Original Article

Energy restriction combined with green coffee bean extract affects serum adipocytokines and the body composition in obese women

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Background and Objectives: Obesity has become a public health problem and is a cause of some preventable illnesses. Among several methods for treating obesity, the use of food supplements is highly common. A commonly used food supplement is green coffee bean extract. The objective of this study was to evaluate the efficacy of green coffee bean extract combined with an energy-restricted diet on the body composition and serum adipocytokines in obese women. **Methods and Study Design:** In this randomised clinical trial, 64 obese women aged 20–45 years were selected and divided into two groups: an intervention group (receiving 400 mg green coffee bean extract for 8 weeks) and control group (receiving placebo). All participants were on an energy-restricted diet. The body composition, leptin, adiponectin, lipid profile, free fatty acids (FFAs), and fasting blood sugar were compared between the two groups. **Results:** We observed significant reductions in the body weight, body mass and fat mass indices, and waist-to-hip circumference ratio in both groups; however, the decrease was higher in the intervention group. Moreover, serum total cholesterol, low-density lipoprotein, leptin, and plasma free fatty acids significantly decreased in the intervention group (p<0.05) after adjustment for energy and fibre intake. The serum adiponectin concentration significantly increased in the intervention group (p<0.05). **Conclusions:** Green coffee bean extract combined with an energy-restricted diet affects fat accumulation and lipid metabolism and is thus an inexpensive method for weight control in obese people.

Key Words: adipocytokine, body composition, chlorogenic acid, lipid profile, obesity

INTRODUCTION

Weight management is an established goal for achieving a healthy life style, and it involves a balance between healthy eating and physical activity.[1] Overweight refers to an increased body weight in relation to height, compared with certain standards of acceptable or desirable weight. Obesity is defined as an excessively high amount of body fat or adipose tissue in relation to lean body mass. Obesity and overweight are chronic conditions and contribute to many preventable illnesses (e.g., diabetes, coronary artery disease, and high blood pressure).[2] According to World Health Organisation predictions for 2015, 3.2 billion adults were predicted to be overweight and more than 700 million were predicted to be obese.[3] Obesity, a public health problem worldwide, has reached epidemic proportions at an alarming rate.1 In the United States, obesity has increased at an epidemic rate during the past 20 years. Overweight, obesity, and associated health problems have engendered a marked economic effect on the healthcare system worldwide. Poor diet and a lack of physical activity are common causes of obesity. Due to the complications of obesity, different treatment strategies have been used for addressing it. Behavioural therapy, diet, drug therapies and surgery are the most frequently used therapeutic strategies for obesity.[4] Recently, many people have had a tendency to use nutraceuticals to lose weight.[2,5] A nutraceutical is any substance that is a food or part of a food and provides medical or health benefits, including disease prevention and treatment. Therapeutic agents and food supplements are developed to treat and prevent obesity. Among these, coffee, one of the most commonly consumed beverages worldwide, and its health effects, are related to its high consumption.[6-10] Roasted coffee is a common form of coffee, and its beneficial effects can be particularly attributed to its caffeine content.[11-14] However, the use of green coffee or unroasted coffee is rather uncommon. Raw coffee beans are rich in chlorogenic acid

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(CGA; 2–5 g/100 g), and related compounds, such as quinic acid, p-coumaric acid, and caffeic acid. Coffee is rapidly absorbed and reaches its peak plasma concentration within 1h. Approximately one-third of CGA is orally absorbed and is typically found in the form of sulphates from caffeic acid or its glucuronide conjugates in plasma.[15-18] Similar compounds are present in green coffee and roasted coffee, however, during the roasting process, several of its compounds are destroyed. Hydroxy hydroquinone produced during the roasting process has been reported to reduce the in vivo CGA performance.[19,20] Farah et al (2008) evaluated the pharmacokinetic profile of CGA compounds and metabolites in human plasma and urine after the acute consumption of decaffeinated green coffee extract, and estimated the apparent bioavailability of CGA in this food matrix. They concluded that the major CGA compounds present in green coffee were highly absorbed and metabolised in humans.[17] Several studies have reported the positive effect of green coffee bean extract (GCBE) and CGA on weight management.[18,20] The reduction of body fat can be related to changes in adipose-derived hormones, therefore, investigating the effects of GCBE on the concentration of serum adipocytokines can confirm the anti-obesity properties of GCBE. Cho et al (2010) reported a decline in leptin after CGA intake in obese mice. These results suggested that CGA improved body weight, lipid metabolism, and obesity-related hormone levels.[21]

As a result of the high prevalence of obesity worldwide and its role in increasing the risk of numerous chronic diseases, developing safe and effective methods of body weight management is crucial. As GCBE is a food supplement that has been introduced as one of the richest CGA sources, several studies have declared its role in reducing weight and body mass in overweight and obese adults.[22,23] Therefore, the current study evaluated the efficacy of GCBE combined with an energy-restricted diet on the body composition and serum adipocytokines in obese women.

