day. Based on this result, it can be concluded that the requirement of alkaline water intake for healthy people is equivalent to the recommended fluid intake for normal people which is 8 glasses of water daily or 30 mL/kg body weight. For the duration of study intervention, 2 studies showed 4 weeks of intervention period (Tanaka, 2018 & Wynn, 2009); while Weidman (2016) required shortest period which was within 4 to 8 hours. Another study by Toxqui (2012) also had a shorter period for intervention which was 1 week. In short, it is appropriate to consider the longer period of time for intake of alkaline water since the short duration demonstrated immediate changes only; whereas the longer duration has proven consistent positive health outcome.

Athletes

Next, the average amount of electrolyzed alkaline water for athletes range from 3.0 to 4.0 L/day (Chycki, 2017 & Chycki, 2018). The amount of electrolyzed alkaline water intake for athletes in the reviewed studies is in accordance with the recommendation of the National Athletic Trainers Association (Casa et al., 2000). While for the duration, both studies have different period of study intervention which were 1 week (Chycki, 2017) and 3 weeks (Chycki, 2018). However, both studies showed consistent results and the biomarkers used were also quite similar which were urinalysis and lactate concentration measurement. Hence, it can be summarized that within a week alkaline water intake could already show a positive outcome for hydration status and aerobic performance among athletes.

Post-menopausal Women

Besides, for the studies involving post-menopausal women (Schoppen 2004 & Schoppen 2005), The amount of alkaline water intake ranges from 1.0 to 1.5 L/day. The required amount is lower compared to the fluid requirement for general population. This is because the average age of the subjects was higher than other reviewed studies and they have higher susceptibility to experienced over-hydration. This is supported by Lindeman (2000) and Negoianu (2008) as

they suggested that older persons who consumed standard fluid recommendation are most likely to be over-hydrated. The total duration was different in both studies since the parameters used were different. Shorter period was used to monitor postprandial lipaemia in post-menopausal women which was 2 weeks; while a longer period was required to observe the ability of alkaline to decrease the risk of cardiovascular disease which was 2 months probably due to increasing the reliability of outcome produced by biomarkers.

Diabetes Mellitus Patient

There was only one study included which recruited patient with diabetes as the subjects (Agustanti, 2019). Thus, outcome is not conclusive as level of evidence for this study is 3 and randomized control trial is therefore warranted to be conducted. However, the amount of alkaline water intake could still be used as reference. The amount consumed was 2 L/day which is similar to the standard fluid recommendation for healthy people. Hence, it can be concluded that the requirement might be similar with healthy people since diabetic patients do not have any fluid restriction. The duration of study was one week which showed short duration compared to other included reviewed studies.

Limitation and Strength of Study

One of the limitations in this review is it has mostly been conducted by only one researcher which could introduce the risk of bias while reviewing articles and making judgement. However, the researcher managed to reduce the bias in reviewing articles through discussion with another researcher in order to achieve a reasonable judgement.

As for its strength, the PRISMA Statement which consisted of PRISMA flow diagram and checklist were used as a guideline to facilitate this review. The use of PRISMA guideline provide assurance that this review was conducted according to recommended scientific standards.

CONCLUSION

Based on the available literature, there were positive, negative and neutral outcomes with the consumption of alkaline water, as shown by the results of the 11 reviewed studies. Based on the findings, the requirement of alkaline water intake which produced positive outcome is equivalent to recommended fluid intake suitable with their health condition in which for people with no fluid restriction is 1.5 to 2 L/day, 1.0 to 1.5 L/day for older age people that have higher risk of over-hydration and 4 L/day for athletes. Besides, the duration which ranged from 1 to 8 weeks and it would depend on how fast the biomarkers react towards alkaline water intake. It is suggested for future study to explore other factors such as pH and also mineral content in alkaline water and to perform meta-analysis in order to provide more comprehensive clinical evidence to establish correlation of ionized alkaline water intake and health effects.

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