# The Effect of Whey Protein on the Components of Metabolic Syndrome in Overweight and Obese Individuals; a Systematic Review and Meta-Analysis

**Article** · November 2019

DOI: 10.1016/j.dsx.2019.11.001

Diabetes & Metabolic Syndrome: Clinical Research & Reviews 13 (2019) 3121–3131

Contents lists available at ScienceDirect

Diabetes & Metabolic Syndrome: Clinical Research & Reviews

journal homepage: www.elsevier.com/locate/dsx

# The effect of whey protein on the components of metabolic syndrome in overweight and obese individuals; a systematic review and meta-analysis

Mustafa Badely [a], Mojtaba Sepandi [a], Mohammad Samadi [b], Karim Parastouei [a, *], Maryam Taghdir [a]

[a] Health Research Center, Life Style Institute, Baqiyatallah University of Medical Sciences, Tehran, Iran
[b] Exercise Physiology Research Center, Life Style Institute, Baqiyatallah University of Medical Sciences, Tehran, Iran

ARTICLE INFO

*Article history:*
Received 29 July 2019
Accepted 11 November 2019

*Keywords:*
Metabolic syndrome
Overweight
Obesity
Whey protein

ABSTRACT

*Background:* The risk of developing chronic diseases such as diabetes, cardiovascular disease, dyslipidemia, and stroke is increased following an outbreak of metabolic syndrome. Whey protein can play a major role in preventing metabolic syndrome.
*Objective:* This study was conducted to systematically evaluate the effect of whey protein on the components of metabolic syndrome in overweight and obesity patients.
*Methods:* This systematic review and meta-analysis was conducted on RCTs (PROSPERO registration number: CDR42019114794). Published articles of controlled trials between 1 January 2000 to 30 May 2019 indexed in PubMed, Scopus, Web of Science and Cochrane Library were reviewed. Keywords were Whey Protein, Metabolic Syndrome, HDL Lipoprotein, Blood Pressure, Triglyceride, Fasting Blood Glucose, Waist Circumference, Overweight and Obesity or a combination of them in the title/abstracts. The mean difference was extracted for each study. All analyses performed using STATA version 11.
*Results:* There were 2344 individuals reviewed in this systematic review of 37 published articles.
*Conclusion:* According to the results, whey supplementation significantly reduced the SBP, DBP, HDL, waist circumference, TG and FBS in intervention groups in comparing to control groups.


## 1. Introduction

Obesity is one of the factors threatening the health worldwide [1]. Metabolic syndrome is consisted of some symptoms including high fasting blood glucose, triglyceride levels, hypertension, low HDL and abdominal obesity [2,3]. Metabolic syndrome is increasing in many developed and developing countries, especially Iran [4,5]. The risk of developing chronic diseases such as diabetes, cardiovascular disease, dyslipidemia, and stroke is increased following an outbreak of metabolic syndrome [6]. There are many effective factors in the development of metabolic syndrome such as age, race, weight, smoking, low income, diet, physical activity, and occupation [7]. Various studies have shown that stressful jobs such as the army forces are prone to metabolic syndrome. According to studies conducted in various countries, including China and Brazil, it has been shown that the prevalence of metabolic syndrome in military personnel is higher than civilians [8,9]. One of the controllable factors in the development of metabolic syndrome is healthy diet. Milk and dairy products are rich regarding protein, calcium, phosphorus, potassium and magnesium [10]. Milk proteins are comprised of essential amino acids including branched-chain amino acids [11]. It has been shown in various studies that milk proteins reduce blood lipids, blood pressure and weight to prevent metabolic syndrome [12,13]. A meta-analysis study, conducted in 2018 in the United States, entitled “Milk protein supplement effect on cardiovascular risk factors,” showed that this protein decreases body weight, body fat mass, and some risk factors for heart disease such as hypertension, HDL and total cholesterol [14]. Some studies have shown that milk and dairy products associate with reduced risk of cardiovascular disease, type II diabetes and hypertension, and dairy products have beneficial effects on cholesterol, HDL, triglyceride, hypertension, fasting glucose levels

* Corresponding author.
*E-mail addresses:* msepandi@bmsu.ac.ir (M. Sepandi), Parastouei@gmail.com (K. Parastouei).

https://doi.org/10.1016/j.dsx.2019.11.001
1871-4021/

and abdominal obesity [15]. In a study by Yuna et al., it has been revealed that whey protein reduces triglyceride concentrations in patients with metabolic syndrome and improves other cardiovascular risk factors [16]. In a study by Cavass et al. it has been shown that whey protein decreases triglyceride, but it has no significant effect on LDL-C [17].

Given the high prevalence of metabolic syndrome in the military personnel and its cost effectiveness, effective interventions are needed to control complications and improve their quality of life. On the other hand, previous studies have less systematically evaluated the effects of this protein in patients with metabolic syndrome by now, and also the effects of this protein on patients have also been shown to be controversial indicating that a comprehensive systematic study is needed in this regard. Therefore, this study was conducted as a systematic review to evaluate the effect of whey protein on the components of metabolic syndrome in overweight and obesity patients.

## 2. Methods and materials

This systematic review and meta-analysis was done according to the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) statement. It was registered in PROSPERO (# CDR42019114794).

### 2.1. Search strategy

Two authors independently reviewed published studies indexed in PubMed, Scopus, Web of Science and Cochrane Central Register of Controlled Trials (CENTRAL). The following main search terms were used: whey protein, metabolic syndrome, HDL lipoprotein, blood pressure, triglyceride, fasting blood glucose, waist circumference, overweight and obesity. The full search terms were attached in Appendix(A).

### 2.2. Inclusion and exclusion criteria

Studies were selected in this meta-analysis if (a) study designs were RCTs; (b) whey protein isolate, concentrate, extract, supplement, powder and hydrolysate were the intervention; (c) participants were aged 18 years older and were overweight or obese; (d) the study had intervention for at least 2 weeks; (e) the study had a comparable placebo or control group; (f) the study assessed the outcomes of HDL lipoprotein, systolic blood pressure (SBP), diastolic blood pressure (DBP), triglyceride, fasting blood glucose and waist circumference.

### 2.3. Data extraction

The two researchers independently studied the papers. The names of the authors, the names of the journals and their results were not hidden by these researchers. In cases, there was a controversy between the researchers, it was decided through negotiation or with the guidance of a third person (observer). After selecting the studies, the required variables such as type of study, sample size, the number of overweight and obese people, and the demographic characteristics of the participants, the time and place of the study, the type and dose of whey protein were independently extracted from the studies. Non-English language studies were translated by relevant language specialists, and then the data were extracted.

### 2.4. Assessment of quality

The quality assessment of each study was done by authors using the Cochrane Collaboration's tool for assessing risk of bias in randomized trials, of which each component was categorized as having high, low, or unclear risk of bias (components were random sequence generation, blinding, allocation concealment, incomplete outcome data, and selective outcome reporting and other source of bias).

### 2.5. Statistical analysis

The mean differences between the baseline and final value of understudy factors were extracted from the studies.

### 2.6. Calculation standard deviations for changes from the baseline

For calculation SD changes from the baseline the correlation coefficient in the experimental and control group was calculated as follows:

$$\mathrm{Corr}_E = \frac{\mathrm{SD}^2_{\mathrm{E,base\ \ line}} + \mathrm{SD}^2_{\mathrm{E,final}} - \mathrm{SD}^2_{\mathrm{E,Change}}}{2 \times \mathrm{SD}_{\mathrm{E,base\ \ line}} \times \mathrm{SD}_{\mathrm{E,final}}}$$

The SD changes from the baseline calculated using the correlation coefficient in each group as follow:

$$\mathrm{SD}_{\mathrm{E,change}} = \sqrt{\mathrm{SD}^2_{\mathrm{E,baseline}} + \mathrm{SD}^2_{\mathrm{E,final}} - \left(2 \times \mathrm{Corr} \times \mathrm{SD}_{\mathrm{E,baseline}} \times \mathrm{SD}_{\mathrm{E,final}}\right)},$$

To asses of the heterogeneity between the studies, the chi-square $\chi 2$ test with P-value less than 0.05 and $I^2$ were used. the significant P Value and higher amount of $I^2$ refer to the presence of the heterogeneity. Due to the presence of heterogeneity between the studies the random-effects model with inverse variance heterogeneity was used to calculate the pooled effect size. The Begg's and Egger's regression tests were used to assessing the publication bias. Also to identify the source of heterogeneity between the studies the meta-regression analysis was conducted. The significant level for Begg's and Egger's regression test was $P < 0.1$ and for other tests the $P < 0.05$ was considered as a significant level. All analyses conducted using STATA software version 11.0 (StataCorp, College Station, TX).

