Review Article

Coffee Consumption, General Obesity and Abdominal Obesity in Adults: A Systematic Review and Meta-Analysis of Cross-Sectional Studies

Mohammad Nemati[1], Sanaz Soltani[2]*, Fatemeh Almasi[3], Asma Salari-Moghaddam[4], Bagher Larijani[5], Armin Ebrahimzadeh[6], Alireza Milajerdi[3], Ahmad Esmaillzadeh[1,7]

[1]Department of Community Nutrition, School of Nutritional Sciences and Dietetics, Tehran University of Medical Sciences, Tehran, Iran, [2]Department of Nutritional Sciences, School of Health, Mazandaran University of Medical Sciences, Sari, Iran, [3]Research Center for Biochemistry and Nutrition in Metabolic Diseases, Institute for Basic Science, Kashan University of Medical Sciences, Kashan, Iran, [4]Department of Biochemistry, School of Medicine, Ilam University of Medical Sciences, Ilam, Iran, [5]Endocrinology and Metabolism Research Center, Endocrinology and Metabolism Clinical Sciences Institute, Tehran University of Medical Sciences, Tehran, Iran, [6]Nutrition Research Center, School of Nutrition and Food Sciences, Shiraz University of Medical Sciences, Shiraz, Iran, [7]Department of Community Nutrition, School of Nutrition and Food Science, Food Security Research Center, Isfahan University of Medical Sciences, Esfahan, Iran

*Co first author

Abstract

Background: Findings from cross-sectional studies on the association between coffee consumption and odds of obesity are inconsistent. We aimed to perform a meta-analysis of earlier cross-sectional studies on the association between coffee consumption and odds of obesity.

Materials and Methods: The online databases of PubMed, ISI Web of Science, Scopus, Science Direct, and EMBASE were systematically searched to identify relevant publications up to April 2023. Cross-sectional studies that considered coffee as the exposure and general and abdominal obesity as the outcome were included. Studies that had reported odds ratios (ORs) as effect size were included in the meta-analysis. To pool data, a random-effects model was used.

Results: In total, 23 studies were included in our systematic review. Twelve publications on general obesity and 15 publications on abdominal obesity were examined in the meta-analysis. Overall, 207551 individuals aged ≥19 years were included. With regards to general obesity, pooling 13 effect sizes from 12 cross-sectional studies showed that coffee intake was not associated with odds of general obesity (overall OR: 1.11; 95% CI: 0.92, 1.33). In subgroup analysis by gender, we found a significant positive association between coffee consumption and odds of general obesity in women (OR: 1.84; 95% CI: 1.51, 2.24). Concerning abdominal obesity, combining 18 effect sizes from 15 studies, we failed to find a significant association between coffee consumption and odds of abdominal obesity (OR: 1.03; 95% CI: 0.92, 1.15).

Conclusion: No significant association was found between coffee intake and odds of obesity. However, gender-stratified analyses revealed significant relationships.

Keywords: Coffee, meta-analysis, obesity

Address for correspondence: Dr. Ahmad Esmaillzadeh, Department of Community Nutrition, School of Nutritional Sciences and Dietetics, Tehran University of Medical Sciences, Tehran, P.O. Box 14155-6117, Iran.
E-mail: a.esmaillzadeh@gmail.com
Dr. Alireza Milajerdi, Kashan University of Medical Sciences, No. 226, Ravand Blv, 1416753955, Kashan, Iran.
E-mail: amkhv@yahoo.com
Submitted: 18-Apr-2024; **Revised:** 09-Jul-2024; **Accepted:** 10-Jul-2024; **Published:** 28-Dec-2024

Access this article online	
Quick Response Code:	**Website:** www.advbiores.net
	DOI: 10.4103/abr.abr_174_24

How to cite this article: Nemati M, Soltani S, Almasi F, Salari-Moghaddam A, Larijani B, Ebrahimzadeh A, *et al*. Coffee consumption, general obesity, and abdominal obesity in adults: A systematic review and meta-analysis of cross-sectional studies. Adv Biomed Res 2024;13:122.

Introduction

Coffee is one of the most frequently consumed beverages worldwide.[1] Its contribution to human health is of great importance. Coffee contains hundreds of bioactive compounds such as caffeine, chlorogenic acid, vitamin E, niacin, potassium, magnesium, and various other micronutrients.[2,3] The beneficial effects of these components on metabolic health have earlier been shown.[4] Caffeine, polyphenols, and melanoidins seem to have antioxidant, anti-inflammatory, and antifibrotic effects.[5] Findings from previous studies have revealed that habitual coffee consumption is associated with reduced risk of several chronic diseases including diabetes,[6] nonalcoholic fatty liver, metabolic syndrome,[7] coronary heart diseases,[8] and some types of cancers.[9]

Obesity is a great health problem in the world and an important risk factor for a wide range of diseases.[10] General obesity is defined as the abnormal or excessive accumulation of fat in the body (regardless of the place of its accumulation), but in abdominal obesity, there is an excessive concentration of visceral fat around the abdomen.[11] According to the latest WHO reports, the prevalence of obesity among adults in the world is 16% in 2022,[12] and a systematic review reported that 41.5% of people in the world have abdominal obesity.[13]

Numerous studies have examined the association between coffee consumption and the odds of obesity. However, the results have been inconsistent. Some studies have reported that coffee consumption is inversely associated with obesity[3,14-17]; others have observed no significant association.[3,18-28] In addition, some publications demonstrated that coffee consumption might have a significant positive association with the odds of obesity.[19,29-33] Findings of the latest published meta-analysis study on the relationship between coffee and obesity in observational studies revealed no significant relationship between coffee consumption and odds of general and abdominal obesity. However, a significant association was found between coffee consumption in women and increased odds of general obesity.[34] However, several relevant observational studies about general[3,16,22,29] and abdominal[3,15,17,21,23,29,31] obesity were not included in that analysis.

Given the controversies among earlier studies, a current systematic review and meta-analysis were performed to investigate the association between coffee consumption and the odds of general and abdominal obesity among observational studies.

Materials and Methods

The study protocol was registered in the International Prospective Register of Systematic Reviews (PROSPERO) database (http://www.crd.york.ac.uk/PROSPERO, registration number: CRD42018099403).

Literature search strategy

A broad range of electronic databases including PubMed, ISI Web of Science, Scopus, Science Direct, and EMBASE were systematically searched for all articles investigating the association between coffee consumption and obesity up to April 2023. Our search terms included (coffee[tiab] OR Coffee[MESH] OR Caffeine[tiab] OR Caffeine[MESH] OR beverage[tiab] OR Beverages[MESH]) AND (obesity[tiab] OR Obesity[MESH] OR "body mass index"[tiab] OR Body Mass Index[MESH] OR BMI[tiab] OR adiposity[tiab] OR "waist circumference"[tiab] OR anthropometr*[tiab] OR Overweight[tiab] OR weight[tiab]).No restriction was considered in terms of time of publication and language. Reference lists of related articles were also reviewed to avoid missing any study.

Selection criteria: In this meta-analysis, studies that met the following criteria were included[1]: studies that had a cross-sectional design[2]; the exposure of interest was coffee consumption[3]; and the outcome of interest was obesity. All studies that met these criteria and reported (ORs) with 95% confidence intervals (CIs) for the highest versus the lowest level of coffee consumption were included.

Excluded studies

Letters, notes, editorials, comments, short communications, reviews, meta-analyses, ecological studies, and animal studies were excluded. Other articles were excluded because they did not have (ORs) with 95% confidence intervals (CIs) for the highest versus the lowest level of coffee consumption,[35-53] and those reported results for green coffee and also those studies assessed coffee consumption in combination with other lifestyle variables[54] or in combination with tea.[55-59]

Data extraction and quality assessment

Study selection and data extraction were independently performed by two investigators (MN and SS), and any discrepancy was resolved through discussion with AE and AM. Data were extracted using a standardized extraction form. The Cohen's kappa analysis[60] was performed to measure the inter-rater reliability between two investigators, and the result demonstrated that there is a perfect agreement between investigators (kappa = 0.72, P value = 0.023). The following information was extracted from each study: the name of the first author, publication year, the country in which the study was conducted; study design; number and gender of participants; mean age or age range of the study population; coffee consumption ranges or medians or means; ORs and 95% CIs for the association; definition of obesity; and covariates (including age, sex, physical activity, and total energy intake [footnote of Table 1]), for which the included studies made adjustment in their analyses. When the published data were inadequate for systematic review and/or meta-analysis, we contacted the corresponding author of the original studies to obtain further details. The information extracted from the included studies is reported in Table 1 and they were also used in the subgroup analysis [Table 2], The quality of studies was assessed using the Newcastle-Ottawa Quality Assessment Scale[61] adapted for cross-sectional studies, and results are shown in Table 3.

