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Review and Meta-analysis

Systematic review and meta-analysis of randomized, controlled trials on the effects of soy and soy products supplementation on serum adiponectin levels

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Background and aims: Our aim in this meta-analysis was to determine the effect of soy and soy product supplementation on serum adiponectin levels.
Method: A systematic search was conducted using Medline (PubMed and Web of Science), Scopus, and Cochrane Library for eligible trials up to August 2020. A random-effects model was used to pool calculated effect sizes.
Results: Seven trials were included in the overall analysis. Our analysis showed that soy and soy product supplementation did not significantly affect adiponectin concentrations (WMD = −0.77 μg/ml, 95% CI: −0.61, 2.15, P = 0.27) in comparison with a placebo. The between-study heterogeneity was high (I^2: 68.2%, P = 0.004). Subgroup analysis, based on participants' health status and duration of the supplementation, could not detect the potential source of the observed heterogeneity. In addition, subgroup analysis showed that the effect was not statistically significant in all subgroups.
Conclusion: Overall, soy and soy product supplementation did not change the circulatory adiponectin levels. In addition, the results were not affected by the participant's health status and duration of supplementation. However, further studies are needed to confirm the present results.

1. Introduction

Soy is a popular legume of Asian origin [1]. This functional food can be used to supply calories, because of its high content of fiber, protein, minerals, vitamins, phytochemicals, antioxidants, and unsaturated fatty acids [2]. The effects of soy protein consumption on cardiovascular risk factors and other endpoints have been studied in a large number of clinical trials [3–5]. Likewise, meta-analyses have documented that soy protein and soy isoflavones improve lipid profile, glycemic status, blood pressure and inflammatory markers, modestly [6–9]. In recent years, the beneficial effects of soy products on adiponectin concentrations has aroused the interest of scientists.

Adipose tissue produces several hormone-like proteins and cytokines termed adipokines [10–12]. Adiponectin is an adipokine that plays a role in several regulatory actions in human metabolism [13]. This fat-derived hormone acts as a protective protein with anti-inflammatory, anti-atherogenic, and anti-diabetic properties

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[13–17]. Decreased levels of adiponectin (hypoadiponectinemia) have been reported in most chronic diseases, including cardiovascular diseases, metabolic syndrome, non-alcoholic fatty liver disease, hypertension, and type 2 diabetes mellitus [10,14,15,18,19]. In addition, adiponectin levels are negatively correlated with overall obesity parameters [20]. Given the positive role of adiponectin in moderating many metabolic processes [13], improving the level of this hormone-like protein is the focus of many researchers.

Lifestyle modification, particularly dietary management in combination with moderate physical activity and pharmacological intervention, have been reported to increase plasma adiponectin levels [21,22]. Recently, herbal medicines have received more attention as complementary medicine because many have phytochemicals that may improve the levels of adipokines. Previous studies have reported that supplementation with curcumin [23], resveratrol [24] and green tea [25] can increase adiponectin concentrations.

Previous information regarding soy and soy product supplementation and adipokines among adults are far from conclusive [26–31]. Some studies support the effectiveness of soy food consumption in increasing adiponectin levels [26,31], while others do not [28,30].

Since the exact effects of soy and soy product supplementation on serum adiponectin concentrations are still inconclusive, a systematic review and meta-analysis of available randomized controlled trials (RCTs) seemed appropriate to summarize the current data to assess their overall effect. Therefore, we conducted a meta-analysis of available RCTs to resolve this inconsistency.

2. Methods

The current systematic review and meta-analysis were conducted in accordance with the guidelines of Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) [32].