METHODS

Participants

This study included 64 obese women aged 20–45 years. Initial anthropometric measurements, namely the weight, height, body fat, waist circumference (WC), and waist-to-hip circumference ratio (WHR), were recorded. In this study, the fat mass index (FMI) was the criterion to determine obesity. Considering the importance of fat mass in the definition of obesity, we used the FMI to estimate body fat. The FMI affords the possibility of separately considering the body fat mass and determining it relative to height; some studies have applied the FMI as a more favourable criterion for determining obesity compared with the body fat percent.[24,25] In the present study, inclusion criteria were an age range of 20–45 years, an FMI equal to or higher than 8.7 (kg/m^2) in the age group 25–34 years, an FMI equal to or more than 9.9 (kg/m^2) in the age group 35–45 years, and patient satisfaction. Exclusion criteria included pregnancy; lactation; menopause; smoking; alcohol and drug abuse; participation in exercise or weight reduction programmes; medications known to affect weight in the past six months; history or presence of other diseases such as diabetes, cardiovascular diseases, hypertension, and infection; other inflammatory disorders; liver and kidney disorders; steroids or hormonal drugs; and the consumption of vitamins and minerals in the past six months. This study was approved by and performed under the guidelines of the Research Ethics Committee of Ahvaz Jundishapur University of Medical Sciences, Iran (ETH-ir.ajums.rec.1394.256). Written consent was obtained from all participants.

Study design

This randomised, double-blind, placebo-controlled clinical trial investigated the effect of a 400-mg GCBE supplement on anthropometric indices, fasting blood sugar (FBS), serum insulin, lipid profile, leptin, adiponectin, and free fatty acids (FFAs) in obese women. The participants were divided into two groups through randomised block allocation, according to the FMI (intervention: n=30 and control: n=34). In this study, an FMI equal to or more than 8.7 (kg/m^2) in the age group 25–34 years and that equal to or more than 9.9 (kg/m^2) in the age group 35–45 years, calculated according to a reference by Schutz, were considered to indicate obesity.[25] The intervention group was provided with one capsule of 400 mg GCBE18 equivalent to 7 g of dry fruits, 180 mg of CGA, and caffeine of less than 0.01% to consume daily for 8 weeks. Similarly, the control group received one placebo capsule of 400 mg starch. The GCBE supplement was produced by Healthy Care, Australia; the placebo was provided by the School of Pharmacy, Ahvaz University of Medical Sciences, Iran. All participants were on an energy-restricted diet (25% energy deficit through energy restriction); the macronutrient content of the diet was 15% protein, 55% carbohydrate, and 30% fat. The diet was recorded before, during, and at the end of the study by using 3-day food records, namely one weekend day and two weekdays, to assess their total energy and macronutrient intake. We asked the participants to not change their physical activity levels during the study. Physical activity was assessed using the International Physical Activity Questionnaire (IPAQ). Data from the IPAQ were converted to metabolic equivalent (MET)-minutes/week by using the existing guidelines.[26] The height, weight, and body fat mass of the participants were measured at the baseline and the end of the study. The height was measured using a non-stretchable tape to the nearest 0.5 cm while standing barefoot with heels sticking to the wall, head straightened, and eyes looking forward. The weight was measured with minimum clothing by using a body composition analyser (BCA) device to the nearest 50 g (InBody Co., Ltd, Japan, Model 230). The body fat mass was also measured with the same device. Subsequently, the body mass index (BMI) and FMI were determined using the formulae BMI = weight in kilograms divided by the square of the height in metres and FMI = fat mass in kilograms divided by the square of the height in metres, respectively.

