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Effects of kimchi on human health: a scoping review of randomized controlled trials

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Abstract

Kimchi is a Korean traditional fermented food which is one of the most popular ethnic fermented foods in Korea and consumed daily. The purpose of this review was to systematically evaluate all prospective clinical studies of kimchi and to estimate the effectiveness of kimchi for health in general. Three English databases, four Korean databases, and two clinical trial registries were searched until November 7, 2022. Two independent reviewers extracted and tabulated the data. The outcomes of this review were any health-related outcomes that studied on kimchi or kimchi-derived probiotics. Eleven randomized controlled trials (RCTs) were included in this review, with 638 participants enrolled in total and 608 participants completing the trials. Most of the included RCTs examined serum lipid profiles and clinical parameters and found that kimchi interventions showed decrease in serum lipids, cholesterols and body fats. Kimchi interventions may be safe and effective treatment option for the treatment of general health, obesity, and irritable bowel syndrome, regardless of the lack of adequate trials. In the future, research that can verify the conflicting results on the health benefits of kimchi should be conducted rigorously to provide the scientific basis for the benefits of kimchi.

Keywords Clinical evidence, Ethnic food, Health benefits, Kimchi

Introduction

Fermented foods are part of the diverse food cultures found in various nations and areas around the world [1]. Fermentation has been used for centuries to extend the shelf life of food and has been linked to several health benefits [2–4]. They have received a lot of attention for their natural, nutritive, and functional qualities that support health [5]. In Korea, kimchi is an ethnic food, consumed daily with every meal [6], and an adult consumes about 50–200 g of kimchi per day on average [7].

The vegetables most frequently used to make kimchi are baechu cabbages (*Brassica rapa*) and radishes (*Raphanus raphanistrum*); however, other vegetables including cucumbers, spring onions, and other plants are also widely used, resulting in hundreds of different kimchi being consumed in Korea [6, 8]. The fermentation of kimchi involves numerous microorganisms, especially lactic acid bacteria (LAB), and the microbial composition of kimchi differs based on the type and amount of ingredients being used in the making of kimchi. Among many microorganisms associated with the fermentation of kimchi, LAB are one of the predominant species with probiotic properties [7, 9]. LAB that are commonly present

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and representative in kimchi include species of genera *Lactobacillus*, *Leuconostoc*, and *Weissella* [8, 10].

Many studies have reported the beneficial effects of kimchi consumption. Kimchi has been found to exhibit anti-inflammatory properties [11, 12], ameliorate cancer cachexia [13], induce apoptosis and prevent colon cancer [14–16], prevent atherosclerosis [17] and hepatic damage caused by high cholesterol [18], improve general metabolic parameters [19, 20], fasting blood glucose and cholesterol [21], improve cognitive impairments [22], enhance immunity [23] and protect against atopic dermatitis [24]. With many beneficial effects, kimchi has been considered as a type of medicinal food [25]. Therefore, the purpose of this review was to systematically evaluate all randomized controlled studies related to kimchi and to evaluate the effectiveness of kimchi for health in general.

Methods

This review was registered on PROSPERO: International prospective register of systematic reviews (CRD42018087375). The review was performed and reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR).

Search strategy

Three English and four Korean databases were searched for data retrieval. The databases searched in English were PubMed/Medline, Embase, and Cochrane Library; the databases searched in Korean were DBpia, Korean Studies Information Service System (KISS), ScienceOn (formerly, National Digital Science Library (NDSL)), and Oriental Medicine Advanced Searching Integrated System (OASIS). The search was done from their inception until November 7, 2022. The search strategy included various terms of different kimchi types, fermented cabbage, and fermented vegetable.

Inclusion criteria and outcomes

Only randomized controlled trials (RCTs) were included as they are regarded as the reference standard to scientifically and rigorously test the hypothesis on the effectiveness of interventions [26]. Other types of clinical studies such as cohort, cross-sectional, case reports or retrospective clinical studies were excluded. As this review did not focus on any specific population group, any participants with or without health conditions were eligible for inclusion. All RCTs that used kimchi or kimchi-derived probiotics as an intervention regardless of their comparators were included. Outcome measures for this review were any health-related outcomes, and additional outcomes were quality of life and adverse events.

Study selection and data extraction

Two review authors (ES and LA) independently performed the screening and selection of the searched records. All titles and abstracts were screened for eligibility. Full-text retrieval of included studies, data extraction, and data tabulation were also performed independently by two review authors. From the included studies, information regarding study design, participants, disease type, interventions, and outcomes were extracted. Any discrepancies were discussed with the third author (MSL).

Results

Literature search

Searches from seven electronic databases and two trial registries identified 15,085 records, resulting in 8,551 records to be screened for inclusion after the removal of duplicates. The titles and abstracts were screened based on the inclusion criteria. The full-text of 111 records was then retrieved for further assessment, of which 100 records were excluded. A total of 11 studies were included in the scoping review (Fig. 1). The characteristics of the included studies are tabulated in Table 1.

