

Effects of Chios mastic gum on cholesterol and glucose levels of healthy volunteers: A prospective, randomized, placebo-controlled, pilot study (CHIOS-MASTIHA)

European Journal of Preventive
Cardiology
0(00) 1–8
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Cardiology 2015
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DOI: 10.1177/2047487315603186
ejpc.sagepub.com


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Abstract

Background: Chios mastic gum (CMG) possesses anti-oxidant, anti-inflammatory, anti-atheromatic, lipid- and glucose-lowering properties. We evaluated the effects of CMG on cholesterol and fasting plasma glucose (FPG) levels of healthy volunteers.

Design: A prospective, randomized, placebo-controlled, pilot study.

Methods: One hundred and seventy nine volunteers with total cholesterol levels >200 mg/dl were randomized to four groups. Finally, 156 volunteers completed the follow-up period and were analysed: (1) control group (C, $n=23$), receiving placebo; (2) total mastic (TM, $n=72$) receiving daily a total dose of 1 g of crude CMG (330 mg capsules, tid); (3) polymer-free mastic (PFM, $n=33$), receiving daily a total dose of 1 g of polymer free mastic (330 mg caps, tid); and (4) powder mastic (PM, $n=28$), receiving daily a total dose of 2 g of crude CMG.

Results: After eight weeks, the TM group reduced total cholesterol by 11.5 mg/dl ($p < 0.05$) and FPG by 4.5 mg/dl ($p < 0.05$) adjusted for age, gender, BMI and baseline characteristics. The effect was stronger in overweight and obese patients (BMI > 25), with an estimated mean reduction of total cholesterol by 13.5 mg/dl ($p < 0.05$) and FPG by 5.1 mg/dl ($p < 0.05$). Administration of PFM and PM resulted in no statistically significant alteration. No effect was observed on LDL, HDL, triglycerides, uric acid and CRP. No gastrointestinal, liver or renal adverse events were recorded.

Conclusions: CMG has a significant lowering effect on total cholesterol and glucose levels of healthy volunteers, with excellent tolerance and no detectable side effects, especially in overweight and obese individuals.

Keywords

Mastic gum, atherosclerosis, cardiovascular, diabetes, lipids, terpenes

Received 10 May 2015; accepted 9 August 2015

Introduction

Dyslipidemia and diabetes mellitus as risk factors for cardiovascular disease

Cardiovascular disease (CVD) is the worldwide leading cause of morbidity and mortality. Atherosclerosis, the main pathological process leading to coronary, cerebral and peripheral artery disease, begins early in life and

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progresses influenced by certain cardiovascular risk factors like tobacco use, unhealthy diet and physical inactivity (resulting in obesity), hypertension, dyslipidemia and diabetes mellitus (DM).¹ Remarkable studies both in primary² and in secondary³ prevention have proved that pharmaceutically reduced cholesterol levels decrease the incidence of adverse cardiovascular events. As far as DM is concerned, the cardiovascular risk increases early, prior to the development of overt DM, due to changes in vasculature, and this poses a great need to intercept the vicious cycle of hyperglycemia–vascular disease at an earlier stage, that of ‘pre-diabetes’, before the development of clinical manifestations and organ damage.⁴

Chios mastic gum

Many natural remedies and herbals claim to possess lipid and glucose lowering effects, although scientific evidence of proven efficacy is usually lacking. Chios mastic gum (Mastiha Chia) is a natural resin that is excreted from the trunk and branches of the mastic tree (*Pistacia Lentiscus* var. *Chia* of the Anacardiaceae family). For thousands of years the southern part of Chios Island has been the only place on the planet where mastic trees are systematically cultivated and mastic gum is produced and exploited commercially. Archaeological findings and historical references establish the medicinal, cosmetic and culinary use of mastic gum in the Mediterranean basin since the 7th century BC.⁵

