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Impact of ginger supplementation on obesity indices and Adipokine profiles in adults: A GRADE-based systematic review and dose-response meta-analysis of randomized controlled trials

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ABSTRACT

Background: Overweight and obesity are major health concerns. The impact of ginger on weight has been studied. In the present systematic review and dose-response meta-analysis we aim to sum up the findings from randomized controlled trials (RCTs) on the effect of ginger on various weight measurements/indices.
Methods: Several databases (PubMed, Scopus, Web of Science Core Collection, and Google Scholar) were comprehensively searched. Relevant studies were selected using defined criteria. Outcomes included: body weight (BW), body mass index (BMI), waist circumference (WC), body fat percentage (BFP), adiponectin and leptin. Weighted mean difference (WMD) and confidence interval (CI) were reported. Subgroup analysis was carried out. Linear and non-linear associations, based on dosage and duration of interventions, were investigated.
Results: Thirty-six RCTs were included. Ginger supplementation significantly improved WC (WMD: −0.65 cm, 95 % CI: −1.07, −0.24), BFP (WMD: −1.49 %, 95 % CI: −2.65, −0.32), and serum adiponectin levels (WMD = 0.84 μg/mL; 95 % CI: 0.01). Other measurements were not improved by the intervention. An inverse, linear association was found between the duration of intervention and changes in BW (BW: coefficient = -0.471, P = 0.001). Also, a non-linear direct association was observed between ginger dosages and WC (P-nonlinearity = 0.023).
Conclusions: Ginger supplementation does not seem effective in improving major measurements/indices of weight, including body weight and BMI. However, ameliorations in other measurements of local adiposity, findings from subgroup analyses, and investigations of linear and non-linear association on dosage and duration, indicate that further studies with longer intervention periods are needed to make a conclusive decision.

1. Introduction

Overweight and obesity are the most prominent metabolic health diseases around the globe.[1] It has been estimated that around 890 million individuals are suffering from obesity.[2] Obesity involves the excessive accumulation of adipose tissue, which is not metabolically inactive. Adipocytes are highly specialized and metabolically active cells that participate in various physiological processes such as lipid

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mobilization and energy regulation, but may also contribute to pathological pathways involved in metabolic disorders.[3] The latter route the reason for various comorbidities associated with accumulated fat, such as type 2 diabetes (T2D), cardiovascular diseases (CVDs), inflammatory conditions, and cancer.[4]

Although the prevention and management of obesity may appear straightforward in theory, they are often complex in practice due to multiple biological, psychological, and societal factors.[5] Lifestyle modifications, most importantly dietary interventions, have been investigated in recent decades.[6] The use of herbs and herbal medicine to lose weight has been extensively commercialized.[7] Despite their unharmful role when used as additives, when adopted as methods to approach serious health problems, such as obesity, their effect can be both unknown and detrimental.[8] Ginger, scientifically known as Zingiber officinale, is one of these plants.[9] Ginger contains multiple bioactive compounds, mostly associated with its anti-inflammatory and anti-oxidant properties.[10] However, the impact of ginger on weight status measurement/status, body composition, and appetite- and energy balance-regulatory hormones—i.e., leptin and adiponectin—has not been systematically studied using a uniform approach. This assessment will not only provide evidence to support or refute the effectiveness of ginger in managing excess body weight, but will also offer insight into the potential mechanisms underlying its effects. In addition, a dose–response analysis will clarify the dosage and duration required to achieve potential benefits.

Thus, the present systematic review and meta-analysis of the randomized controlled trials (RCTs) investigated the effect of supplementation with ginger products on weight measurements/indices, body fat percentage, and appetite-regulating hormones of leptin and adiponectin.

1.1. Methods

This current study was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.[11] The study protocol has been registered in PROSPERO under the registration number CRD420251010460.

1.2. Search strategy

The study selection criteria were developed based on the PICOS framework, which encompasses the following elements: participants (adults aged 18 and above), intervention (ginger supplementation), comparison (presence of a control group), outcomes (Weight, body mass index (BMI), waist circumference (WC), Body fat percentage, adiponectin and leptin), and study design (randomized controlled trials). A thorough search was performed across multiple online databases, including PubMed, Scopus, Web of Science Core Collection, and Google Scholar, incorporating all available records until January 2025, without restrictions on language or publication year. We applied an open search and used the following medical subject headings (MeSH) and non-MeSH terms to obtain relevant studies: (“ginger” OR “zinziber” OR “zingiber” OR “Zingiber officinale” OR “gingifere” OR “gingembre” OR “jiang” OR “shokyo” OR “shengjiang” OR “zingiberis rhizoma recens”) AND (“intervention” OR “intervention Studies” OR “randomized” OR “randomised” OR “randomly” OR “controlled trial” OR “clinical trial” OR “random” OR “trial” OR “randomized controlled trial” OR “randomized clinical trial” OR “RCT”). Additional relevant studies were identified by manually reviewing reference lists from previous studies and systematic reviews.

1.3. Study selection and eligibility criteria

Eligible studies were included if they met the following criteria: randomized controlled trials (RCTs) involving adult participants (18 years and older), assessing weight, BMI, WC, body fat percentage, adiponectin, and leptin in both the intervention and control groups, and involving an intervention period exceeding two weeks. Studies were excluded if they contained duplicate data, lacked a placebo group, did not follow an RCT design, were conducted on animals, children, pregnant or lactating women, or failed to provide adequate data on the outcomes of interest.

1.4. Data extraction

Two independent reviewers extracted data from the selected studies. The extracted details included the first author’s last name, study location and duration, year of publication, participants’ age and gender, study design, type and dosage of ginger supplementation, sample sizes for each group, and outcome measures (mean values and standard deviations before and after the intervention) (Table 1).

1.5. Risk of bias assessment

The risk of bias assessment for the included studies is outlined in Table 2. This evaluation was conducted using the revised Cochrane risk-of-bias tool (RoB-2),[12] which considers various methodological aspects, such as the randomization process, deviations from intended interventions, missing outcome data, selective reporting, measurement of outcomes, and final assessment. Each study was categorized as having a low risk, some concerns, or a high risk of bias based on the Cochrane Handbook guidelines.

1.6. Certainty assessment

The overall certainty of the evidence was evaluated using the Grading of Recommendations, Assessment, Development, and Evaluation (GRADE) approach.[13] This framework assesses the quality of evidence based on five domains: risk of bias, inconsistency, imprecision, indirectness, and publication bias. Based on these factors, the studies were classified into four categories: high, moderate, low, or very low quality.

1.7. Statistical analysis

Effect sizes were calculated based on mean changes and standard deviations (SDs) for the outcomes in both intervention and placebo groups. The results were presented as weighted mean differences (WMD) with a 95 % confidence interval (CI). If mean changes were not reported, they were computed using the outcome differences over the study duration. Additionally, standard errors (SEs), confidence intervals (CIs), and interquartile ranges (IQRs) were converted into SDs using the method proposed by Hozo et al.[14] Missing standard deviations were estimated using the following formula: $SDchange = sqrt\ [(SDbaseline^2 + SDfinal^2) - (2 \times R \times SDbaseline \times SDfinal)]$, where R was set to 0.9.[15] The overall effect size was determined using a random-effects model, specifically the DerSimonian-Laird method, which accounts for variations among studies. Between-study heterogeneity was assessed using the I^2 statistic and Cochrane’s Q test, with heterogeneity deemed significant if I^2 exceeded 50 % or the Q-test p-value was below 0.05.[16] Subgroup analyses were performed to explore potential sources of heterogeneity, considering factors such as baseline BMI (kg/m^2), participants’ health status, ginger dosage (g/day), intervention duration (weeks), and participant age (years). A sensitivity analysis was conducted using the leave-one-out method to assess the influence of individual studies on the overall effect size.[17] Publication bias was evaluated using funnel plot visualization and the Begg rank correlation test. The trim-and-fill method was applied to examine the impact of publication bias and adjust the overall effect size. Furthermore, meta-regression and non-linear dose-response analysis, using fractional polynomial modeling, were conducted to assess the relationship between ginger dosage (mg/day), intervention duration (weeks), and the measured outcomes.[18] The meta-analysis was performed using Stata Software,

Table 1
Characteristics of included studies.