Biochemical analysis

We collected blood samples to assay biochemical parameters at the baseline and the end of the study. The parameters were FBS, total cholesterol, low- and high-

density lipoprotein (LDL and HDL, respectively), triglyceride (TG), serum insulin, leptin, adiponectin, and FFAs. Serum glucose, TG, and total and HDL cholesterol were measured using the enzymatic method. LDL cholesterol was calculated using the Friedewald formula [total cholesterol – (HDL + TG/5)].[27] Serum insulin was measured using an enzyme linked immune sorbent assay (ELISA) test kit (Diaplus, Canada), and the homoeostasis model assessment of insulin resistance was calculated using the following formula: fasting plasma glucose (mmol/L) × fasting insulin (μU/mL)/22.5. Serum leptin was measured using a leptin ELISA test kit (Diagnostics Biochem Canada Inc, London, ON, Canada). For quantitatively detecting human adiponectin in samples, we used a human adiponectin ELISA test kit (Boster Biological Technology, USA). Human FFA was assayed using an FFA ELISA test kit (Eastbiopharm Co., Ltd, USA). Visceral fat was assayed using the visceral adiposity index, and it is proposed as a reliable indicator of visceral fat function. The visceral adiposity index was calculated using the following formula: ((WC (cm))/(36.58+(1.89×BMI))) × ((TG (mmol/L))/(0.81)) × ((1.52)/(HDL-C(mmol/L))).

Statistical analysis

Quantitative variables are expressed as mean±standard deviation. The Kolmogorov–Smirnov test was used to test the normality of variable distributions. Independent samples comparisons in terms of quantitative variables were performed using two independent samples t tests, repeated measures ANOVA, and the Mann–Whitney U test, as appropriate. Univariate ANCOVA was used for adjustment of potential confounding variables, namely the energy intake (kcal/day), fibre intake (g/day), and physical activity level (MET-minutes/week). All statistical analyses were performed using SPSS (Version 20; SPSS Inc., Chicago, IL, USA). A p value of less than 0.05 was considered significant. In this study, dietary intake was analysed using Nutritionist IV (First Databank, San Bruno, CA, USA), which was modified for Iranian foods.

RESULTS

We observed no significant differences between the two groups in anthropometric and biomedical measurements, energy intake, and physical activity levels in the beginning of the study. The mean ages of the intervention and control groups were 36.1 and 35.7 years, respectively. Table 1 shows some demographic and anthropometric characteristics of the participants at the baseline and the end of the study. Statistical analysis showed that after eight weeks, the weight, BMI, FMI, and WHR significantly decreased in both groups, however, the decrease was more prominent in the intervention group. No significant change was observed in visceral fat in the beginning and at the end of the study. Moreover, a comparison of the two groups showed a significant change in the body composition. The intervention group showed a significant reduction in weight, BMI, FMI, and WHR, and the changes after adjustments for energy and fibre intake and physical activity levels were significant; p values for the weight, BMI, FMI, and WHR were 0.03, 0.02, 0.04, and 0.01, respectively. Table 2 presents the dietary intake in the beginning, during, and at the end of the study in both groups. No difference was observed in the dietary intake between the two groups, except for fibre intake. Table 3

Table 1. Demographic and anthropometric characteristics of the study population

Variable		Green coffee group M±SD[†]	Placebo group M±SD	$p1^{*}$	$p2^{**}$
Weight (kg)	Week 0	11.98±80.09	12.43±81.42	0.54	0.42
	Week 8	10.4±75.25	12.16±78.8	0.02	0.03
	$p3^{***}$	0.001	0.01	-	-
BMI (kg/m^2)	Week 0	4.37±31.58	4.96±32.07	0.53	0.54
	Week 8	3.89±27.49	4.84±31.06	0.02	0.02
	$p3^{***}$	0.000	0.01	-	-
Fat mass (kg)	Week 0	4.27±36.09	4.07±37.99	0.53	0.54
	Week 8	3.75±33.1	4.74±36.02	0.02	0.02
	$p3^{***}$	0.000	0.01	-	-
FMI (kg/m^2)	Week 0	3.23±14.22	3.69±14.99	0.38	0.31
	Week 8	3.23±12.07	3.23±13.98	0.02	0.04
	$p3^{***}$	0.000	0.01	-	-
WHR	Week 0	0.08±0.96	0.2±0.97	0.58	0.63
	Week 8	0.02±0.92	0.04±0.91	0.000	0.01
	$p3^{***}$	0.01	0.01	-	-
Visceral fat	Week 0	0.3±4.44	0.5±4.53	0.24	0.5
	Week 8	0.13±4.34	0.33±4.51	0.38	0. 4
	$p3^{***}$	0.05	0.07	-	-
IPAQ (metabolic equivalent of task-min/wk)	Week 0	49.06±2091	48.5±2094	0.83	0.3
	Week 8	49.41±2093	49.03±2093	0.97	0. 4
	$p3^{***}$	0.3	0.4	-	-

IPAQ: International Physical Activity Questionnaire; BMI: body mass index; FMI: fat mass index; WHR: waist-to-hip circumference ratio.