In the modern era, CMG has been many times the subject of scientific research, and many beneficial biological activities – anti-indigestion, anti-ulcer (acting against *Helicobacter pylori*), antimicrobial, antifungal, antioxidant, hypolipidemic, anti-inflammatory, anti-Crohn’s disease and anti-neoplastic – have been reported.^{5–8}

CMG’s main components are an insoluble polymer (25%) and a triterpenic fraction (67%), which is further sub-classified as acidic (39%) and neutral (28%) fractions.^{9–11} The acidic fraction seems to have the greatest anti-microbial activity and its main components are the masticadienonic acid (30%), isomasticadienonic acid (30%), oleanonic acid (15%) and moronic acid (10%). The neutral fraction’s main components include butyspermol, tirucallol, oleanolic aldehyde, oleanonic aldehyde and betulonal. Neutral compounds like butyspermol and tirucallol present a typical phytosterolic structure.^{11,12} Another monoterpenic constituent of CMG, camphene, seems to possess promising hypolipidemic activity.¹³ Furthermore, anti-oxidant effects of Chios mastic, that may result in reducing LDL cholesterol oxidation, could be attributed to the resin’s remarkable concentration of various polyphenols.¹⁴

CMG is a natural anti-oxidant, extremely efficient in preventing LDL oxidation *in vitro*^{15,16} and its hypolipidemic effect has been demonstrated in animal^{13,17,18} and human¹⁹ studies. CMG could be a potential anti-diabetic agent, as is the case with many other natural products rich in terpenes,^{17,19} and exhibits remarkable anti-inflammatory activity.^{12,20}

Aim of the study

We designed a prospective, randomized, placebo controlled, clinical pilot study in order to evaluate the effect of three different formulations of CMG on lipid and glucose metabolism in healthy volunteers, not amenable to pharmaceutical interventions according to current guidelines, in order to detect the most effective formulation and to investigate their safety profile.

Methods

End-points

The *primary end-point* was to record any changes in cholesterol (total, HDL, LDL-directly measured), triglycerides and glucose levels after continuous administration of three different formulations of CMG for eight weeks. *Secondary end-points* included changes in other serum biochemical parameters, such as alanine aminotransferase (ALT), aspartate aminotransferase (AST), urea, creatinine, uric acid and high sensitivity C-reactive protein (hsCRP), and gastrointestinal or other adverse events.

Inclusion–exclusion criteria

The recruitment period was between 1 April 2012 and 31 March 2013, and informed written consent was provided by each volunteer. The study received approval by the hospital’s Ethics Committee and Scientific Council, and included adult volunteers of both genders with increased total cholesterol >200 mg/dl, not amenable or not willing to receive pharmaceutical therapy. The exclusion criteria were: participation in any other study during the recruitment period, contribution in the design or accomplishment of the study, coronary heart disease or equivalent (carotid artery disease, peripheral vascular disease, stroke, diabetes mellitus, aortic aneurysm), European Society of Cardiology Score ≥ 5 , subjects amenable to pharmaceutical lipid-lowering regimens according to current guidelines, and any pharmaceutical regimen or substance with known effects on serum lipids, glucose or uric acid metabolism.

CMG formulations

Pure CMG was dispensed in capsule form, with no flavourings added to the natural product, as follow: The mastic granules were milled to fine powder (particle size $<100\mu\text{m}$) using a Hosokawa Al-pine Mill (Fine Impact Mill 100 UP2). The encapsulation of powder was performed using an AF 40T PAM automatic capsule filling machine. Capsule cells (capsugel, V caps, size 0) were made of Hpromellose (hydroxypropyl methylcellulose) and each contained $0.35 (\pm 0.02)$ g of mastic powder. The total extract of CMG was performed by Hittex France using CO_2 extraction without the use of solvent. The total liquid extract was then mixed (1:1) with Fujicalin, a dibasic anhydrous calcium phosphate, in order to be solid for the encapsulation. The encapsulation was as above. Placebo capsules were identical in size and filled with starch. Quality control of the mastic gum was assured by the Mastic Gum Growers Cooperative.