2.1. Searches

In this systematic review and meta-analysis, two investigators searched Medline (PubMed and Web of Science), Scopus, and Cochrane Library for studies listed from the database inception to August 1, 2020. The following search terms were used in the current study: ("Soy Foods," OR "Soy," OR "Soya," OR "Tofu," OR "Natto," OR "Soybeans," OR "Soy Products," OR "Isoflavones,") AND ("adipokines," OR "adipocytokines," OR "adiponectin). Language restrictions were not applied to all search sections. Searches of potential articles were also done by analyzing the list of references of eligible studies. Discrepancies were resolved through discussion between reviewers until consensus was reached. After loading retrieved records into EndNote, duplicates were removed.

2.2. Inclusion and exclusion criteria

Two independent reviewers screened the titles and abstracts of all retrieved articles in the initial literature search, and a third author resolved disagreements. After applying inclusion and exclusion criteria, the full texts of relevant articles were further evaluated. The inclusion criteria for this meta-analysis were the PICOS (Participants, Intervention, Comparison, Outcome, Study types) framework as follows: 1) population: healthy and unhealthy adults (>18 years); 2) intervention: natural or commercial soy products; 3) comparison: control group; 4) outcome: reporting the baseline and follow-up levels of the serum concentrations of adiponectin in the intervention group or the comparison group, and 5) study design: RCTs (parallel design).

The exclusion criteria included 1) non-English articles, 2) studies without a clear control arm, 3) study duration <2 weeks, 4) studies in which participants took other food or drug supplements besides soy and soy products, and 5) the articles reporting no information on the serum concentration of adiponectin at baseline or after intervention and gave no information with which to compute it.

2.3. Data extraction and quality assessment

Data extraction was conducted independently by two reviewers. Data was extracted after the perfect match with the full manuscript reading. Conflicts over data extraction were resolved by consensus. The following information was extracted: last-named author; study location; date; the number of participants; the characteristics of the target population, such as age, sex, health status, body mass index (BMI); intervention features (including dose, type, and duration of exposure); and mean and standard deviation (SD) of the adiponectin at baseline and end of the intervention.

The RCTs were assessed for risk of bias using the Cochrane tool [30], and the quality of each article was studied by two authors. Any discrepancy was addressed through re-evaluation and consensus among the authors. This tool contains seven domains, which are random sequence generation, allocation concealment, reporting bias, performance bias, detection bias, attrition bias, and other sources of bias. A judgment of "adequate" (L) indicated a low risk of bias, whereas "inadequate" (H) indicated a high risk of bias, taking into account the recommendations of the Cochrane Handbook. We labeled uncertain or unknown risk of bias as "U".

2.4. Statistical analysis and data synthesis

All analyses were conducted using STATA statistical software (version 13.0; STATA Corporation LP, College Station, TX) using a DerSimonian-Laird random-effects model to account for heterogeneity between studies [33]. The change in means and SD of adiponectin levels between intervention and control groups was used to calculate effect sizes (weighted mean differences, WMD) with 95% confidence intervals (CI) to compare reported outcomes across studies by a meta-analysis. Heterogeneity among the studies was estimated through the use of the I^2 statistic, with values of 0–25%, 26–75%, or 76–100% representing a low, moderate, or high degree of heterogeneity, respectively [34]. Subgroup analyses were conducted based on the duration of flow up and health status to explore potential sources of heterogeneity. In order to evaluate the influence of each study on the overall effect size, sensitivity analysis was conducted using the leave-one-out method (i.e. removing one study at a time and repeating the analysis). A two-sided p-value < 0.05 was considered statistically significant.

3. Results

3.1. Literature search

The study selection process and the number of studies at each review stage are shown in a PRISMA flow diagram (Fig. 1). The initial search identified 603 articles for screening. We identified 162 duplication records. After removing duplicates, 441 relevant articles were screened by title and abstract. After screening by title and abstract 419 papers were excluded, which 22 papers were retained for full-text review; of these articles, 15 were excluded due to the lack of our inclusion criteria. Finally, a total of 7 papers [26,28–31,35,36] met the objectives and were included in the current meta-analysis.