Author, Year (Location)	Study design	Population	Gender	Number (Case/ control)	Intervention Mean (range) age (years)	Intervention Mean BMI (Kg/m2)	Duration (Weeks)	Intervention Intervention group Control group	Outcome
Fatima et al., 2018 (Pakistan)	RCT, SB, Parallel	Hyperlipidaemic	M/F	27/30	NR	NR	12	Ginger's pasted-powder (5000 mg/ day) Placebo (Grinded wheat)	Weight
Bakhshi et al., 2019 (Iran) (a)	RCT, Parallel	Obese	M	14/14	22.86	33.14	10	Ginger (3000 mg/ day) Placebo (Starch)	Weight BMI WC Body fat%
Bakhshi et al., 2019 (Iran) (b)	RCT, Parallel	Obese	M	14/13	22.79	32.45	10	Ginger (3000 mg/ day) + high intensity interval training (HIIT) Placebo + HIIT	Weight BMI WC Body fat%
Helli et al., 2022 (Iran)	RCT, DB, Parallel	Migraine	M/F	51/52	31.7	26.3	12	Ginger (1000 mg/ day) + 40 mg propranolol Placebo + propranolol)	Weight BMI WC
Tabibi et al., 2015 (Iran)	RCT, DB, Parallel	Peritoneal dialysis	M/F	18/18	56	27	10	Ginger (1000 mg/ day) Placebo (Starch)	Weight BMI
Rostamkhani et al., 2023 (Iran)	RCT, DB, Parallel	Diabetic patients with ESRD undergoing haemodialysis	M/F	20/21	60.05	26.48	8	Ginger powder (2000 mg/day) Placebo (Starch)	Weight BMI WC
Babaahmadi-Rezaei et al.,2020 (Iran)	RCT, DB, Parallel	Atherosclerosis	M	30/27	56.40	27.81	8	Ginger rhizome powder (1600 mg/ day) Placebo (Wheat flour)	Weight BMI
Imani et al., 2014 (Iran)	RCT, DB, Parallel	Peritoneal dialysis	M/F	18/18	56	27	10	Ginger (1000 mg/ day) Placebo (Starch)	Weight BMI
Dastgheib et al., 2022 (Iran)	RCT, DB, Parallel	PCOS	F	21/22	28.45	26.14	8	Zingiber officinale Roscoe powder (1500 mg/day) Placebo (Rice flour)	Weight BMI WC
Rahimlou et al., 2019 (Iran)	RCT, DB, Parallel	Metabolic syndrome	M/F	19/19	44.16	30.02	12	Ginger (2000 mg/ day) Placebo (Starch)	Weight BMI WC
Nikkhah-Bodaghi et al., 2019 (Iran)	RCT, DB, Parallel	UC	M/F	22/24	41.41	26.35	6	Dried ginger powder (2000 mg/day) Placebo (Maltodexterin powder)	Weight BMI
Nikkhah-Bodaghi et al., 2019 (Iran)	RCT, DB, Parallel	UC	M/F	22/24	41.41	26.35	12	Dried ginger powder (2000 mg/day) Placebo (maltodexterin powder)	BMI
Mohammadzadeh Honarvar et al., 2019, (Iran)	RCT, DB, Parallel	T2D	M/F	23/22	51.74	29.94	10	Dried ginger powder (2000 mg/day) Placebo (Wheat flour)	Weight BMI WC
Azimi et al., 2015 (Iran)	RCT, SB, Parallel	T2DM	M/F	41/39	55.21	29.05	8	Rhizome of the Zingiber officinale (3000 mg/day) + black tea Placebo (black tea)	Weight BMI WC
Veisi et al., 2023 (Iran)	RCT, DB, Parallel	Diabetic patients with ESRD undergoing haemodialysis	M/F	20/21	60.05	26.48	8	Ginger powder (2000 mg/day) Placebo (starch)	Weight BMI WC
Aghdashi et al., 2017 (Iran)	RCT, DB, Parallel	RA	M/F	33/34	49.05	28.37	8	Ginger (1500 mg/ day) Placebo	Weight BMI
Rafie et al., 2020 (Iran)	RCT, DB, Parallel	NAFLD	M/F	23/23	50.04	31.70	12	Ginger rhizome powder (1500 mg/ day) Placebo (wheat flour)	Weight BMI WC Adiponectin
Mahluji et al., 2013 (Iran)	RCT, DB, Parallel	T2DM	M/F	28/30	49.2	29.2	8	Powder of rhizomes of Z. officinale (2000	Weight BMI

(*continued on next page*)

Table 1 (*continued*)

Author, Year (Location)	Study design	Population	Gender	Number (Case/ control)	Intervention Mean (range) age (years)	Intervention Mean BMI (Kg/m2)	Duration (Weeks)	Intervention Intervention group Control group	Outcome
								mg/day) Placebo (corn starch)	
Arablou et al., 2014 (Iran)	RCT, DB, Parallel	T2DM	M/F	33/30	52.6	26.9	12	Powdered rhizome of ginger (1600 mg/ day) Placebo (wheat flour)	Weight BMI
Tibaes et al., 2022 (Brazil)	RCT, DB, Parallel	High body adiposity	F	30/36	29	22.8	12	Ginger extract (600 mg/day) Placebo (cellulose)	Weight BMI Body fat%
Ghoreishi et al., 2023 (Iran)	RCT, DB, Parallel	T2DM with NAFLD	M/F	36/36	51.25	30.92	12	Ginger powder (2000 mg/day) Placebo (starch)	Weight BMI WC
Shidfar et al., 2015 (Iran)	RCT, DB, Parallel	T2DM	M/F	22/23	45.2	29.5	12	Powdered ginger (3000 mg/day) Placebo (lactose)	Weight BMI WC
Andallu et al., 2001 (India)	RCT, Parallel	Diabetic (NIDDM)+ hypercholesterolemic	M	8/8	NR	NR	4	Rhizomes of ginger (3000 mg/day) Placebo	Weight
Park et al., 2019 (Korea)	RCT, DB, Parallel	Obese	F	36/34	32.38	27.2	12	Steamed ginger ethanolic extract (200 mg/day) Placebo (microcrystalline cellulose)	Weight BMI WC Body fat% Adiponectin Leptin
Zarezadeh et al., 2018 (Iran)	RCT, DB, Parallel	T2DM	M/F	23/22	51.74	29.94	10	Ginger dried powder (2000 mg/day) Placebo (wheat flour)	Weight BMI WC
Ebrahimzadeh Attari et al., 2015 (Iran)	RCT, DB, Parallel	Obese	F	39/31	35.25	34.34	12	Ginger rhizomes powder (2000 mg/ day) Placebo (corn starch)	Weight BMI WC Body fat%
Ebrahimzadeh Attari et al., 2015 (Iran)	RCT, DB, Parallel	Obese	F	39/31	35.25	34.34	12	Ginger rhizomes powder (2000 mg/ day) Placebo (corn starch)	Adiponectin Leptin
Makhdoomi Arzati et al., 2017 (Iran)	RCT, DB, Parallel	T2DM	M/F	23/22	51.7	29.9	10	Grinded ginger (2000 mg/day) Placebo (wheat flour)	Weight BMI
Talaei et al., 2017 (Iran)	RCT, DB, Parallel	T2D	M/F	40/41	49.83	28.09	8	Ginger powder (3000 mg/day) Placebo (cellulose microcrystalline)	BMI
Mozaffari-Khosravi et al., 2014 (Iran)	RCT, DB, Parallel	T2D	M/F	40/41	49.83	28.09	8	Ginger powder (3000 mg/day) Placebo (cellulose microcrystalline)	BMI
Nayebifar et al., 2016 (Iran)	RCT, Parallel	Overweight	F	8/8	21.88	28.68	10	Ginger (3000 mg/ day) + HIIT Placebo + HIIT	Body fat%
El Gayar et al., 2019 (Egypt)	RCT, SB, Parallel	T2DM	M/F	40/40	46.35	32.35	8	Dried rhizomes of ginger (1800 mg/ day) Placebo (wheat flour)	BMI
Atashak et al., 2011 (Iran) (a)	RCT, DB, Parallel	Obese	M	8/8	23.66	31.24	10	Ginger (1000 mg/ day) Placebo (maltodextrin)	BMI WC Body fat%
Atashak et al., 2011 (Iran) (b)	RCT, DB, Parallel	Obese	M	8/8	23.65	32.56	10	Ginger (1000 mg/ day) + resistance training Placebo + resistance training	BMI WC Body fat%
Foshati et al., 2023 (Iran)	RCT, DB, Parallel	Multiple sclerosis	M/F	26/26	36.5	25.33	12	Ginger (1500 mg/ day) Placebo (Corn)	BMI
Afzalpour et al., 2017 (Iran)	RCT, SB, Parallel	Overweight	F	10/10	NR	26.68	10	Ginger (3000 mg/ day) + high intensity interval training (HIIT) Placebo + HIIT	BMI
Afzalpour et al., 2016 (Iran)	RCT, SB, Parallel	Overweight	F	8/8	21.87	28.68	10	Ginger (3000 mg/ day) + high intensity interval training	Body fat%

