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Anti-hyperlipidemia of garlic by reducing the level of total cholesterol and low-density lipoprotein

A meta-analysis

Yue-E Sun, PhD, Weidong Wang, PhD*, Jie Qin, MS

Abstract

Background: This study aimed to understand the impact of garlic on improving blood lipids using a meta-analysis.

Methods: A literature search of the PubMed, EMBASE, and Cochrane Library databases was performed using keywords such as “garlic” and “hypercholesterolemia,” and the deadline “July 14 (th), 2017.” After extracting relevant details, each selected literature was evaluated for quality according to the quality evaluation criteria of bias risk recommended by Cochrane Collaboration recommendations and heterogeneity tests were performed. Standardized mean difference (SMD) and 95% confidence interval (CI) were evaluated using R 3.12 software. The publication bias was assessed using Egger method.

Results: A total of 14 eligible papers published from 1981 to 2016 were included. The quality of the literatures was of moderate to high qualities. The values of TC (SMD=–1.26, 95% CI, –1.86 to –0.66), low-density lipoprotein (LDL) (SMD=–1.07, 95% CI, –1.67 to –0.47), and high-density lipoprotein (HDL) (SMD=0.50, 95% CI, 0.06–0.94) after taking garlic in the experimental group and the control group have statistical significance, while there was no significant difference of TG in the 2 groups (SMD=–0.16, 95% CI, –0.87–0.55). However, the result of HDL was reversed when removed some of the literatures. No significant publication bias among the eligible studies with values of TC (P=.0625), LDL (P=.0770), HDL (P=.2293), and TG (P=.3436).

Conclusion: Garlic can reduce the level of TC and LDL instead of HDL and TG, indicating the ability of anti-hyperlipidemia.

Abbreviations: BG = aged black garlic, BMI = body mass index, CI = confidence interval, CVD = cardiovascular disease, GO = garlic oil, GP = garlic powder, HDL = high-density lipoprotein, HMG-CoA = 3-hydroxy-3-methylglutaryl-coenzyme A, LDL = low-density lipoprotein, PRISMA = Preferred Reporting Items for Systematic Reviews and Meta-Analyses, SMD = standardized mean difference, TC = total cholesterol, TG = triglyceride.

Keywords: cardiovascular disease, garlic, high-density lipoprotein, hypercholesterolemia, low-density lipoprotein, total cholesterol, triglyceride

High Lights

1. Garlic had anti-hyperlipidemia ability.
2. Intake of garlic induced the level of TC and LDL.
3. The level of TG in serum had no obvious difference with and without garlic treatment.

1. Introduction

Recently, cardiovascular disease (CVD), a complex and multifactorial disease, remains one of the serious diseases that threaten human health worldwide with increasing incidence and mortality year by year.[1] Unfortunately, 17 million people die to CVD each year and it is estimated to reach 24.8 million in 2030 in the world.[2] The most important risk factors of CVD are hypertension, high cholesterol, alcohol intake, and tobacco usage, etc. according to the World Health Organization

Editor: Fadi Khasawneh.

Ethics committee: This is a meta-analysis manuscript, there is no ethics committee or institutional review board approved by the study.

This work was supported by National Natural Science Foundation of China (Program No. 31301535), Six Talent Peaks project in Jiangsu Province (Program No. NY-167), and 333 Project of Jiangsu Province (Program No. BRA2017289).

Competing Interests: The authors declare that they have no competing interests.

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Medicine (2018) 97:18(e0255)

Received: 16 August 2017 / Received in final form: 8 February 2018 / Accepted: 1 March 2018

http://dx.doi.org/10.1097/MD.0000000000010255

statistics.[3] Dyslipidemia including high total cholesterol (TC), low-density lipoprotein cholesterol (LDL-C), and triglyceride (TG), as well as decreased high-density lipoprotein cholesterol (HDL-C) are important causes of CVD.[4] It is well known that an increase in LDL-C concentration is a risk factor for CVD and is therefore considered to be the primary goal of CVD prevention and treatment.[5] However, nowadays, most of hypolipidemic drugs have relatively great side effects during the treatment of CVD. Thus, a certain component from food with slight side-effect or free of side effects has been paid more and more attentions on the treatment of hyperlipidemia.

Garlic, a perennial herb, plays an important medicinal and dietary role throughout the history. Garlic is used in numerous forms such as extracted oil, powdered garlic tablets, or raw garlic.[6] Ancient Indian and Chinese medicine recommend that garlic can be used to help respiration and digestion, and to treat leprosy and parasitic diseases.[7] Besides, garlic plays important roles in the treatment of many diseases such as infectious diseases (as antibiotic), gynecologic diseases, toothache, arthritis, chronic cough.[7] Because of the widespread effects of garlic in maintaining good health, it has attracted particular attention of modern medicine. Importantly, the favorable effects are mainly attributed to diminution of risk factors for CVDs, antimicrobial effect, antioxidant effect, reduction of cancer risk.[8,9] The protective mechanisms of the beneficial effects of garlic in CVDs may be achieved by suppressing LDL oxidation, increasing HDL, as well as decreasing TC and TG.[10–12] A class of sulfur-containing organic compounds (including S-allylcysteine, alliin, ajoene, diallyl disulfide) in garlic has pharmacological effects.[13,14]

The effect of garlic in anti-hyperlipidemia has been confirmed in some animal studies, but all of them have small size of samples. Besides, a meta-analysis was performed in 2013 by Ried et al,[15] but the studies published by Jung et al,[5] Ahmad Alobaidi,[16] and Negar et al[6] are not included. Thus, in this study to increase the sample size, we used meta-analysis to understand the impact of garlic on improving blood lipids. Our study might provide a basis for clinical research.