Table 1: Characteristics of cross-sectional studies included in the systematic review

Authors (Year)	Country	Age range/mean age	Sample size	Exposure	Exposure assessment	Outcome	Comparison	OR (95% CI)	Adjustments
General obesity									
Suadicani P *et al*. (2005)	Denmark	53-75	Men: 3290 Women: 0 Total: 3290	Coffee	Questionnaire	General obesity (BMI ≥30)	≤6 cups/day >6 cups/day	OR: 0.62 (0.44–0.90)	1, 4, 5, 6, 7, 8, 9, and 19
Kim H-J *et al*. (2014)	Korea	19-65	Men: 6879 Women: 11074 Total: 17953	Coffee	FFQ	General obesity (BMI ≥23)	<1/week 1–6/week 1/day 2/day ≥3/day	OR: 1.28 (1.09-1.50)	1, 2, 6, 4, 5, 10, 3, and 11
Nordestgaard A-T *et al*. (2015)	Denmark	42-71	Men: 37392 Women: 46044 Total: 83436	Coffee	Questionnaire	General obesity (BMI ≥30)	None 0.1-1 cup/day 1.1–2 cups/day 2.1–3 cups/day 3.1-4 cups/day 4.1-5cups/day >5 cups/day	OR: 1.02 (0.94-1.11)	1, 2, 4, 6, and 25
Platt DE *et al*. (2016)	Lebanon	61.30	Men: 5120 Women: 2487 Total: 7607	Coffee	Questionnaire	General obesity (BMI >30)	<3 cups/day 3-5 cups/day >5 cups/day	OR: 0.68 (0.46-1.00)	1 and 2
Song F *et al*. (2016)	Korea	19-65	Men: 1960 Women: 2846 Total: 4806	Black coffee include brewed coffee	24-h recall method	General obesity (BMI ≥25)	Tertile 1 Tertile 2 Tertile 3	OR: 0.92 (0.75–1.13)	1, 2, 10, 6, and 5
Kim J-H *et al*. (2017)	Korea	≥40	Men: 2833 Women: 4073 Total: 6906	Coffee	FFQ	General obesity (BMI ≥25)	<1 cup/day 1 cup/day 2 cups/day ≥3 cups/day	OR: Men: 1.25 (0.95–1.66) Women: 1.57 (1.18–2.10)	1, 6, 5, 13, 4, and 11
Lee J *et al*. (2017)	Korea	30-70	Men: 0 Women: 5995 Total: 5995	Coffee	FFQ	General obesity (BMI ≥25)	None <1 cup/day 1–2 cups/day 2–3 cups/day ≥3 cups/day	OR: 2.52 (1.91–3.34)	1, 3, 12, 5, 6, 4, 10, and 20
Koyama T *et al*. (2020)	Japan	mean±SD: 57.6±10.0	Men: 1239 Women: 2300 Total: 3539	Coffee	Self-administered questionnaire	General obesity (BMI ≥25)	<1 time/day ≥1 time/day	OR: 0.87 (0.72–1.06)	1, 2, 5, 4, 23, 24, and 25
Sakboonyarat B *et al*. (2020)	Thailand	≥20	Men: 214 Women: 413 Total: 627	instant coffee-mix	Standardized questionnaires	General obesity (BMI ≥25)	≤1 cup/week >1 cup/week	OR: 1.44 (1.02–2.04)	NR

Contd...

Table 1: Contd...

Authors (Year)	Country	Age range/mean age	Sample size	Exposure	Exposure assessment	Outcome	Comparison	OR (95% CI)	Adjustments
General obesity									
Yonekura Y *et al*. (2020)	Japan	40-65	Men: 0 Women: 115 Total: 115	Coffee	Brief self-administered diet history questionnaire	General obesity (BMI ≥25)	<1 cup/day ≥1 cup/day	OR: 0.14 (0.05–0.46)	1, 30, 31, 10, 6, 5, and 4
Li Q-H *et al*. (2022)	China	mean±SD: 43.8±14.8	Men: 620 Women: 0 Total: 620	Coffee	FFQ	General obesity (BMI ≥28)	<1 time/week 1–2 times/week 3–4 times/week >4 times/week	OR: 2.00 (0.70–5.70)	-
Senftinger J *et al*. (2023)	Germany	median: 63 (IQR: 55; 69)	Men: 4399 Women: 4610 Total: 9009	Coffee	questionnaires	General obesity (BMI ≥30)	<3 cups/day 3–4 cups/day >4 cups/day	OR: 1.32 (1.08–1.62)	1, 2, 15, 6, 28, and 20
Abdominal obesity									
Takami H *et al*. (2013)	Japan	35-70	Men: 409 Women: 145 Total: 554	Coffee	Self-administered questionnaire	Abdominal obesity (WC: men: ≥90, women: ≥80)	<1.5 cups/day ≥1.5 and<3 cups/day ≥3 cups/day	OR: 1.10 (0.79-1.54)	1, 2, 10, 4, 6, and 5
Grosso G *et al*. (2014)	Italy	50.2	Total: 816	Espresso coffee	FFQ	Abdominal obesity (WC: men: ≥90, women: ≥80)	0 ml/day 45-90 ml/day >90 ml/day	OR: 1.23 (0.80-1.89)	1, 2, 10, 14, 6, and 4
Kim H-J *et al*. (2014)	Korea	19-65	Men: 6879 Women: 11074 Total: 17953	Coffee	FFQ	Abdominal obesity (WC: men: ≥90, women: ≥80)	<1/week 1–6/week 1/day 2/day ≥3/day	OR: 1.24 (1.05–1.40)	1, 2, 6, 4, 5, 10, 3, and 11
Grosso G *et al*. (2015)	Poland	45–69	Men: 1288 Women: 2053 Total: 3341	Coffee	FFQ	Abdominal obesity (WC: men: ≥90, women: ≥80)	<1 cup/day 1–2 cups/day >2 cups/day	OR: 0.86 (0.75–0.97)	2, 1, 3, 12, 4, 6, 5, 10 and 9
Kim K *et al*. (2016)	Korea	42.20	Men: 0 Women: 15691 Total: 15691	Coffee	FFQ	Abdominal obesity (WC: men: ≥90, women: ≥85)	~ 0 cup <1 cup/day ~1 cup/day >1 cup/day	OR: 0.88 (0.79-0.97)	1, 15, 3, 11, 6, 5, 4, and 16
Song F *et al*. (2016)	Korea	19-65	Men: 1960 Women: 2846 Total: 4806	Black coffee include brewed coffee	24-h recall method	Abdominal obesity (WC: men: ≥90, women: ≥85)	Tertile 1 Tertile 2 Tertile 3	OR: 0.76 (0.71–0.81)	1, 2, and 10, 6, and 5
Suliga E *et al*. (2017)	Poland	37–66	Men: 3500 Women: 6867 Total: 10367	Coffee	FFQ	Abdominal obesity (WC)	Q1 Q2 Q3 Q4	OR: 0.85 (0.77-0.94)	1, 2, 17, 3, 18, 6, 21, 5, 4 and 22

Contd...

Table 1: Contd...