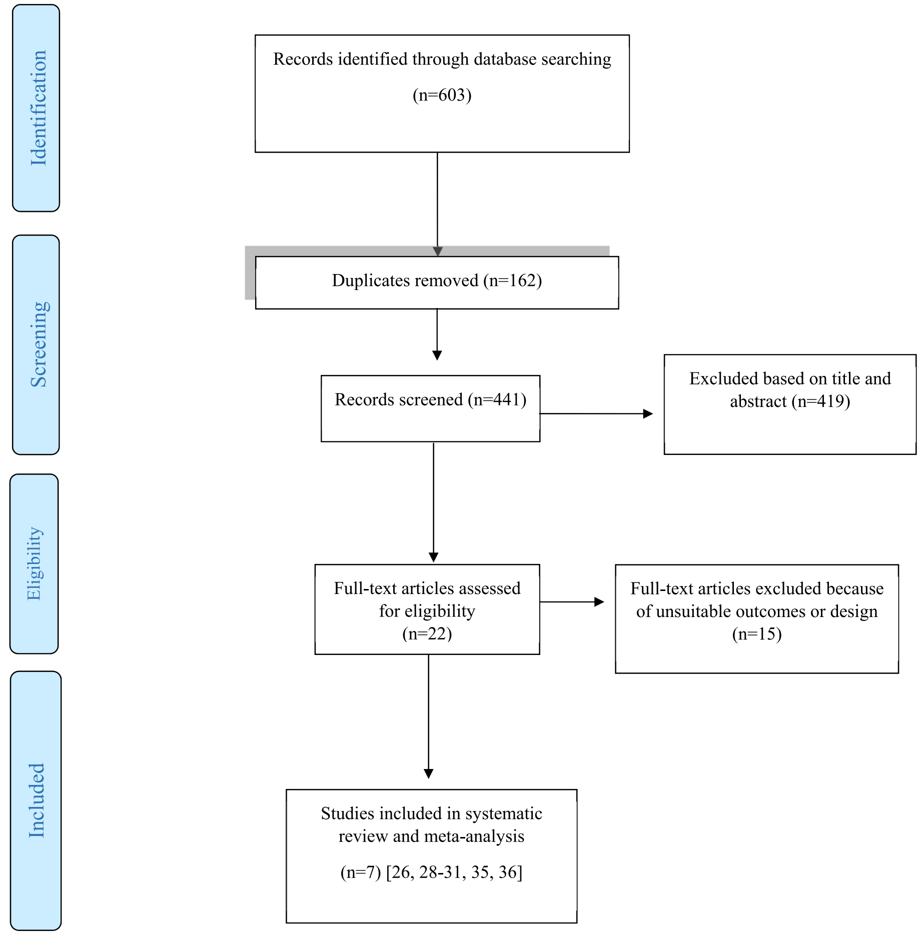

Fig. 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram of the study selection process.

3.2. *Study characteristics*

Table 1 lists the characteristics of the included studies. There were 500 participants included in these RCTs dated between 2009 and 2016. Four of the included trials were performed in the USA and the remaining studies were done in Spain, Canada, and Brazil. The RCTs' lengths ranged from between 8 and 96 weeks, with sample sizes ranging from 30 to 183 participants. The mean age of participants ranged from 43 to 69 years. Soy was used in different forms including soy protein, soybean, soy isoflavones, and soy products. All articles except one study [29] were performed on female participants. Participants were healthy, postmenopausal women [26,28,31,36], patients with metabolic syndrome [35], and prostate cancer [29]. Quality assessment characteristics of the studies are provided in Table 2.

Table 1
Summary characteristics of 7 randomized controlled trials identified in the current systematic review and meta-analysis assessing the effect of soy and soy product supplementation on adiponectin levels in adults.