Study characteristics

Eleven randomized controlled trials (RCTs) were included in this review, with 638 participants enrolled in total and 608 participants completing the trials. Most of the trials were conducted in Korea with the trial duration ranging from 7 days to 12 weeks. Five trials [21, 27–30] studied on healthy subjects, two trials [31, 32] studied on obese subjects, one trial [33] studied on both healthy and obese subjects, one trial [34] studied on cancer patients, one trial [35] studied on prediabetic subjects, and one trial [36] studied on irritable bowel syndrome patients. In terms of intervention, five trials [21, 28, 29, 31, 36] used kimchi consumption, two trials [27, 33] used kimchi supplement, and four trials [30, 32, 34, 35] used kimchi-derived probiotics. In terms of control, seven [27, 30, 32–35] used placebo, four [21, 29, 31, 36] used other types of kimchi, and one [28] used non-kimchi diet (Table 1).

Outcome assessment

Kimchi on healthy subjects

In a clinical trial by Choi et al. [21], high amount consumption of kimchi compared to low amount consumption of kimchi improved serum lipid profiles and

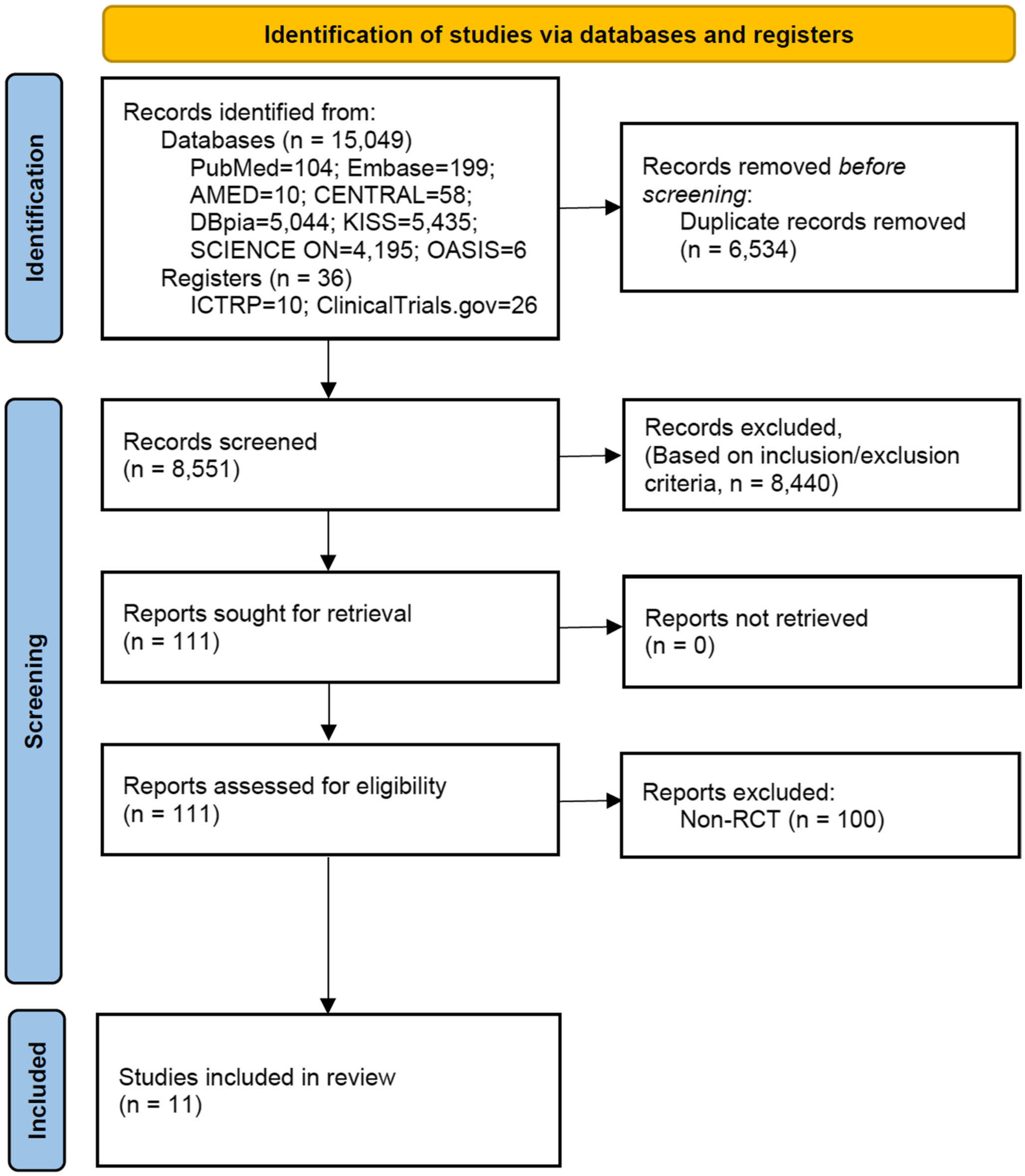

Fig. 1 PRISMA flow diagram illustrating the screening process

fasting glucose levels. Concentrations of fasting blood glucose (FBG), total glucose, total cholesterol (TC) and low-density lipoprotein (LDL)-C decreased in both groups. FBG was reduced in the high kimchi consumption group from 80.7 ± 5.4 mg/dL to 75.1 ± 6.0 mg/dL ($p < 0.001$), which showed a significant decrease compared to the low-intake group ($p = 0.003$).