2. Materials and methods

This meta-analysis was performed based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.[17]

2.1. Data sources

The related clinical researches were obtained from the electronic databases PubMed (http://www.ncbi.nlm.nih.gov/pubmed/), Embase (http://www.embase.com), and Cochrane Library (http://www.cochranelibrary.com) with garlic ("ALLIUM SATIVUM" OR "Garlic") and hypercholesterolemia ("Hypercholesterolemia" OR "Hypercholesterolaemia" OR "Hypercholesterolemic" OR "Hyperlipidemic" OR "Hyperlipidaemia" OR "Hyperlipidemia" OR "Dyslipidemia" OR "Dyslipidemias") as searched keywords; and a deadline of "July 14 (th); 2017."

2.2. Eligibility criteria

Articles meeting the following criteria were selected (based on the PICOS principle): published English literatures to study the efficacy of garlic in the treatment of hypercholesterolemia (P); participants in the experimental group was hyperlipidemia patients treated with garlic (I) and that in the control group was hyperlipidemia patients with placebo (C) treatment; the outcomes of the study included the initial values as well as the values after treatment of TC (serum total cholesterol), LDL (low density lipoprotein), HDL (high density lipoprotein), and TG (triglyceride), and the amount of changes was included (O); the study type was randomized parallel study (study design: parallel; crossover study: excluded) (S). The following articles were removed: studies with incomplete data or can't be used for statistical analysis; literatures such as reviews, reports, comments, and letters. Besides, if multiple literatures were repeatedly published or multiple literatures studied based on the same population data, only the latest research or the research with complete information was included.

2.3. Data extraction and quality evaluation of literature

Data were independently extracted from the included literatures by 2 reviewers and included details such as: first author, published year, area of study, year of study, the type and dose of garlic, follow-up time, number as well as general demographic data (e.g., sex ratio, age composition, body mass index [BMI], etc.) of inclusion in the garlic group and the control group; the initial values as well as the values after treatment of TC, LDL, HDL, and TG in the garlic group and the control group.

The aggregate quality of the included studies was evaluated according to the quality evaluation criteria of bias risk, recommended by Cochrane Collaboration recommendations.[18] A third reviewer should join in and discuss with the other 2 reviewers to get an agreement if there was disagreement in the process of data extraction and quality evaluation.

2.4. Statistical analysis

The meta-analysis of direct comparison was conducted using R 3.12 software (R Foundation for Statistical Computing, Beijing1, China, "meta" package), SMD (standardized mean difference), and 95% confidence interval (CI) were used to show the effect index of quantitative data. The heterogeneity test between studies was assessed based on the Q test[19] and the I^2 statistic, and $P < .05$ or $I^2 > 50\%$ was used as the heterogeneity threshold. The random effect model was chosen when they had significant heterogeneity; otherwise, the fixed-effect model was chosen to pool the data.[20] The publication bias was assessed using Egger method. Finally, the sensitivity analysis was performed by examining the effect of this document on the overall SMD value by ignoring a document each time.

3. Results

3.1. Characteristics of the selected literature

A total of 956 articles (243 articles came from PubMed database, 645 articles came from Embase database, 68 ones came from Cochrane Library) were identified based on the literature search criteria. Among them, 207 articles were repeated, and 618 articles were irrelevant after reading title and abstract. In addition, 117 articles (including 15 letters, 11 case series/report, 28 reviews, 31 animal study, 13 descriptive studies, 12 non-RCT, and 7 reduplicative studies) of the remaining 131 articles were removed by reviewing full text. Finally, 14 eligible papers which were published from 1981 to 2016 were included (Fig. 1).[5,6,16,21–31]

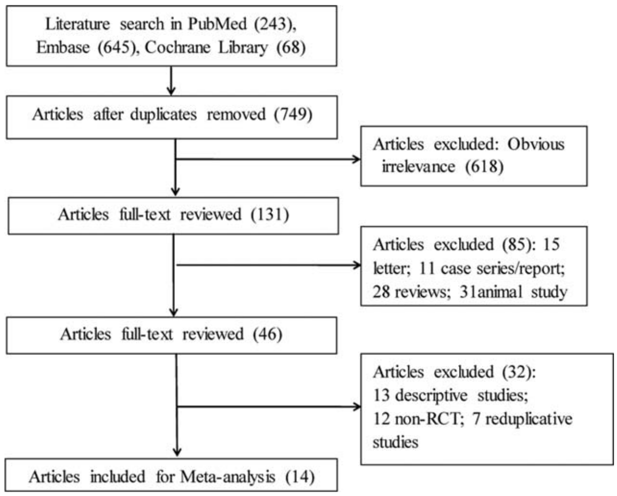


Figure 1. Literature search and study selection.