Study (publication year)	Location	Sample size	Gender	Mean age (year)	Mean BMI (kg/m^2)	Duration (weeks)	Health status	Intervention	Comparator
Nadadur et al. (2016) [28]	USA	37	Female	58	NR	8	Healthy postmenopausal women	Soy protein	Control diet
Lozovoy et al. (2012) [35]	Brazil	30	Female	47	35	12	Metabolic syndrome	Soybean	Usual diet
Llaneza et al. (2011) [31]	Spain	87	Female	56	34	24	Healthy obese postmenopausal women	Diet + exercise + soy isoflavones extract	Diet + exercise
Riesco et al. (2012) [36]	Canada	55	Female	58	28	24	Healthy postmenopausa women	Exercise + soy extract	Placebo + exercise
Napora et al. (2011) [29]	USA	33	Male	69	29	12	Prostate Cancer	Soy protein	Whole milk protein
Charles et al. (2009) [26]	USA	75	Female	56	25	12	Healthy postmenopausal women	Soy protein powder	Placebo powder
Maskarinec et al. (2009) [30]	USA	183	Female	43	26	96	Healthy postmenopausal women	Soy products	Regular diet

BMI, body mass index.

Table 2
Quality of included randomized controlled trials assessing the effect of soy and soy product supplementation on adiponectin levels in adults using the Cochrane risk of bias tool.

Study (publication year)	Random Sequence Generation	Allocation concealment	Blinding of participants, personnel	Blinding of outcome assessment	Incomplete outcome data	Selective outcome reporting	Other sources of bias
Nadadur et al. (2016) [28]	L	U	L	L	U	L	U
Lozovoy et al. (2012) [35]	U	U	H	U	L	L	U
Llaneza et al. (2011) [31]	L	H	L	L	L	L	U
Riesco et al. (2012) [36]	U	L	L	U	U	U	U
Napora et al. (2011) [29]	L	U	L	U	L	U	U
Charles et al. (2009) [26]	L	L	L	U	L	L	U
Maskarinec et al. (2009) [30]	U	U	U	L	L	U	U

U, unclear risk of bias; L, low risk of bias; H, high risk of bias.

3.3. *Effects of soy and soy products supplementation on serum adiponectin concentrations*

Seven trials [26,28–31,35,36] with 500 subjects provided information on changes of adiponectinlevels following soy and soy product supplementation. As shown in Fig. 2, the results showed no significant increase in adiponectin levels after soy and soy product supplementation, compared with control groups (WMD = −0.77 μg/ml, 95% CI: −0.61, 2.15, P = 0.27), and the between-study heterogeneity was high (I2: 68.2%, P = 0.004). Subgroup analysis based on participants' health status and duration of the intervention could not detect the potential source of the observed heterogeneity. In addition, subgroup analysis showed that the effect was not statistically significant in all subgroups (Figs. 3 and 4).

3.4. *Sensitivity analysis*

We tested the robustness of our findings by sensitivity analysis. Results showed that overall estimates were not affected by the elimination of any study.

4. Discussion

The current meta-analysis showed that soy and soy product supplementation had no significant effect on serum adiponectin

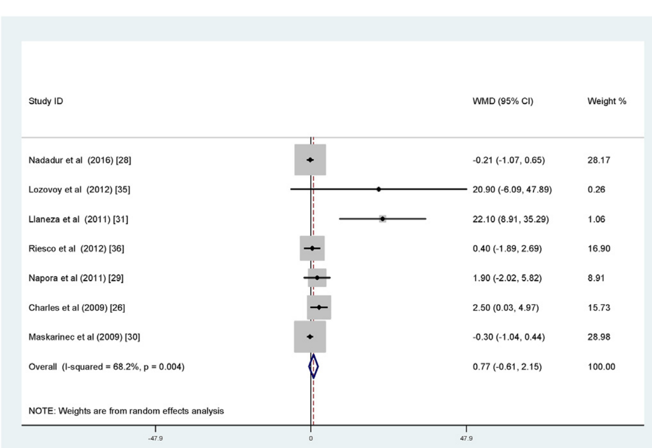

Fig. 2. Forest plot showing pooled WMDs with 95% CI for the effect of soy and soy product supplementation on adiponectin (μg/ml) in adults.