## 3. Results

The total founded records in the first search were about 13461 documents. About 10392 of mentioned records excluded due to observational or other types of studies, different study groups, and different intervention or outcomes. Finally, 37 articles entered to final analysis after quality assessments. (see Table 1 and Fig. 1).

**Table 1**
Summary of the intervention and results of the included randomized controlled trials.

| Study | Follow-up | Participants | Whey Protein Group | | | Control Group | | | Results |
|---|---|---|---|---|---|---|---|---|---|
| | | | Form of Whey Protein | Dosage of Whey Protein (g/d) | Energy | Other Form of Non–Whey Protein Supplement | Dosage of Non – Whey Protein (g/d) | Energy | |
| Aldrich NO,et al(2011) [18] | 20 week | N = 18 Age:49.2 ± 1.6 BMI (kg/m$^2$):30.6 ± .6 Sex(m): male and female | powder | 56 | 6699 kj per day | Placebo and protein whey and mix | 0 | 6699 kj per day | In the whey protein group, blood pressure dropped |
| Verreijen A et al. [19](2017) | 10week | N = 100 Age:62.4 ± 5.4 BMI (kg/m$^2$):32.2 ± 4.3 Sex(m): male and female | supplement | 1.3 g/kg body mass per day | No restricted calories | control diet, exercise and exercise and whey | 1.3 g/kg body mass per day | No restricted calories | The components of metabolic syndrome in the intervention group did not change significantly |
| Arciero P.et al. [20](2016) | 16 week | N = 30 Age:50 ± 2.5 BMI (kg/m$^2$):32.5 ± 1.5 Sex(m): male and female | supplement | 25 | No restricted calories | Food protein | 25 | No restricted calories | In both groups, systolic and fasting blood glucose was similarly reduced |
| Beavers K et al. [21](2015) | 12 week | N = 24 Age:68.4 ± 5.5 BMI (kg/m$^2$):36 ± 6 Sex(m): female | powder | 3 | 1100 kj per day | Soy protein | 9 | 1100 kj per day | Diastolic blood pressure improved in the whey protein group |
| Bell K et al. [22](2017) | 19 week | N = 49 Age:73 ± 1 BMI (kg/m$^2$):28.5 ± 1.5 Sex(m): male and female | supplement | 30 | 2146 kj per day | Placebo | 22 | 2336 kj per day | The metabolic syndrome factors measured in this study, including triglyceride, HDL and waist circumference, did not significantly improve. |
| Berthold H et al. [23](2011) | 12 week | N = 131 Age:55 ± 10 BMI (kg/m$^2$):35 Sex(m): male and female | supplement | 30 | No restricted calories | Placebo | 30 | No restricted calories | Triglyceride decreased in people who received the whey protein |
| Bohl M et al. [24](2016) | 12 week | N = 25 Age:56.7 BMI (kg/m$^2$):28.8 Sex(m): female | powder | 60 | No restricted calories | casein | 60 | No restricted calories | In both groups, none of the components of metabolic syndrome was improved |
| DeNysschen C aet al. [25](2009) | 12week | N = 19 Age:28.6 ± .63 BMI (kg/m$^2$):27.5 Sex(m): male and female | supplement | 36.5 | No restricted calories | Soy and placebo | 36.5 | No restricted calories | HDL and triglyceride did not change significantly in the three groups studied |
| Fekete A et al. [26](2016) | 8week | N = 26 Age:52.9 ± 2.1 BMI (kg/m$^2$):27.1 ± .8 Sex(m): male and female | isolate | 56 | No restricted calories | Placebo and calcium caseinat | 56 | No restricted calories | The risk of lipid factors including triglyceride and blood pressure decreased significantly in the intervention group |
| Fernandes R et al. [27](2018) | 26 week | N = 32 Age:67.5 ± 4.05 BMI (kg/m$^2$):25.65 ± 2.65 Sex(m): male and female | supplement | 35 | No restricted calories | placebo | 35 | No restricted calories | Both HDL and triglyceride were recovered in both groups |
| Figueroa A et al. [28](2010) | 4 week | N = 22 Age:28 ± 1 BMI (kg/m$^2$):34.3 ± 1.4 Sex(m): male and female | supplement | 30 | No restricted calories | Casein and carbohydrate | 30 | No restricted calories | Systolic blood pressure dropped in those who received the whey protein |
| Fluegel S et al. [29](2010) | 12 week | N = 71 Age:42.8 ± 1.15 BMI (kg/m$^2$):35.55 ± .7 | hydrolyze | 28 | No restricted calories | Whey protein | 28 | No restricted calories | In the intervention group, systolic blood pressure improved |

(continued on next page)

**Table 1** (*continued* )

| Study | Follow-up | Participants | Whey Protein Group | | | Control Group | | | Results |
|---|---|---|---|---|---|---|---|---|---|
| | | | Form of Whey Protein | Dosage of Whey Protein (g/d) | Energy | Other Form of Non–Whey Protein Supplement | Dosage of Non – Whey Protein (g/d) | Energy | |
| Gouni-Berthold I et al. [16](2012) | 12week | Sex(m): male and female<br>N = 180<br>Age:53.4 ± 9.9<br>BMI (kg/m2):31.05 ± 4.1 | hydrolyze | 15.3 | No restricted calories | placebo | 14.7 | No restricted calories | Fasting triglyceride concentration decreased significantly in the intervention group |
| Gryson C et al. [30](2014) | 16 week | Sex(m): male and female<br>N = 19<br>Age:60.75 ± .4<br>BMI (kg/m$^2$):26.75 ± 1.2 | Supplement | 10 | No restricted calories | trained group with placebo drink containing 4 g of total milk protein and untrained group with placebo drink containing 4 g of total milk protein | 4 | No restricted calories | The components of metabolic syndrome measured in this study did not change significantly |
| Gulati S et al. [31](2017) | 12 week | Sex(m): male and female<br>N = 122<br>Age:37.5<br>BMI (kg/m$^2$):30.4 ± 3.5 | isolate | 100.2 | 2092 kj per day | Control diet | 44.8 | 2092 kj per day | In the intervention group, components of metabolic syndrome including waist circumference, blood pressure and triglycerides were significantly reduced |
| Hodgson J et al. [32](2011) | 96 week | Sex(m): male and female<br>N = 104<br>Age:74.3 ± 2.6<br>BMI (kg/m$^2$):26.75 ± 3.85 | isolate | 30 | No restricted calories | placebo | 2 | No restricted calories | It has been shown in this study that whey protein has no effect on blood pressure over the long term |
| Kemmler W et al. [33](2018) | 16 week | Sex(m): female<br>N = 100<br>Age:77.6<br>BMI (kg/m$^2$):26.05 | supplement | 1.7 g/kg body mass per day | No restricted calories | Placebo and high intensity training | 1.7 g/kg body mass per day | No restricted calories | In the group where the milk protein was taken with whole-body electromyostimulation, the waist circumference was reduced |
| Kemmler W et al. [34](2015) | 22 week | Sex(m): male<br>N = 118<br>Age:42.9 ± 5.62<br>BMI (kg/m$^2$): | supplement | 1.5 g/kg body mass per day | No restricted calories | Placebo and more time consuming high volume training and high intensity training | 1.5 g/kg body mass per day | No restricted calories | The metabolic syndrome factors studied were improved |
| Keogh B et al. [35](2008) | 36 week | Sex(m): male and female<br>N = 72<br>Age:50.3 ± 12.4<br>BMI (kg/m$^2$):34.4 ± 3.7 | isolate | 15 | No restricted calories | skim milk powder | 15 | No restricted calories | The risk factors for metabolic syndrome in the intervention group improved |
| Kinsey A et al. [36](2014) | 2 week | Sex(m): male and female<br>N = 44<br>Age:28.7 ± 6.76<br>BMI (kg/m$^2$):35.53 ± 6.4 | supplement | 30 | No restricted calories | Carbohydrate and casein | 30 | No restricted calories | In the short-term intervention, there was no effect on the components of the metabolic syndrome |
| Kjolbaek L et al. [37](2019) | 32 week | Sex(m): female<br>N = 86<br>Age:39<br>BMI (kg/m$^2$): 33.2 ± 3.31 | supplement | 48 | No restricted calories | Soy protein and Whey and calcium and placebo | 48 | No restricted calories | The metabolic syndrome components studied had no significant effect after intervention |
| Larsen A et al. [38](2018) | 4 week | Sex(m): male and female<br>N = 29<br>Age:<br>BMI (kg/m$^2$):35 | supplement | 110 | 895 kj per day | placebo | 110 | 2906 kj per day | The components of the metabolic syndrome of the intervention group have improved compared to control |
| Lee Y et al. [39](2006) | 12week | Sex(m): male and female<br>N = 53<br>Age:51.55 ± 11<br>BMI (kg/m$^2$):27.85 ± 4.1 | powder | 2.6 | No restricted calories | placebo | .2 | No restricted calories | whey protein had no significant effect on blood pressure |
| Matsuoka R et al. [40](2017) | 12 week | Sex(m): male and female<br>N = 37<br>Age:<br>BMI (kg/m$^2$):27.5 ± .7<br>Sex(m): male and female | powder | 8 | No restricted calories | lactic fermented egg white | 8 | No restricted calories | In the intervention group, the components studied did not improve |