(*continued on next page*)

Table 1 (*continued*)

Author, Year (Location)	Study design	Population	Gender	Number (Case/ control)	Intervention Mean (range) age (years)	Intervention Mean BMI (Kg/m2)	Duration (Weeks)	Intervention Intervention group Control group	Outcome
								(HIIT) placebo+ HIIT	
Alizadeh et al., 2015 (Iran) (a)	RCT, Parallel	Obese women with breast cancer	F	10/10	46	32	6	Ginger (3000 mg/ day) Placebo (Starch)	Adiponectin
Alizadeh et al., 2015 (Iran) (b)	RCT, Parallel	Obese women with breast cancer	F	10/10	47	33	6	Ginger powder (3000 mg/day) Placebo	Adiponectin

DB: double-blind/ SB: single blind/ WC: waist circumference/ BMI: body mass index/ PCOS: polycystic ovary syndrome/ NAFLD: non-alcoholic fatty liver disease/ T2DM: type 2 diabetes mellitus/ HIIT: high intensity interval training/ ESRD: end stage renal disease/ RCT: randomized controlled trial/ M: male/ F: female/ NR: not reported.

Table 2
Results of risk of bias assessment for randomized clinical trials included in the current meta-analysis.

Study	Sequence generation	Allocation concealment	Blinding of participants and personnel	Blinding of outcome assessment	Incomplete outcome data	Selective outcome reporting	Other potential threats to validity
Fatima et al. 2018	U	U	H	U	U	U	U
Bakhshi et al. 2019	L	U	H	U	L	U	U
Helli et al. 2022	L	L	L	L	L	L	U
Tabibi et al. 2015	L	L	L	L	L	L	U
Rostamkhani et al. 2023	L	L	L	L	L	L	U
Babaahmadi-Rezaei et al. 2020	L	L	L	L	L	L	U
Imani et al. 2014	L	U	L	L	L	L	U
Dastgheib et al. 2022	L	L	L	L	L	L	U
Rahimlou et al. 2019	L	L	L	L	L	L	U
Nikkhah-Bodaghi et al. 2019	L	L	L	L	U	L	U
Nikkhah-Bodaghi et al. 2019	L	L	L	L	L	L	U
Mohammadzadeh Honarvar et al. 2019	L	L	L	L	L	L	U
Azimi et al. 2015	L	U	H	U	L	U	U
Veisi et al. 2023	L	L	L	L	L	L	U
Aghdashi et al. 2017	L	L	L	L	L	L	U
Rafie et al. 2020	L	L	L	L	L	L	U
Mahluji et al. 2013	L	L	L	L	L	L	U
Arablou et al. 2014	L	L	L	L	U	L	U
Tibaes et al. 2022	L	L	L	L	L	L	U
Ghoreishi et al. 2023	L	L	L	L	L	L	U
Shidfar et al. 2015	L	L	L	L	L	L	U
Andallu et al. 2001	U	U	H	U	L	U	U
Park et al. 2019	L	L	L	L	L	L	U
Zarezadeh et al. 2018	L	L	L	L	L	L	U
Ebrahimzadeh Attari et al. 2015	L	L	L	L	L	L	U
Ebrahimzadeh Attari et al. 2015	L	L	L	L	L	L	U
Makhdoomi Arzati et al. 2017	L	L	L	L	L	L	U
Talaei et al. 2017	L	L	L	L	L	L	U
Mozaffari-Khosravi et al. 2014	L	L	L	L	L	L	U
Nayebifar et al. 2016	L	L	H	H	L	U	U
El Gayar et al. 2019	L	L	H	U	L	L	U
Atashak et al. 2011	L	L	L	L	L	L	U
Foshati et al. 2023	L	L	L	L	L	L	U
Afzalpour et al. 2017	L	L	H	L	L	L	U
Afzalpour et al.2016	L	L	H	L	L	L	U
Alizadeh et al. 2015	L	L	H	H	L	U	U

H: high risk of bias, L: low risk of bias, U: unknown risk of bias.

version 14 (StataCorp), and a p-value below 0.05 was considered as statistically significant.

2. Results

2.1. Study selection

Our initial search yielded 6701 articles. Then, duplicate articles were removed (n = 1285). After screening the remaining 5416 records, 5001

irrelevant articles were eliminated based on title and abstract evaluation. Eventually, 415 papers were retained for more comprehensive full-text evaluation. Among those, 278 RCTs were excluded due to reporting irrelevant outcomes. Also, we had to exclude an additional 6 articles due to insufficient duration of intervention (i.e., less than two weeks). Moreover, we eliminated 79 RCTs from the analysis that used ginger in combination with other compounds only in the intervention group. Sixteen RCTs were also excluded because they were conducted on children. Finally, 36 eligible RCTs were used in the current systematic review and meta-analysis,[19–54] among which 25 articles assessed the impact of ginger on weight,[21,23,24,26–28,30,31,34,36–41,44–50,52–54] 30 articles on BMI,[19,21,24–31,33,35–42,44–54] 15 articles on WC,[25,26,28,30,31,36,37,41,45–49,53,54] 7 articles on BFP,[20,25,28,31,43,45,52] 4 articles on adiponectin,[22,32,45,46] 2 articles on leptin.[32,45] Fig. 1 depicts the flow diagram of the study selection process.