Totally, 1093 hyperlipidemia patients were included in the study, including 527 cases in the experimental group and 566 cases in the control group. Most of the areas of these studies were India, Canada, the United States, and South Korea; the types of garlic were aged black garlic (BG), garlic oil (GO), and garlic powder (GP) with the doses ranged from 0.3 to 20 g/d; the patients were followed up for 4 weeks to 10 months; the baseline characteristics between the experimental group and the control group were comparable in terms of age, sex, and BMI/Body weight (Tables 1 and 2). The results of RCT quality evaluation showed that the quality of the literatures we incorporated were of moderate to high qualities (Fig. 2A, B).

3.2. Combination of quantitative data of meta-analysis

The values of TC, LDL, HDL, and TG in the experimental group and the control group after taking garlic were analyzed by meta-analysis. Based on the heterogeneity test results ($P<.05$, $I^2>50\%$), all results including TC ($P<.0001$, $I^2=94\%$), LDL ($P<.0001$, $I^2=94.2\%$), HDL ($P<.0001$, $I^2=91.1\%$), and TG ($P<.0001$, $I^2=95.9\%$) were pooled using random model.

The results of meta-analysis showed that the values of TC, LDL, and HDL after taking garlic in the experimental group and the control group have statistical significance. Among that, garlic treatment decreased the values of TC (SMD=–1.26, 95% CI, –1.86 to –0.66, Fig. 3) and LDL (SMD=–1.07, 95% CI, –1.67 to –0.47, Fig. 4) while increased that of HDL (SMD=0.50, 95% CI, 0.06–0.94, Fig. 5), indicating the important role of garlic in changing blood lipids. However, there was no significant difference of TG in the 2 groups (SMD=–0.16, 95% CI, –0.87–0.55, Fig. 6).

3.3. Publication bias

Egger test was used to assess the publication biases in the analyses of TC, LDL, HDL, and TG values. Our results showed no significant publication bias among the eligible studies with values of TC ($P=.0625$), LDL ($P=.0770$), HDL ($P=.2293$), and TG ($P=.3436$, Table 3).

Table 1

Characteristics of the included literatures.

Author	Year	Study location	Type	Dose	Duration	Group	N	Sex (M/F)	Age	BMI/Body weight
Adler AJ	1997	Canada	GP	900 mg/d	12 w	Garlic	12	12 (M)	45.9±12.6	27.2±3.0
						Placebo	11	11 (M)	45.4±9.8	26.4±3.5
Ahmad Alobaidi AH	2014	Iraq	GO	500 mg/d	4 w	Garlic	150	66/84	46.13±5.25	26.38±5.91
						Placebo	150	61/89	45.03±7.52	27.15±6.73
Ashraf R	2005	Pakistan	GP	300 mg/d	12 w	Garlic	35	15/20	60±5.04	62.2±10.45 kg
						Placebo	35	17/18	58±5.80	63±9.80 kg
Aslani N	2016	Iran	Garlic	20 g/d	8 w	Garlic	27	14/13	45.3±9.3	28.1±5.9
						Placebo	28	16/12	39.3±6.2	27.2±3.2
Bordia A	1981	India	GO	15 mg/d	10 m	Garlic	20	NA	54.7 (44–62)	NA
						Placebo	62		53.0 (42–60)	NA
Gardner CDa	2007	USA	Others	4 g/d	6 m	Raw garlic	49	22/27	49±9	25±3
						Placebo	48	24/24	49±9	25±3
Jain AK	1993	USA	GP	900 mg/d	12 w	Garlic	20	11/9	48±15	78±17 kg
						Placebo	22	8/14	55±9	77±14 kg
Jung ES	2014	Korea	ABG	6 g/d	12 w	Garlic	30	12/18	50.13±9.21	64.69±9.88 kg
						Placebo	30	8/22	50.83±8.04	63.57±9.76 kg
Kannar D	2001	Australia	GP	880 mg/d	12 w	Garlic	22	12/10	52.6±10.4	24.5±2.6
						Placebo	24	13/11	57.4±9.0	28.4±6.3
Peleg A	2003	Israel	GP	22.4 mg/d	16 w	Garlic	18	8/10	52.4±7.5	69.3+11.8 kg
						Placebo	21	9/12	54.7±7.5	70.1+8.4 kg
Satitvipawee P	2003	Thailand	Others	333 mg/d	12 w	Garlic	70	23/47	47±6.6	24.6±3.3
						Placebo	66	25/41	47±6.0	24.3±3.4
Sobenin LA	2008	Russia	GP	600 mg/d	12 w	Garlic	23	42 (M)	51.7±2.0	26.6±0.5
						Placebo	19		51.7±2.0	27.0±0.7
Sobenin LA	2010	Russia	GP	300 mg/d	12 m	Garlic	26	14/12	56.7±1.8	27.0±0.9
						Placebo	25	14/11	56.3±1.7	27.9±0.9
Superko HR	2000	USA	GP	900 mg/d	12 w	Garlic	25	NA	53±107	163±30 lbs
						Placebo	25			

Garlic type: a=raw garlic group, ABG=aged black garlic, BMI=body mass index, GO=garlic oil, GP=garlic powder, M/F=Male/Female.