**Table 1** (*continued* )

| Study | Follow-up | Participants | Whey Protein Group | | | Control Group | | | Results |
|---|---|---|---|---|---|---|---|---|---|
| | | | Form of Whey Protein | Dosage of Whey Protein (g/d) | Energy | Other Form of Non—Whey Protein Supplement | Dosage of Non — Whey Protein (g/d) | Energy | |
| Mohammadi-Sartang M et al. [41](2018) | 10 week | N = 87<br>Age:45.5 ± 8.8<br>BMI (kg/m$^2$):30.45 ± 2.4<br>Sex(m): male and female | powder | 30 | No restricted calories | Law fat conventional yogurt | 20 | No restricted calories | In the intervention group, the components of the study were recovered from metabolic syndrome |
| Hellen C et al. [42](2019) | 16 week | N = 30<br>Age:68.8 ± 4.3<br>BMI (kg/m$^2$):27 ± 4.25<br>Sex(m): female | supplement | 35 | No restricted calories | placebo | 35 | No restricted calories | In the intervention group, waist circumference was improved as one of the components of metabolic syndrome |
| Michael j et al. [43](2014) | 4 week | N = 27<br>Age:29 ± 1.8<br>BMI (kg/m$^2$):34.66 ± 1.93<br>Sex(m): female | isolate | 30 | No restricted calories | Carbohydrate and casein | 30 | No restricted calories | In the intervention group, all components of the metabolic syndrome recovered only waist circumference |
| Padhi E et al. [44](2015) | 6 week | N = 243<br>Age:55 ± 8.8<br>BMI (kg/m$^2$):28 ± 4.6<br>Sex(m): male and female | isolate | 25 | No restricted calories | High dose soy and low dose soy | 25 | No restricted calories | whey protein supplement did not affect the components of the metabolic syndrome |
| Pal S et al. [45](2009) | 12 week | N = 45<br>Age:48.3 ± 1.86<br>BMI (kg/m$^2$):31.3 ± 8.5<br>Sex(m): male and female | supplement | 54 | No restricted calories | casein | 54 | No restricted calories | Blood pressure improved in people who received the whey protein |
| Pal S et al. [46](2010) | 12 week | N = 89<br>Age: 48.3 ± 1.86<br>BMI (kg/m$^2$): 31.3 ± 8.5<br>Sex(m): male and female | supplement | 54 | No restricted calories | Casein and placebo | 54 | No restricted calories | Lipid factors, including triglyceride, have been improved in whey supplement recipients |
| Petyaev I et al. [47](2012) | 4 week | N = 20<br>Age:54.85 ± 4.38<br>BMI (kg/m$^2$):27.05 ± 3.75<br>Sex(m): male and female | isolate | 0.7 | No restricted calories | Glucose and lycopene | 0.07 | No restricted calories | The components of metabolic syndrome did not recover significantly in the recipients of whey protein supplementation |
| Piccolo B et al. [48](2014) | 8 week | N = 25<br>Age:<br>BMI (kg/m$^2$):36.45 ± 0.98<br>Sex(m): male and female | supplement | 10 | No restricted calories | Gelatin | 10 | No restricted calories | In the recipients of whey protein supplementation, the components of metabolic syndrome did not recover significantly |
| Pins J et al. [49](2006) | 6 week | N = 60<br>Age:46.1 ± 13.65<br>BMI (kg/m$^2$):28.95 ± 4.5<br>Sex(m): male and female | supplement | 4 | No restricted calories | placebo | 4 | No restricted calories | Blood pressure decreased in intervention group |
| Reimer A et al. [50](2017) | 12 week | N = 96<br>Age:39.9 ± 13.45<br>BMI (kg/m$^2$):31.52 ± 5.5<br>Sex(m): male and female | supplement | 5 | No restricted calories | Placebo and insulin-type fructans and insulin-type fructans and whey | 5 | No restricted calories | The components of the metabolic syndrome were not significantly altered |
| Vatani D et al. [51](2012) | 6 week | N = 19<br>Age:23.4 ± 3.6<br>BMI (kg/m$^2$):26.86 ± 1.9<br>Sex(m): male and female | isolate | 30 | No restricted calories | resistant exercise + placebo and placebo | 30 | No restricted calories | In the intervention group, HDL and triglyceride were significantly improved |
| Tahavorgar A et al. [52](2015) | 12week | N = 45<br>Age:39.1 ± 7.85<br>BMI (kg/m$^2$):32.1 ± 2.95 | concentrate | 65 | No restricted calories | soy | 65 | No restricted calories | In the intervention group, components of metabolic syndrome were improved |

(continued on next page)

**Table 1** (*continued*)

| Study | Follow-up | Participants | Whey Protein Group | | | Control Group | | | Results |
|---|---|---|---|---|---|---|---|---|---|
| | | | Form of Whey Protein | Dosage of Whey Protein (g/d) | Energy | Other Form of Non–Whey Protein Supplement | Dosage of Non – Whey Protein (g/d) | Energy | |
| Tovar J et al. [53](2015) | 8 week | Sex(m): male and female N = 47 Age: BMI (kg/m$^2$):25 ± 02 Sex(m): male and female | powder | 4.3 | No restricted calories | Control diet | 0 | No restricted calories | In the intervention group, lipid factors such as triglyceride and systolic blood pressure improved significantly |

### 3.1. *Effect of whey protein on components of metabolic syndrome (see Table 2 and Fig. 2)*

1. Systolic blood pressure (SBP)

According to pooled estimation results that whey supplementation significantly reduced the SBP in intervention groups in comparing to control groups (−7.46, 95% CI: 9.39,-6.13; P = <0.001).in term of heterogeneity about this parameter there was significant heterogeneity between different studies ($I^2$:99.6%, $P_{heterogeneity}$:<0.001).

#### 3.1.1. *Meta-regression*

To identify the cause of different factors on heterogeneity between studies the variables like as years of study, mean Age of participants, used dose of Protein Whey, and mean of BMI were assessed. The effect of year of Study (P: 0.65), age of participants (P: 0.47), duration of follow up (P: 0.28), mean of BMI (P: 0.09) and used dose of Whey protein (P: 0.05) on heterogeneity between studies not statistically significant.