Authors (Year)	Country	Age range/mean age	Sample size	Exposure	Exposure assessment	Outcome	Comparison	OR (95% CI)	Adjustments
					Abdominal obesity				
Kim J-H *et al*. (2017)	Korea	≥40	Men: 2833 Women: 4073 Total: 6906	Coffee	FFQ	Abdominal obesity (WC: men: ≥90, women: ≥85)	<1 cup/day 1 cup/day 2 cups/day ≥3 cps/day	OR: Men: 1.13 (0.85–1.50) Women: 1.33 (1.01–1.75)	1, 6, 5, 13, 4 and 11
Lee J *et al*. (2017)	Korea	30-70	Men: 0 Women: 5995 Total: 5995	Coffee	FFQ	Abdominal obesity (WC: ≥80)	None <1 cup/day 1–2 cups/day 2–3 cups/day ≥3 cups/day	OR: 2.11 (1.59–2.79)	1, 3, 12, 5, 6, 4, 10 and 20
Shin H *et al*. (2017)	Korea	≥20	Men: 1268 Women: 2053 Total: 3321	Coffee (without sugar and cream)	Medical record	Abdominal obesity (WC: men: >90, women: >85)	<1 cup/day 1-2 cup/day ≥3 cps/day	OR: Men: 0.53 (0.27–1.02) Women: 1.59 (0.97–2.61)	-
Micek A *et al*. (2018)	Poland	≥20	Men: 1389 Women: 1949 Total: 3338	Coffee	24-h recall method	Abdominal obesity (WC: men: ≥94, women: ≥80)	0 g/day (None) 0-200 g/day (Low) 200-400g/day (Moderate) >400g/day (High)	OR: 1.17 (0.94–1.47)	2, 1, 3, 12, 4, 6, 5, 10, and 9
Stutz B *et al*. (2018)	Finland	46.7	Men: 468 Women: 572 Total: 1040	Coffee	Questionnaire	Abdominal obesity (WC: men: ≥94, women: ≥80)	<1 cup/d (None) ≥1 cups/d <3 (Low) ≥3 cups/d <5 (Moderate) ≥5 cups/d (High)	OR: 1.17 (0.66–2.08)	1, 2, 10, 5, 4, and 6
Kim Y *et al*. (2018)	Korea	19-64	Men: 3359 Women: 5028 Total: 8387	Coffee	112-item dish-based FFQ	Abdominal obesity (WC: men: ≥90, women: ≥80)	<1 time/day 1–2 time/day 3–4 time/day ≥5 time/day	OR: 1.11 (0.86–1.43)	1 and 2
Kim S *et al*. (2019)	Korea	40-69	Men: 3862 Women: 10270 Total: 14132	Coffee	2-day 24-h dietary recall	Abdominal obesity (WC: men: ≥90, WC: women: ≥80)	None ≤1 serving/day >1 serving/day	OR: Men: 0.85 (0.66–1.11) Women: 0.87 (0.75–1.01)	1, 15, 10, 3, 5, 6, and 4

Contd...

Table 1: Contd...

Authors (Year)	Country	Age range/mean age	Sample size	Exposure	Exposure assessment	Outcome	Comparison	OR (95% CI)	Adjustments
					Abdominal obesity				
Lee D-Y and Shin S (2023)	Korea	≥65	Total: 2661	Coffee	FFQ	Abdominal obesity (WC: men: >90, women: >85)	<1 cup/day 1 cups/day 2 cups/day ≥3 cups/day	OR: 0.70 (0.42–1.16)	1, 2, 5, 6, 32, 33, 34, 35, 13, 18, 10, 36, 37, 38, and 39

FFQ: Food Frequency Questionnaire; BMI: Body mass index; WC: waist circumference; OR: Odds Ratio; NR: Not Reported. Age (1), sex (2), education level (3), physical activity (4), alcohol consumption (5), smoking (6), sugar intake in hot beverages (7), high coffee intake (8), tea intake (9), total energy intake (10), income (11), occupational status (12), macronutrients intake (13), adherence to the Mediterranean diet (14), BMI (15), nutrient information (16), place of residence (city, country) (17), marital status (18), leisure time physical activity (19), sugar and creamer additive use (20), sugar and sweets consumption (21), sitting time (22), brinkman index (23), sleeping time (24), drug treatment for hypertension, dyslipidemia, diabetes (25), Fruit and vegetable intake (26), Physical activity at work (27), diabetes, high cholesterol, hypertension (28), waist circumference (29), menopausal status (30), Basal metabolism (31), weight (32), height (33), triglyceride (34), fasting glucose (35), resistance exercise (36), aerobic exercise (37), total cholesterol (38), HDL-C (39)

Statistical analysis

We used ORs (and its 95% CIs) for obesity to calculate log ORs and their SEs. The overall effect size was calculated by using random-effects model, which takes the between-study variation into account. Cochran's Q test and I-squared (I^2) were applied to evaluate between-study heterogeneity. In this study, I^2 values of >50% were considered as a significant between-study heterogeneity. To evaluate possible publication bias, funnel plots were produced, and meta bias analysis with Begg's method was performed.[62,63] Risk of bias assessed through quality assessment of included studies, and results are shown in Table 3. To explore probable sources of heterogeneity, we performed a subgroup analysis. The predefined criteria for subgroup analyses were as follows: gender, geographic region, sample size, and methods used to assess coffee intake, adjustment of energy in OR calculation, and BMI cutoff used to assess obesity. For subgroup analyses, we used fixed-effects models. Statistical analyses were performed with use of STATA version 14 (Stata Corp). P values were considered significant at <0.05.

Results

In our initial search, we found 23403 articles. After removing duplicate citations, 21105 papers remained. Based on title and abstract screening, 21052 studies were excluded, and 53 potential related articles remained for further assessment. After removing studies that did not report necessary data, 23 studies[3,14-33,64,65] have remained to be included in this systematic review and meta-analysis. The diagram of the study selection process is shown in Figure 1.

Study characteristics

The characteristics of these studies are shown in Table 1. The sample size of included studies ranged from 115 to 83436 individuals. In total, 207551 individuals aged ≥19 years were included in this study. These articles were published between 2005 and 2023. Nine studies were conducted in Korea,[3,15,19-21,25,28-30] three in Poland,[14,17,31] three in Japan[24,64,65] two in Denmark,[16,27] and others were from Lebanon,[22] China,[26] Thailand,[32] Italy,[18] Finland,[23] and Germany.[33] Eight studies had considered general obesity as the outcome,[16,22,26,27,32,33,64,65] eleven studies considered abdominal obesity,[14,15,17,18,20,21,23-25,28,31] and four studies considered both types of obesity[3,19,29,30] as the outcome. Two studies were conducted on men,[16,26] three on women,[15,30,65] fifteen studies on both genders,[3,14,17,18,21-25,27,29,31-33,64] and three other studies had considered men and women, separately.[19,20,28] For exposure assessment, ten studies used a food frequency questionnaire (FFQ),[14,15,17-19,21,25,26,29,30] three studies used 24-h dietary recalls,[3,20,31] and ten studies had used a simple questionnaire.[16,22-24,27,28,32,33,64,65] In terms of outcome assessment, abdominal obesity was assessed by measuring waist circumference (WC) in all studies.[3,14,15,17-21,23-25,28-31]

Three studies showed a significant inverse association between coffee consumption and the odds of general obesity.[16,64,65] By

Table 2: Subgroup analysis for coffee consumption and obesity

Subgroups		Number of effect sizes	I^2	OR (95% CI)	$P_{between}$
Coffee consumption and general obesity					
Gender	Female	3	92.5	1.84 (1.51,2.24)	<0.001
	Male	3	81.8	0.99 (0.80,1.23)	
	Both	7	75.5	1.05 (0.99,1.12)	
Country	Europe	3	85.2	1.03 (0.96,1.11)	0.023
	Asia	10	87.6	1.18 (1.08,1.28)	
Sample size	Less than 1000	3	87.8	1.23 (0.90,1.68)	0.472
	more than 1000	10	87.9	1.09 (1.03,1.16)	
Assessment of coffee consumption	FFQ	5	78.9	1.48 (1.32,1.66)	<0.001
	NonFFQ	8	81.1	1.00 (0.93,1.06)	
Energy adjustment	Yes	4	93.7	1.26 (1.13,1.42)	0.005
	No	9	77.6	1.05 (0.98,1.12)	
BMI^2 cut-off used to assess obesity	BMI <30 kg/m^2	9	87.6	1.21 (1.11,1.32)	0.003
	BMI ≥30 kg/m^2	4	83.2	1.02 (0.95,1.10)	
Coffee consumption and abdominal obesity					
Gender	Female	6	90.3	1.03 (0.97,1.11)	<0.001
	Male	3	60.1	0.92 (0.77,1.11)	
	Both	9	72.6	0.83 (0.79,0.87)	
Country	Europe	5	59.4	0.90 (0.83,0.96)	0.928
	Asia	13	88.3	0.89 (0.85,0.93)	
Sample size	Less than 1000	2	0.00	1.15 (0.88,1.49)	0.061
	More than 1000	16	86.2	0.89 (0.86,0.92)	
Assessment of coffee consumption	FFQ	10	86.0	0.97 (0.92,1.02)	<0.001
	NonFFQ	8	75.4	0.82 (0.77,0.86)	
Energy adjustment	Yes	11	88.9	0.88 (0.84,0.92)	0.002
	No	7	72.1	0.92 (0.86,0.98)	