2.2. Characteristics of the included studies

Table 1 presents the characteristics of the 36 RCTs included in the current systematic review and meta-analysis. These RCTs were conducted in Iran,[19–22,24–32,35–44,46–51,53,54] India,[23] Egypt,[33] Korea,[45] Brazil,[52] and Pakistan,[34] and were published between years 2001 and 2024. Nine studies were exclusively performed on female subjects,[19,20,22,30–32,43,45,52] four studies on male subjects,[23,25,27,28] and others on both genders. The number of participants in the included RCT samples ranged from 16 to 103, yielding a total sample size of 1832 individuals. The mean age of participants was between 18 and 79 years. The dosage of ginger supplementation varied between 200 mg/day and 5000 mg/day, and the duration of intervention ranged from 4 to 12 weeks across selected RCTs. All studies took advantage of a parallel design. The included studies were conducted on patients with type 2 diabetes,[23,26,33,36,40–42,48,51,53,54] non-alcoholic fatty liver disease,[36,46] overweight and obese individuals,[19,20,22,25,28,31,32,43,45] and patients undergoing hemodialysis.[48,53]

2.3. Results from quality assessment

Random sequence generation of participants was mentioned in all included trials, and all studies had low risk of sequence generation bias, except two studies.[23,34] Five trials did not report allocation

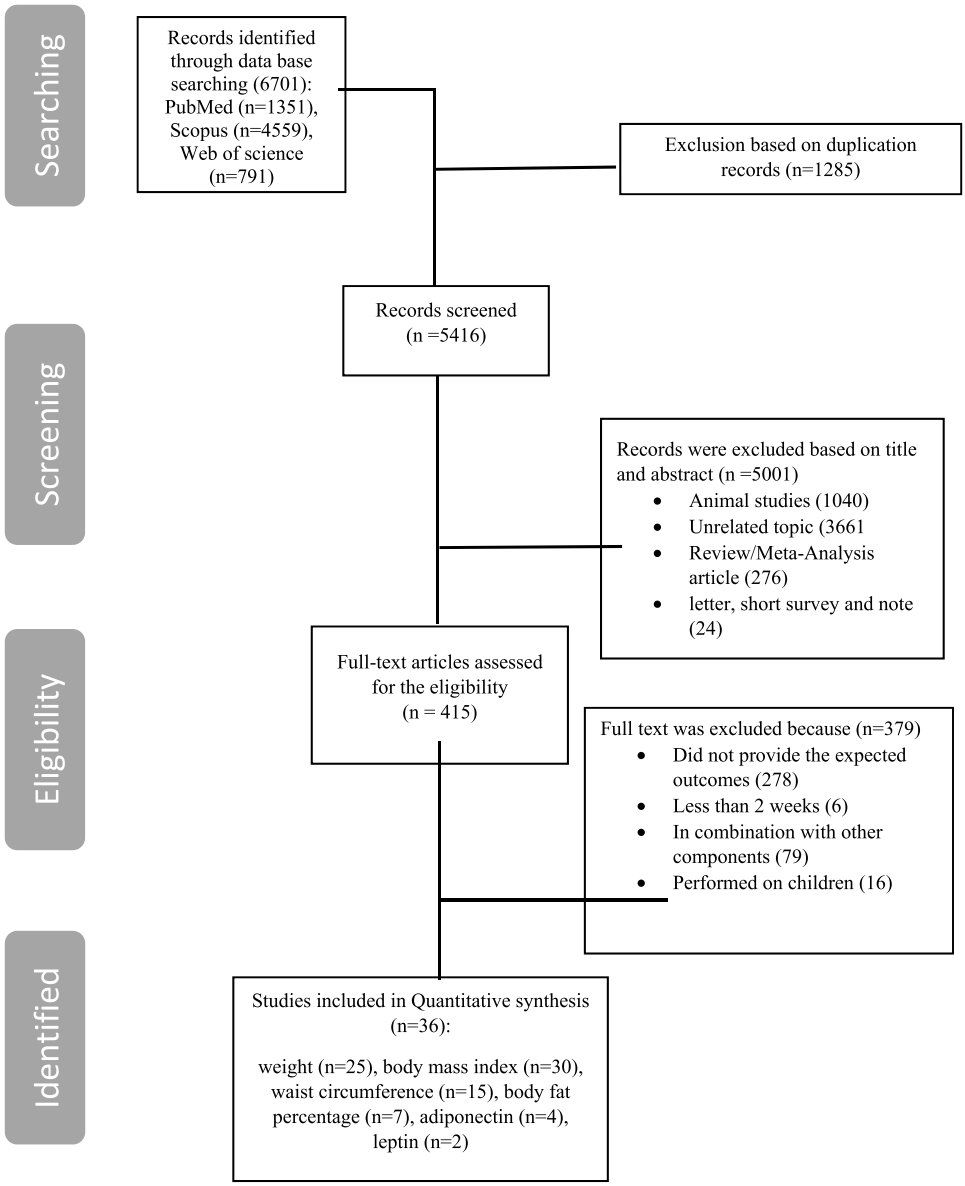


Fig. 1. PRISMA flow diagram of study selection.

concealment.[23,26,28,34,38] Moreover, nine trials had high risk of bias concerning blinding of participants and personnel,[19,20,22,23,26,28,33,34,43] and two studies had high risk of bias with respect to blinding outcome assessors.[22,43] Most studies showed low risk of bias based on incomplete outcome data, and three studies had unclear risk of attrition bias. Thirty studies had low risk of bias regarding selective outcome reporting. All studies had unclear risk of bias with regard to other potential threats to validity (Table 2).

2.4. Effect of ginger supplementation on body weight

The impact of ginger supplementation on body weight was examined across 26 clinical trial arms. The results showed no significant change in body weight as a result of the intervention (WMD: −0.26 kg, 95 % CI:

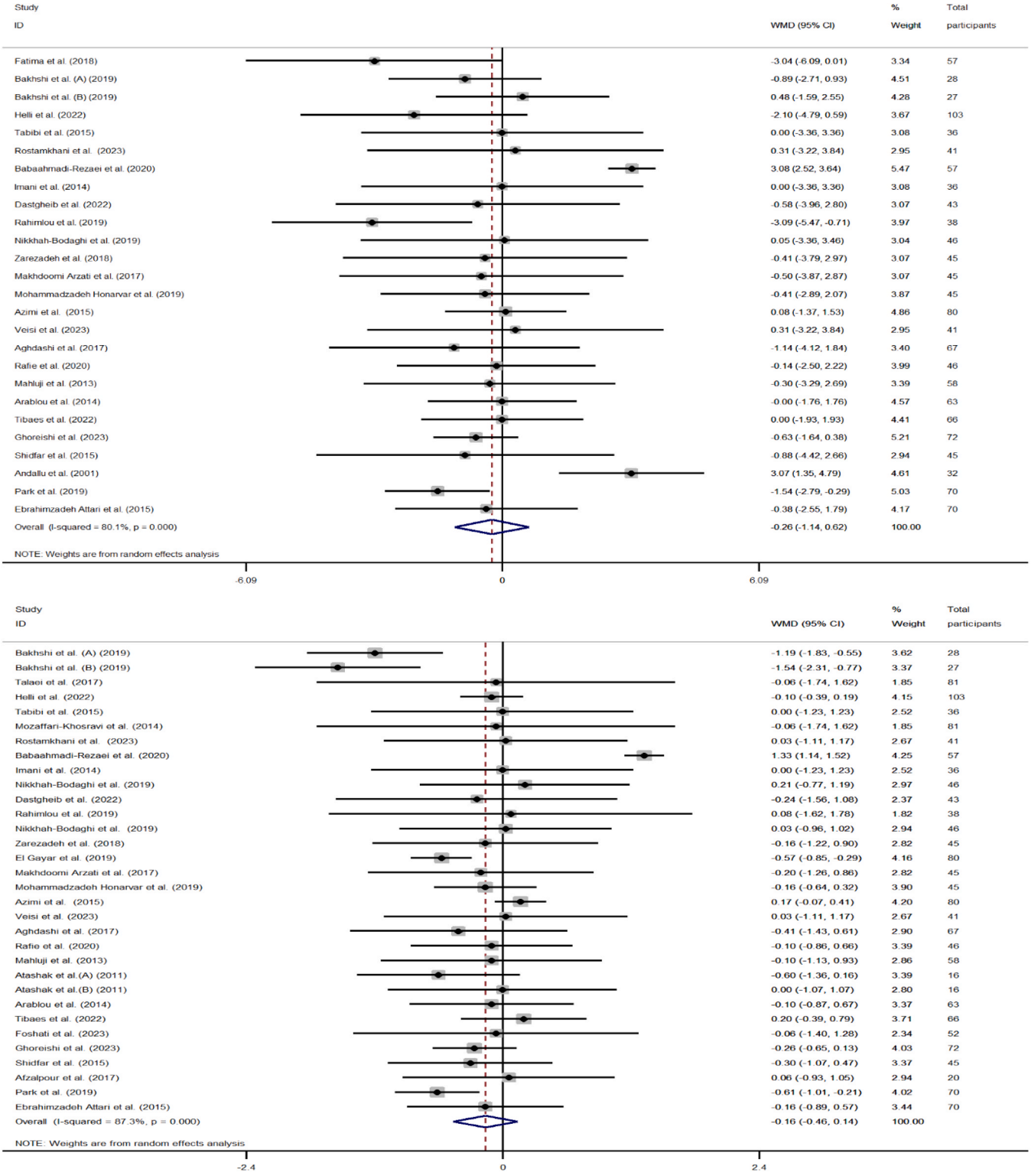


Fig. 2. Forest plots for the effect of ginger supplementation on weight, body mass index (BMI), waist circumference (WC), and body fat percentage (BFP). Horizontal lines represent 95 % CIs. Diamonds represent pooled estimates from random-effects analysis. WMD: weighted mean difference, CI: confidence interval.

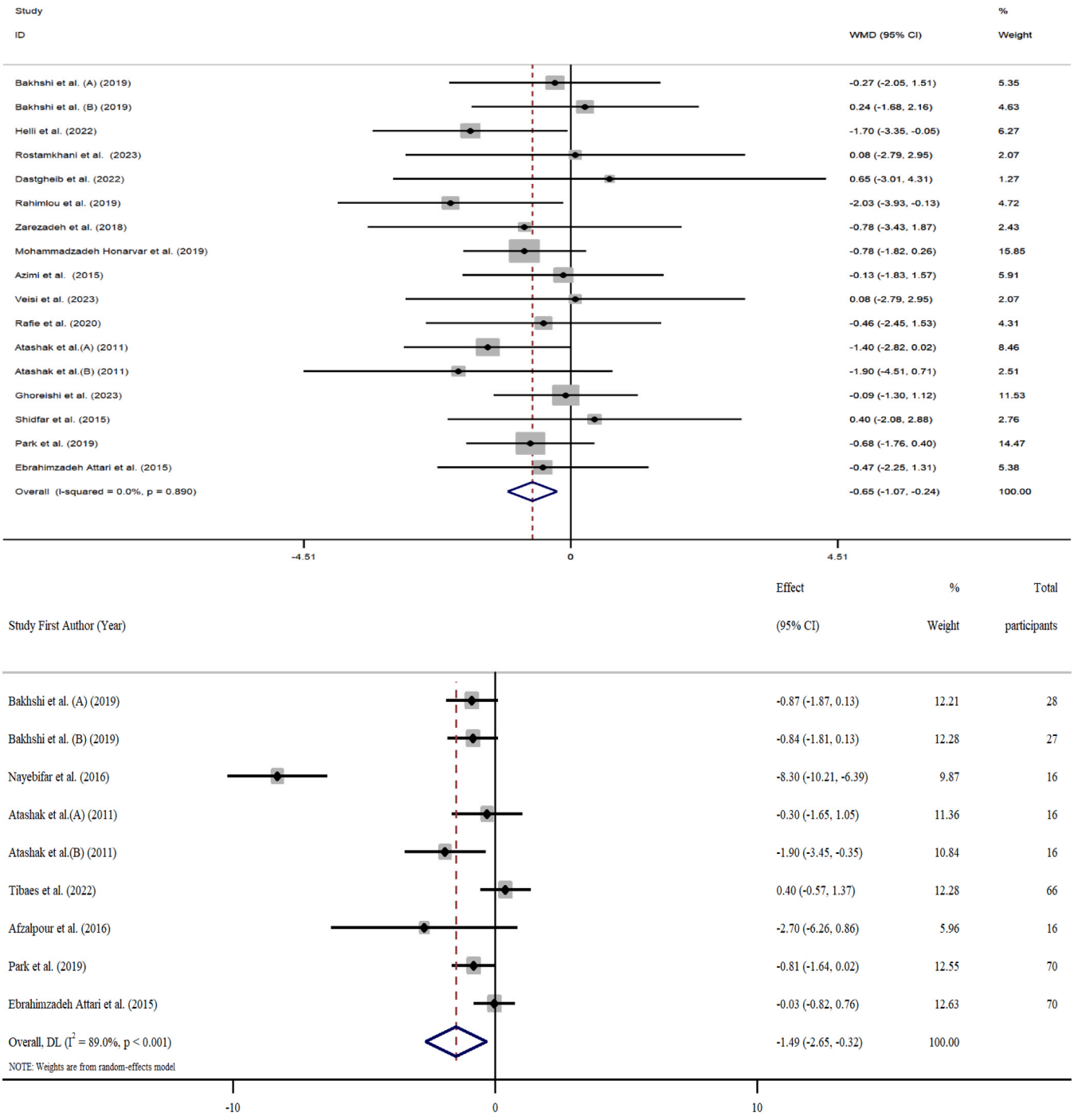


Fig. 2. (*continued*).

−1.14, 0.62; P = 0.569), with considerable variability between studies (P < 0.001, I^2= 80.1 %) (Fig. 2). Due to significant heterogeneity, a subgroup analysis was conducted. This revealed that factors such as participants' mean age, supplementation dosage, health status of participants, and study duration could explain the between-study heterogeneity (Table 3). Additionally, the subgroup analysis indicated that reduction in body weight (BW) by ginger supplementation was observed in studies exceeding 8 weeks, involving obese participants and those under 45 years old (Table 3).

2.5. Effect of ginger supplementation on BMI

Through the analysis of 32 effect sizes from 30 studies using a random-effects model, it was found that ginger consumption did not significantly lower BMI (WMD: −0.16 kg/m^2, 95 % CI: −0.46, 0.14, P = 0.304). However, there was high heterogeneity between the studies (I^2= 87.3 %, P < 0.001) (Fig. 2).

The subgroup analysis suggested that factors such as health status, supplementation dosage, BMI status, and participants' mean age might explain the observed heterogeneity (Table 3). Moreover, the analysis indicated a reduction in BMI due to ginger supplementation in studies lasting over 8 weeks, involving obese participants, healthy individuals, and those younger than 45 years old (Table 3).

Table 3
Subgroup analysis to assess the effect of ginger supplementation on obesity indices.