2. Diastolic Blood Pressure(DBP)

According to pooled estimation results that whey supplementation significantly reduced the DBP in intervention groups in comparing to control groups (−5.68, 95% CI: 6.69,-4.67; P = <0.001).in term of heterogeneity about this parameter there was significant heterogeneity between different studies ($I^2$:98.9%, $P_{heterogeneity}$:<0.001).

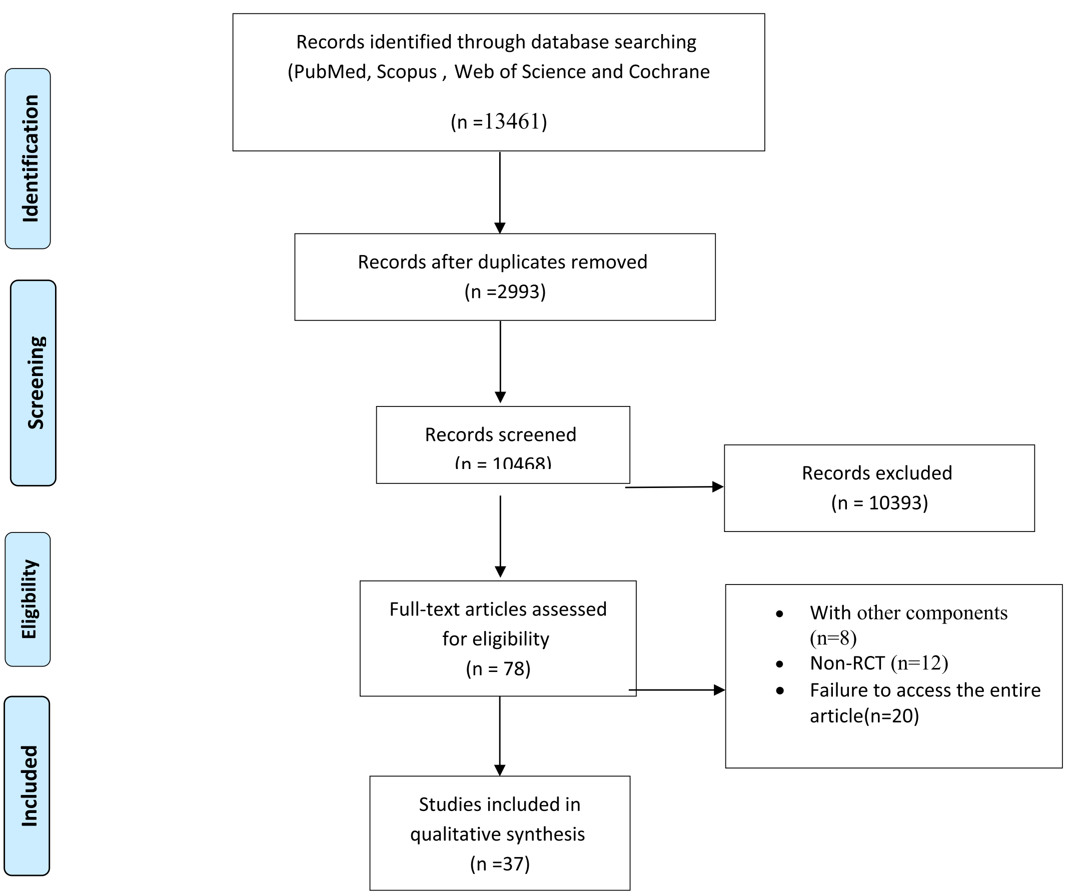


**Fig. 1.** Summary of search strategy and selection process based on included and excluded studies.

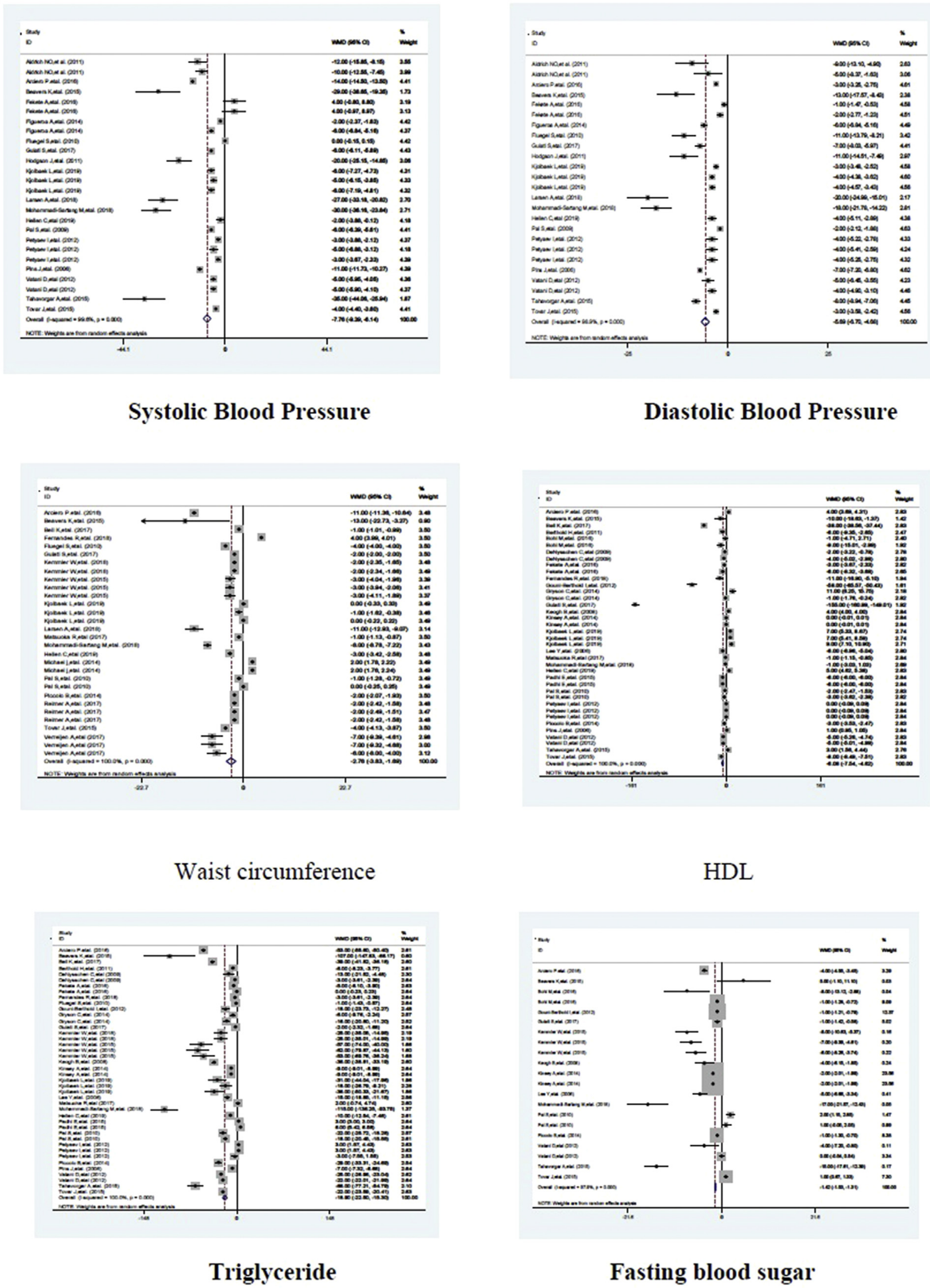


**Fig. 2.** The forest plot of Effect of Whey protein on Components of Metabolic Syndrome.

**Table 2**
The result of Effect of Whey protein on Components of Metabolic Syndrome.

| Factor | n Sample size | WMD[a] (95% CI) | P-value | $P_{heterogeneity}$ | $I^2$ (%) |
|---|---|---|---|---|---|
| SBP | | −7.46(-9.39,-6.13) | <001 | <001 | 99.6 |
| DBP | | −5.68(-6.69,-4.67) | <001 | <001 | 98.9 |
| HDL | | −6.07(-7.53, −4.61) | <001 | <001 | 100.0 |
| Waist circumference | | −2.76(-3.83, −1.69) | <001 | <001 | 100.0 |
| TG | | −18.9(-22.49,-15.30) | <001 | <001 | 100.0 |
| FBS | | −1.42(-1.52, −1.31) | <001 | <001 | 100.0 |

[a] Weighted mean difference.