contrast, five studies reported a significant positive association between coffee consumption and odds of general obesity.[19,29,30,32,33] However, five other studies failed to reach a significant association.[3,19,22,26,27] Figure 2 Regarding abdominal obesity, four studies reported a significant inverse association between coffee intake and the odds of abdominal obesity.[3,14,15,17] Three other studies reported a significant positive association,[19,29,30] and nine studies reported no significant association [Figure 3].[18-21,23-25,28,31]

Findings from meta-analysis on coffee consumption and the odds of general obesity

Twelve studies with thirteen effect sizes were included in the meta-analysis of coffee consumption and the odds of general obesity.[3,16,19,22,26,27,29,30,32,33,64,65] One study, which had reported ORs separately for men and women, was considered as two separate studies.[19] Combining 13 effect sizes, there was no significant association between coffee consumption and odds of general obesity (OR: 1.11; 95% CI: 0.92, 1.33) [Figure 2]. A significant between-study heterogeneity was observed (I^2 = 86.9%, P < 0.001). In evaluation of publication bias, symmetry around the effect estimate line in funnel plot rejected the appearance of publication bias [Figure 4]. In addition, the results of Begg's publication bias assessment showed no evidence of publication bias in included studies on general obesity (P value = 0.127). Risk of bias for included studies on general obesity evaluated by quality assessment of them and results showed that four studies received less than 6 scores[22,26,32,65] [Table 3]. In subgroup analysis [Table 2], we found a significant positive association between coffee consumption and odds of general obesity in women (OR: 1.84; 95% CI: 1.51, 2.24) and for studies performed in Asia (OR: 1.18; 95% CI: 1.08, 1.28), those used FFQ for assessing coffee consumption (OR: 1.48; 95% CI: 1.32, 1.66), those had a sample size of more than 1000 (OR: 1.09; 95% CI: 1.03, 1.16), those considered BMI cutoff less than 30 kg/m^2 for obesity assessment (OR: 1.21; 95% CI: 1.11, 1.32), and those adjusted energy intakes in their analyses (OR: 1.26; 95% CI: 1.13, 1.42).

Findings from the meta-analysis on coffee consumption and odds of abdominal obesity

All included studies considered the lowest category of coffee intake as the reference group in their analyses, except for the study of Suliga E *et al*.[17] and Lee D-Y and Shin S.[25] We converted their reference categories before the final analysis. Therefore, the odds ratio and 95% CI for these studies were recalculated using relevant formulas. Moreover, in the study of Suliga E *et al*.,[17] the effect size was reported separately for two groups of participants, which were combined using relevant formulas. In addition, Takami H *et al*.[24] reported two ORs for abdominal obesity, based on two different cutoff points for waist circumference. Moreover, studies that reported ORs separately for men and women have considered two separate studies.[15,19,28]

Table 3: Quality of included studies based on Newcastle-Ottawa quality assessment scale adapted for cross-sectional studies

First author (Year)	Selection	Comparability	Outcome	Total
General obesity				
Suadicani P *et al*. (2005)	**	**	***	7
Kim H-J *et al*. (2014)	****	**	**	8
Nordestgaard A-T *et al*. (2015)	**	**	***	7
Platt DE *et al*. (2016)	*	*	***	5
Song F *et al*. (2016)	****	**	**	8
Kim J-H *et al*. (2017)	****	**	**	8
Lee J *et al*. (2017)	****	**	**	8
Koyama T *et al*. (2020)	**	**	**	6
Sakboonyarat B *et al*. (2020)	*		**	3
Yonekura Y *et al*. (2020)	*	**	**	5
Li Q-H *et al*. (2022)	***		**	5
Senftinger J *et al*. (2023)	***	**	***	8
Abdominal obesity				
Takami H *et al*. (2013)		**	***	5
Grosso G *et al*. (2014)	***	**	***	8
Kim H-J *et al*. (2014)	****	**	***	9
Grosso G *et al*. (2015)	****	**	***	9
Kim K *et al*. (2016)	****	**	**	8
Song F *et al*. (2016)	****	**	**	8
Suliga E *et al*. (2017)	****	**	*	7
Kim J-H *et al*. (2017)	****	**	**	8
Lee J *et al*. (2017)	****	**	***	9
Shin H *et al*. (2017)	***		**	5
Micek A *et al*. (2018)	****	**	***	9
Stutz B *et al*. (2018)	*	**	**	5
Kim Y *et al*. (2018)	****	*	**	7
Kim S *et al*. (2019)	****	**	***	9
Lee D-Y and Shin S (2023)	****	**	**	8

Finally, pooling 18 effect sizes from 15 studies,[3,14,15,17-21,23-25,28-31] we failed to find a significant association between coffee consumption and the odds of abdominal obesity (OR: 1.03; 95% CI: 0.92, 1.15) [Figure 3]. A significant between-study heterogeneity was observed ($I^2 = 84.9\%$, $P < 0.001$). In evaluation of publication bias, moderate symmetry around effect estimate line in funnel plot rejected the appearance of publication bias [Figure 4]. In addition, results of publication bias analysis with Begg's method showed no evidence of publication bias in included studies on abdominal obesity (P value = 0.089). Risk of bias for included studies on abdominal obesity evaluated by quality assessment of them and results showed that three studies received less than 6 scores[23,24,28] [Table 3]. When we did subgroup analysis [Table 2], a significant inverse association was found in both gender (OR: 0.83; 95% CI: 0.79, 0.87) and for studies performed in Europe (OR: 0.90; 95% CI: 0.83, 0.96) and Asia (OR: 0.89; 95% CI: 0.85, 0.93), those have a sample size of more than 1000 (OR: 0.89; 95% CI: 0.86, 0.92), those used other methods for assessing coffee consumption than FFQ (OR: 0.82; 95% CI: 0.77, 0.86) and those with (OR: 0.88; 95% CI: 0.84, 0.92) and without energy intake adjustment (OR: 0.92; 95% CI: 0.86, 0.98).

Discussion

Findings of the current meta-analysis on cross-sectional studies indicated no significant association between coffee consumption and odds of general and abdominal obesity. In some subgroup analyses, such as studies performed exclusively among women, we found a significant positive association between coffee consumption and odds of general obesity in women.