Table 2

Detailed data of the included literatures.

Author	Year	Group	N	TC		LDL		HDL		Triglyceride	
				Base, mg/dL	Posttreatment, mg/dL	Base, mg/dL	Posttreatment, mg/dL	Base, mg/dL	Posttreatment, mg/dL	Base, mg/dL	Posttreatment, mg/dL
Adler AJ	1997	Garlic	12	6.54±0.25a	5.79±0.23a	4.39±0.18a	3.77±0.24a	1.26±0.06a	1.29±0.08a	1.98±0.32a	1.85±0.37a
		Placebo	11	6.46±0.26a	6.49±0.31a	4.32±0.25a	4.26±0.31a	1.20±0.10a	1.26±0.1la	1.95±0.49a	1.94±0.51a
AhmadAlobaidi AH	2014	Garlic	150	217±46.1	176±34.7	139.4±28.5	98.3±30.13	37.8±13.9	45.9±15.1	199±39.7	159±33.1
		Placebo	150	213.6±41.5	198.6±35.4	134.7±33.6	119.1±35.4	38.1±13.5	42.1±13.7	201±46.6	187±37.6
Ashraf R	2005	Garlic	35	228.23±4.54	200.77±5.07	163.57±4.66	133.42±4.61	38±1.73	41.35±1.31	202.03±8.59	203.45±8.81
		Placebo	33	220.45±2.25	218.34±3.05	167±3.37	164.3±3.56	36.58±3.45	37.2±3.86	200.6±5.05	198.58±5.25
Aslani N	2016	Garlic	27	234.4±26.5	215.3±23	119.9±26.8	105.1±23	37.2±7.4	41±8.6	195.9±123.7	162±98.6
		Placebo	28	239±18.8	243.1±14.2	119.2±19.0	127.2±22.1	41.4±6.5	41.3±7.8	135.6±64.9	151.1±67.1
Bordia A	1981	Garlic	20	298.4±22.7	228.0±13.5	NA	NA	17.0±1.1	30.0±2.6	NA	NA
		Placebo	62	280.1±25.1	282.4±18.0	NA	NA	17.8±1.3	17.4±1.8	NA	NA
Gardner CDa	2007	Raw garlic	49	226±18	NA	151±15	142±22	58±15	58±14	97±44	95±49
		Placebo	48	228±21	NA	150±14	133±21	54±14	52±13	122±54	134±74
Jain AK	1993	Garlic	20	262±35	247±40	188±37	168±43	47±12	46±13	151±81	165±86
		Placebo	22	276±34	274±29	191±34	185±25	49±14	50±17	195±112	199±101
Jung ES	2014	Garlic	30	241.07±23.97	233.50±24.63	150.64±14.12	155.75±21.94	46.86±9.40	50.36±8.85	139.79±54.55	120.21±63.61
		Placebo	30	228.93±20.01	227.33±32.51	150.11±15.65	156.33±29.83	50.81±9.19	50.48±9.76	124.11±47.65	128.11±65.50
Kannar D	2001	Garlic	22	7.5±0.8a	7.4±1.1a	5.3±0.9a	5.4±1.1a	1.34±0.34a	1.33±0.39a	2.0±1.3a	1.8±1.0a
		Placebo	24	7.6±0.9a	7.1±0.9a	5.3±0.9a	4.9±0.9a	1.35±0.49a	1.26±0.47a	2.2±1.6a	2.3±2.4a
Peleg A	2003	Garlic	18	262.6±25.3	259.6±38.6	172.7±18.8	171.0±28.3	54.0±11.9	49.8±13.3	179.5±69.6	231.4±13.9
		Placebo	21	275.4±23.9	267.7±29.6	186.6±16.8	182.0±23.5	54.9±15.8	54.0±11.9	169.6±70.7	157.9±44.3
Satitvipawee P	2003	Garlic	70	6.65±0.89a	6.59±0.93a	4.52±0.86a	4.52±0.77a	1.50±0.37a	1.45±0.28a	1.19±0.02a	1.17±0.02a
		Placebo	66	6.85±0.83a	6.80±0.90a	4.63±0.90a	4.65±0.83a	1.55±0.26a	1.47±0.26a	1.27±0.02a	1.26±0.02a
Sobenin LA	2008	Garlic	23	6.97±0.20a	6.41±0.22a	5.00±0.17a	4.37±0.20a	1.06±0.07a	1.17±0.09a	2.00±0.26a	1.91±0.21a
		Placebo	19	7.04±0.18a	7.24±0.18a	4.93±0.18a	5.07±0.16a	1.20±0.09a	1.16±0.10a	2.25±0.20a	2.06±0.22a
Sobenin LA	2010	Garlic	26	269.2±11.5	235.7±8.4	185.9±9.3	155.6±7.8	50.9±3.6	51.5±3.1	162.1±19.5	142.9±16.5
		Placebo	25	252.5±9.1	242.0±6.9	178.3±9.1	169.9±7.2	48.7±2.5	50.7±2.2	127.8±9.7	106.9±6.8
Superko HR	2000	Garlic	25	250±29	248±23	169±25	167±25	51.3±11.5	51.2±10.1	145±54	141±57.2
		Placebo	25	239±23	248±22	162±18	159±19	51.9±12.8	52.1±11.0	128±63	150±111.5