Another trial by Kim and Park [29] investigated the effects of kimchi consumption (standard kimchi and functional kimchi) on healthy subjects and found improvements in dietary fiber intake. The functional kimchi group showed significant improvements in body fat percentage, skeletal muscle mass, TC, triglycerides (TG), LDL-C, adiponectin, and interleukin (IL)-6 ($p < 0.05$), and a significant improvement in HDL-C ($p < 0.01$), while the standard kimchi group showed significant improvements in LDL-C and adiponectin only ($p < 0.05$). The trial also revealed an increase in beneficial bacteria such as Faecalibacterium and Bifidobacterium and a decrease in harmful bacteria such as Clostridium and *Escherichia coli*).

A trial by Han [30] investigated effects of kimchi-derived probiotics (*Lactobacillus plantarum*) on skin health of young healthy subjects in comparison with placebo. Skin pH was decreased significantly in

Table 1 Summary of randomized controlled trials investigating the health benefits of kimchi

Author/year	Study population, Study duration	Intervention	Control	Outcomes	Conclusion (quotes)
Choi et al. 2001 [27]	Healthy subjects, $n=12$ 6 weeks	Kimchi supplement (6 pills of 500 mg, 3 g/day, equivalent of 30 g of kimchi, $n=6$)	Placebo (rice powder pill, $n=6$)	1. Serum lipid profiles	"Kimchi supplementation seems to have beneficial effects on controlling plasma TG."
Choi et al. 2013 [21]	Healthy subjects, $n=100$ 7 days	High kimchi consumption (210 g/day, $n=50$)	Low kimchi consumption (15 g/day, $n=50$)	1. Serum lipid profiles 2. Fasting glucose levels	"Greater consumption of kimchi improved FBG and serum total cholesterol in young healthy adults."
Lee et al. 2014 [28]	Healthy subjects, $n=43$ 4 weeks	Kimchi diet (100 g/day, $n=19$)	Non-kimchi diet (100 g radish/day, $n=20$)	1. Anthropometrics 2. Clinical parameters	"The short-term consumption of kimchi has no immunomodulatory effects."
Kim & Park 2018 [29]	Healthy subjects, $n=28$ 4 weeks	Standard kimchi (210 g/day, $n=14$)	Functional kimchi (210 g/day, $n=14$)	1. Anthropometrics 2. Serum lipid profiles 3. Fecal pH and enzyme activity 4. Fecal microbiota	"FK more effectively improved markers of obesity and metabolic disease as well as enhanced human colon health than SK."
Han et al. 2019 [30]	Healthy subjects in 20's and 30's, $n=78$ 12 weeks	Lactobacillus plantarum (CJLP55) from kimchi (10^{10} CFU, 2 g/day, $n=39$)	Placebo ($n=39$)	1. Skin pH 2. Epidermal levels (epidermal lactate, FFA, FAA)	"Kimchi supplement promotes acidic skin pH with a selective increase in epidermal lactate."
Song & Baek 2001 [33]	Healthy subjects, $n=12$ 6 weeks	Kimchi supplement (3 g/day, $n=6$)	Placebo (rice powder pill, $n=6$)	1. Serum lipid profiles	"Kimchi supplement had serum lipids lowering effect."
	Healthy subjects, $n=19$ 6 weeks	1. Water-soluble kimchi supplement ($n=6$) 2. Insoluble kimchi supplement ($n=7$)	Placebo ($n=6$)	1. Serum lipid profiles	"Water-soluble kimchi supplement was more effective than insoluble kimchi supplement in lowering serum lipids."
	Obese adolescent subjects, $n=28$ Healthy adolescent subjects, $n=10$ 6 weeks	1. Kimchi supplement and exercise ($n=8$), 2. Exercise (60 min each time, HRmax 60%~85%, 4 times a week $n=8$), 3. Kimchi supplement (twice a day, 3 pills each time, 500 mg/pill, $n=12$)	No intervention ($n=10$)	1. Body composition 2. Serum lipid profiles	"Kimchi supplement reduced weight, body fat, body fat percentage, abdominal fat percentage, and degree of obesity, but had no effect on HDL-C. In addition, kimchi supplementation with exercise showed greater effect in changes of body composition and serum lipids."
Han et al. 2015 [31]	Obese female subjects, $n=24$ 8 weeks	Fermented kimchi (180 g/day, $n=11$)	Fresh kimchi (180 g/day, $n=12$)	1. Clinical parameters 2. Composition of gut microbiota 3. Gene expression related to metabolic syndrome	"Consumption of fermented kimchi can either directly influence expression of human genes related to metabolic and immunity pathways or indirectly influence human metabolism by altering gut microbial composition."
Lim et al. 2020 [32]	Obese subjects, $n=114$ 12 weeks	Lactobacillus sakei (CJLS03) derived from kimchi (5×10^9 CFU, $n=47$)	Placebo ($n=48$)	1. Body compositions 2. Biochemical parameters	"L. sakei (CJLS03) might help people with obesity reduce body fat mass without serious side effects."