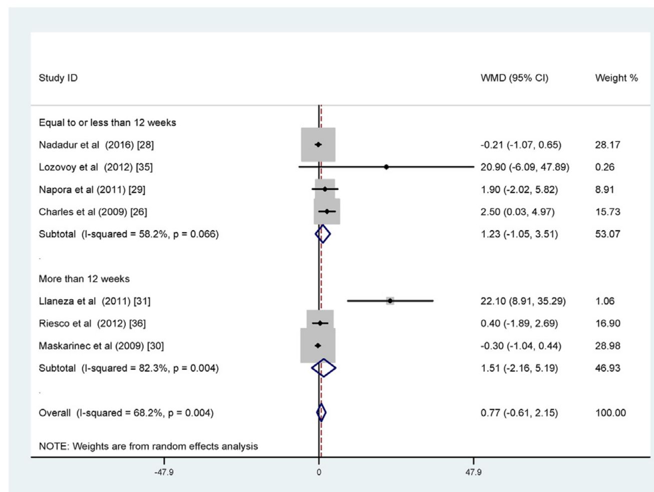

Fig. 3. Forest plot showing pooled WMDs with 95% CI for the effect of soy and soy product supplementation on adiponectin levels with subgroup analysis stratified by the duration of intervention.

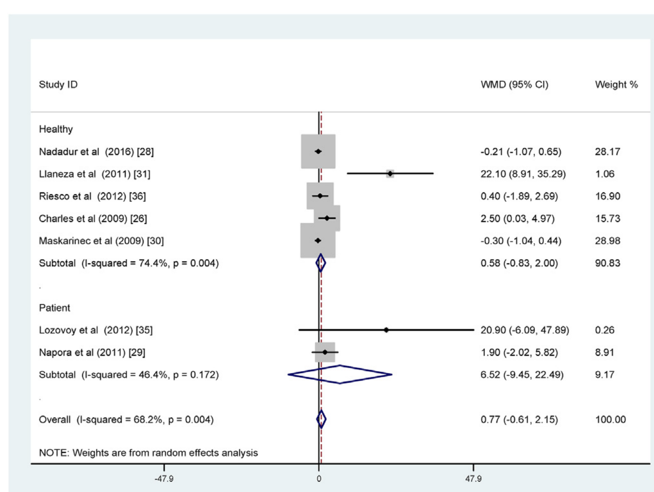

Fig. 4. Forest plot showing pooled WMDs with 95% CI for the effect of soy and soy product supplementation on adiponectin levels with subgroup analysis stratified by the participant's health status.

concentrations in adults. Statistical analysis also revealed that the heterogeneity between the seven studies was significant and the overall effects were stable in the sensitivity analysis. In addition, the results were not varied by participant's health status or duration of supplementation.

The present systematic review is not consistent with the suggestion made by a recent meta-analysis [37] which claimed that there were beneficial effects of soy isoflavone supplementation on adiponectin levels in postmenopausal women. Post menopause is associated with changes in several metabolic risk factors including decreased adiponectin [38]. Therefore, it is possible that soy and its products have a better effect on people with lower levels of adiponectin. This discrepancy is probably attributed to the difference in the method of calculating the effect size. In addition, given the high heterogeneity and the low number of studies in our analysis, these results should be interpreted with caution.

The exact mechanisms by which soy products may influence adiponectin secretion are still unclear. However, previous studies have reported that adiponectin secretion from adipocytes is reduced by oxidative stress and inflammation [39,40]. Therefore, antioxidant factor-like soy products might increase adiponectin secretion from adipose tissue [41,42]. Another mechanism that could be associated with the adiponectin increase is the nitric oxide (NO) pathway. Previous studies have reported that soy and its products can increase the production of NO in endothelial cells, resulting in increased secretion of adiponectin [43,44].