During the study, three different formulations of CMG and placebo were continuously provided to the subjects for eight weeks. (1) Capsules containing 330 mg of CMG (three capsules per day, total dose 1 g). (2) Capsules factory processed (where the polymer had been extracted) containing 330 mg of CMG (three capsules per day, total dose 1 g). (3) Capsules, of similar morphology to the above, containing 330 mg of starch used as placebo (three capsules per day, total dose 1 g). (4) CMG powder, in a total daily dose of 2 g, according to local traditional medicine.

A randomization plan for treatment assignment to the study participants was generated using our statistical software. To insure treatment allocation concealment, capsules used for the administration of placebo, total mastic and polymer free mastic were of the same morphology with no distinguishing signs or characteristics. Allocation concealment could not be achieved in the case of mastic powder only administration.

Study sample

Minimum required sample size for multiple regression analysis was *a priori* determined to be 140 volunteers, given the desired probability level (0.05), the number of predictors in the model, the anticipated effect size (0.15-medium) and the desired statistical power level (0.9). There was a 4:2:2:1 randomization ratio to total mastic capsules (TM), polymer-free mastic capsules (PFM), mastic powder (MP) and placebo (C), respectively. 210 volunteers were initially screened, 179 were recruited and randomized to the three formulations of CMG and the placebo, and 156 (TM:72, PFM:33, MP:28 and C:23) completed the follow-up period.

Statistical analysis

Associations between baseline characteristics and intervention groups were assessed using analysis of variance (ANOVA) or χ^2 test as appropriate. Multiple linear regression models were used to estimate the main effects of various forms of CMG intake on total, HDL and LDL cholesterol, triglycerides and glucose, with or without adjustment for potential confounders. Potential confounders considered were baseline levels of dependent variables, BMI, age, gender and smoking status. Potential confounders were entered into multiple regression models with backward stepwise procedures. Assumptions of linear regression analysis were tested by normal probability plots and histograms. Gender, age, smoking and BMI were considered as covariates due to their potential associations with lipid and glucose metabolism. When considered significant, further analyses were performed in subgroups. For all models $p < 0.05$ was considered as significant. All statistical analyses were performed using Stata Statistical Software (Stata 9.1).

Results

The baseline characteristics (visit 1) of the study population are provided in Table 1. Biochemical parameter values for each study group at visit 2 are presented in Table 2. Two linear models (not adjusted – Model 1 and adjusted for gender, age, BMI and respective baseline characteristics – Model 2) were built in order to evaluate differences in biochemical parameters between the three CMG formulations and placebo at visit 2.

Total mastic gum caps administration resulted in a mean reduction of total cholesterol by 17.4 mg/dl ($p = 0.015$), triglycerides by 29.4 mg/dl ($p = 0.04$) and fasting plasma glucose (FPG) by 7.3 mg/dl ($p = 0.001$). Total mastic powder administration resulted in a mean reduction of total cholesterol by 14.7 mg/dl ($p = 0.09$), triglycerides by 46.8 mg/dl ($p = 0.01$) and FPG by 5.4 mg/dl ($p = 0.04$). Polymer-free mastic caps administration resulted in no statistically significant effect (Table 3, Model 1).

Adjusting our models for age, gender, BMI and baseline values differences amongst study groups produced an estimated mean reduction of total cholesterol by 11.5 mg/dl ($p = 0.02$) and FPG by 4.5 mg/dl ($p = 0.01$) after total mastic caps administration, but no statistically significant reduction after polymer-free caps and mastic powder administration (Table 3, Model 2; Figure 1). Further analysis revealed that the effect was stronger in overweight and obese subjects ($\text{BMI} > 25$) receiving total mastic caps, with an estimated mean reduction of total cholesterol by 13.5 mg/dl ($p = 0.03$) and FPG by 5.1 mg/dl ($p = 0.03$), adjusted for age, gender, BMI and baseline values

Table 1. Baseline characteristics of the study population (visit 1).