Table 1 (continued)

Author/year	Study population, Study duration	Intervention	Control	Outcomes	Conclusion (quotes)
Yoon et al. 2020 [34]	Rectal cancer subjects, $n=40$ 3 weeks	Lactobacillus plantarum (CJLP243) derived from kimchi (1×10^{10} CFU, $n=20$)	Placebo ($n=20$)	1. Bowel function index (BFI) total score 2. Low anterior resection syndrome (LARS) scores 3. Quality of life 4. Adverse events	"… no significant effects supporting the use of a probiotic for improved bowel function."
Oh et al. 2021 [35]	Prediabetic subjects, $n=40$ 8 weeks	*L. plantarum* HAC01 (4×10^9 CFU, $n=20$)	Placebo ($n=17$)	1. Parameters of glucose metabolism 2. Serum lipid profiles, adiponectin, and leptin 3. Fecal microbiota and SCFAs 4. Adverse events	"…show a beneficial effect of single-strain probiotic supplementation administered over eight weeks on HbA1c levels in prediabetic subjects."
Kim et al. 2022 [36]	IBS subjects, $n=90$ 12 weeks	(a) Dead nano-sized Lactobacillus plantarum nF1 plus standard kimchi (210 g/day, $n=28$) (b) Functional kimchi (Viscum album (mistletoe) extract added with Lab. plantarum, (210 g/day, $n=29$)	3 kinds of kimchi (210 g/day, $n=30$)	1. Dietary intake 2. Anthropometric measurements and serum analysis 3. IBS symptoms 4. Fecal enzyme activity 5. Fecal microbiota 6. Inflammatory factors	"Kimchi intake helps alleviate IBS by increasing dietary fiber intake and reducing serum inflammatory cytokine levels and harmful fecal enzyme activities."

2h-PPG, 2-h postprandial glucose; BMI, body mass index; CFU, colony-forming units; DBP, diastolic blood pressure; DI, disposition index; FAA, free amino acids; FBG, fasting blood glucose; FFA, free fatty acids; FINS, fasting insulin; FK, functional kimchi; HDL-C, high-density lipoprotein cholesterol; IBS, irritable bowel syndrome; IR, insulin resistance; LDL-C, low-density lipoprotein cholesterol; QUICKI, quantitative insulin sensitivity check index; RCT, randomized controlled trial; SCFA, fecal short-chain fatty acids; SBP, systolic blood pressure; SK, standard kimchi; TC, total cholesterol; TG, triglycerides; WC, waist circumference; WHR, waist-to-hip ratio; OH, hydroxyl radical the kimchi group from 5.18 ± 0.07 to 4.80 ± 0.06 at 12 weeks and showed a significant change compared to the control group ($p = 0.025$). The epidermal level of lactate (percent change) in the kimchi group was increased by $25.56 \pm 13.65\%$ while the control group showed $9.76 \pm 9.70\%$ decrease ($p < 0.05$). Epidermal levels of FAA were not changed in both groups, but those of FFA were lower in the kimchi group ($p = 0.029$).

In a trial involving healthy subjects and kimchi supplement by Choi et al. [27], kimchi supplement in comparison with placebo (rice powder pills) showed beneficial effects on controlling serum lipid profiles. The plasma TG concentration decreased from 115.2 ± 57.7 to 97.3 ± 52.3 mg/dL in the kimchi supplement group and the group's average change in TG was 16.8% ($p < 0.05$), while plasma TG concentration increased from 98.5 ± 34.9 to 105.7 ± 32.9 mg/dL in the control group with the group's average change in TG being 9.8% increase.

In another kimchi supplement trial by Song et al. [33], effects of kimchi supplement were investigated in comparison with placebo or no intervention. Kimchi was found to reduced body mass index (BMI), body fat percentage, and systolic blood pressure. TG was decreased in the kimchi supplement group by $-15.8 \pm 10.7\%$, while TG was increased in the control group by $9.8 \pm 15.8\%$. LDL/LDL-C was also decreased in the kimchi supplement group by $-6.7 \pm 17.1\%$. Body weight, BMI, body fat mass, and body fat percentage decreased in all intervention groups compared to the control group.

However, in a trial by Lee et al. [28], the kimchi diet group in comparison with the non-kimchi diet did not show positive immunomodulatory effects. Between the two groups, lymphocyte subsets, pro-inflammatory cytokines, anti-inflammatory cytokines, and immunoglobulins did not show significant improvements.

Kimchi on obese subjects

In a trial by Han et al. [31], effects of fermented kimchi were compared with fresh kimchi. Waist circumferences and body fat percentage showed a significant decrease in the fresh kimchi group ($p < 0.05$), while HDL-C showed a significant improvement in the fermented kimchi group ($p < 0.05$). However, no significant changes were seen in clinical parameters between both groups. Fermented kimchi was found to influence metabolic pathways and immunity.