Our meta-analysis had several limitations that must be kept in mind. The main limitations of this systematic review and meta-analysis include a limited number of studies, a small sample size, and study duration. In addition, there was a notable heterogeneity between studies, resulting from differences between participants' characteristics, and the soy dosage used in the included studies. Regarding the aforementioned limitations, more investigations must be conducted to have a better understanding of the precise effect of soy products on adiponectin levels. Furthermore, we did not register the protocol of the current study on the PROSPERO registry system due to the delay in processing the submitted protocols for studies outside the UK. This lack of registration might be a source of bias for this review.

5. Conclusion

In conclusion, we found that soy and its products could not increase adiponectin levels, but we still need more RCTs with longer intervention duration, higher doses, and studies in different countries. Furthermore, the confounding effect of diet should be adjusted.

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Declaration of competing interest

The authors declare no conflict of interest.

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References

[1] Ghadimi D, Hemmati M, Karimi N, Khadive T. Soy isoflavone genistein is a potential agent for metabolic syndrome treatment: a narrative review. J Adv Medical Biomed Res 2020;28:64–75.
[2] Asbaghi O, Yaghubi E, Nazarian B, Kelishadi MR, Khadem H, Moodi V, et al. The effects of soy supplementation on inflammatory biomarkers: a systematic review and meta-analysis of randomized controlled trials. Cytokine 2020;136:155282.
[3] Teede HJ, Giannopoulos D, Dalais FS, Hodgson J, McGrath BP. Randomised, controlled, cross-over trial of soy protein with isoflavones on blood pressure and arterial function in hypertensive subjects. J Am Coll Nutr 2006;25:533–40.
[4] Ho SC, Chen Y-m, Ho SS, Woo JL. Soy isoflavone supplementation and fasting serum glucose and lipid profile among postmenopausal Chinese women: a double-blind, randomized, placebo-controlled trial. Menopause 2007;14:905–12.
[5] Kani AH, Alavian SM, Esmaillzadeh A, Adibi P, Haghighatdoost F, Azadbakht L. Effects of a low-calorie, low-carbohydrate soy containing diet on systemic inflammation among patients with nonalcoholic fatty liver disease: a parallel randomized clinical trial. Horm Metab Res 2017;49:687–92.
[6] Mosallanezhad Z, Mahmoodi M, Ranjbar S, Hosseini R, Clark CC, Carson-Chahhoud K, et al. Soy intake is associated with lowering blood pressure in adults: a systematic review and meta-analysis of randomized double-blind placebo-controlled trials. Compl Ther Med 2021;59:102692.
[7] Barańska A, Błaszczuk A, Polz-Dacewicz M, Kanadys W, Malm M, Janiszewska M, et al. Effects of soy isoflavones on glycemic control and lipid profile in patients with type 2 diabetes: a systematic review and meta-analysis of randomized controlled trials. Nutrients 2021;13:1886.
[8] Mohammadifard N, Sajjadi F, Haghighatdoost F. Effects of soy consumption on metabolic parameters in patients with metabolic syndrome: a systematic review and meta-analysis. EXCLI journal 2021;20:665.
[9] Khodarahmi M, Foroumandi E, Asghari Jafarabadi M. Effects of soy intake on circulating levels of TNF-α and interleukin-6: a systematic review and meta-analysis of randomized controlled trials. Eur J Nutr 2021;60:581–601.