[†]Mean±standard deviation (95% confidence interval).

[*]$p1$: are results from Independent sample t-test.

[**]$p2$: are results from analysis of covariance in the adjusted models (adjusted for daily fibre, energy and physical activity).

[***]$p3$: are results from Paired sample t-test.

Table 2. Dietary intake at the baseline, mid and end of the study in two groups

Variable		Green coffee group M±SD†	Placebo group M±SD	$p1^*$
Energy (kcal)	Week 0	240±1568	1600±177	0.4
	Week 4	240±1573	181±1561	0.3
	Week 8	221±1510	101±1612	0.4
	$p2^{**}$	0.3	0.4	-
Protein (percent of energy)	Week 0	4.07±16	4.23±17	0.71
	Week 4	4.05±17	3.16±16	0.09
	Week 8	4.78±20	2.96±21	0.66
	$p2^{**}$	0.65	0.72	-
Carbohydrate (percent of energy)	Week 0	4.21±55	2.2±53	0.11
	Week 4	3.88±55	3.1±54	0.2
	Week 8	3.07±53	3.01±55	0.2
	$p2^{**}$	0.2	0.2	-
Fat (percent of energy)	Week 0	4.11±29	3.2±30	0.21
	Week 4	4.78±28	2.96±30	0.36
	Week 8	4.05±27	3.16±24	0.09
	$p2^{**}$	0.12	0.22	-
SFA (g)	Week 0	1.64±12	1.46±14	0.15
	Week 4	1.08±13	1.91±12	0.1
	Week 8	1.05±11	1.46±12	0.15
	$p2^{**}$	0.9	0.9	-
MUFA (g)	Week 0	2.04±14	2.16±13	0.83
	Week 4	1.97±14	1.51±13	0.8
	Week 8	2.16±13	2.01±14	0.71
	$p2^{**}$	0.9	0.9	-
PUFA (g)	Week 0	1.7±15	1.72±14	0.82
	Week 4	1.17±16	1.58±17	0.5
	Week 8	1.76±18	1.31±16	0.63
	$p2^{**}$	0.8	0.9	-
Cholesterol (g)	Week 0	12.02±122	12.57±128	0.81
	Week 4	12.48±124	11.96±121	0.7
	Week 8	12.03±126	12.5±120	0.5
	$p2^{**}$	0.7	0.9	-
Fibre (g)	Week 0	1.32±9.1	1.17±10.9	0.01
	Week 4	1.59±9	1.85±11.2	0.001
	Week 8	1.7±9.2	1.9±11.2	0.001
	$p2^{**}$	0.34	0.2	-

SFA: saturated fatty acid; MUFA: monounsaturated fatty acid; PUFA: polyunsaturated fatty acid.
†Mean±standard deviation (95% confidence interval).
*$p1$: are results from Independent sample t-test.
**$p2$: are results from Repeated measures ANOVA.

shows the measured FBS, fasting insulin, and lipid profile in the beginning and at the end of the study in the two groups. After eight weeks, total cholesterol significantly decreased in both groups. A comparison between the two groups revealed that total serum cholesterol, LDL cholesterol, and FFAs significantly decreased in the intervention group. The changes after adjustments for energy and fibre intake and the physical activity levels were significant; p values for total cholesterol, LDL, and FFAs were 0.02, 0.04, and 0.001, respectively. Moreover, serum TG decreased in both groups, but the corresponding change was not significant. No change was observed in FBS, serum insulin, and HDL cholesterol between the two groups after eight weeks. Table 4 shows the effect of GCBE on lipid metabolism. After eight weeks, a comparison of the two groups showed a reduction in the serum leptin concentration and an increase in the serum adiponectin concentration in the intervention group. The changes were significant after adjustments for energy and fibre intake and the physical activity levels; p values for leptin and adiponectin were 0.01 and 0.02, respectively. Moreover, in the intervention group, the serum leptin concentration significantly decreased (p=0.001), and the serum adiponectin concentration significantly increased at the end of the study, compared with those observed at the baseline (p=0.001).