	Placebo (n = 23)	Total mastic (n = 72)	Polymer-free mastic (n = 33)	Total mastic powder (n = 28)
Continuous variables				
Age (years)	56.3 (10.4)	53.3 (9.7)	53 (9.2)	50 (9.3)
Weight (kg)	75.7 (15.5)	76.2 (12.6)	73.1 (10.0)	76.1 (12.7)
BMI (kg/m ²)	27.6 (4.6)	27.4 (2.9)	26.5 (2.4)	27.0 (3.3)
Total cholesterol (mg/dl)	257.5 (20.5)	250 (23.5)	257.5 (27.2)	247.5 (27.4)
LDL-C (mg/dl)	180.2 (26.9)	174.0 (21.6)	182.7 (33)	176.6 (28.4)
HDL-C (mg/dl)	62.2 (20.9)	61.9 (17.5)	58.2 (16.9)	55.8 (16.5)
Triglycerides (mg/dl)	146.2 (67.2)	112.4 (42.6)	132.5 (53.9)	113.4 (51.8)
Glucose (mg/dl)	90.4 (8.1)	86.8 (10.0)	86.9 (7.9)	87.5 (9.1)
Uric acid (mg/dl)	4.9 (1.4)	5.1 (1.2)	5.0 (1.1)	5.4 (1.3)
ALT (SGPT) (U/L)	20.2 (9.0)	21.3 (14.6)	20.9 (9.2)	25.4 (19.1)
AST (SGOT) (U/L)	20.5 (5.9)	19.7 (7.7)	19.6 (5.2)	20.7 (5.3)
Creatinine (mg/dl)	0.72 (0.17)	0.73 (18)	0.74 (0.15)	0.74 (0.18)
CRP (mg/dl)	0.21 (0.1)	0.18 (0.1)	0.22 (0.1)	0.22 (1)
BUN (mg/dl)	30.7 (7.7)	33 (7.5)	32.5 (7.3)	31.9 (7.9)
Categorical variables				
Gender (female)	17 (77.3)	43 (60.5)	19 (57.6)	14 (50.0)
Smoking status (no.)	18 (78)	58 (80.5)	25 (75.2)	24 (85.7)
Hypertension (no.)	17 (74)	62 (86)	26 (89.3)	25 (89)
Family history of CHD (no.)	17 (74)	55 (76.4)	26 (78.8)	21 (75)

Table 2. Biochemical parameter values for each study group in visit 2.

	Placebo (n = 23)	Total mastic (n = 72)	Polymer-free mastic (n = 33)	Total mastic powder (n = 28)
Total cholesterol (mg/dl)	259.9 (31.2)	242.5 (26.2)	252.1 (31.5)	245.2 (26.1)
LDL cholesterol (mg/dl)	181.1 (32.4)	168.9 (26)	178.5 (38)	172.8 (27.4)
HDL cholesterol (mg/dl)	62.4 (24.2)	60.1 (17.9)	59.5 (21.9)	58.2 (17.5)
Triglycerides (mg/dl)	145.6 (82.3)	116.2 (45.5)	128.2 (67.2)	98.8 (51.5)
FPG (mg/dl)	94.6 (8.2)	87.3 (9)	91.7 (7.7)	89.2 (8.7)
Uric acid (mg/dl)	4.9 (1.3)	5.0 (1.1)	4.8 (1.0)	4.9 (1.4)
CRP (mg/dl)	0.28 (0.3)	0.23 (0.3)	0.28 (0.3)	0.15 (0.1)
ALT (SGPT) (U/L)	20 (8.2)	18.3 (9.2)	26.9 (30.6)	27.9 (17.1)
AST (SGOT) (U/L)	20.2 (4.3)	19.1 (4.5)	21.6 (6.4)	24.1 (7.6)
BUN (mg/dl)	33.4 (9.6)	31.2 (6.6)	29.7 (6.3)	32.7 (8.4)
Creatinine (mg/dl)	0.72 (0.16)	0.71 (0.14)	0.75 (0.16)	0.72 (0.22)

(Table 4, Model 2). Administration of polymer-free mastic caps and mastic powder resulted in no statistically significant alteration.