[10] Hajer GR, Van Haeften TW, Visseren FL. Adipose tissue dysfunction in obesity, diabetes, and vascular diseases. Eur Heart J 2008;29:2959–71.
[11] Ghiasi S, Maleki Mansourabad S, Faridniya S, Abdollahzade Fard A, Abdollahzade Fard N. Response of leptin and C-reactive protein serum levels to 12 Weeks moderate intensity aerobic exercise in obese men. J chemical health risks 2017;7:33–7.
[12] Boghrabadi V, Hejazi M, Soltani M, Behnam Vashani H, Kharazian S, Soltani A. The effect of aerobic exercise on leptin, fasting blood sugar, blood insulin levels and insulin resistant factor in patients with type II diabetes Mellitus. Evidence Based Care 2012;2:41–9.
[13] Esmaili S, Hemmati M, Karamian M. Physiological role of adiponectin in different tissues: a review. Arch Physiol Biochem 2020;126:67–73.
[14] Ghadge AA, Khaire AA, Kuvalekar AA. Adiponectin: a potential therapeutic target for metabolic syndrome. Cytokine Growth Factor Rev 2018;39:151–8.
[15] Hui X, Lam KS, Vanhoutte PM, Xu A. Adiponectin and cardiovascular health: an update. Br J Pharmacol 2012;165:574–90.
[16] Balsan GA, Vieira JLdC, Oliveira AMd, Portal VL. Relationship between adiponectin, obesity and insulin resistance. Rev Assoc Méd Bras 2015;61:72–80.
[17] Aprahamian TR, Sam F. Adiponectin in cardiovascular inflammation and obesity. Int J Inflamm 2011;2011.
[18] Rojas E, Rodríguez-Molina D, Bolli P, Israili ZH, Faría J, Fidilio E, et al. The role of adiponectin in endothelial dysfunction and hypertension. Curr Hypertens Rep 2014;16:1–8.
[19] Tretyakova V, Zhernakova N, Arisheva O, Garmash I, Tretyakov A, Gerasimov N, et al. Meta-analysis of non-alcoholic fatty liver disease and electromechanical reconstruction of myocardium. Archives of Razi Institute 2022;77:123–8.
[20] Ricci R, Bevilacqua F. The potential role of leptin and adiponectin in obesity: a comparative review. Vet J 2012;191:292–8.
[21] Janiszewska J, Ostrowska J, Szostak-Węgierek D. The influence of nutrition on adiponectin—a narrative review. Nutrients 2021;13:1394.
[22] Sirico F, Bianco A, D'Alicandro G, Castaldo C, Montagnani S, Spera R, et al. Effects of physical exercise on adiponectin, leptin, and inflammatory markers in childhood obesity: systematic review and meta-analysis. Child Obes 2018;14:207–17.
[23] Clark CC, Ghaedi E, Arab A, Pourmasoumi M, Hadi A. The effect of curcumin supplementation on circulating adiponectin: a systematic review and meta-analysis of randomized controlled trials. Diabetes Metabol Syndr: Clin Res Rev 2019;13:2819–25.
[24] Mohammadi-Sartang M, Mazloom Z, Sohrabi Z, Sherafatmanesh S, Barati-Boldaji R. Resveratrol supplementation and plasma adipokines concentrations? A systematic review and meta-analysis of randomized controlled trials. Pharmacol Res 2017;117:394–405.
[25] Asbaghi O, Fouladvand F, Ashtary-Larky D, Bagheri R, Choghakhori R, Wong A, et al. Effects of green tea supplementation on serum concentrations of adiponectin in patients with type 2 diabetes mellitus: a systematic review and meta-analysis. Arch Physiol Biochem 2020:1–8.
[26] Charles C, Yuskavage J, Carlson O, John M, Tagalicud AS, Maggio M, et al. Effects of high-dose isoflavones on metabolic and inflammatory markers in healthy postmenopausal women. Menopause 2009;16:395.
[27] Mohammad-Shahi M, Mowla K, Haidari F, Zarei M, Choghakhori R. Soy milk consumption, markers of inflammation and oxidative stress in women with rheumatoid arthritis: a randomised cross-over clinical trial. Nutr Diet. 2016;73:139–45.