### 3.1.2. Meta-regression

To identify the cause of different factors on heterogeneity between studies the variables like as years of study, mean Age of participants, used dose of Protein Whey, and mean of BMI were assessed. The effect of year of Study (P: 0.76), age of participants (P: 0.51), duration of follow up(P:0.89) on heterogeneity between studies not statistically significant. But the mean of BMI (P: 0.02) and the used dose of Whey protein (P:0.02) in studies have a significant effect on heterogeneity between studies.

## 3. **HDL**

According to pooled estimation results that whey supplementation significantly reduced the HDL in intervention groups in comparing to control groups (−6.07, 95% CI: 7.53,-4.61; P = <0.001).in term of heterogeneity about this parameter there was significant heterogeneity between different studies ($I^2$:100.0%, $P_{heterogeneity}$:<0.001).

### 3.1.3. Meta-regression

To identify the cause of different factors on heterogeneity between studies the variables like as years of study, mean Age of participants, used dose of Protein Whey, and mean of BMI were assessed. The effect of year of Study (P: 0.35), age of participants (P: 0.47), duration of follow up (P:0.27), mean of BMI (P:0.91) and used dose of Whey protein(P: 0.76) on heterogeneity between studies not statistically significant.

## 4. Waist circumference

According to pooled estimation results that whey supplementation significantly reduced the HDL in intervention groups in comparing to control groups (−2.76, 95% CI: 3.83,-1.69; P = <0.001).in term of heterogeneity about this parameter there was significant heterogeneity between different studies ($I^2$:100.0%, $P_{heterogeneity}$:<0.001).

### 3.1.4. Meta-regression

To identify the cause of different factors on heterogeneity between studies the variables like as years of study, mean Age of participants, used dose of Protein Whey, and mean of BMI were assessed. The effect of year of Study (P: 0.59), age of participants (P: 0.48), duration of follow up(P(0.36), mean of BMI (0.30) and used dose of Whey protein(P: 0.25) on heterogeneity between studies not statistically significant.

## 5. Triglyceride (TG)

According to pooled estimation results that whey supplementation significantly reduced the HDL in intervention groups in comparing to control groups (−18.19, 95% CI: 22.49,-15.30; P = <0.001).in term of heterogeneity about this parameter there was significant heterogeneity between different studies ($I^2$:100.0%, $P_{heterogeneity}$:<0.001).

### 3.1.5. Meta-regression

To identify the cause of different factors on heterogeneity between studies the variables like as years of study, mean Age of participants, used dose of Protein Whey, and mean of BMI were assessed. The effect of year of Study (P: 0.13), age of participants (P: 0.98), duration of follow up(P:0.28), mean of BMI (P:0.07) and used dose of Whey protein(P: 0.23) on heterogeneity between studies not statistically significant.

## 6. Fasting blood sugar(FBS)

According to pooled estimation results that whey supplementation significantly reduced the HDL in intervention groups in comparing to control groups (−1.42, 95% CI: 1.52,-1.31; P = <0.001).in term of heterogeneity about this parameter there was significant heterogeneity between different studies ($I^2$:100.0%, $P_{heterogeneity}$:<0.001).

### 3.1.6. Meta-regression

To identify the cause of different factors on heterogeneity between studies the variables like as years of study, mean Age of participants, used dose of Protein Whey, and mean of BMI were assessed. The effect of year of Study (P: 0.19), age of participants (P: 0.84), duration of follow up (P: 0.33), mean of BMI (P: 0.81) on heterogeneity between studies not statistically significant. But the effect of the used dose of Whey protein on heterogeneity was statistical significant (P: 0.0.4).

### 3.1.7. Publication bias

According to results of Begg's test there was publication bias in some factors (0.34,0.03,0.01,0.07,0.001,0.15) But according to Egger's test, there was no evidence of publication bias (0.31, 0.37, 0.51, 0.23, 0.83,0.64) about understudy subject.

## 4. Discussion

Metabolic syndrome is increasing in many developed and developing countries, especially in Iran [54]. Groening et al. reported the prevalence of metabolic syndrome 15% to 63% in European countries and 12.1% to 31.1% in Asian countries [55]. According to global statistics, one-fourth of the adult populations in the United States suffer from metabolic syndrome [5]. Studies in different provinces of Iran have reported that the prevalence of metabolic syndrome is 21.9%–31.1% [5,56]. This study was carried out on the effect of whey protein on the components of metabolic syndrome in overweight and obesity patients. According to the results, whey supplementation significantly reduced metabolic syndrome's components including SBP, DBP, HDL, waist circumference, TG and FBS in intervention groups in comparing to control groups. Totally results showed effective role of whey protein on metabolic syndrome. Albeit some studies in our review were inconsistent with the pooled results of this systematic review e.g. Verreijen A et al., in 2017, Gryson C et al., in 2014, Padhi E et al., in 2015, Petyaev I et al., in 2012, Piccolo B et al., in 2014 and Reimer A et al., in 2017 revealed that the components of metabolic syndrome in the intervention group did not change significantly.

Wirunsawanya et al., in 2017 conducted a study to investigate the effect of whey protein supplementation on the physical and risk factors of cardiovascular disease in overweight and obese individuals. This study was conducted by searching the Medline, Embase, Cochrane Central databases by 2015 on the human who used the whey supplement. In this study, a total of eight clinical trials were selected for a period of intervention of at least two weeks and a total of 439 subjects. Parameters included HDL, LDL, GLUCOSE, total cholesterol, triglyceride, and body composition. The results of this study showed that HDL, cholesterol and glucose decreased with consumption of whey protein [14]. This study had significant results just in HDL, cholesterol and glucose. In this regard, there were some studied consistent with the mentioned results e.g. Pal et al. conducted a study in 2008 for examining the effects of whey protein on cardio-metabolic risk factors. This article, by searching the Pubmed database, published studies between 1970 and 2012 examined the effect of whey protein on the treatment of metabolic syndrome. In this study, protein was studied as a beverage, food additive, powder and isolate. The results of the study showed that whey proteins improves the level of blood glucose, insulin response and lipid profiles [57].

Zhang et al., in 2016 conducted a study to investigate the effects of whey protein on lipid profiles. In this study, a total of 13 clinical trials that intervened for at least four weeks were studied. The parameters studied were LDL, HDL, cholesterol and triglyceride. Protein was isolated as food additive and supplements with doses ranging from 0.6 to 51 g/day for 4–48 weeks. The results of the study showed that the concentration of triglyceride decreased, while the concentration of cholesterol, LDL, and HDL had no significant effect [58]. Some studies were consistent with the results of Pal et al. e.g. Berthold H et al., in 2011 indicated that triglyceride decreased in people who received the whey protein. Gouni-Berthold et al., in 2012 indicated that fasting triglyceride concentration decreased significantly in the intervention group.

Tovar J et al., in 2015 showed that in the intervention group, lipid factors such as triglyceride improved significantly or Vatani D in 2012 confirmed the reductive effect of whey protein on HDL and triglyceride. These results were approved by Fekete A et al., in 2016 and Gulati S et al., in 2017. But some studies were not consistent as well such as Bell K et al., in 2017 showed that triglyceride, HDL and waist circumference did not significantly improve. Also, in the study of DeNysschen C et al., in 2009, HDL and triglyceride did not change significantly in the three groups studied. In the study of Fernandes R et al., in 2018, both HDL and triglyceride were recovered in the both groups without significant difference. In a study by Wright et al., in 2015, on the possible effects of whey protein on glucose tolerance and insulin response in overweight and obese individuals, blood glucose parameters, insulin response were evaluated. After 36 weeks of intervention, it has been shown that there is no relationship between the uses of protein supplementation with hemostatic glucose, including fasting blood glucose [59].