Variable	Number of effect sizes	WMD (95 % CI)	P-Value[1]	I^2 (%)[2]	P for heterogeneity[3]	P for between Subgroup heterogeneity[4]
Body weight						
Overall	26	−0.26 (−1.14, 0.62)	0.569	80.1	< 0.001	-
Age (years)						< 0.001
< 45	10	−1.07 (−1.77, −0.36)	0.003	7.7	0.371	
≥ 45	16	0.30 (−0.78, 1.38)	0.585	79.2	< 0.001	
BMI (kg/m^2)						< 0.001
< 30	17	−0.04 (−1.22, 1.13)	0.943	82.4	< 0.001	
≥ 30	9	−0.64 (−1.29, −0.007)	0.048	0.0	0.695	
Dosage (g/day)						< 0.001
< 2	16	−0.16 (−1.80, 1.46)	0.849	87.6	< 0.001	
≥ 2	10	−0.27 (−1.02, 0.47)	0.470	40.3	0.048	
Duration (weeks)						< 0.001
≤ 8	9	0.84 (−0.54, 2.23)	0.233	75.0	< 0.001	
> 8	17	−0.78 (−1.27, −0.29)	0.002	0.0	0.745	
Health status						< 0.001
Healthy	5	−0.73 (−1.51, 0.03)	0.062	0.0	0.460	
Unhealthy	21	−0.19 (−1.22, 0.84)	0.713	80.4	< 0.001	
BMI						
Overall	32	−0.16 (−0.46, 0.14)	0.304	87.3	< 0.001	-
Age (years)						< 0.001
< 45	14	−0.34 (−0.63, −0.05)	0.020	52.8	0.010	
≥ 45	18	−0.03 (−0.46, 0.38)	0.867	90.2	< 0.001	
BMI (kg/m^2)						< 0.001
< 30	20	0.26 (−0.35, 0.40)	0.893	87.1	< 0.001	
≥ 30	12	−0.46 (−0.71, −0.21)	< 0.001	41.8	0.063	
Dosage (g/day)						< 0.001
< 2	18	−0.08 (−0.61, 0.45)	0.767	45.0	0.020	
≥ 2	14	−0.24 (−0.48, 0.006)	0.056	93.2	< 0.001	
Duration (weeks)						< 0.001
≤ 8	11	0.64 (−0.54, 0.67)	0.837	93.1	< 0.001	
> 8	21	−0.29 (−0.48, −0.11)	0.001	28.6	0.109	
Health status						< 0.001
Healthy	9	−0.48 (−0.87, −0.09)	0.016	61.1	0.008	
Unhealthy	23	−0.02 (−0.38, 0.32)	0.875	88.0	< 0.001	
WC						
Overall	17	−0.65 (−1.07, −0.24)	0.002	0.0	0.890	-
Age (years)						0.181
< 45	9	−0.91 (−1.48, −0.35)	0.001	0.0	0.624	
≥ 45	8	−0.35 (−0.95, 0.24)	0.250	0.0	0.981	
BMI (kg/m^2)						0.709
< 30	7	−0.54 (−1.24, 0.15)	0.126	0.0	0.751	
≥ 30	10	−0.71 (−1.22, −0.20)	0.006	0.0	0.743	
Dosage (g/day)						0.172
< 2	6	−1.02 (−1.70, −0.35)	0.003	0.0	0.723	
≥ 2	11	−0.43 (−0.95, 0.09)	0.105	0.0	0.903	
Duration (weeks)						0.243
≤ 8	4	0.03 (−1.19, 1.26)	0.956	0.0	0.986	
> 8	13	−0.74 (−1.17, −0.30)	0.001	0.0	0.783	
Health status						0.797
Healthy	8	−0.71 (−1.36, −0.07)	0.029	0.0	0.706	
Unhealthy	20	−0.60 (−1.14, −0.07)	0.026	0.0	0.770	
BFP						
Overall	9	−1.49 (−2.65, −0.32)	0.012	89.0	< 0.001	-
Age (years)						0.076
< 45	7	−1.92 (−3.60, −0.23)	0.025	91.1	< 0.001	
≥ 45	2	−0.40 (−1.17, 0.35)	0.294	43.5	0.184	
BMI (kg/m^2)						0.168
< 30	4	−1.12 (−1.71, −0.53)	< 0.001	95.4	< 0.001	
≥ 30	5	−0.59 (−1.06, −0.13)	0.011	25.9	0.249	
Dosage (g/day)						0.117
< 2	4	−0.55 (−1.42, 0.13)	0.211	57.6	0.069	
≥ 2	5	−2.38 (−4.57, −0.20)	0.032	93.6	< 0.001	
Duration (weeks)						-
≤ 8	-	-	-	-	-	
> 8	9	−0.80 (−1.16, −0.43)	< 0.001	89.0	< 0.001	
Health status						-
Healthy	9	−1.48 (−2.65, −0.32)	0.012	89.0	< 0.001	
Unhealthy	-	-	-	-	-	

Abbreviation: WMD: weighted mean difference, CI: confidence interval, BMI; body mass index, WC; waist circumference, BFP: body fat percentage
[1]Refers to the mean (95 % CI)
[2]Inconsistency, percentage of variation across studies due to heterogeneity
[3]Obtained from the Q-test
[4]Obtained from the fixed-effects model

2.6. Effect of ginger supplementation on WC

Analyzing results from 17 trial arms, a significant decrease in waist circumference (WC) was found (WMD: −0.65 cm, 95 % CI: −1.07, −0.24, P = 0.002), with no between-study heterogeneity (I^2 = 0.0 %, P = 0.890) (Fig. 2). However, the subgroup analysis revealed that ginger supplementation did not reduce waist circumference (WC) in studies lasting less than 8 weeks, involving non-obese participants, those receiving doses exceeding 2 g/day, and participants older than 45 years (Table 3).

2.7. Effect of ginger supplementation on body fat percentage (BFP)

A total of 9 clinical trial arms evaluated the effect of ginger supplementation on body fat percentage (BFP). The pooled effect size showed a significant reduction in BFP (WMD: −1.49 %, 95 % CI: −2.65, −0.32, P = 0.012), accompanied by significant heterogeneity between studies (I^2 = 89.0 %, P < 0.001) (Fig. 2). However, subgroup analysis revealed no significant impact of ginger on BFP in studies where participants received doses greater than 2 g/day or were older than 45 years (Table 3).

2.8. Effect of ginger supplementation on adiponectin and leptin

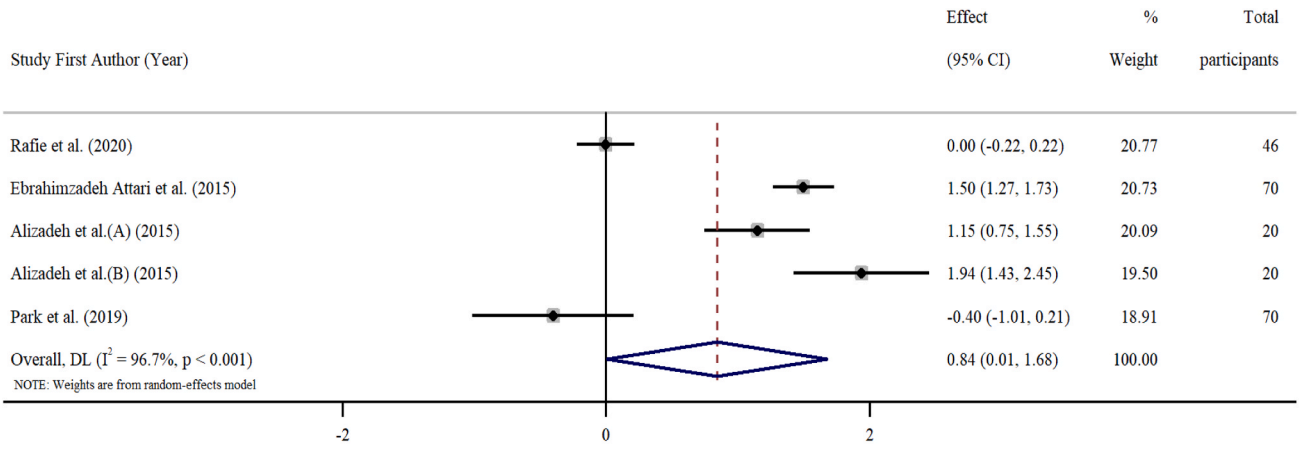
Data from five clinical trial arms showed that ginger supplementation significantly increased serum adiponectin levels (WMD = 0.84 μg/mL; 95 % CI: 0.01, 1.68, P = 0.047), with significant heterogeneity among studies (I^2 = 96.7 %, P < 0.001) (Fig. 3). The effect of ginger supplementation on serum leptin levels was analyzed in two combined clinical trials, revealing no significant impact (WMD = −4.40 ng/mL; 95 % CI: −9.78, 0.98, P = 0.109), and significant heterogeneity was also observed (I^2 = 85.2 %, P = 0.009) (Fig. 3). Subgroup analysis for adiponectin and leptin was not conducted due to the limited number of the included studies.