[28] Nadadur M, Stanczyk FZ, Tseng C-C, Kim L, Wu AH. The effect of reduced dietary fat and soy supplementation on circulating adipocytokines in postmenopausal women: a randomized controlled 2-month trial. Nutr Cancer 2016;68:554–9.
[29] Napora JK, Short RG, Muller DC, Carlson OD, Odetunde JO, Xu X, et al. High-dose isoflavones do not improve metabolic and inflammatory parameters in androgen-deprived men with prostate cancer. J Androl 2011;32:40–8.
[30] Maskarinec G, Steude JS, Franke AA, Cooney RV. Inflammatory markers in a 2-year soy intervention among premenopausal women. J Inflamm 2009;6:1–7.
[31] Llaneza P, González C, Fernandez-Iñarrea J, Alonso A, Diaz F, Arnott I, et al. Soy isoflavones, diet and physical exercise modify serum cytokines in healthy obese postmenopausal women. Phytomedicine 2011;18:245–50.
[32] Moher D, Liberati A, Tetzlaff J, Altman DG. Group* P. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. Ann Intern Med 2009;151:264–9.
[33] DerSimonian R, Laird N. Meta-analysis in clinical trials. Contr Clin Trials 1986;7:177–88.
[34] Higgins JP, Thompson SG, Deeks JJ, Altman DG. Measuring inconsistency in meta-analyses. Br Med J 2003;327:557–60.
[35] Lozovoy MAB, Bahls LD, Morimoto HK, Matsuo T, Dichi I. Blood pressure decrease with ingestion of a soya product (kinako) or fish oil in women with the metabolic syndrome: role of adiponectin and nitric oxide. Br J Nutr 2012;108:1435–42.
[36] Riesco E, Choquette S, Audet M, Lebon J, Tessier D, Dionne IJ. Effect of exercise training combined with phytoestrogens on adipokines and C-reactive protein in postmenopausal women: a randomized trial. Metabolism 2012;61:273–80.
[37] Tutunchi S, Koushki M, Amiri-Dashatan N, Khodabandehloo H, Hosseini H, Panahi G, et al. Effect of soy isoflavones supplementation on adiponectin levels in postmenopausal women: a meta-analysis. J Pharm Nutr Sci 2021;11:184–95.
[38] Wildman R, Mancuso P, Wang C, Kim M, Scherer P, Sowers M. Adipocytokine and ghrelin levels in relation to cardiovascular disease risk factors in women at midlife: longitudinal associations. Int J Obes 2008;32:740–8.
[39] Soares A, Guichardant M, Cozzone D, Bernoud-Hubac N, Bouzaidi-Tiali N, Lagarde M, et al. Effects of oxidative stress on adiponectin secretion and lactate production in 3T3-L1 adipocytes. Free Radic Biol Med 2005;38:882–9.
[40] Maslov LN, Naryzhnaya NV, Boshchenko AA, Popov SV, Ivanov VV, Oeltgen PR. Is oxidative stress of adipocytes a cause or a consequence of the metabolic syndrome? J clini transl endocrinol 2019;15:1–5.
[41] Detopoulou P, Panagiotakos D, Chrysohoou C, Fragopoulou E, Nomikos T, Antonopoulou S, et al. Dietary antioxidant capacity and concentration of adiponectin in apparently healthy adults: the ATTICA study. Eur J Clin Nutr 2010;64:161–8.
[42] Rizzo G. The antioxidant role of soy and soy foods in human health. Antioxidants 2020;9:635.
[43] Taku K, Lin N, Cai D, Hu J, Zhao X, Zhang Y, et al. Effects of soy isoflavone extract supplements on blood pressure in adult humans: systematic review and meta-analysis of randomized placebo-controlled trials. J Hypertens 2010;28:1971–82.
[44] Hall WL, Formanuik NL, Harnpanich D, Cheung M, Talbot D, Chowienczyk PJ, et al. A meal enriched with soy isoflavones increases nitric oxide-mediated vasodilation in healthy postmenopausal women. J Nutr 2008;138:1288–92.