DISCUSSION

Studies related to the effect of GCBE on body composition have reported inconsistent results,[18,22,28] and hence, we evaluated the synergistic effect of an energy-restricted diet and GCBE on body composition. Only a few human studies have analysed the effects of ingestion of green coffee extract. Samadi et al (2015) conducted a review and used GCBE as a weight loss supplement, and most of its weight loss properties were proposed to be related to its CGA content.[22] Vinson et al (2012) reported a weight loss of more than 8kg after the consumption of 700 mg of GCBE for six weeks, which was more than 10% of the body weight. The study concluded that GCBE is a low-

Table 3. Effect of GCBE on FBS, fasting insulin and lipid profile in the study population

Variable		Green coffee group M±SD†	Placebo group M±SD	$p1^*$	$p2^{**}$
FBS (mg/dL)	Week 0	5.83±84	5.63±83.7	0.83	0.7
	Week 8	5.56±83.1	5.08±83.36	0.88	0.7
	$p3^{***}$	0.8	0.7	-	-
Fasting insulin (μu/mL)	Week 0	0.68±11.2	0.71±11.1	0.4	0.5
	Week 8	0.67±11.1	0.7±11.3	0.5	0.3
	$p3^{***}$	0.08	0.1	-	-
Insulin resistance index	Week 0	2.77±3.16	2.89±3.12	0.44	0.83
	Week 8	2.81±3.11	2.64±3.14	0.14	0.85
	$p3^{***}$	0.85	0.91	-	-
Total cholesterol (mg/dL)	Week 0	14.06±208	13.5±207	0.79	0.81
	Week 8	10.53±196	12.58±202	0.01	0.02
	$p3^{***}$	0.000	0.04	-	-
LDL (mg/dL)	Week 0	10.71±113	9.24±109	0.61	0.75
	Week 8	3.62±102	7.79±107	0.02	0.04
	$p3^{***}$	0.001	0.05	-	-
HDL (mg/dL)	Week 0	1.61±48	1.47±49	0.9	0.73
	Week 8	1.02±49	1.39±47	0.21	0.8
	$p3^{***}$	0.15	0.09	-	-
TG (mg/dL)	Week 0	33.99±164	26.52±158	0.47	0.06
	Week 8	31.25±160	25.73±153	0.44	0.05
	$p3^{***}$	0.07	0.08	-	-
FFA (μmol/L)	Week 0	27.26±260.27	23.85±264.2	0.55	0.6
	Week 8	24.99±150.21	23.44±251.22	0.000	0.001
	$p3^{***}$	0.000	0.05	-	-

FBS: fasting blood sugar; LDL: low density lipoprotein; HDL: high density lipoprotein; TG: triglyceride; FFA: free fatty acid.
†Mean±standard deviation (95% confidence interval).
*$p1$: are results from Independent sample t-test
**$p2$: are results from analysis of covariance in the adjusted models (adjusted for daily fibre, energy and physical activity)
***$p3$: are results from Paired sample t-test.

Table 4. Effect of green coffee bean extract on leptin and adiponectin

Variable		Green coffee group M±SD†	Placebo group M±SD	$p1^*$	$p2^{**}$
Leptin (ng/mL)	Week 0	8.06±29.8	9.05±30.4	0.07	0.08
	Week 8	8.31±22.7	7.32±27.7	0.001	0.01
	$p3^{***}$	0.001	0.04	-	-
Adiponectin (μg/mL)	Week 0	1.07±7.7	1.05±7.6	0.6	0.6
	Week 8	2.03±8.9	2.8±7.8	0.001	0.02
	$p3^{***}$	0.001	0.08	-	-

†Mean±standard deviation (95% confidence interval).
*$p1$: are results from Independent sample t-test.
**$p2$: are results from analysis of covariance in the adjusted models (adjusted for daily fibre, energy and physical activity).
***$p3$: are results from Paired sample t-test.

cost source and an effective therapy for obese people.[29] However, in the current study, we observed a weight loss of 5 kg, a 2-unit drop in the FMI, and a 4-unit drop in the BMI in the intervention group. A meta-analysis of three human studies concluded a mean weight loss of 2.5 kg after the consumption of green coffee extract (180–200 mg GCBE per day).[18] Some antiobesity mechanisms of GCBE are described as follows.