Findings of our study are in line with an earlier meta-analysis published in this field. In that meta-analysis, there was no significant association between coffee consumption and the odds of general and abdominal obesity; however, a significant positive association was found between coffee consumption in women and increased odds of general obesity.[34] Regarding general obesity, we failed to show a significant association between coffee consumption and the odds of obesity. In line with our findings, several previous studies reported that coffee consumption was not associated with BMI as an indicator of general obesity.[37,52,66] For instance, Bouchard *et al*.,[37] in a cross-sectional study on 3823 National Health and Nutrition Examination Survey participants in the United States, reported that the frequency of

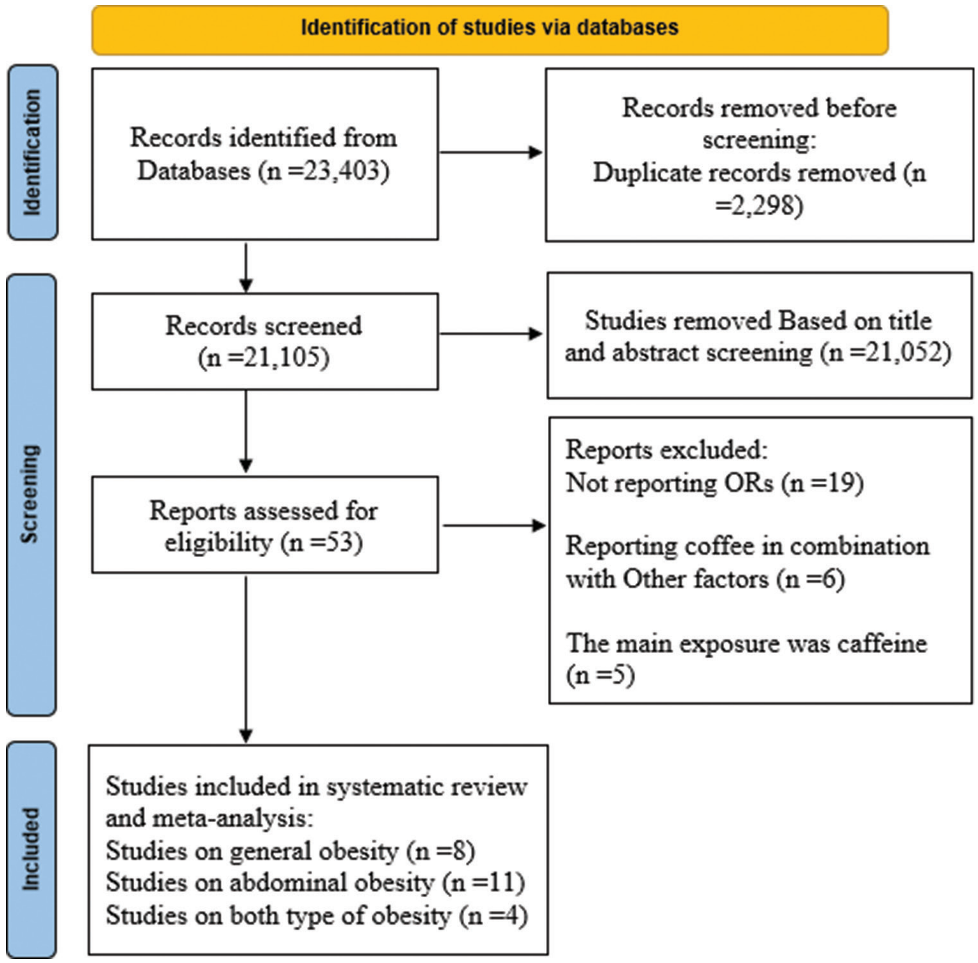

Figure 1: Flowchart of the study selection process

coffee consumption was not related to BMI in either gender. In addition, in a randomized, crossover, blind trial that assessed the effectiveness of green coffee polyphenols (300 mg twice a day for 8 weeks) in weight loss in 29 volunteers, the green coffee supplement did not significantly reduce weight.[67] In contrast with these findings, the results from a cohort study on 83436 individuals in Denmark revealed that high coffee intake was associated with a lower risk of obesity (as measured by BMI), metabolic syndrome, and type 2 diabetes.[27] Moreover, findings from Yonekura Y *et al*.[65] study showed that coffee consumption is related to the reduced odds of general obesity (assessed through body fat percentage ≥30). In addition, the findings of a meta-analysis of 15 randomized controlled trials showed that green coffee supplements significantly reduced body weight (weighted mean difference: –0.94 kg; 95% CI: –1.73, -0.16).[68] Moreover, several animal studies have also shown the beneficial effects of coffee in controlling obesity.[69-71] On the other hand, findings from two prospective studies showed that BMI increased significantly as coffee intake increased.[72,73] These discrepancies might be explained by different study designs (i.e., cohort vs cross-sectional studies). In addition, different types of consumed coffee and cutoffs used in the included studies might be other reasons for such different findings.

When we did subgroup analysis, a significant positive association was observed between coffee intake and odds of general obesity in women; however, this relationship was not significant in men. This can be attributed to the physiological and hormonal differences between the two genders.[74] For instance, studies showed that the amount of fat mass and fat-free mass in women compared with men can affect the plasma levels of caffeine and its effect.[75] The results of Domaszewski showed that about 54% of women participating in the study had reported side effects such as stress and insomnia after consuming coffee, which was significantly higher than men. Stress and insomnia can be associated with increased energy intake.[74] It must be kept in mind that most studies that reported a positive association between coffee intake and general obesity in women were conducted in Asian countries, where people usually consume their coffee with sugar and creamer which increases total energy intake.[30]

Our results indicated that coffee consumption was not associated with odds of abdominal obesity. Some other studies also reported the same findings for the association of coffee intake with waist circumference (WC) as an indicator of abdominal obesity.[37,66,76,77] In contrast to our findings, a cross-sectional study on 1902 Japanese men and women aged >40 y

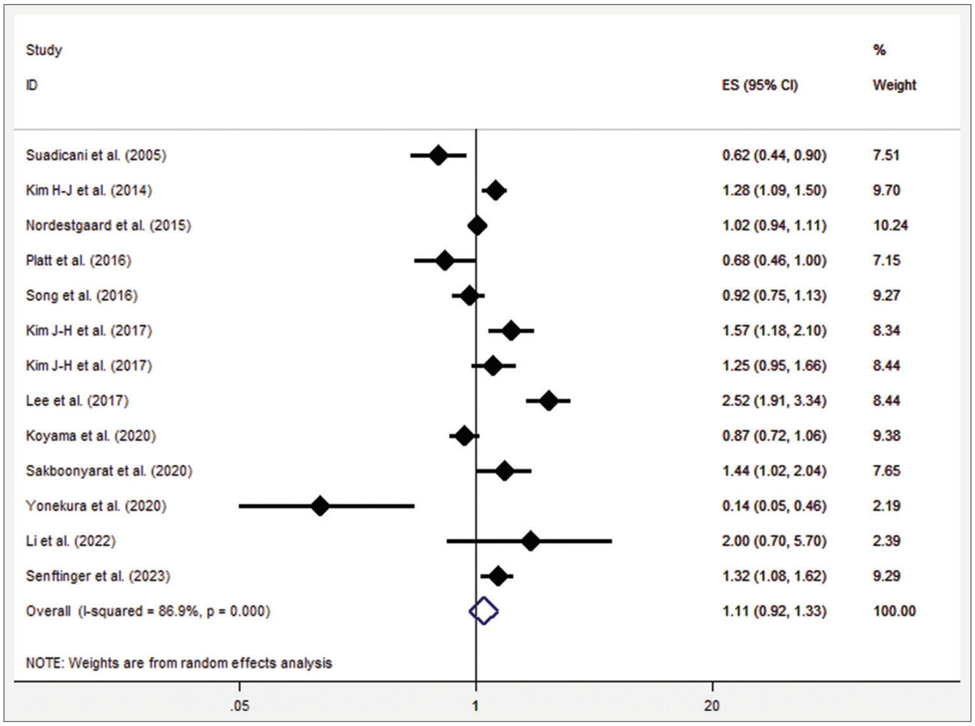

Figure 2: Forest plot of the association between coffee consumption and general obesity