No significant effect was observed on LDL-cholesterol, HDL-cholesterol, triglycerides, uric acid or CRP values in any of our statistical models. No significant changes were documented for BMI during the study, in any of the groups. No gastrointestinal adverse

events were reported. Furthermore, there was no liver and renal toxicity (no significant changes were noted in BUN, creatinine, AST and ALT values).

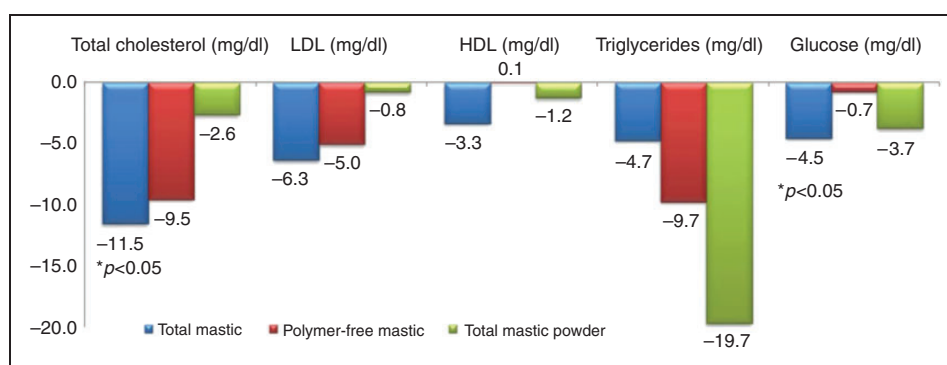
Discussion

CHIOS-MASTIHA is the first human in-vivo, prospective, randomized, placebo-controlled, pilot

Table 3. Regression coefficients (β) of mastic treatment and metabolic biomarkers according to a linear model among hyperlipidemic individuals ($n = 156$).

Mastic treatment	Model 1			Model 2		
	β	95% CI	P	β	95% CI	P
Total mastic (caps)						
Total cholesterol (mg/dl)	-17.4	-31.4 -3.4	0.015	-11.5	-21.3 -1.59	0.02
LDL (mg/dl)	-12.0	-27.1 2.7	0.1	-6.3	-16.3 3.7	0.2
HDL (mg/dl)	-2.2	-12.2 7.6	0.6	-3.3	-7.7 1.1	0.1
Triglycerides (mg/dl)	-29.4	-58.3 -0.6	0.04	-4.7	-26.5 17.0	0.66
FPG (mg/dl)	-7.3	-11.6 -3	0.001	-4.5	-8.0 -1.1	0.01
Polymer-free mastic (caps)						
Total cholesterol (mg/dl)	-7.8	-23.6 7.9	0.33	-9.5	-14.9 9.8	0.09
Triglycerides (mg/dl)	-17.4	-50.0 15.1	0.3	-9.7	-33.5 14.0	0.7
FPG (mg/dl)	-2.9	-7.9 1.9	0.2	-0.7	-4.5 3.2	0.72
Mastic powder						
Total cholesterol (mg/dl)	-14.7	-31.9 2.55	0.09	-2.6	-14.9 9.8	0.68
Triglycerides (mg/dl)	-46.8	-82.4 -11.3	0.01	-19.7	-46.2 6.7	0.14
FPG(mg/dl)	-5.4	-10.7 -0.18	0.04	-3.7	-7.8 0.34	0.07

CI: confidence intervals; Model 1: Not adjusted; Model 2: Adjusted for gender, age, BMI and respective baseline characteristics.

**Figure 1.** Effects of the different CMG formulations on total, LDL and HDL cholesterol, triglycerides and glucose levels, compared to placebo, according to the adjusted linear Model 2 among hyperlipidemic individuals ($n = 156$).

study comparing the action of three different formulations of CMG on lipid and glucose metabolism of otherwise healthy, hypercholesterolemic volunteers.