Effect of green coffee bean extract on the body composition and lipid profile

CGA and its related compounds are involved in the enhancement of fat metabolism in the liver. In rats, CGA inhibits β-hydroxy-β-methyl glutaric acyl coenzyme A reductase, which is the principal enzyme involved in the synthesis of cholesterol and in strengthening the activity of carnitine palmitoyl transferase, a fatty acid oxidation enzyme.[30] This mechanism was proposed to be responsible for the anti hyperlipidemia effect of CGA in GCBE and its effect on lipid metabolism.[31] These mechanisms are assumed to be involved in the reduction in total cholesterol and LDL after GCBE intake in the current study. Dellalibera et al (2006) also identified another antiobesity mechanism of GCBE. The study confirmed that CGA inhibited glucose absorption in the small intestine by inhibiting the activity of glucose-6-phosphatase and the release of glucose into general circulation, which reduced the serum insulin level.[23] This mechanism induced less fatty acid deposits in the adipose tissue and reduced the level of glucose as an energy source from fat reserves,

consequently resulting in weight loss.[32] Some studies have demonstrated anti-obesity effect of GCBE on changes in the expression of hepatic peroxisome proliferator-activated receptor (PPAR). PPARs, members of the nuclear receptor super family, play a key role in regulating glucolipid metabolism.[33] Li et al (2009) demonstrated that CGA significantly elevated the level of mRNA and protein expression in hepatic PPAR-α and the hypolipidemia effect of CGA that is related to the effect of PPAR-α on the ability of lipid clearance from the liver.[34] Wan et al (2013) reported that CGA reduced plasma total and LDL cholesterol through PPAR-α mRNA regulation.[35]

Effect of green coffee bean extract on serum adipocytokines

Our study is the first intervention trial to investigate the effect of GCBE on serum adipocytokine concentrations. The proposed mechanisms that explain the metabolic conditions of body weight loss could be related to changes in adipose-derived hormones.[36,37] Cho et al (2010) stated that reduced leptin levels after CGA intake in obese mice were related to the inhibition of fatty acid synthase, 3-hydroxy-3-methylglutaryl CoA reductase, and acyl-CoA cholesterol acyl transferase activities, which induced body fat loss and reduced leptin, while increasing adiponectin concentrations. These results suggest that CGA improved body weight, lipid metabolism, and obesity-related hormonal levels.[21]

Synergistic effect of GCBE and an energy-restricted diet

In this study, we administered an energy-restricted diet that resulted in thermogenesis. Studies have reported a reduction in leptin during energy restriction, which can explain variations in adaptive thermogenesis,[38,39] and the ability of leptin to prevent a reduction in energy expenditure that occurs after an energy-restricted diet, which is related to an increase in uncoupling protein (UCP) expression in adipose tissue and muscle. UCP has a role in inducing mitochondrial proton leak and consequently increases thermogenesis.[38]

Although our study had several strengths, it also had some limitations. The major limitations were the use of a one-dose study design and evaluation of only two biomarkers of obesity. However, our study is the first intervention trial to investigate the effect of GCBE on the concentration of serum adipocytokines. Moreover, we evaluated the synergistic effect of an energy-restricted diet and GCBE.

We conclude that energy restriction combined with GCBE may effectively reduce the BMI, FMI, total cholesterol, and LDL and may also alter serum adipocytokines. GCBE use is an inexpensive method to control weight in obese people, therefore, it would be an effective method for preventing illnesses, particularly obesity and its related complications. However, studies on the dose–response effects of GCBE are necessary to ensure successful treatment and prevention of obesity.