In a trial by Lim et al. [37], kimchi-derived probiotics (*Lactobacillus sakei*) in comparison with placebo were investigated. The trial found to reduce body fat mass by 0.2 kg in the kimchi group, while it increased by 0.6 kg in the placebo group. Waist circumference was significantly reduced in the kimchi group than in the placebo group ($p = 0.013$). Adverse events, including gastrointestinal discomfort, were mild.

Others

In a trial by Yoon et al. [34] effects of kimchi on bowel function and quality of life in rectal cancer patients were investigated, and found no significant effect of kimchi-derived probiotics (*Lactobacillus plantarum*) in comparison with the placebo.

In a trial involving prediabetic subjects, Oh et al. [35] studied effects of kimchi-derived probiotics (*Lactobacillus plantarum*) compared with placebo. The 2h-PPG ($p = 0.045$) and HbA1c ($p = 0.013$) levels in the kimchi group were significantly reduced. No serious adverse effects were reported.

In a trial by Kim et al. [36], effects of kimchi on irritable bowel syndrome were compared by using kimchi with different properties: standard kimchi, *Lactobacillus plantarum* (nF1) added standard kimchi, and functional kimchi (Viscum album (mistletoe) extract added with *Lactobacillus plantarum*). For IBS symptoms, all three types of kimchi groups had significant improvements in abdominal pain or inconvenience ($p < 0.001$), desperation ($p < 0.001$), incomplete evacuation ($p < 0.001$), and bloating ($p < 0.001$). However, there were no significant differences between the kimchi groups for improvement of overall IBS symptoms. For serum inflammatory cytokine levels, all three kimchi groups had significant improvements in tumor necrosis factor (TNF)-α ($p < 0.001$). For other inflammatory factors, nF1 kimchi group and functional kimchi group showed significant improvements in IL-4 ($p < 0.001$), IL-10 ($p < 0.001$), IL-12 ($p < 0.01$).

Discussion

Kimchi is a traditional Korean fermented vegetable dish that is stored and preserved in a special way. There are various pickled vegetable foods all over the world, but kimchi differs from other salted vegetables as they are first salted and then seasoned and fermented secondarily [38]. Korean kimchi was selected as the world's top five healthiest foods along with Spanish olive oil, Japanese bean products, Greek yogurt, and Indian lentils. The reason for the selection of kimchi as a super food was based on the fact that it is rich in lactic acid bacteria, fiber, and various minerals and vitamins, which are beneficial for health and for cancer prevention [39].

Currently, various studies report the effectiveness of kimchi in improving overall health. A controlled clinical trial, [40] which was excluded from this review because it was not randomized controlled trial, involved 12 young female adults, 6 participants in each group. The trial interventions were low consumption of kimchi (15 g/day) and high consumption of kimchi (150 g/day) for 7 days, and reported the decrease in potentially harmful microorganism (such as Listeria and Clostridium, Enterobacter, Prevotella, and Shigella) percentage in the high-consumption group. There were 34 species of intestinal microorganisms whose percentage changes between the two groups were significantly different ($p < 0.05$). Thus, kimchi consumption was found to influence the formation of intestinal microbiota. Also, the functionality of kimchi as a probiotic is expected to improve with the increase in the percentage of kimchi LAB in the intestine.

One crossover study [19] excluded from this review investigated the effects of fermented kimchi on body weight and metabolic parameters in 22 overweight and obese patients in 2 sets of 4-week interventions with 2-week washout period. The clinical study found that the fermented kimchi group showed significant improvements in the waist-hip ratio, fasting blood glucose, total cholesterol, body fat percentage, systolic blood pressure, and diastolic blood pressure ($p < 0.05$) in the fermented kimchi group compared to those in the fresh kimchi group. Even though fresh kimchi also showed significant improvement from initial value to final value in terms of body weight, BMI, body fat percentage, TG, E-selectin, and adiponectin ($p < 0.05$), fermentation of kimchi was found to provide more positive effects.

Similarly, another crossover study [20] of 2 sets of 8-week interventions with 4-week washout period investigated the effects of fresh and fermented kimchi in 21 participants with prediabetes. The parameters associated with prediabetes such as hemoglobin A1C (HbA1c), fasting insulin, insulin resistance, and Matsuda index (whole-body insulin sensitivity index) showed significant improvements within the group ($p < 0.05$) in both the fresh kimchi group and the fermented kimchi group. For quantitative insulin sensitivity check index and disposition index, only the fermented kimchi group showed improvements compared to before intervention ($p < 0.05$). Overall, the fermented kimchi group showed better effects on insulin resistance and insulin sensitivity than the fresh kimchi group.

In terms of anticancer and cancer prevention effects reported by previous studies, kimchi was found to have inhibitory effects of cancer cell growth for gastric cancer (AGS cell and KATOIII), lung cancer (A549 cell), colon cancer (HT-29 cell and HCT-116 cell), breast cancer (MCF-7 cell), liver cancer (HepG2 cell) and uterine cancer (Hela cell) [41]. Even though there are numerous cell and animal studies exploring anti-inflammation and anticancer effects of kimchi, clinical trial data on such effects are currently not available yet.