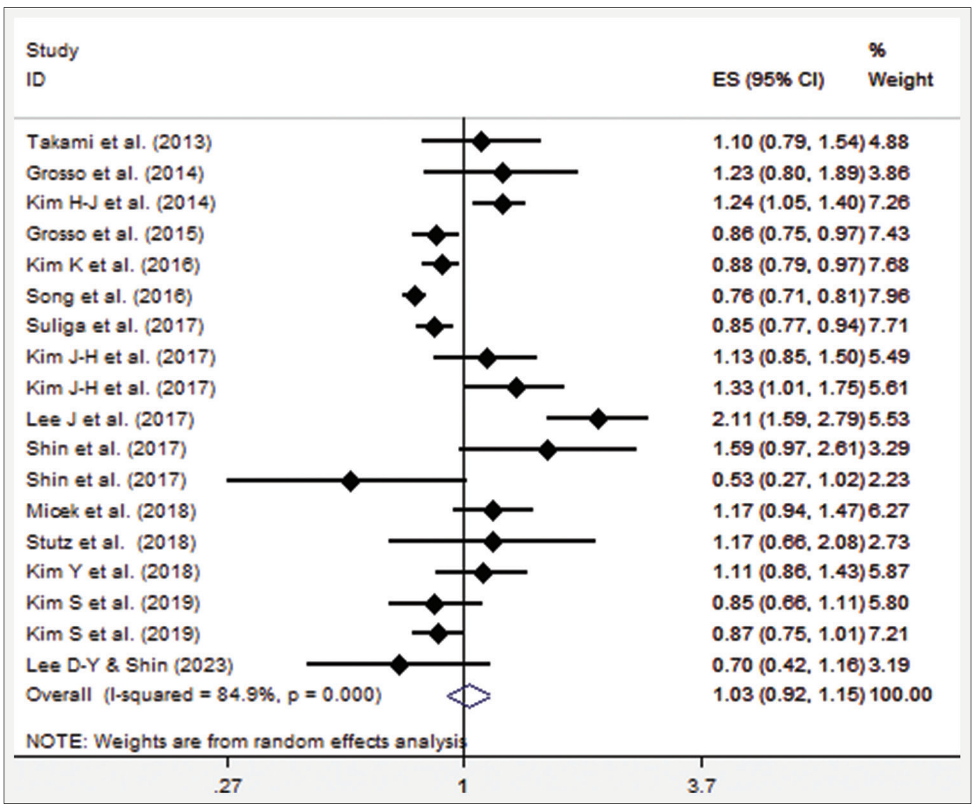

Figure 3: Forest plot of the association between coffee consumption and abdominal obesity

showed an inverse association between coffee consumption and WC.[41] Furthermore, a prospective cohort study on obesity on 1141 individuals revealed that waist circumference was significantly decreased with an increase in coffee intake.[78] Different characteristics of our included studies such as age of participants, ethnicity, cutoff points for obesity diagnosis, type of consumed coffee, and use of additives such as sugar and milk may be responsible for these discrepant results. Further

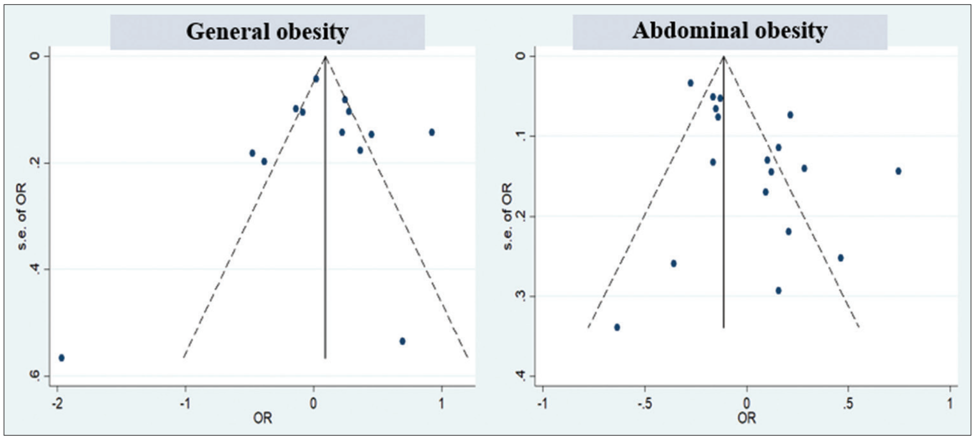

Figure 4: Funnel plot of the association between coffee and general and abdominal obesity

studies especially with prospective design are required to reach a definitive conclusion.

Coffee consumption might result in weight loss by increasing thermogenesis, fat oxidation, and lipolysis.[79] It has been demonstrated that plasma concentrations of free fatty acid (FFA) and urinary catecholamine excretion increase after caffeine or coffee ingestion.[80,81] The increased lipolysis was partly because of the enhanced release of catecholamine.[82]

This meta-analysis has an extensive literature search completed by 2 authors which resulted in a considerable number of included studies and our analysis involved studies that were not included in previous meta-analyses. Also, in this study, we examined the relationship between coffee and obesity in the form of both general and abdominal obesity. In addition, in this study, subgroup analysis was performed based on different factors to explore possible sources of heterogeneity. However, this study has several limitations. First, all included studies had a cross-sectional design, and it was impossible to confer causality. Second, evaluation of the type of coffee consumed was not performed in many included studies. Different types of coffee differ in terms of nutrients and phytochemicals. Third, different preparation methods of coffee in different cultures and different methods of coffee consumption among participants of the included studies may influence our final results. For example, in some countries, coffee is usually consumed with creamer or sugar, which cannot accurately evaluate the relationship if it is not assessed and controlled. Also, the type of coffee consumed was not evaluated in most of the studies. Fourth, our main findings might be affected by confounding factors which existed in the original included studies. Finally, the included studies did not adjust their analyses for all important covariates.

It is suggested that stronger prospective studies and more long-duration clinical trials should be conducted in the future to help clarify the relationship. Also, future studies should evaluate the type of coffee consumed and other additives that are added to coffee. It is also suggested that the effects of green coffee be further evaluated in future studies. It is also suggested to investigate the effects of decaffeinated coffee on weight control in future studies.

In conclusion, cumulative evidence from cross-sectional studies suggested that coffee consumption was not associated with the odds of obesity. Additional well-designed prospective studies in different societies are needed to confirm our findings.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1. Paiva M, Yumeen S, Kahn BJ, Nan H, Cho E, Saliba E, *et al*. Coffee, citrus, and alcohol: A review of what we drink and how it may affect our risk for skin cancer. Yale J Biol Med 2023;96:205-10.
2. Ranheim T, Halvorsen B. Coffee consumption and human health--beneficial or detrimental?--Mechanisms for effects of coffee consumption on different risk factors for cardiovascular disease and type 2 diabetes mellitus. Mol Nutr Food Res 2005;49:274-84.
3. Song F, Oh J, Lee K, Cho MS. The effect of coffee consumption on food group intake, nutrient intake, and metabolic syndrome of Korean adults—2010 KNHANES (V-1). NFS J 2016;4:9-14.
4. Shafiei F, Salari-Moghaddam A, Milajerdi A, Larijani B, Esmaillzadeh A. Coffee and caffeine intake and risk of ovarian cancer: A systematic review and meta-analysis. Int J Gynecol Cancer 2019;29:579-84.
5. Bojarczuk A, Dzitkowska-Zabielska M. Polyphenol supplementation and antioxidant status in athletes: A narrative review. Nutrients 2022;15:158.
6. Ding M, Bhupathiraju SN, Chen M, van Dam RM, Hu FB. Caffeinated and decaffeinated coffee consumption and risk of type 2 diabetes: A systematic review and a dose-response meta-analysis. Diabetes Care 2014;37:569-86.
7. Marventano S, Salomone F, Godos J, Pluchinotta F, Del Rio D, Mistretta A, *et al*. Coffee and tea consumption in relation with non-alcoholic fatty liver and metabolic syndrome: A systematic review and meta-analysis of observational studies. Clin Nutr 2016;35:1269-81.
8. Ding M, Bhupathiraju SN, Satija A, van Dam RM, Hu FB. Long-term coffee consumption and risk of cardiovascular disease: A systematic review and a dose-response meta-analysis of prospective cohort studies. Circulation 2014;129:643-59.
9. Yu X, Bao Z, Zou J, Dong J. Coffee consumption and risk of cancers: A meta-analysis of cohort studies. BMC Cancer 2011;11:96.
10. Mayoral LP, Andrade GM, Mayoral EP, Huerta TH, Canseco SP, Rodal Canales FJ, *et al*. Obesity subtypes, related biomarkers & heterogeneity. Indian J Med Res 2020;151:11-21.