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AUTHOR DISCLOSURES

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REFERENCES

1. Chevance G, Caudroit J, Romain AJ and Boiche J. The adoption of physical activity and eating behaviors among persons with obesity and in the general population: the role of implicit attitudes within the Theory of Planned Behavior. Psychol Health Med. 2016;7:1-6.
2. Ormsbee MJ, Rawal SR, Baur DA, Kinsey AW, Elam ML, Spicer MT, Fischer NT, Madzima TA, Thomas DD. The effects of a multi-ingredient dietary supplement on body composition, adipokines, blood lipids, and metabolic health in overweight and obese men and women: a randomized controlled trial. J Int Soc Sports Nutr. 2014;11:37-47.
3. Inoue M, Kurahashi N, Iwasaki M, Shimazu T, Tanaka Y. Effect of coffee and green tea consumption on the risk of liver cancer: cohort analysis by hepatitis virus infection status. Cancer Epidemiol Biomarkers Prev. 2009;18:1746-53.
4. Umstattd Meyer MR, Perry CK, Sumrall JC, Patterson MS, Walsh SM, Clendennen SC et al. Physical activity-related policy and environmental strategies to prevent obesity in rural communities: a systematic review of the literature, 2002-2013. Prev Chronic Dis. 2016;7:13:E03. doi: 10.5888/pcd13.150406.
5. Tverdal A, Skurtveit S. Coffee intake and mortality from liver cirrhosis. Ann Epidemiol. 2003;13:419-23.
6. Van Dam RM, Hu FB. Coffee consumption and risk of type 2 diabetes: a systematic review. JAMA. 2005;294:97-104.
7. Greenberg JA, Boozer CN, Geliebter A. Coffee, diabetes, and weight control. Am J Clin Nutr. 2006;84:682-93.
8. Icken D, Feller S, Engeli S, Mayr A, Muller A, Hilbert A, de Zwaan M. Caffeine intake is related to successful weight loss maintenance. Eur J Clin Nutr. 2016;70:532-4.
9. MuraseT, Misawa K, Minegishi Y, Aoki M, Ominami H, Suzuki Y, Shibuya Y, Hase T. Coffee polyphenols suppress diet-induced body fat accumulation by down regulating SREBP-1c and related molecules in C57BL/6J mice. Am J Physiol Endocrinol Metab. 2011;300:122-33.
10. H Ho L, Varghese M, Wang J, Zhao W, Chen F, Knable LA, Ferruzzi M, Pasinetti GM. Dietary supplementation with decaffeinated green coffee improves diet-induced insulin resistance and brain energy metabolism in mice. Nutr Neuroscience. 2012;15:37-45.
11. Ong KW, Hsu A, Tan BKH. Chlorogenic acid stimulates glucose transport in skeletal muscle via AMPK activation: a contributor to the beneficial effects of coffee on diabetes. PLoS One. 2012;3:e32718. doi: 10.1371/journal.pone.0032718.
12. Slee SJ, Coffin AB. Cutting-edge science and coffee: Auditory System Gordon Research Conference and Seminar 2012 report. J Assoc Res Otolaryngol. 2013;14:1-2.
13. Sotillo D, Hadley M. Chlorogenic acid modifies plasma and liver concentrations of: cholesterol, triacylglycerol, and minerals in (fa/fa) Zucker rats. J Nutr Biochem. 2002;13:717-26.
14. Lopez-Garcia E, Van Dam RM, Rajpathak S, Willett WC, Manson JE, Hu FB. Changes in caffeine intake and long-term weight change in men and women. Am J Clin Nutr. 2006;83:674-80.