In this review, the included RCTs reported on lipid-lowering effects, colon health improvement, and anti-obesity effects of kimchi, although there were differences depending on the amount of kimchi consumed and the fermentation stage. Despite the differences in the types and amount of kimchi consumed, all kimchi consumption in general was found to have benefits in improving health. Other types of clinical studies have similar results which also support the effects of kimchi on body fat and serum lipid profiles [41].

For lipid-lowering effect, various animal studies support the effects of kimchi by inducing hyperlipidemia with a high-fat or high-cholesterol diet. In particular, the lipid-lowering effect of kimchi was reported by experimenting on obese rats and diabetic rats [42–44]. In other experiments with rabbits, the beneficial effects of kimchi were supported by demonstrating lipid inhibitory effect and changes of lipid content in various tissues [17, 45]. In a cross-sectional study, the correlation between kimchi intake and lipid indicators showed a positive correlation with HDL cholesterol and a negative correlation with LDL cholesterol [46]. This further confirms the positive effects of kimchi consumption in improving serum lipid profiles.

Despite beneficial effects of kimchi, there were concerns about consuming salted vegetables that some studies addressed kimchi's association with hypertension. However, a cross-sectional study [47] explored kimchi's effects on hypertension among 20,114 participants using the Korea National Health and Nutrition Examination Survey (KNHANES) data and found that consumption of kimchi was not associated with increased prevalence of hypertension (odds ratio: 0.87; 95% CI 0.70–1.08). In a community-based cohort study of 12-year follow-up [48], 5,932 participants were included and it also concluded that consuming kimchi was not linked to a higher risk of hypertension.

Kimchi is considered as probiotic food. Kimchi is made by fermentation process with many bacteria, but pathogenic and putrefactive bacteria are suppressed, leaving probiotic LAB as dominant one remaining [49]. Kimchi involves its ingredients to go through fermentation, but different LAB strains are found in different stages of kimchi fermentation and in different kimchi samples. Kimchi microorganisms vary depending on the ingredients, methods, and environment (such as acidity and temperature), and thus, its functionality may differ from kimchi to kimchi. Therefore, certain kimchi may have certain LAB strain that may work better on specific disease which can be investigated further for custom-made kimchi.

Various components and compounds found in kimchi provide health benefits. Kimchi has important nutritional and functional properties as kimchi includes vitamins, minerals, dietary fibers, probiotics, capsaicin, gingerol, chlorophyll, allyl compounds, benzyl isothiocyanate, indole compounds, thiocyanate, and beta-sitosterol [50]. Also, previous cell studies concluded that the kimchi LAB strains were sensitive to antimicrobial agents such as erythromycin, ampicillin, chloramphenicol, and benzylpenicillin [51] and that the LAB were not only safe for human consumption but also met the functional criteria [52]. Numerous studies support the beneficial effects of LAB, including anticancer effects and immune-stimulating effects [53–57].

There were several limitations in this review. The search for this review was restricted to English and Korean databases only, which may have resulted in several non-English and non-Korean studies to be overlooked. Also, the Korean terms of various types of kimchi are expressed in many different ways in English romanization letters, and due to lack of standardized terms, there are possibilities of missing studies.

Conclusion

Numerous clinical studies reported on the positive effects of kimchi. In particular, this review found that kimchi interventions may be safe and effective treatment option for the treatment of general health, obesity, and irritable bowel syndrome. However, questions have been raised about its health functionality due to the lack of adequate trials. In the future, research that can verify the conflicting results on the health benefits of kimchi should be conducted rigorously to provide the scientific basis for the benefits of kimchi.

Author contributions

Conceptualization: MSL and MSK; methodology: ES and LA; formal analysis: ES; investigation: HWL; data curation: ES and LA; writing—original draft: ES and LA; writing—review and editing: MSL, MSK, and DJJ; supervision: MSL; funding acquisition: MSL. All authors read and approved the final manuscript.

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Availability of data and materials

Not applicable.

Declarations

Competing interests

DJJ, MSK, and MSL are the editorial board members of the journal but their role had no influence on the editorial process or decision. The authors declare no other competing interests.