11. Carmienke S, Freitag MH, Pischon T, Schlattmann P, Fankhaenel T, Goebel H, *et al*. General and abdominal obesity parameters and their combination in relation to mortality: A systematic review and meta-regression analysis. Eur J Clin Nutr 2013;67:573-85.
12. WHO. Obesity and overweight 2022. Available from: https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight.
13. Dagne S, Menber Y, Petrucka P, Wassihun Y. Prevalence and associated factors of abdominal obesity among the adult population in Woldia town, Northeast Ethiopia, 2020: Community-based cross-sectional study. PloS One 2021;16:e0247960.
14. Grosso G, Stepaniak U, Micek A, Topor-Mądry R, Pikhart H, Szafraniec K, *et al*. Association of daily coffee and tea consumption and metabolic syndrome: Results from the Polish arm of the HAPIEE study. Eur J Nutr 2015;54:1129-37.
15. Kim K, Kim K, Park SM. Association between the prevalence of metabolic syndrome and the level of coffee consumption among Korean women. PloS One 2016;11:e0167007.
16. Suadicani P, OleHein H, Gyntelberg F. Lifestyle, social class, and obesity - The Copenhagen male study. Eur J Cardiovasc Prev Rehabil 2005;12:236-42.
17. Suliga E, Kozieł D, Cieśla E, Rębak D, Głuszek S. Coffee consumption and the occurrence and intensity of metabolic syndrome: A cross-sectional study. Int J Food Sci Nut 2017;68:507-13.
18. Grosso G, Marventano S, Galvano F, Pajak A, Mistretta A. Factors associated with metabolic syndrome in a mediterranean population: Role of caffeinated beverages. J Epidemiol 2014;24:327-33.
19. Kim JH, Park YS. Light coffee consumption is protective against sarcopenia, but frequent coffee consumption is associated with obesity in Korean adults. Nutr Res (New York, NY) 2017;41:97-102.
20. Kim SA, Shin S. The association between coffee consumption pattern and prevalence of metabolic syndrome in Korean adults. Nutrients 2019;11:2992.
21. Kim Y, Je Y. Moderate coffee consumption is inversely associated with the metabolic syndrome in the Korean adult population. Br J Nutr 2018;120:1279-87.
22. Platt DE, Ghassibe-Sabbagh M, Salameh P, Salloum AK, Haber M, Mouzaya F, *et al*. Caffeine impact on metabolic syndrome components is modulated by a CYP1A2 variant. Ann Nutr Metab 2016;68:1-11.
23. Stutz B, Ahola AJ, Harjutsalo V, Forsblom C, Groop PH. Association between habitual coffee consumption and metabolic syndrome in type 1 diabetes. Nutr Metab Cardiovasc Dis 2018;28:470-6.
24. Takami H, Nakamoto M, Uemura H, Katsuura S, Yamaguchi M, Hiyoshi M, *et al*. Inverse correlation between coffee consumption and prevalence of metabolic syndrome: Baseline survey of the Japan multi-institutional collaborative cohort (J-MICC) study in Tokushima, Japan. J Epidemiol 2013;23:12-20.
25. Lee DY, Shin S. Sarcopenic obesity is associated with coffee intake in elderly Koreans. Front Public Health 2023;11:990029.
26. Li QH, Zou YW, Lian SY, Liang JJ, Bi YF, Deng C, *et al*. Sugar-sweeten beverage consumption is associated with more obesity and higher serum uric acid in chinese male gout patients with early onset. Front Nutr 2022;9:916811.
27. Nordestgaard AT, Thomsen M, Nordestgaard BG. Coffee intake and risk of obesity, metabolic syndrome and type 2 diabetes: A Mendelian randomization study. Int J Epidemiol 2015;44:551-65.
28. Shin H, Linton JA, Kwon Y, Jung Y, Oh B, Oh S. Relationship between coffee consumption and metabolic syndrome in Korean adults: Data from the 2013-2014 Korea National Health and Nutrition Examination Survey. Korean J Fam Med 2017;38:346-51.
29. Kim HJ, Cho S, Jacobs DR, Jr., Park K. Instant coffee consumption may be associated with higher risk of metabolic syndrome in Korean adults. Diabetes Res Clin Pract 2014;106:145-53.
30. Lee J, Kim HY, Kim J. Coffee consumption and the risk of obesity in Korean women. Nutrients 2017;9:1340.
31. Micek A, Grosso G, Polak M, Kozakiewicz K, Tykarski A, Puch Walczak A, *et al*. Association between tea and coffee consumption and prevalence of metabolic syndrome in Poland - results from the WOBASZ II study (2013-2014). Int J Food Sci Nutr 2018;69:358-68.
32. Sakboonyarat B, Pornpongsawad C, Sangkool T, Phanmanas C, Kesonphaet N, Tangthongtawi N, *et al*. Trends, prevalence and associated factors of obesity among adults in a rural community in Thailand: Serial cross-sectional surveys, 2012 and 2018. BMC Public Health 2020;20:850.
33. Senftinger J, Nikorowitsch J, Borof K, Ojeda F, Aarabi G, Beikler T, *et al*. Coffee consumption and associations with blood pressure, LDL-cholesterol and echocardiographic measures in the general population. Sci Rep 2023;13:4668.
34. Lee A, Lim W, Kim S, Khil H, Cheon E, An S, *et al*. Coffee intake and obesity: A meta-analysis. Nutrients 2019;11:1274.
35. Abu-Taha M, Dagash R, Mohammad BA, Basheiti I, Abu-Samak MS. Combined effect of coffee consumption and cigarette smoking on serum levels of vitamin B12, folic acid, and lipid profile in young male: A cross-sectional study. Int J Gen Med 2019;12:421-32.
36. Björner S, Rosendahl AH, Tryggvadottir H, Simonsson M, Jirström K, Borgquist S, *et al*. Coffee is associated with lower breast tumor insulin-like growth factor receptor 1 levels in normal-weight patients and improved prognosis following tamoxifen or radiotherapy treatment. Front Endocrinol 2018;9:306.
37. Bouchard DR, Ross R, Janssen I. Coffee, tea and their additives: Association with BMI and waist circumference. Obes Facts 2010;3:345-52.
38. Cao C, Liu Q, Abufaraj M, Han Y, Xu T, Waldhoer T, *et al*. Regular coffee consumption is associated with lower regional adiposity measured by DXA among US women. J Nutr 2020;150:1909-15.
39. Damiri B, Khatib O, Nazzal Z, Sanduka D, Igbaria S, Thabaleh A, *et al*. Metabolic syndrome associated with tobacco and caffeine products use among refugee adolescents: Risk of dyslipidemia. Diabetes Metab Syndr Obes 2021;14:4121-33.
40. Ghavami HS, Khoshtinat M, Sadeghi-Farah S, Kalimani AB, Ferrie S, Faraji H. The relationship of coffee consumption and CVD risk factors in elderly patients with T2DM. BMC Cardiovasc Disord 2021;21:241.
41. Hino A, Adachi H, Enomoto M, Furuki K, Shigetoh Y, Ohtsuka M, *et al*. Habitual coffee but not green tea consumption is inversely associated with metabolic syndrome: An epidemiological study in a general Japanese population. Diabetes Res Clin Pract 2007;76:383-9.
42. Jacobsen BK, Thelle DS. The Tromsø heart study: The relationship between food habits and the body mass index. J Chron Dis 1987;40:795-800.
43. Je Y, Jeong S, Park T. Coffee consumption patterns in Korean adults: The Korean national health and nutrition examination survey (2001-2011). Asia Pac J Clin Nutr 2014;23:691-702.
44. Kent LM, Worsley A. Trends in BMI, diet and lifestyle between 1976 and 2005 in North Sydney. Asia Pac J Clin Nutr 2009;18:453-61.
45. Muhammad HFL, Sulistyoningrum DC, Huriyati E, Lee YY, Manan Wan Muda WA. The interaction between coffee: Caffeine consumption, UCP2 gene variation, and adiposity in adults - A cross-sectional study. J Nutr Metab. 2019;2019:9606054.
46. Nerurkar PV, Gandhi K, Chen JJ. Correlations between coffee consumption and metabolic phenotypes, plasma folate, and vitamin B12: NHANES 2003 to 2006. Nutrients 2021;13:1348.
47. Oh MG, Han MA, Kim MW, Park CG, Kim YD, Lee J. Coffee consumption is associated with lower serum aminotransferases in the general Korean population and in those at high risk for hepatic disease. Asia Pac J Clin Nutr 2016;25:767-75.
48. Puig T, Marti B, Rickenbach M, Dai SF, Casacuberta C, Wietlisbach V, *et al.* Some determinants of body weight, subcutaneous fat, and fat distribution in 25-64 year old Swiss urban men and woman. Soz Praventivmed 1990;35:193-200.
49. Schreiber GB, Robins M, Maffeo CE, Masters MN, Bond AP, Morganstein D. Confounders contributing to the reported associations of coffee or caffeine with disease. Prev Med 1988;17:295-309.
50. Tuomilehto J, Tanskanen A, Pietinen P, Aro A, Salonen JT, Happonen P, *et al*. Coffee consumption is correlated with serum cholesterol in middle-aged Finnish men and women. J Epidemiol Commun Health 1987;41:237-42.
51. Ulvik A, Vollset SE, Hoff G, Ueland PM. Coffee consumption and circulating B-vitamins in healthy middle-aged men and women. Clin Chem 2008;54:1489-96.