Biological actions of CMG

There are several possible biological mechanisms to explain CMG effects on lipid and glucose metabolism. Restoration of intracellular glutathione (GSH) and

Table 4. Regression coefficients (β) of mastic treatment and metabolic biomarkers according to a linear model among hyperlipidemic overweight and obese individuals (BMI > 25, $n = 100$).

	Model 1			Model 2		
	β	95% CI	P	β	95% CI	P
Mastic treatment						
Total mastic (caps)						
Total cholesterol (mg/dl)	-28	-46.6 -9.3	0.008	-13.5	-25.8 -1.2	0.03
Triglycerides (mg/dl)	-54	-87.8 -20.2	0.002	-18.2	-43.2 6.8	0.15
FPG (mg/dl)	-8.3	-13.8 -2.6	0.004	-5.1	-9.8 -0.36	0.03
Mastic powder						
Total cholesterol (mg/dl)	-21.7	-45.1 1.7	0.07	-2.0	-17.5 13.7	0.8
Triglycerides (mg/dl)	-56.3	-97.7 -15	0.008	-27.9	-57.7 1.9	0.06
FPG (mg/dl)	-6.9	13.7 -0.08	0.04	-3.7	-9.1 1.6	0.17

CI: confidence intervals; Model 1: Not adjusted; Model 2: Adjusted for gender, age, BMI, and respective baseline characteristics.

down-regulation of CD36 expression are possible pathways for CMG triterpenes to exert their antioxidant and antiatherogenic effects.^{16,21} Camphene, one of CMG's triterpenic compounds, in synergy with other CMG constituents demonstrates a significant hypolipidemic effect, possibly via lipoprotein lipase (LPL) activation.¹³ CMG seems to act as a PPAR- γ (and possibly a PPAR- α) agonist affecting lipid and glucose metabolism.^{22,23} Some CMG triterpenic constituents could act as α -glucosidase inhibitors,²⁴ while others demonstrate phytoesterolic effects.^{18,25} Triterpenes are also known to exert beneficial effects on pancreatic β -cells, enhancing insulin secretion, and to inhibit protein tyrosine phosphatase-1B (PTP-1B) enhancing insulin action.²⁶

In vitro CMG studies

Andrikopoulos et al.¹⁵ compared several naturally occurring gums and resins and concluded that CMG was the most effective in protecting human LDL from copper-induced oxidation in vitro. Loizou et al.¹² proved that the neutral fraction of CMG significantly inhibits in vitro the expression of endothelial adhesion molecules (VCAM-1, ICAM-1) and other inflammatory mediators in human aortic endothelial cells, thus interfering with the initial stages of atherosclerosis.

Animal studies

Administration of CMG in hypercholesterolemic rabbits resulted in reduced total cholesterol levels and prevented subintimal accumulation of lipids and foamy macrophages.¹⁸ Peripheral anti-inflammatory and anti-oxidant activities of CMG have also been reported in the limbs of mice and rats, although the mechanism of action was not fully elucidated.¹⁴ Vallianou et al.¹³ demonstrated that camphene, a monoterpenic compound of CMG, reduced total and LDL cholesterol

and triglycerides in hyperlipidemic rats. The authors suggested that the hypolipidemic action of camphene was independent of HMG-CoA reductase activity, which is the main mechanism of action of statins. In a recent study by Georgiadis et al.¹⁷ CMG significantly lowered total cholesterol, LDL, triglycerides and glucose levels, and improved HDL cholesterol levels and hepatic steatosis in diabetic mice.