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References

1. Bell V, et al. One health, fermented foods, and gut microbiota. Foods. 2018;7(12):195.
2. Das G, et al. Traditional fermented foods with anti-aging effect: a concentric review. Food Res Int. 2020;134:109269.
3. Şanlier N, Gökcen BB, Sezgin AC. Health benefits of fermented foods. Crit Rev Food Sci Nutr. 2019;59(3):506–27.
4. Marco ML, et al. Health benefits of fermented foods: microbiota and beyond. Curr Opin Biotechnol. 2017;44:94–102.
5. Wilburn JR, Ryan EP. Chapter 1—fermented foods in health promotion and disease prevention: an overview. In: Frias J, Martinez-Villaluenga C, Peñas E, editors. Fermented foods in health and disease prevention. Boston: Academic Press; 2017. p. 3–19.
6. Hongu N, et al. Korean kimchi: promoting healthy meals through cultural tradition. J Ethn Foods. 2017;4(3):172–80.
7. Chang JH, et al. Probiotic characteristics of lactic acid bacteria isolated from kimchi. J Appl Microbiol. 2010;109(1):220–30.
8. Surya R, Lee AG-Y. Exploring the philosophical values of kimchi and kimjang culture. J Ethn Foods. 2022;9(1):20.
9. Patra JK, et al. Kimchi and other widely consumed traditional fermented foods of Korea: a review. Front Microbiol. 2016;7:1493.
10. Song HS, et al. Microbial niches in raw ingredients determine microbial community assembly during kimchi fermentation. Food Chem. 2020;318:126481.
11. Yu HS, et al. Anti-inflammatory potential of probiotic strain Weissella cibaria JW15 isolated from kimchi through regulation of NF-κB and MAPKs pathways in LPS-induced RAW 264.7 cells. J Microbiol Biotechnol. 2019;29(7):1022–32.
12. Han KJ, et al. Antioxidant and anti-inflammatory effect of probiotic *Lactobacillus plantarum* KU15149 derived from Korean homemade diced-radish kimchi. J Microbiol Biotechnol. 2020;30(4):591–8.
13. An JM, et al. Dietary intake of probiotic kimchi ameliorated IL-6-driven cancer cachexia. J Clin Biochem Nutr. 2019;65(2):109–17.
14. Han YM, et al. Dietary intake of fermented kimchi prevented colitis-associated cancer. J Clin Biochem Nutr. 2020;67(3):263–73.
15. Kim HY, et al. Kimchi protects against azoxymethane/dextran sulfate sodium-induced colorectal carcinogenesis in mice. J Med Food. 2014;17(8):833–41.
16. Yu T, et al. Kimchi markedly induces apoptosis in HT-29 human colon carcinoma cells. J Food Biochem. 2021;45(1):e13532.
17. Kim HJ, et al. 3-(4′-hydroxyl-3′,5′-dimethoxyphenyl)propionic acid, an active principle of kimchi, inhibits development of atherosclerosis in rabbits. J Agric Food Chem. 2007;55(25):10486–92.
18. Woo M, et al. Preventative activity of kimchi on high cholesterol diet-induced hepatic damage through regulation of lipid metabolism in LDL receptor knockout mice. Food Sci Biotechnol. 2018;27(1):211–8.
19. Kim EK, et al. Fermented kimchi reduces body weight and improves metabolic parameters in overweight and obese patients. Nutr Res. 2011;31(6):436–43.
20. An SY, et al. Beneficial effects of fresh and fermented kimchi in prediabetic individuals. Ann Nutr Metab. 2013;63(1–2):111–9.
21. Choi IH, et al. Kimchi, a fermented vegetable, improves serum lipid profiles in healthy young adults: randomized clinical trial. J Med Food. 2013;16(3):223–9.
22. Woo M, Kim MJ, Song YO. Bioactive compounds in kimchi improve the cognitive and memory functions impaired by amyloid beta. Nutrients. 2018;10(10):1554.
23. Yang SJ, et al. Antioxidant and immune-enhancing effects of probiotic *Lactobacillus plantarum* 200655 isolated from kimchi. Food Sci Biotechnol. 2019;28(2):491–9.
24. Kim HJ, Ju SY, Park YK. Kimchi intake and atopic dermatitis in Korean aged 19–49 years: The Korea National Health and Nutrition Examination Survey 2010–2012. Asia Pac J Clin Nutr. 2017;26(5):914–22.
25. Oktay S, Ekinci EK. Medicinal food understanding in Korean gastronomic culture. J Ethn Foods. 2019;6(1):4.
26. Hariton E, Locascio JJ. Randomised controlled trials—the gold standard for effectiveness research. BJOG Int J Obstet Gynaecol. 2018;125(13):1716–1716.
27. Choi S-H, et al. The effect of kimchi pill supplementation on plasma lipid concentration in healthy people. J Korean Soc Food Sci Nutr. 2001;30(5):913–20.