2.9. Meta-regression

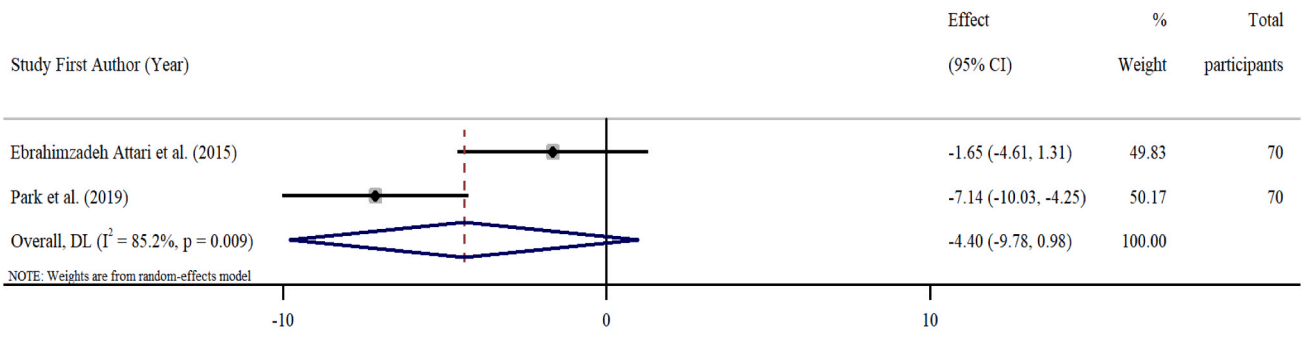
We applied a random-effect meta-regression model to assess the impact of potential moderators, such as intervention duration and dosage of supplementation, on the estimated effect size. Meta-regression analysis indicated that ginger supplementation's effects on BW, BMI, WC, and BFP were not linked to the dose (BW: coefficient = 0.00001, P = 0.975; BMI: coefficient = −0.0001, P = 0.430; WC: coefficient = -0.0002, P = 0.154; BFP: coefficient = -0.0009, P = 0.222). Additionally, the effect of ginger supplements on BMI, WC, and BFP was independent of study duration (BMI: coefficient = −0.064, P = 0.310; WC: coefficient = −0.108, P = 0.495; BFP: coefficient = -1.112, P = 0.240). However, there was a significant inverse association between changes in BW and the duration of the studies (BW: coefficient = -0.471, P = 0.001). The meta-regression analysis for leptin and adiponectin was not conducted due to the limited number of studies.

2.10. Sensitivity analysis

We performed a sensitivity analysis on the outcomes of interest, and the results indicated that removing any individual study did not change that statistically significance of the pooled effect sizes of the variables. The results are as follows: BW (95 % CI: −1.32, 0.74), BMI (95 % CI: −0.50, 0.19), WC (95 % CI: −1.17, −0.15), and BFP (95 % CI: −3.09, −0.08). However, sensitivity analysis was not conducted for adiponectin



Adiponectin



Leptin

Fig. 3. Forest plots for the effect of ginger supplementation on adiponectin and leptin. Horizontal lines represent 95 % CIs. Diamonds represent pooled estimates from random-effects analysis. WMD: weighted mean difference, CI: confidence interval.

and leptin due to the insufficient number of studies to derive reliable results.

2.11. Publication bias and trim-and-fill analysis

All of the included studies were assessed for publication bias by Egger's weighted regression tests and visual inspection. Based on the visual evaluation, the funnel plots showed slightly asymmetry for the anthropometric indices (Supplementary Figure 1). Egger's test results showed no publication bias for body weight (BW) (P = 0.074), waist circumference (WC) (P = 0.499), and body fat percentage (BFP) (P = 0.081). However, publication bias was observed for body mass

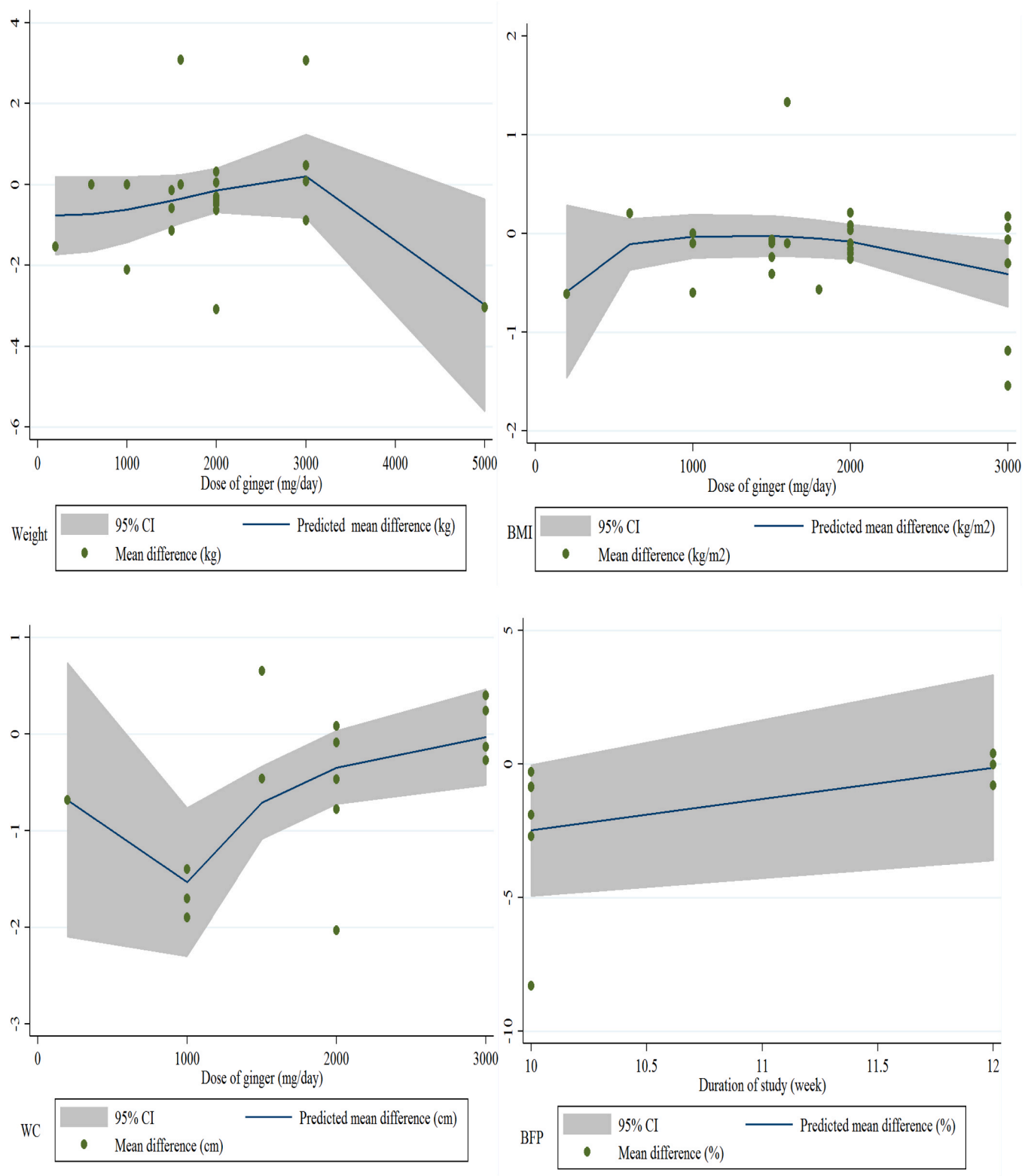


Fig. 4. Dose-response relations between ginger dosage (mg/day) with absolute (unstandardized) mean differences of the outcomes (weight, body mass index (BMI), waist circumference (WC), and body fat percentage (BFP)) in nonlinear fashion.

index (BMI) (P = 0.019). By applying the trim-and-fill method, adding the missing hypothesized studies for BMI altered the overall non-significant effect size to a statistically significant effect size (WMD: −0.38 kg/m², 95 % CI: −0.73, −0.03, P = 0.032). The publication bias analysis for adiponectin and leptin was not conducted due to the insufficient number of studies.