a=mmol/L, HDL=high density lipoprotein, LDL=low density lipoprotein, TC=serum total cholesterol, TG=triglyceride.

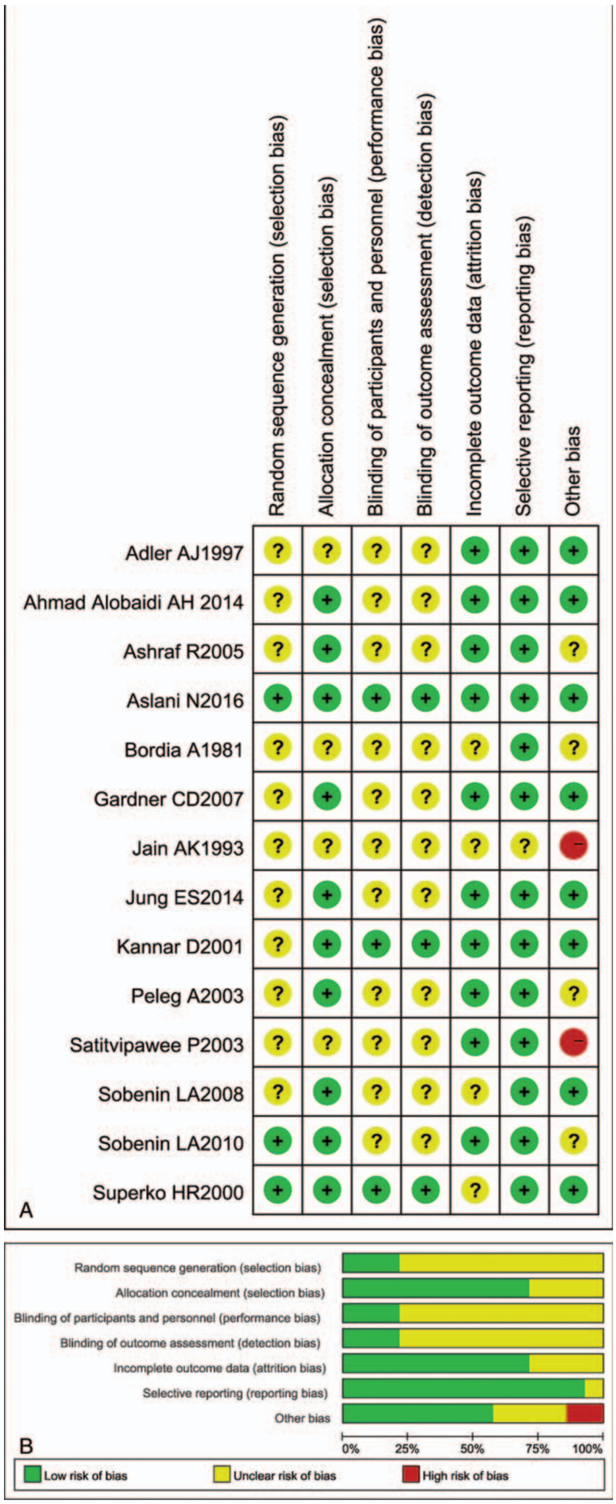


Figure 2. Quality assessments of the included studies. A. Sensitivity and specificity of the included studies. B. Bias risk of the included studies. "+": low risk of bias; "–": high risk of bias, and "?": unclear risk of bias.

3.4. Sensitivity analysis

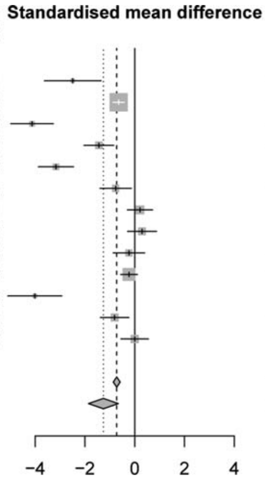
The sensitivity analysis results revealed that any of the literature can't change the results of TC, LDL, and TG, indicating that the results of TC, LDL, and TG were stable. However, the result of HDL was reversed when removed some of the literatures (Ashraf[23] and Bordia[24]).

4. Discussion

In order to evaluate the reliability of previous studies, a meta-analysis evaluating the hypolipidemic effect of garlic was conducted in this study. Our finding revealed that the values of TC, LDL, and HDL after taking garlic in the experimental group and the control group have statistical significance. However, there was no significant difference of TG in the 2 groups.