52. Wan CJ, Lin LY, Yu TH, Sheu WH. Metabolic syndrome associated with habitual indulgence and dietary behavior in middle-aged health-care professionals. J Diabetes Investig 2010;1:259-65.
53. Yamaji T, Mizoue T, Tabata S, Ogawa S, Yamaguchi K, Shimizu E, *et al*. Coffee consumption and glucose tolerance status in middle-aged Japanese men. Diabetologia 2004;47:2145-51.
54. Kim J, Jo I, Joung H. A rice-based traditional dietary pattern is associated with obesity in Korean adults. J Acad Nutr Diet 2012;112:246-53.
55. Fontes AS, Pallottini AC, Vieira D, Fontanelli MM, Marchioni DM, Cesar CLG, *et al*. Demographic, socioeconomic and lifestyle factors associated with sugar-sweetened beverage intake: A population-based study. Rev Bras Epidemiol 2020;23:e200003.
56. Mirmiran P, Moslehi N, Hosseinpanah F, Sarbazi N, Azizi F. Dietary determinants of unhealthy metabolic phenotype in normal weight and overweight/obese adults: Results of a prospective study. Int J Food Sci Nutr 2020;71:891-901.
57. Pereira JL, Félix PV, Mattei J, Fisberg RM. Differences over 12 years in food portion size and association with excess body weight in the city of São Paulo, Brazil. Nutrients 2018;10:696.
58. Shih YH, Wu HC, Pan WH, Chang HY. Increased coffee, tea, or other sugar-sweetened beverage consumption in adolescents is associated with less satisfactory dietary quality, body fatness and serum uric acid profiles over the past 18 years in Taiwan. Asia Pac J Clin Nutr 2019;28:371-82.
59. Zheng M, Rangan A, Huang RC, Beilin LJ, Mori TA, Oddy WH, *et al.* Modelling the effects of beverage substitution during adolescence on later obesity outcomes in early adulthood: Results from the Raine study. Nutrients 2019;11:2928.
60. McHugh ML. Interrater reliability: The kappa statistic. Biochem Med (Zagreb) 2012;22:276-82.
61. Wells GA SB OCD, Peterson J, Welch V, Losos M, Tugwell P. The Newcastle-Ottawa Scale (NOS) for assessing the quality of nonrandomized studies in meta-analyses. 2014. Available from: http://www.ohri.ca/programs/clinical_epidemiology/oxford.htm. 2021.
62. Duval S, Tweedie R. Trim and fill: A simple funnel-plot-based method of testing and adjusting for publication bias in meta-analysis. Biometrics 2000;56:455-63.
63. Lin L, Chu H, Murad MH, Hong C, Qu Z, Cole SR, *et al*. Empirical comparison of publication bias tests in meta-analysis. J Gen Intern Med 2018;33:1260-7.
64. Koyama T, Maekawa M, Ozaki E, Kuriyama N, Uehara R. Daily consumption of coffee and eating bread at breakfast time is associated with lower visceral adipose tissue and with lower prevalence of both visceral obesity and metabolic syndrome in Japanese populations: A cross-sectional study. Nutrients 2020;12:3090.
65. Yonekura Y, Terauchi M, Hirose A, Odai T, Kato K, Miyasaka N. Daily coffee and green tea consumption is inversely associated with body mass index, body fat percentage, and cardio-ankle vascular index in middle-aged Japanese women: A cross-sectional study. Nutrients 2020;12:1370.
66. Barrea L, Muscogiuri G, Di Somma C, Annunziata G, Megna M, Falco A, *et al*. Coffee consumption, metabolic syndrome and clinical severity of psoriasis: Good or bad stuff? Arch Toxicol 2018;92:1831-45.
67. García-Cordero J, Sierra-Cinos JL, Seguido MA, González-Rámila S, Mateos R, Bravo-Clemente L, *et al*. Regular consumption of green coffee phenol, oat β-glucan and green coffee phenol/Oat β-glucan supplements does not change body composition in subjects with overweight and obesity. Foods 2022;11:679.
68. Gorji Z, Varkaneh-Kord H, Talaei S, Nazary-Vannani A, Clark CCT, Fatahi S, *et al*. Corrigendum to "The effect of green-coffee extract supplementation on obesity: A systematic review and dose-response meta-analysis of randomized controlled trials" [Phytomedicine Volume 63 October 2019 Article 153018]. Phytomedicine 2020;68:153199.
69. Bashir KMI, Kim JW, Park HR, Lee JK, Choi BR, Choi JS, *et al.* Validating the health benefits of coffee berry pulp extracts in mice with high-fat diet-induced obesity and diabetes. Antioxidants (Basel) 2023;13:10.
70. Martins BC, Soares AC, Martins FF, Resende AC, Inada KOP, Souza-Mello V, *et al*. Coffee consumption prevents obesity-related comorbidities and attenuates brown adipose tissue whitening in high-fat diet-fed mice. J Nutr Biochem 2023;117:109336.
71. Pimpley VA, Das M, Gurusiddhaiah SK, Murthy PS. Modulatory effect of green coffee bioactives on high-fat diet-induced obesity in C57BL6 mice model. Nutrition 2023;115:112141.
72. Rosengren A, Dotevall A, Wilhelmsen L, Thelle D, Johansson S. Coffee and incidence of diabetes in Swedish women: A prospective 18-year follow-up study. J Intern Med 2004;255:89-95.
73. Tuomilehto J, Hu G, Bidel S, Lindström J, Jousilahti P. Coffee consumption and risk of type 2 diabetes mellitus among middle-aged Finnish men and women. JAMA 2004;291:1213-9.
74. Domaszewski P. Gender differences in the frequency of positive and negative effects after acute caffeine consumption. Nutrients 2023;15:1318.
75. Domaszewski P, Konieczny M, Dybek T, Łukaniszyn-Domaszewska K, Anton S, Sadowska-Krępa E, *et al.* Comparison of the effects of six-week time-restricted eating on weight loss, body composition, and visceral fat in overweight older men and women. Exp Gerontol 2023;174:112116.
76. Balk L, Hoekstra T, Twisk J. Relationship between long-term coffee consumption and components of the metabolic syndrome: The Amsterdam Growth and Health Longitudinal Study. Eur J Epidemiol 2009;24:203-9.
77. Matsuura H, Mure K, Nishio N, Kitano N, Nagai N, Takeshita T. Relationship between coffee consumption and prevalence of metabolic syndrome among Japanese civil servants. J Epidemiol 2012;22:160-6.
78. Zhang Y, Lee ET, Cowan LD, Fabsitz RR, Howard BV. Coffee consumption and the incidence of type 2 diabetes in men and women with normal glucose tolerance: The strong heart study. Nutr Metab Cardiovasc Dis 2011;21:418-23.
79. Greenberg JA, Boozer CN, Geliebter A. Coffee, diabetes, and weight control. Am J Clin Nutr. 2006;84:682-93.
80. Bellet S, Kershbaum A, Finck EM. Response of free fatty acids to coffee and caffeine. Metabolism 1968;17:702-7.
81. Bellet S, Roman L, DeCastro O, Kim KE, Kershbaum A. Effect of coffee ingestion on catecholamine release. Metabolism 1969;18:288-91.
82. Takeuchi N, Higashida K, Li X, Nakai N. Glucose enhances catecholamine-stimulated lipolysis via increased glycerol-3-phosphate synthesis in 3T3-L1 adipocytes and rat adipose tissue. Mol Biol Rep 2021;48:6269-76.