28. Lee H, et al. Immunomodulatory effects of kimchi in Chinese healthy college students: a randomized controlled trial. Clin Nutr Res. 2014;3(2):98–105.
29. Kim H-Y, Park K-Y. Clinical trials of kimchi intakes on the regulation of metabolic parameters and colon health in healthy Korean young adults. J Funct Foods. 2018;47:325–33.
30. Han S, et al. Dietary effect of Lactobacillus plantarum CJLP55 isolated from kimchi on skin pH and its related biomarker levels in adult subjects. J Nutr Health. 2019;52(2):149–56.
31. Han K, et al. Contrasting effects of fresh and fermented kimchi consumption on gut microbiota composition and gene expression related to metabolic syndrome in obese Korean women. Mol Nutr Food Res. 2015;59(5):1004–8.
32. Lim S, et al. Effect of *Lactobacillus sakei*, a probiotic derived from kimchi, on body fat in Koreans with obesity: a randomized controlled study. Endocrinol Metab (Seoul). 2020;35(2):425–34.
33. Song Y, Baek Y. Clinical study on the intake of kimchi pills on the lowering of blood lipids. Res Bull Kimchi Sci Technol. 2000;6:3.
34. Yoon BJ, et al. Effects of probiotics on bowel function restoration following ileostomy closure in rectal cancer patients: a randomized controlled trial. Colorectal Dis. 2021;23(4):901–10.
35. Oh MR, et al. *Lactobacillus plantarum* HAC01 supplementation improves glycemic control in prediabetic subjects: a randomized, double-blind, placebo-controlled trial. Nutrients. 2021;13(7):2337.
36. Kim HY, et al. Kimchi improves irritable bowel syndrome: results of a randomized, double-blind placebo-controlled study. Food Nutr Res. 2022;66:8268.
37. Lim S, et al. Effect of *Lactobacillus sakei*, a probiotic derived from kimchi, on body fat in Koreans with obesity: a randomized controlled study. Endocrinol Metab. 2020;35(2):425–34.
38. Ang L, et al. Chapter 17—kimchi and other fermented foods for gastrointestinal health. In: Bagchi D, Ohia SE, editors., et al., Nutrition and functional foods in boosting digestion, metabolism and immune health. New York: Academic Press; 2022. p. 235–53.
39. Raymond J. World's healthiest foods: kimchi (Korea); 2013. https://www.health.com/condition/digestive-health/worlds-healthiest-foods-kimchi-korea. 14 Nov 2022.
40. Kim J, et al. Changes in Korean adult females intestinal microbiota resulting from kimchi intake. J Nutr Food Sci. 2016;6(2):4172.
41. Kim B, et al. A survey of research papers on the health benefits of kimchi and kimchi lactic acid bacteria. J Nutr Health. 2018;51(1):1–13.
42. Park MY, et al. Lactobacillus curvatus KFP419 and *Leuconostoc mesenteroides* subsp mesenteroides KDK411 isolated from kimchi ameliorate hypercholesterolemia in rats. J Med Food. 2018;21(7):647–53.
43. Jo SY, et al. Characterization of starter kimchi fermented with Leuconostoc kimchii GJ2 and its cholesterol-lowering effects in rats fed a high-fat and high-cholesterol diet. J Sci Food Agric. 2015;95(13):2750–6.
44. Islam MS, Choi H. Antidiabetic effect of Korean traditional Baechu (Chinese cabbage) kimchi in a type 2 diabetes model of rats. J Med Food. 2009;12(2):292–7.
45. Jeon H-N, Kwon M-J, Song Y-O. Effects of kimchi solvent fractions on accumulation of lipids in heart, kidney and lung of rabbit fed high cholesterol diet. J Korean Soc Food Sci Nutr. 2002;31(5):814–8.
46. Kwon M-J, et al. Daily kimchi consumption and its hypolipidemic effect in middle-aged men. J Korean Soc Food Sci Nutr. 1999;28(5):1144–50.
47. Song HJ, Lee H-J. Consumption of kimchi, a salt fermented vegetable, is not associated with hypertension prevalence. J Ethn Foods. 2014;1(1):8–12.
48. Song HJ, et al. High consumption of salt-fermented vegetables and hypertension risk in adults: a 12-year follow-up study. Asia Pac J Clin Nutr. 2017;26(4):698–707.
49. Park K-Y, et al. Health benefits of kimchi (Korean fermented vegetables) as a probiotic food. J Med Food. 2014;17(1):6–20.
50. Park KY, Kim HY, Jeong JK. Chapter 20—kimchi and its health benefits. In: Frias J, Martinez-Villaluenga C, Peñas E, editors. Fermented foods in health and disease prevention. Boston: Academic Press; 2017. p. 477–502.
51. Ji Y, et al. Functionality and safety of lactic bacterial strains from Korean kimchi. Food Control. 2013;31(2):467–73.
52. Ryu EH, Chang HC. In vitro study of potentially probiotic lactic acid bacteria strains isolated from kimchi. Ann Microbiol. 2013;63(4):1387–95.
53. Cuevas-González PF, et al. Protective role of lactic acid bacteria and yeasts as dietary carcinogen-binding agents—a review. Crit Rev Food Sci Nutr. 2022;62(1):160–80.
54. Shoukat S. Potential anti-carcinogenic effect of probiotic and lactic acid bacteria in detoxification of benzo[a]pyrene: a review. Trends Food Sci Technol. 2020;99:450–9.
55. Saez-Lara MJ, et al. The role of probiotic lactic acid bacteria and bifidobacteria in the prevention and treatment of inflammatory bowel disease and other related diseases: a systematic review of randomized human clinical trials. Biomed Res Int. 2015;2015:505878.
56. Liu C, et al. Anti-cancer substances and safety of lactic acid bacteria in clinical treatment. Front Microbiol. 2021;12:722052.
57. Lee J, Kim S, Kang C-H. Screening and probiotic properties of lactic acid bacteria with potential immunostimulatory activity isolated from kimchi. Fermentation. 2023. https://doi.org/10.3390/fermentation9010004.

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