2.12. Non-linear dose-responses effect of duration of intervention and dose of ginger supplement on the anthropometric indices

Non-linear dose-response analysis indicated that higher doses significantly enhance the likelihood of a significant reduction trend in WC (P-nonlinearity = 0.023). However, no significant associations were observed for ginger supplementation dosage on body weight (P-nonlinearity = 0.07), BMI (P-nonlinearity = 0.122), or BFP (P-nonlinearity = 0.380) (Fig. 4).

There was an association between the duration of the intervention and the reduction in body weight (P-nonlinearity = 0.001). However, no such effects were observed for BMI (P-nonlinearity = 0.147), WC (P-nonlinearity = 0.123), or BFP (P-nonlinearity = 0.233) (Supplementary Figure 2).

2.13. Grading of evidence

The GRADE framework was applied to determine the quality of evidence of the outcomes of interest. According to the GRADE protocol, the quality of evidence for body weight, adiponectin, and leptin was classified as low. Moreover, evidence regarding BMI was considered as very low, BFP was rated as moderate, and WC was classified as high (Supplementary Table 1).

3. Discussion

The following observations were made in the present systematic review and meta-analysis: 1) supplementation with ginger products had no impact on BMI, BW, nor leptin levels, 2) intervention was effective in improving WC, BFP, and adiponectin levels, 3) dosage/duration of intervention, health status, and age of participants are the sources of heterogeneity among included studies, 4) with increased study duration, the impact of ginger supplements on WC was diminished, and 5) there were non-linear associations between dosage and duration of intervention and WC and BW, respectively.

Our findings suggest that, despite claims on its anti-obesogenic effect,[55] and widespread commercialization of ginger products, supplementation with ginger cannot ameliorate BMI or BW. This effect might be best described by the ginger's inability to ameliorate leptin levels, a hormone most prominently associated with appetite regulation and homeostasis of energy intake/deposits in the body.[56] This finding differs from previous evidence derived primarily from animal models, which have reported beneficial effects of ginger on leptin regulation. This discrepancy highlights the translational gap between experimental and clinical contexts.[57] Given the lack of improvement in both BMI and leptin levels, and considering the limited number of studies, current evidence remains inconclusive regarding long-term benefits. In this interpretation, two factors should be kept in mind. Firstly, we detected significant publication bias regarding BMI. When trim-and-fill method applied to observe the impact of adding hypothetical missing data, the association turned significant. Secondly, only two of the included studies investigated leptin. Based on both observations, we propose further data needs to be accumulated to make a conclusive statement on the effect of ginger on improvement of long-term obesity status.

On the other hand, ginger was effective in improving WC, BFP, and adiponectin. Given all these parameters are indicators of modifications in fat deposits of the body,[58] rather that total weight status (as is the case for BMI), it can be deduced that supplementation with ginger can induce mobilization of lipids. The observed reductions in these factors hold clinical significance, as central adiposity is strongly associated with increased risk of metabolic syndrome, type 2 diabetes, and cardiovascular disease.

The findings of this review indicate that ginger supplementation does not significantly influence body weight or BMI, and the inconsistency among studies limits the reliability of these outcomes. Conversely, the observed reduction in waist circumference was both statistically significant and consistent across studies, with no detectable heterogeneity, suggesting a more robust and reproducible effect on central adiposity. This highlights the potential short-term benefits of ginger in targeting abdominal fat rather than total body mass.

There is some evidence that ginger, mainly via its anti-inflammatory properties, can do so by alteration of the activity of several transcription factors. For instance, peroxisome proliferator–activated receptors (PPARs), nuclear factor-κB (NF-κB), and adenosine monophosphate–activated protein kinase (AMPK)—all associated with lipid metabolism—have been shown to be affected by ginger.[59] Moreover, sterol regulatory element-binding protein 1 (SREBP-1c), a transcription factor responsible for regulation of lipid metabolism through controlling the expression of enzymes in fatty acid synthesis and uptake/mobilization of triglycerides, has been shown to be affected by ginger intake in rats.[60] Adiponectin, an adipocytokine known for its appetite-regulation role, increases with reduced body fat accumulation.[61] Based on that, the statistically significant increase observed in adiponectin levels can be best justified by the decrease of local adiposity in the trunk area—as evident by WC reduction. The lipid-altering impact of ginger has been attributed to 6-gingerol, its prominent bioactive compound, which exerts the effect through inhibition of several adipocytokines—namely interleukin-6 (IL-6), tumor necrosis factor-α (TNF- α), and leptin—when examined in animal models.[62,63] However, these mechanisms are primarily derived from animal studies and may not fully translate to human physiology; thus, further clinical research is needed to confirm these pathways in humans.

We also observed that higher doses of ginger are linearly associated with improved impacts on WC. However, no such association was observed for BMI nor leptin, as indicators of long-term efficacy of the intervention. These observations highlight the effectiveness of ginger supplementation on acute improvement of weight status, as opposed to long-term regulatory impacts on appetite and energy homeostasis.

Previous reviews have also investigated the impact on ginger on weight indices. Among them, two studies,[64,65] only included human trials, while the other,[66] included animal models as well. They reported significant reductions in BMI following intervention. However, the number of included studies were smaller compared to the present investigation. Per these discrepancies and the publication bias observed with regard to BMI, we cannot settle on a unanimous decision on the efficacy of ginger on BMI. However, we propose that should the prominent goal of the clinician is to improve weight status in the long-term, modification in dietary patterns and other lifestyle changes should be prioritized and, then, complemented with ginger products.

The present systematic review and meta-analysis comprehensively examined the existing literature on measurements/indices of weight status and energy homoeostasis. Nonetheless, several limitations need to be addressed. Firstly, the quality of evidence was low and very low for most of the outcome variables. Secondly, publication bias was observed for one of the outcomes. Finally, significant heterogeneity was seen for which the sources were investigated through thorough sub-group analysis; except for two of the variables.

4. Conclusion

Based on our observations, supplementation with ginger is effective in ameliorating several indicators of weight status, including WC, BFP, and adiponectin. However, no such effect could be detected with regards to BMI, BW, nor leptin levels. Therefore, ginger cannot be recommended as a primary intervention for weight or appetite regulation. Nonetheless,

ginger may serve as an adjunct, but not a replacement, for lifestyle-based interventions targeting long-term obesity management. Its benefits appear to be more evident in short-term reductions of localized fat, as reflected in improved WC and BFP, rather than in overall weight loss. Given inconsistencies with previous studies and the overall low certainty of evidence, further high-quality trials are needed to confirm these results and clarify the optimal dosage and duration of supplementation.

CRediT authorship contribution statement

Behzad Zamani: Writing – original draft, Supervision, Methodology. **Moein Askarpour:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Project administration, Methodology, Formal analysis, Data curation, Conceptualization. **Ehsan Aliabadi:** Writing – review & editing, Writing – original draft, Funding acquisition. **Mehran Nouri:** Writing – review & editing, Writing – original draft, Visualization. **Soroush Talakesh:** Writing – review & editing, Writing – original draft, Visualization. **Mohammad Reza Ahmadi:** Writing – review & editing, Writing – original draft, Investigation. **Saeede Alimohamadi:** Writing – review & editing, Writing – original draft, Methodology. **Seyed Sina Seyedhatami:** Writing – review & editing, Writing – original draft, Data curation. **Maede Makhtoomi:** Writing – review & editing, Writing – original draft, Methodology. **Shrin Rjabi:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Conceptualization.

Ethical approval

Ethical approval was not required for this secondary analysis.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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This study is based on previously published data and does not involve any primary data collection.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.ctim.2025.103260.

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