Garlic is gained substantial interest by many researchers because of the its impact on lipid levels.[32,33] Garlic is discovered has multiple useful cardiovascular effects including reduction in cholesterol and TG, lowering of blood pressure, and enhancement of fibrinolytic activity.[34] Many studies have demonstrated that different extracts of garlic can alone lower the level of serum TC, LDL, and TG in humans and rodents.[35,36] Similarly, Maha et al[37] have revealed that the level of plasma TC and LDL-C can be decreased by adding 8% raw garlic into the diet of rats. In 1993, Warshafsky et al[38] have proved that intake of garlic can reduce the cholesterol level by about 10%. Besides, combination of lemon juice and garlic obviously decreased serum TC, LDL-C, and blood pressure.[6] Nevertheless, someone have indicated that garlic powder doesn't reduce cholesterol levels, which may due to the loss of active compound(s) during processing.[39] Garlic may decrease the absorption of cholesterol, and the synthesis of cholesterol and fatty acid, and thereby reduces the level of cholesterol.[40] The human enzymes required in cholesterol biosynthesis such as squalene monooxygenase and HMG-CoA (3-hydroxy-3-methylglutaryl-coenzyme A) reductase can be inhibited by garlic and various constituents.[41–45] Garlic may decrease the level of LDL-C by reduction of hepatic cholesterol 7α-hydroxylase, HMG-CoA reductase, pentose-phosphate pathway activities,[46] enhancement of bile acid excretion, microsomal triglyceride transfer protein,[47] cholesteryl ester transfer protein activity,[48] bile acid excretion,[38] and prohibiting hepatic fatty acid synthesis,[49] which was conducted by allicin and/or other components in garlic.[41] Our finding showed the significant differences of TC, LDL, and HDL between the experimental group and the control group, nevertheless, the level of LG was not obviously different. Our results might suggest that the ability of garlic to lower cholesterol and LDL was better than that to lower TG.

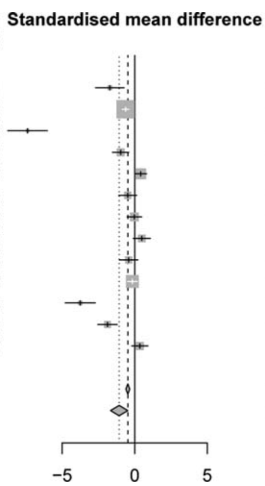
Based on the heterogeneity test results, all results including TC, LDL, HDL, and TG were pooled using random model indicating the exist of significant heterogeneity. The appearance of heterogeneity may be due to the following reasons: garlic types were different between different articles, the patients in studies published by Ahmad Alobaidi[16] and Bordia[24] were treated via garlic oil, and that in the study of Jung et al[5] were given via aged black garlic; the dose and duration were dissimilar between different articles, indicating the dose and duration can affect the result of anti-hyperlipidemia; altered detected method might be the influencing factor; the unit of BMI/body weight was dissimilar, Ashraf,[23] Jain et al,[21] Jung et al,[5] and Peleg et al[28] evaluated the physical quality via body weight, while others evaluated that by BMI, thus, it is difficult to compare the physical quality, suggesting physical quality might also affect the results. Besides, in the present study, when removed the literatures published by Ashraf[23] and Bordia,[24] the result of HDL was reversed. The reason might be that garlic increased the level of HDL, and the participants with type 2 diabetes and coronary heart disease were enrolled in the two studies.



Study	Experimental Total	Experimental Mean	Experimental SD	Control Total	Control Mean	Control SD	SMD	95%−CI	W(fixed)	W(random)
Adler AJ 1997	12	5.79	0.23	11	6.49	0.31	−2.49	[−3.63; −1.35]	1.5%	6.5%
Ahmad Alobaidi AH 2014	150	176.00	34.70	150	198.60	35.40	−0.64	[−0.88; −0.41]	34.8%	8.4%
Ashraf R 2005	35	200.77	5.07	33	218.34	3.05	−4.12	[−4.98; −3.26]	2.6%	7.3%
Aslani N 2016	27	215.30	23.00	28	243.10	14.20	−1.44	[−2.04; −0.84]	5.3%	7.9%
Bordia A 1981	20	228.00	13.50	62	282.40	18.00	−3.16	[−3.87; −2.46]	3.8%	7.6%
Jain AK 1993	20	247.00	40.00	22	274.00	29.00	−0.76	[−1.39; −0.13]	4.7%	7.8%
Jung ES 2014	30	233.50	24.63	30	227.33	32.51	0.21	[−0.30; 0.72]	7.3%	8.0%
Kannar D 2001	22	7.40	1.10	24	7.10	0.90	0.29	[−0.29; 0.88]	5.5%	7.9%
Peleg A 2003	18	259.60	38.60	21	267.70	29.60	−0.23	[−0.87; 0.40]	4.7%	7.8%
Satitvipawee P 2003	70	6.59	0.93	66	6.80	0.90	−0.23	[−0.57; 0.11]	16.5%	8.3%
Sobenin LA 2008	23	6.41	0.22	19	7.24	0.18	−4.01	[−5.10; −2.92]	1.6%	6.7%
Sobenin LA 2010	26	235.70	8.40	25	242.00	6.90	−0.81	[−1.38; −0.23]	5.7%	7.9%
Superko HR 2000	25	248.00	23.00	25	248.00	22.00	0.00	[−0.55; 0.55]	6.1%	7.9%
Fixed effect model	**478**			**516**			**−0.72**	**[−0.86; −0.59]**	**100%**	**--**
Random effects model							**−1.26**	**[−1.86; −0.66]**	**--**	**100%**