15. Andrade KS, Goncalvez RT, Maraschin M, Ribeiro-do-Valle RM, Martinez J, Ferreira SR. Supercritical fluid extraction from spent coffee grounds and coffee husks: antioxidant activity and effect of operational variables on extract composition. Talanta. 2012;88:544-52.
16. Watanabe T, Arai Y, Mitsui Y, Kusaura T, Okawa W, Kajihara Y, Saito I. The blood pressure-lowering effect and safety of chlorogenic acid from green coffee bean extract in essential hypertension. Clin Exp Hypertens. 2006;28:439-49.
17. Farah A, Monteiro M, Donangelo CM and Lafay S. Cholorogenic Acids from Green Coffee Extract are Highly Bioavailable in Humans. J Nutr. 2008;138:2309-15.
18. Onakpoya I, Terry R, Ernst E. The use of green coffee extract as a weight loss supplement: a systematic review and meta-analysis of randomised clinical trials. Gastroenterol Res Pract. 2011;2011:pii382852. doi: 10.1155/2011/3828 52.
19. Mills CE, Oruna-Concha MJ, Mottram DS, Gibson GR, Spencer JP. The effect of processing on chlorogenic acid content of commercially available coffee. Food Chem. 2013; 141:3335-40.
20. Zheng G, Qiu Y, Zhang QF and Li D. Cholorogenic acid and caffeine in combination inhibit fat accumulation by regulating hepatic lipid metabolism RELATED enzymes in mice. Br J Nutr. 2014;112:1034-40.
21. Cho AS, Jeon SM, Kim MJ, Yeo J, Seo KI, Choi MS, Lee MK. Chlorogenic acid exhibits anti-obesity property and improves lipid metabolism in high-fat diet-induced-obese mice. Food Chem Toxicol. 2010;48:937-43.
22. Samadi M, Mohammadshahi M, Haidari F. Green coffee bean extract as a weight loss supplement. J Nutr Disorders Ther. 2015;5:180. doi: 10.4172/2161-0509.1000180.
23. Dellalibera O, Lemaire B, Lafay S. Svetol, green coffee extract, induces weight loss and increases the lean to fat mass ratio in volunteers with overweight problem. Phytotherapie. 2006;4:194-7.
24. Samadi M, Sadrzadeh-Yeganeh H, Azadbakht L, Jafarian K, Rahimi A, Sotoudeh G. Sensitivity and specificity of body mass index in determining obesity in children. J Res Med Sci. 2013;18:536-41.
25. Schutz Y, Kyle U, Pichard C. Fat-free mass index and fat mass index percentiles in Caucasians aged 18 – 98 y. Int J Obes. 2002;26:953-60.
26. Wolin KY, Heil DP, Askew S, Matthews CE, Bennett GG. Validation of the International Physical Activity Questionnaire-Short among Blacks. J Phys Act Health. 2008; 5:746-60.
27. Chen Y, Zhang X, Pan B, Jin X, Yao H, Chen B, Zou Y, Ge J, Chen H. A modified formula for calculating low-densitylipoprotein cholesterol values. Lipids in Health and Disease. 2010;9:52. doi: 10.1186/1476-511X-9-52.
28. Li Kwok Cheong JD, Croft KD, Henry PD, Matthews V, Hodgson JM, Ward NC. Green coffee polyphenols do not attenuate features of the metabolic syndrome and improve endothelial function in mice fed a high fat diet. Arch Biochem Biophys. 2014;559:46-52.
29. Vinson J, Burnham B, Nagendran MV. Randomized, double-blind, placebo-controlled, linear dose, crossover study to evaluate the efficacy and safety of a green coffee bean extract in overweight subjects. Diabetes Metab Syndr Obes. 2012;5:21-7.
30. Shimoda H, Seki E, Aitani M. Inhibitory effect of green coffee bean extract on fat accumulation and body weight gain in mice. BMC Complement Altern Med. 2006;6:9-15.
31. Meng S, Cao J, Feng Q, Peng J, Hu Y. Roles of chlorogenic acid on regulating glucose and lipids metabolism: a review. Evid Based Complement Alternat Med. 2013;2013:801457. doi: 10.1155/2013/801457.
32. Henry-Vitrac C, Ibarra A, Roller M, Merillon JM, Vitrac X. Contribution of chlorogenic acids to the inhibition of human hepatic glucose-6-phosphatase activity in vitro by Svetol, a standardized decaffeinated green coffee extract. J Agric Food Chem. 2010;58:4141-4.
33. Goto T, Nakayama R, Yamanaka M, Takata M, Takazawa T, Watanabe K, Maruta K, Nagata R, Nagamine J, Tsuchida A, Kato H. Effects of DSP-8658, a novel selective peroxisome proliferator-activated receptors a/γ modulator, on adipogenesis and glucose metabolism in diabetic obese mice. Exp Clin Endocrinol Diabetes. 2015;123:492-9.
34. Li SY, Chang CQ, Ma F Y and Yu CL. Modulating effects of chlorogenic acid on lipids and glucose metabolism and expression of hepatic peroxisome proliferator-activated receptor in golden hamsters fed on high fat diet. Biomed Environ Sci. 2009;22:122-9.
35. Wan CW, Wong CN, Pin WK. Exhibits cholesterol lowering and fatty liver attenuating properties by up-regulating the gene expression of PPAR-α. Phytother Res. 2013;27:545-51.
36. Jung SH, Park HS, Kim KS, Choi WH, Ahn CW, Kim BT et al. Effect of weight loss on some serum cytokines in human obesity: increase in IL-10 after weight loss. J Nutr Biochem. 2008;19:371-5.
37. Camps SG, Verhoef SP, Westerterp KR. Leptin and energy restriction induced adaptation in energy expenditure. Metabolism. 2015;64:1284-90.
38. Miller LE, Volpe J, Coleman-Kelly MD, Gwazdauskas FC, Nickols-Richardson SM. Anthropometric and leptin changes in women following different dietary approaches to weight loss. Obesity. 2009;17:199-201.
39. Varady KA, Tussing L, Bhutani S and Braunschweig CL. Degree of weight loss required to improve adipokine concentrations and decrease fat cell size in severely obese women. Metab Clin Exp. 2009;58:1096-101.