Human studies

The only in vivo human study of CMG (not placebo controlled) included 133 volunteers of both genders, randomized to two groups, one receiving daily 5 g of mastic powder for a period of 18 months and a second group, receiving daily 0.7 g of CMG in an aqueous solution for 12 months. In the high dose group (of 5 g mastic powder per day) total cholesterol, LDL, total cholesterol/HDL ratio, apoA, apoB, Lp(a), AST, ALT and gamma-GT levels were significantly decreased, while glucose, HDL and triglyceride levels did not exhibit significant changes. Total cholesterol, total cholesterol/HDL ratio and AST were reduced in males, while only Lp(a) was significantly reduced in females. In the low-dose group (0.7 g of CMG in solution) a statistically significant decrease in glucose levels among male subjects was observed.¹⁹

Effect of CMG formulations in current study

In our study the administration of TM capsules resulted in a significant reduction of total cholesterol levels by 11.5 mg/dl ($p = 0.02$). This effect was stronger in overweight and obese patients (mean BMI = 28.5 kg/m² SD \pm 2.74) with an estimated mean reduction of total cholesterol by 13.5 mg/dl ($p = 0.03$). A trend for reduction, although not statistically significant, was observed for LDL-cholesterol (-6.0 mg/dl),

HDL-cholesterol (-3.2 mg/dl), triglycerides (-4.7 mg/dl) justifying the reduction in total cholesterol levels.

The absence of any statistical significant effect on LDL-cholesterol and on triglycerides levels is in contrast to all the aforementioned literature, where LDL reduction was a stable finding in animals.^{13,17,18} Triantafyllou et al.¹⁹ also showed some degree of LDL reduction, but with a much higher mastic powder dose (5 g compared to 2 g in this study).

Triglyceride levels were also not affected by any CMG formulation, in contrast with some animal studies,^{13,17} but in accordance with the other human study by Triantafyllou et al.¹⁹

Favourable effects on glucose levels from the use of CMG have been shown so far by Georgiadis et al.¹⁷ in diabetic mice and by Triantafyllou et al.¹⁹ only in male volunteers. In the present study, total CMG capsules significantly reduced FPG levels in healthy volunteers by 4.5 mg/dl ($p=0.01$). The effect was stronger in overweight and obese patients, with an estimated mean reduction of FPG by 5.1 mg/dl ($p=0.03$). Total CMG powder and polymer-free CMG caps did not show any favourable effect, in agreement with the results by Triantafyllou et al.,¹⁹ where 5 g of Chios mastic powder did not exhibit any significant changes in glucose levels of 133 volunteers (including subjects with DM) for an 18-month follow-up period. However, in the aforementioned study, a mastic solution of about 0.7 g of Chios mastic significantly decreased glucose levels, only in males, by 3.1 mg/dl.¹⁹

Total CMG capsules at a daily dose of 1 g produced the most beneficial effects regarding total cholesterol and FPG. Failure to reduce serum levels of LDL cholesterol and triglycerides could be attributed to the relatively low dose. A daily dose of 2 or 3 g, could be more effective, as is the case in some of the aforementioned studies. On the other hand, total CMG powder failed to produce any significant result, even though it was administered at a higher dose of 2 g daily. The fact that CMG powder was administered once daily could be the cause of its failure. Polymer free CMG capsules, despite our hopes, failed also to produce any significant effect. This failure could be attributed to insufficient dose, different absorption rate in the GI tract, or to some unknown biological activity of the missing polymer.

Conclusion

In conclusion, the CHIOS-MASTIHA study showed that CMG capsules with the polymer in total daily dose of 1 g, seem to have the most powerful effect in lowering total cholesterol and glucose levels in healthy volunteers. The polymer-free CMG capsules and total CMG powder failed to produce any significant benefit.

Overweight and obese volunteers received the greatest benefit, achieving lower total cholesterol and glucose levels. The innovative finding of this study is the glucose-lowering effect of CMG in healthy volunteers. Taking into account the pilot character of this study, a larger study should be conducted in order to confirm its results before final and more robust conclusions can be extracted.

Acknowledgements

We would like to gratefully thank the Chios Gum Mastic Growers' Association for freely providing the different formulations of Chios mastic gum investigated in the study.

Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

Conflict of interest

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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