Tahavorgar et al., in 2015 performed a study to compare the effects of whey protein with soy protein in a number of cardiovascular risk factors. In this study, a 26-membered group of protein drinkers and a 19-member soy drink group consumed 30 min before meals. After 12 weeks of intervention, it was shown that in the group that consumed whey protein, blood pressure, LDL and HDL had a significant decrease compared to the other group [52]. These results were consistent with our systematic and meta-analysis. Regarding blood pressure, there are some studies with the same results e.g. Tovar J et al., in 2015 showed that in the intervention group, systolic blood pressure improved significantly consistent with the studies of Pins J et al., in 2006, Gulati S et al., in 2017, Fluegel S et al., in 2010, Fekete A et al., in 2016 and Pal S et al., 2009. But Lee Y et al., in 2006 and Hodgson J et al., in 2011 showed the opposite results indicating increasing effect of whey protein on blood pressure.

## Ethical considerations

Ethical subjects such as plagiarism and double publication have observed in this study.

## Declaration of competing interest

The authors declare that there is no conflict of interest in this study.

## Appendix A

*PubMed:*

("Whey Protein" OR (Protein AND Whey)) AND ("Metabolic Syndrome" OR (Syndrome AND Metabolic) OR "Metabolic Syndrome X″ OR "Insulin Resistance Syndrome X″ OR ("Syndrome X″ AND Metabolic) OR ("Syndrome X″ AND "Insulin Resistance") OR "Metabolic X Syndrome" OR (Syndrome AND Metabolic) OR ("X Syndrome" AND Metabolic) OR "Dysmetabolic Syndrome X" OR ("Syndrome X″ AND Dysmetabolic) OR "Reaven Syndrome X″ OR ("Syndrome X″ AND Reaven) OR "Metabolic Cardiovascular Syndrome" OR ("Cardiovascular Syndrome" AND Metabolic) OR (Syndrome AND "Metabolic Cardiovascular") OR "HDL Lipoprotein" OR "Heavy Lipoprotein" OR (Lipoprotein AND Heavy) OR "High Density Lipoprotein" OR (Lipoprotein AND "High Density") OR "HDL" OR "HDL-c" OR "HDL cholesterol" OR cholesterol OR hypertension OR ("Blood Pressure" AND High) OR "High Blood Pressure" OR Triglyceride OR "TG" OR Triacylglycerol OR "Fasting Blood Sugar" OR "Fasting Blood glucose" OR (Sugar AND Blood) OR (Glucose AND Blood) OR "FBS" OR (Circumference AND Waist) OR "Waist Circumference" OR "WC")

*Scopus:*

(ALL("Whey Protein") OR (ALL(Protein) AND ALL(Whey))) AND (TITLE-ABS("Metabolic Syndrome") OR (TITLE-ABS(Syndrome) AND TITLE-ABS(Metabolic)) OR ALL("Metabolic Syndrome X") OR ALL("Insulin Resistance Syndrome X″) OR (ALL("Syndrome X″) AND ALL(Metabolic)) OR (ALL("Syndrome X″) AND ALL("Insulin Resistance")) OR ALL("Metabolic X Syndrome") OR (ALL(Syndrome) AND ALL(Metabolic)) OR (ALL("X Syndrome") AND ALL(Metabolic)) OR ALL("Dysmetabolic Syndrome X") OR (ALL("Syndrome X″) AND ALL(Dysmetabolic)) OR ALL("Reaven Syndrome X″) OR (ALL("Syndrome X″) AND ALL(Reaven)) OR ALL("Metabolic Cardiovascular Syndrome") OR (ALL("Cardiovascular Syndrome") AND ALL(Metabolic)) OR (ALL(Syndrome) AND ALL("Metabolic Cardiovascular")) OR ALL("HDL Lipoprotein") OR ALL("Heavy Lipoprotein") OR (ALL(Lipoprotein) AND ALL(Heavy)) OR ALL("High Density Lipoprotein") OR (TITLE-ABS(Lipoprotein) AND TITLE-ABS("High Density")) OR ALL("HDL") OR ALL("HDL-c") OR ALL("HDL cholesterol") OR TITLE-ABS(cholesterol) OR ALL(hypertension) OR (ALL("Blood Pressure") AND ALL(High)) OR ALL("High Blood Pressure") OR TITLE-ABS(Triglyceride) OR ALL("TG") OR ALL(Triacylglycerol) OR ALL("Fasting Blood Sugar") OR ALL("Fasting Blood glucose") OR (ALL(Sugar) AND ALL(Blood)) OR (ALL(Glucose) AND ALL(Blood)) OR ALL("FBS") OR (TITLE-ABS(Circumference) AND TITLE-ABS(Waist)) OR ALL("Waist Circumference") OR ALL("WC"))

*Web of Science:*

(TS=("Whey Protein") OR (TS=(Protein) AND TS=(Whey))) AND (TS=("Metabolic Syndrome") OR (TS=(Syndrome) AND TS=(Metabolic)) OR TS=("Metabolic Syndrome X") OR TS=("Insulin Resistance Syndrome X″) OR (TS=("Syndrome X″) AND TS=(Metabolic))

OR (TS=("Syndrome X") AND TS=("Insulin Resistance")) OR TS=("Metabolic X Syndrome") OR (TS=(Syndrome) AND TS=(Metabolic)) OR (TS=("X Syndrome") AND TS=(Metabolic)) OR TS=("Dysmetabolic Syndrome X") OR (TS=("Syndrome X") AND TS=(Dysmetabolic)) OR TS=("Reaven Syndrome X") OR (TS=("Syndrome X") AND TS=(Reaven)) OR TS=("Metabolic Cardiovascular Syndrome") OR (TS=("Cardiovascular Syndrome") AND TS=(Metabolic)) OR (TS=(Syndrome) AND TS=("Metabolic Cardiovascular")) OR TS=("HDL Lipoprotein") OR TS=("Heavy Lipoprotein") OR (TS=(Lipoprotein) AND TS=(Heavy)) OR TS=("High Density Lipoprotein") OR (TS=(Lipoprotein) AND TS=("High Density")) OR TS=("HDL") OR TS=("HDL-c") OR TS=("HDL cholesterol") OR TS=(cholesterol) OR TS=(hypertension) OR (TS=("Blood Pressure") AND TS=(High)) OR TS=("High Blood Pressure") OR TS=(Triglyceride) OR TS=("TG") OR TS=(Triacylglycerol) OR TS=("Fasting Blood Sugar") OR TS=("Fasting Blood glucose") OR (TS=(Sugar) AND TS=(Blood)) OR (TS=(Glucose) AND TS=(Blood)) OR TS=("FBS") OR (TS=(Circumference) AND TS=(Waist)) OR TS=("Waist Circumference") OR TS=("WC"))

*Cochrane:*

("Whey Protein" OR (Protein AND Whey)) AND ("Metabolic Syndrome" OR (Syndrome AND Metabolic) OR "Metabolic Syndrome X" OR "Insulin Resistance Syndrome X" OR ("Syndrome X" AND Metabolic) OR ("Syndrome X" AND "Insulin Resistance") OR "Metabolic X Syndrome" OR (Syndrome AND Metabolic) OR ("X Syndrome" AND Metabolic) OR "Dysmetabolic Syndrome X" OR ("Syndrome X" AND Dysmetabolic) OR "Reaven Syndrome X" OR ("Syndrome X" AND Reaven) OR "Metabolic Cardiovascular Syndrome" OR ("Cardiovascular Syndrome" AND Metabolic) OR (Syndrome AND "Metabolic Cardiovascular") OR "HDL Lipoprotein" OR "Heavy Lipoprotein" OR (Lipoprotein AND Heavy) OR "High Density Lipoprotein" OR (Lipoprotein AND "High Density") OR "HDL" OR "HDL-c" OR "HDL cholesterol" OR cholesterol OR hypertension OR ("Blood Pressure" AND High) OR "High Blood Pressure" OR Triglyceride OR "TG" OR Triacylglycerol OR "Fasting Blood Sugar" OR "Fasting Blood glucose" OR (Sugar AND Blood) OR (Glucose AND Blood) OR "FBS" OR (Circumference AND Waist) OR "Waist Circumference" OR "WC")

## References


[1] Sun B, Karin M. Obesity, inflammation, and liver cancer. J Hepatol 2012;56(3):704–13.