Heterogeneity: I−squared=94%, tau−squared=1.102, p<0.0001

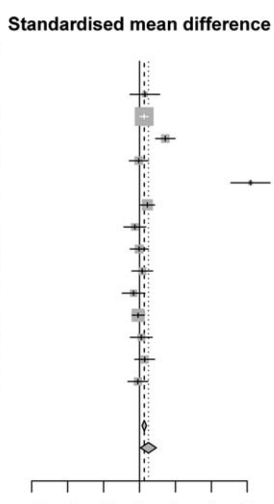
Figure 3. Comparison of TC value after garlic treatment between the experimental group and the control group. TC=serum total cholesterol.



Study	Experimental Total	Experimental Mean	Experimental SD	Control Total	Control Mean	Control SD	SMD	95%−CI	W(fixed)	W(random)
Adler AJ 1997	12	3.77	0.24	11	4.26	0.31	−1.71	[−2.70; −0.73]	1.8%	7.0%
Ahmad Alobaidi AH 2014	150	98.30	30.13	150	119.10	35.40	−0.63	[−0.86; −0.40]	32.8%	8.5%
Ashraf R 2005	35	133.42	4.61	33	164.30	3.56	−7.38	[−8.75; −6.02]	0.9%	5.9%
Aslani N 2016	27	105.10	23.00	28	127.20	22.10	−0.97	[−1.53; −0.41]	5.6%	8.0%
Gardner CDa 2007	49	142.00	22.00	48	133.00	21.00	0.42	[0.01; 0.82]	10.9%	8.2%
Jain AK 1993	20	168.00	43.00	22	185.00	25.00	−0.48	[−1.10; 0.13]	4.7%	7.9%
Jung ES 2014	30	155.75	21.94	30	156.33	29.83	−0.02	[−0.53; 0.48]	6.9%	8.1%
Kannar D 2001	22	5.40	1.10	24	4.90	0.90	0.49	[−0.10; 1.08]	5.1%	7.9%
Peleg A 2003	18	171.00	28.30	21	182.00	23.50	−0.42	[−1.05; 0.22]	4.4%	7.8%
Satitvipawee P 2003	70	4.52	0.77	66	4.65	0.83	−0.16	[−0.50; 0.18]	15.6%	8.3%
Sobenin LA 2008	23	4.37	0.20	19	5.07	0.16	−3.75	[−4.79; −2.71]	1.6%	6.8%
Sobenin LA 2010	26	155.60	7.80	25	169.90	7.20	−1.87	[−2.54; −1.21]	4.0%	7.7%
Superko HR 2000	25	167.00	25.00	25	159.00	19.00	0.35	[−0.20; 0.91]	5.7%	8.0%
Fixed effect model	**507**			**502**			**−0.48**	**[−0.61; −0.34]**	**100%**	**--**
Random effects model							**−1.07**	**[−1.67; −0.47]**	**--**	**100%**

Heterogeneity: I−squared=94.2%, tau−squared=1.081, p<0.0001

Figure 4. Comparison of LDL value after garlic treatment between the experimental group and the control group. LDL=low density lipoprotein.



Study	Experimental Total	Experimental Mean	Experimental SD	Control Total	Control Mean	Control SD	SMD	95%−CI	W(fixed)	W(random)
Adler AJ 1997	12	1.29	0.08	11	1.26	0.11	0.30	[−0.52; 1.13]	2.3%	6.4%
Ahmad Alobaidi AH 2014	150	45.90	15.10	150	42.10	13.70	0.26	[0.04; 0.49]	29.8%	8.0%
Ashraf R 2005	35	41.35	1.31	33	37.20	3.86	1.44	[0.90; 1.98]	5.3%	7.3%
Aslani N 2016	27	41.00	8.60	28	41.30	7.80	−0.04	[−0.56; 0.49]	5.5%	7.3%
Bordia A 1981	20	30.00	2.60	62	17.40	1.80	6.18	[5.09; 7.28]	1.3%	5.4%
Gardner CDa 2007	49	58.00	14.00	48	52.00	13.00	0.44	[0.04; 0.84]	9.5%	7.6%
Jain AK 1993	20	46.00	13.00	22	50.00	17.00	−0.26	[−0.87; 0.35]	4.2%	7.1%
Jung ES 2014	30	50.36	8.85	30	50.48	9.76	−0.01	[−0.52; 0.49]	6.0%	7.4%
Kannar D 2001	22	1.33	0.39	24	1.26	0.47	0.16	[−0.42; 0.74]	4.6%	7.2%
Peleg A 2003	18	49.80	13.30	21	54.00	11.90	−0.33	[−0.96; 0.31]	3.8%	7.0%
Satitvipawee P 2003	70	1.45	0.28	66	1.47	0.26	−0.07	[−0.41; 0.26]	13.6%	7.8%
Sobenin LA 2008	23	1.17	0.09	19	1.16	0.10	0.10	[−0.50; 0.71]	4.2%	7.1%
Sobenin LA 2010	26	51.50	3.10	25	50.70	2.20	0.29	[−0.26; 0.84]	5.0%	7.2%
Superko HR 2000	25	51.20	10.10	25	52.10	11.00	−0.08	[−0.64; 0.47]	5.0%	7.2%
Fixed effect model	**527**			**564**			**0.27**	**[0.15; 0.39]**	**100%**	**--**
Random effects model							**0.50**	**[0.06; 0.94]**	**--**	**100%**