[2] Shiwaku K, Nogi A, Kitajima K, Anuurad E, Enkhmaa B, Yamasaki M, et al. Prevalence of the metabolic syndrome using the modified ATP III definitions for workers in Japan, Korea and Mongolia. J Occup Health 2005;47(2):126–35.

[3] Mcneill AM, Rosamond WD, Girman CJ, Schmidt MI, East HE, Ballantyne CM, et al. The metabolic syndrome and 11-year risk of incident cardiovascular disease in the atherosclerosis risk in communities study. Diabetes Care 2005;28.

[4] Nolan PB, Carrick-Ranson G, Stinear JW, Reading SA, Dalleck LC. Prevalence of metabolic syndrome and metabolic syndrome components in young adults: a pooled analysis. Prev Med Rep. 2017;7:211–5.

[5] Azizi F, Salehi P, Etemadi A, Zahedi-Asl S. Prevalence of metabolic syndrome in an urban population: tehran lipid and glucose study. Diabetes Res Clin Pract 2003;61(1):29–37.

[6] Jaber LA, Brown MB, Hammad A, Zhu Q, Herman WH. The prevalence of the metabolic syndrome among Arab Americans. Diabetes Care 2004;27(1):234–8.

[7] Park Y-W, Zhu S, Palaniappan L, Heshka S, Carnethon MR, Heymsfield SB. The metabolic syndrome: prevalence and associated risk factor findings in the US population from the Third National Health and Nutrition Examination Survey, 1988-1994. Arch Intern Med 2003;163(4):427–36.

[8] Feng Y-l, Zheng G-y, Ling C-q. The investigation of the correlation between metabolic syndrome and Chinese medicine constitution types in senior retired military personnel of the People's Liberation Army. Chin J Integr Med 2012;18(7):485–9.

[9] Filho RTB, D'Oliveira Jr A. The prevalence of metabolic syndrome among soldiers of the military police of Bahia state, Brazil. Am J Men's Health 2014;8(4):310–5.

[10] Kratz M, Baars T, Guyenet S. The relationship between high-fat dairy consumption and obesity, cardiovascular, and metabolic disease. Eur J Nutr 2013;52(1):1–24.

[11] Traverso N, Balbis E, Sukkar SG, Furfaro A, Sacchi-Nemours AM, Ferrari C, et al. Oxidative stress in the animal model: the possible protective role of milk serum protein. Mediterr J Nutr Metab 2010;3(2):173–8.

[12] Bowen J, Noakes M, Clifton PM. Appetite regulatory hormone responses to various dietary proteins differ by body mass index status despite similar reductions in ad libitum energy intake. J Clin Endocrinol Metab 2006;91(8):2913–9.

[13] Petersen BL, Ward LS, Bastian ED, Jenkins AL, Campbell J, Vuksan V. A whey protein supplement decreases post-prandial glycemia. Nutr J 2009;8(1):47.

[14] Wirunsawanya K, Upala S, Jaruvongvanich V, Sanguankeo A. Whey protein supplementation improves body composition and cardiovascular risk factors in overweight and obese patients: a systematic review and meta-analysis. J Am Coll Nutr 2018;37(1):60–70.

[15] Rice BH, Cifelli CJ, Pikosky MA, Miller GD. Dairy components and risk factors for cardiometabolic syndrome: recent evidence and opportunities for future research. Adv Nutr 2011;2(5):396–407.

[16] Gouni-Berthold I, Schulte DM, Krone W, Lapointe J-F, Lemieux P, Predel H-G, et al. The whey fermentation product malleable protein matrix decreases TAG concentrations in patients with the metabolic syndrome: a randomised placebo-controlled trial. Br J Nutr 2012;107(11):1694–706.

[17] Kawase M, Hashimoto H, Hosoda M, Morita H, Hosono A. Effect of administration of fermented milk containing whey protein concentrate to rats and healthy men on serum lipids and blood pressure. J Dairy Sci 2000;83(2):255–63.

[18] Aldrich ND, Reicks MM, Sibley SD, Redmon JB, Thomas W, Raatz SK. Varying protein source and quantity do not significantly improve weight loss, fat loss, or satiety in reduced energy diets among midlife adults. Nutr Res (NY) 2011;31(2):104–12.

[19] Verreijen AM, Engberink MF, Memelink RG, Van der Plas SE, Visser M, Weijs PJ. Effect of a high protein diet and/or resistance exercise on the preservation of fat free mass during weight loss in overweight and obese older adults: a randomized controlled trial. Nutr J 2017;16(1):10.

[20] Arciero P, Edmonds R, Bunsawat K, Gentile C, Ketcham C, Darin C, et al. Protein-pacing from food or supplementation improves physical performance in overweight men and women: the PRISE 2 study. Nutrients 2016;8(5):288.

[21] Beavers KM, Gordon M, Easter L, Beavers D, Hairston K, Nicklas B, et al. Effect of protein source during weight loss on body composition, cardiometabolic risk and physical performance in abdominally obese, older adults: a pilot feeding study. J Nutr Health Aging 2015;19(1):87–95.

[22] Bell KE, Snijders T, Zulyniak M, Kumbhare D, Parise G, Chabowski A, et al. A whey protein-based multi-ingredient nutritional supplement stimulates gains in lean body mass and strength in healthy older men: a randomized controlled trial. PLoS One 2017;(7):12. e0181387.

[23] Berthold H, Schulte D, Lapointe J-F, Lemieux P, Krone W, Gouni-Berthold I. The whey fermentation product malleable protein matrix decreases triglyceride concentrations in subjects with hypercholesterolemia: a randomized placebo-controlled trial. J Dairy Sci 2011;94(2):589–601.

[24] Bohl M, Bjørnshave A, Larsen M, Gregersen S, Hermansen K. The effects of proteins and medium-chain fatty acids from milk on body composition, insulin sensitivity and blood pressure in abdominally obese adults. Eur J Clin Nutr 2017;71(1):76.

[25] DeNysschen CA, Burton HW, Horvath PJ, Leddy JJ, Browne RW. Resistance training with soy vs whey protein supplements in hyperlipidemic males. J Int Soc Sport Nutr 2009;6(1):8.

[26] Fekete AA, Giromini C, Chatzidiakou Y, Givens DI, Lovegrove JA. Whey protein lowers blood pressure and improves endothelial function and lipid biomarkers in adults with prehypertension and mild hypertension: results from the chronic Whey2Go randomized controlled trial. Am J Clin Nutr 2016;104(6):1534–44.

[27] Fernandes RR, Nabuco HC, Junior PS, Cavalcante EF, Fabro PM, Tomeleri CM, et al. Effect of protein intake beyond habitual intakes following resistance training on cardiometabolic risk disease parameters in pre-conditioned older women. Exp Gerontol 2018;110:9–14.

[28] Figueroa A, Wong A, Kinsey A, Kalfon R, Eddy W, Ormsbee MJ. Effects of milk proteins and combined exercise training on aortic hemodynamics and arterial stiffness in young obese women with high blood pressure. Am J Hypertens 2013;27(3):338–44.

[29] Fluegel SM, Shultz TD, Powers JR, Clark S, Barbosa-Leiker C, Wright BR, et al. Whey beverages decrease blood pressure in prehypertensive and hypertensive young men and women. Int Dairy J 2010;20(11):753–60.

[30] Gryson C, Ratel S, Rance M, Penando S, Bonhomme C, Le Ruyet P, et al. Four-month course of soluble milk proteins interacts with exercise to improve muscle strength and delay fatigue in elderly participants. J Am Med Dir Assoc 2014;15(12). 958. e1-. e9.

[31] Gulati S, Misra A, Tiwari R, Sharma M, Pandey RM, Yadav CP. Effect of high-protein meal replacement on weight and cardiometabolic profile in overweight/obese Asian Indians in North India. Br J Nutr 2017;117(11):1531–40.