Heterogeneity: I−squared=91.1%, tau−squared=0.6188, p<0.0001

Figure 5. Comparison of HDL value after garlic treatment between the experimental group and the control group. HDL=high density lipoprotein.

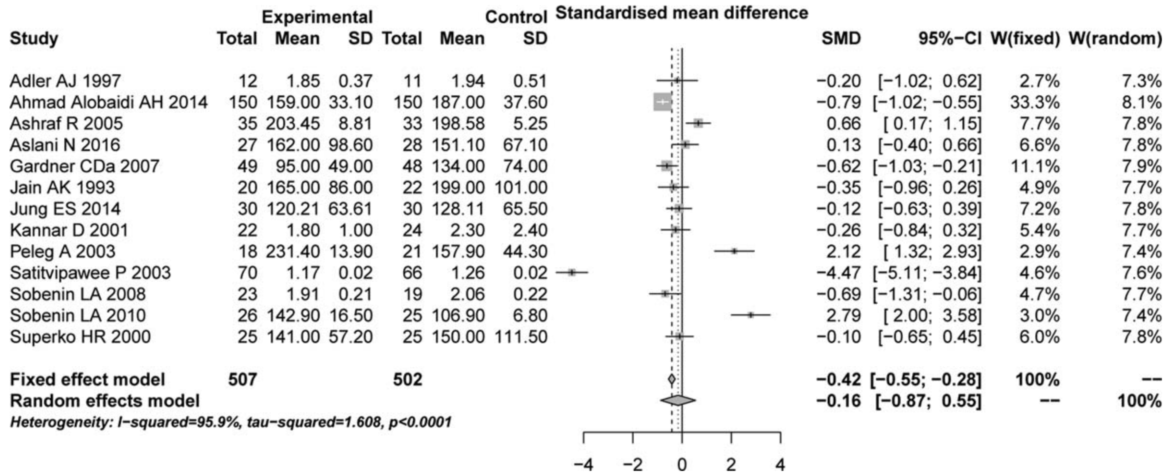


Figure 6. Comparison of TG value after garlic treatment between the experimental group and the control group. TG = triglyceride.

Table 3

Results of meta-analysis.

Variable	Sample size			Test of association			Model	Test of heterogeneity*,†			Egger's test‡	
	K	Cases	Control	SMD (95% CI)	*Z*	*P*		*Q*	*P*	I^2 (%)	*t*	*P*
TC	13	478	516	−1.2575 [−1.8582; −0.6568]	−4.1031	<.0001	Random	198.43	<0.01	94.0	2.0722	.0625
LDL	13	507	502	−1.0705 [−1.6669; −0.4741]	−3.5178	.0004	Random	208.50	<0.01	94.2	1.9511	.0770
HDL	14	527	564	0.4986 [0.0579; 0.9394]	2.2172	.0266	Random	146.16	<0.01	91.1	1.2666	.2293
TG	13	507	502	−0.1616 [−0.8708; 0.5477]	−0.4465	.6553	Random	295.84	<0.01	95.9	0.9898	.3436

$P < .05$ is considered statistically significant; OR = odds ratio; CI = confidence interval; K = number of studies combined.

* Random-effects model was used when the P for heterogeneity test $<.05$, otherwise the fixed-effect model was used.

† $P < .05$ is considered statistically significant for Q statistics.

‡ Egger's test to evaluate publication bias.

However, this research had some limitations as following: this study did not adjust for covariates, and no further conduct subgroup analysis due to the incomplete data of some studies; the reason why specific heterogeneity exit was not determined; the results of HDL value were unstable due to the reverse finding after removed some of the articles.

In conclusion, this study using a meta-analysis demonstrated that garlic can reduce the level of TC and LDL instead of HDL and TG, indicating the ability of anti-hyperlipidemia. Thus, it is recommended that people with high blood lipids can eat more garlic. But this result requires more high-quality studies or a larger sample size of updated meta-analysis to verify.

Author contributions

Conceptualization: Weidong Wang, Yue-E Sun.
Data curation: Jie Qin.
Formal analysis: Jie Qin.
Writing – original draft: Yue-E Sun.
Writing – review and editing: Weidong Wang.

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