[32] Hodgson JM, Zhu K, Lewis JR, Kerr D, Meng X, Solah V, et al. Long-term effects of a protein-enriched diet on blood pressure in older women. Br J Nutr 2012;107(11):1664–72.

[33] Kemmler W, Kohl M, Freiberger E, Sieber C, von Stengel S. Effect of whole-

body electromyostimulation and/or protein supplementation on obesity and cardiometabolic risk in older men with sarcopenic obesity: the randomized controlled FranSO trial. BMC Geriatr 2018;18(1):70.

[34] Kemmler W, Wittke A, Bebenek M, Fröhlich M, von Stengel S. High intensity resistance training methods with and without protein supplementation to fight cardiometabolic risk in middle-aged males: a randomized controlled trial. BioMed Res Int 2016:2016.

[35] Keogh JB, Clifton P. The effect of meal replacements high in glycomacropeptide on weight loss and markers of cardiovascular disease risk. Am J Clin Nutr 2008;87(6):1602–5.

[36] Amber W, Kinsey WRE, Madzima Takudzwa A, Panton Lynn B, Arciero Paul J, Kim Jeong-Su, Michael J. Ormsbee. Influence of night-time protein and carbohydrate intake on appetite and cardiometabolic risk in sedentary overweight and obese women. Br J Nutr 2014:320–7.

[37] Louise Kjølbæk LBS, Søndertoft Nadja Buus, Rasmussen Carrie Klestrup, Lorenzen Janne Kunchel, Serena Anja, Astrup Arne, Larsen Lesli Hingstrup. Protein supplements after weight loss do not improve weight maintenance compared with recommended dietary protein intake despite beneficial effects on appetite sensation and energy expenditure: a randomized, controlled, double-blinded trial. Am J Clin Nutr 2017;106:684–97. Printed in USA 2017 American Society for Nutrition. 2017.

[38] Larsen A, Bibby B, Hansen M. Effect of a whey protein supplement on preservation of fat free mass in overweight and obese individuals on an energy restricted very low caloric diet. Nutrients 2018;10(12):1918.

[39] Yu-Mi Lee TS, Hennig Michael, Hauner Hans. Effect of a milk drink supplemented with whey peptides on blood pressure in patients with mild hypertension. Eur J Nutr 2007;46:21–7. https://doi.org/10.1007/s00394-006-0625-8. 2007.

[40] Ryosuke Matsuoka KK, Mika Usuda, Wei Wang, Yasunobu Masuda, Masaaki Kunou, Akira Tanaka, Kazunori Utsunomiya. Lactic-fermented egg white improves visceral fat obesity in Japanese subjects—double-blind. Placebo Control Stud 2017;16:237. https://doi.org/10.1186/s12944-017-0631-2. Matsuoka et al Lipids in Health and Disease.

[41] Mohsen Mohammadi Sartang NB, Julia O, Totosy de Zepetnek, Neil R Brett, Seyed Mohammad Mazloomi, Mohammad Fararouie, Alireza Bedeltavana, Mandana Famouri, Zohreh Mazloom. The effect of daily fortified yogurt consumption on weight loss in adults with metabolic syndrome: a 10-week randomized controlled trial. Nutr Metab Cardiovasc Dis 2018.

[42] Hellen CG, Nabuco CMT, Rodrigo R Fernandes, Paulo Sugihara, Edilaine F Cavalcante, Danielle Venturini, Décio S Barbosa, Analiza M Silva, Luís B Sardinha, Edilson S Cyrino. Effects of protein intake beyond habitual intakes associated with resistance training on metabolic syndrome-related parameters, isokinetic strength and body composition in older women. J Aging Phys Act 2019.

[43] Michael J, Ormsbee AWK, Eddy Wyatt R, Madzima Takudzwa A, Arciero Paul J, Figueroa Arturo, Panton Lynn B. The influence of nighttime feeding of carbohydrate or protein combined with exercise training on appetite and cardiometabolic risk in young obese women. Appl Physiol Nutr Metabol 2015;40: 1–9. https://doi.org/10.1139/apnm-2014-0256.

[44] Padhi Emily MT, Blewett Heather J, Duncan Alison M, Guzman Randolph P, Hawke Aileen, Seetharaman Koushik, Tsao Rong, Wolever Thomas MS, Ramdath D Dan. Whole soy flour incorporated into a muffin and consumed at 2 doses of soy protein does not lower LDL cholesterol in a randomized, double-blind controlled trial of hypercholesterolemic adults. J Nutr October 7, 2015. https://doi.org/10.3945/jn.115.219873. 2015.

[45] SPaV Ellis1. The chronic effects of whey proteins on blood pressure, vascular function, and inflammatory markers in overweight individuals. Intervention Prev 2010.

[46] Sebely Pal VEaSD. Effects of whey protein isolate on body composition, lipids, insulin and glucose in overweight and obese individuals. Br J Nutr 2010;104: 716–23. 2010.

[47] Petyaev IM, Dovgalevsky PY, Klochkov VA, Chalyk NE, Kyle N. Whey protein lycosome formulation improves vascular functions and plasma lipids with reduction of markers of inflammation and oxidative stress in prehypertension. Sci World J 2012:2012.

[48] Piccolo BD, Comerford KB, Karakas SE, Knotts TA, Fiehn O, Adams SH. Whey protein supplementation does not alter plasma branched-chained amino acid profiles but results in unique metabolomics patterns in obese women enrolled in an 8-week weight loss trial. J Nutr 2015;145(4):691–700.

[49] Pins JJ, Keenan JM. Retracted: effects of whey peptides on cardiovascular disease risk factors. J Clin Hypertens 2006;8(11):775–82.

[50] Reimer RA, Willis HJ, Tunnicliffe JM, Park H, Madsen KL, Soto-Vaca A. Inulin-type fructans and whey protein both modulate appetite but only fructans alter gut microbiota in adults with overweight/obesity: a randomized controlled trial. Mol Nutr Food Res 2017;61(11). 1700484.

[51] Vatani DS, Golzar FAK. Changes in antioxidant status and cardiovascular risk factors of overweight young men after six weeks supplementation of whey protein isolate and resistance training. Appetite 2012;59(3):673–8.

[52] Tahavorgar A, Vafa M, Shidfar F, Gohari M, Heydari I. Beneficial effects of whey protein preloads on some cardiovascular diseases risk factors of overweight and obese men are stronger than soy protein preloads–A randomized clinical trial. J Nutr Intermediary Metabol 2015;2(3–4):69–75.

[53] Tovar J, Johansson M, Björck I. A multifunctional diet improves cardiometabolic-related biomarkers independently of weight changes: an 8-week randomized controlled intervention in healthy overweight and obese subjects. Eur J Nutr 2016;55(7):2295–306.

[54] Grundy SM, Brewer Jr HB, Cleeman JI, Smith Jr SC, Lenfant C. Definition of metabolic syndrome: report of the National Heart, Lung, and Blood Institute/American Heart Association conference on scientific issues related to definition. Circulation 2004;109(3):433–8.

[55] Ford ES, Giles WH, Dietz WH. Prevalence of the metabolic syndrome among US adults: findings from the third National Health and Nutrition Examination Survey. Jama 2002;287(3):356–9.

[56] Sadrbafoghi S, Salari M, Rafiee M, Namayandeh S, Abdoli A, Karimi M. Prevalence and criteria of metabolic syndrome in an urban population: Yazd Healthy Heart Projectvol. 64. Tehran University Medical Journal TUMS Publications; 2006. p. 90–6. 10.

[57] Pal S, Radavelli-Bagatini S. The effects of whey protein on cardiometabolic risk factors. Obes Rev 2013;14(4):324–43.

[58] Zhang J, Tong X, Wan Z, Wang Y, Qin L, Szeto I. Effect of whey protein on blood lipid profiles: a meta-analysis of randomized controlled trials. Eur J Clin Nutr 2016;70(8):879.

[59] Wright CS, Craddock A, Weinheimer-Haus EM, Lim E, Conley TB, Janle EM, et al. Thyroid status, insulin sensitivity and glucose tolerance in overweight and obese adults before and after 36 weeks of whey protein supplementation and exercise training. Endocr Res 2016;41(2):103–9.