Review

Dietary supplements for obesity

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Keywords

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Summary

Obesity and associated complications including diabetes, cardiometabolic dysfunction, disability, malignancy and premature mortality are considered epidemic. Research on obesity is therefore of worldwide importance. The development of obesity is a multifactorial phenomenon with contributions from biological, behavioral, genetic and environmental factors. Obesity and its associated issues require various lifestyle modifications and treatment options such medication, exercise, diet, surgery, pharmacological therapy and dietary supplements. Dietary supplements are considered an attractive alternative to traditional therapy due to their low toxicity profile and their accessibility to the general population. Dietary supplements may include one or more dietary ingredients. In this narrative review, we analyze the effects on obesity and obesity-related issues of various natural components. For example, there are a myriad of supplements that have been used as dietary supplements for weight loss such as minerals, vitamins, amino acids, metabolites, herbs, and plant extracts. This narrative review aims to present the benefits and side-effects of several ingredients of dietary supplements for weight loss and treatment of obesity. In particular, the mechanism of action, results of clinical trials, and possible side effects will be presented for the following ingredients: β-Glucans, bitter orange, calcium, vitamin D, chitosan, chromium, cocoa, coleus forskohlii, conjugate linoleic acid, ephedra sinica, fucoxanthin, garcinia cambogia, glucomannan, green coffee, green tea, guar gum, raspberry, hoodia gordonii, irvingia gabonensis, phenylpropylamine, pyruvate, white kidney bean.

Introduction

Obesity is one of the most prevalent nutritional diseases in industrialized countries and is recognized as a significant public health issue. By definition, obesity is the excessive accumulation of adipose tissue. Excess body weight is classically determined on the basis of a person's BMI (body mass index): BMI = weight (kg)/height (m)^2. A BMI of 30 kg/m^2 is recognized as the obesity threshold, while a BMI comprised between 25 and 29.9 kg/m^2 is used to identify overweight people; BMIs over the obesity threshold are associated with higher morbidity and mortality rates and a wide range of symptoms. Excessive weight gain is considered a multifactorial phenomenon that involves variably interacting biological, behavioral, genetic, and environmental factors [1-4].

Obesity and associated complications like cardiometabolic dysfunction, diabetes, disability, malignancy, and premature death are considered epidemic in the western world [5-7]. Treatment of obesity is therefore of major significance for researchers around the world. In the United States, the obesity rate continues to increase, and worsened during the COVID-19 pandemic [8]. Obesity, overweight and associated issues call for preventive and treatments approaches. Indeed, several solutions have been proposed, such as following a healthy lifestyle, following eating plans for weight loss, and exercising. Moreover, interventional approaches such as surgery, pharmacological therapy and dietary supplements have also been developed [7, 9]. The U.S. Food and Drug Administration (FDA) has approved various traditional approaches including pharmacological, surgical, and endoscopic bariatric therapies that may promote weight loss of 5-35% [10]. Dietary supplements are considered an attractive alternative to traditional therapy due to their low toxicity and accessibility to the general population. Almost 33.9% of adults attempting weight loss, largely young adults, women, and lower socioeconomic groups, use dietary supplements [7, 10].

Dietary supplements are products intended to aid or supplement the diet and enhance nutritional status. They may include one or more ingredients such as minerals, vitamins, amino acids, metabolites, herbs, or extracts. Since they are generally taken orally, they are mostly available in the form of tablets, capsules, powders, or liquids. Dietary supplements are not suggested alone for treatment of a disease, but they should act synergistically with other treatments to facilitate healing or recovery. Though dietary ingredients may show certain effects in preclinical and clinical settings, the evidence may not be clinically significant in clinical trials [10-12]. Thus, clinical studies and meta-analyses should be performed to prove the effectiveness of a dietary supplement. Moreover, different factors must be considered in selecting dietary supplements, among which purity of the supplement, the patient's overall lifestyle (such as dietary habits and exercise), other health-associated conditions of

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the patient (such as concomitant diseases and nutritional status), accurate dosage, food–drug interactions, absorption profiles, and potential side effects are the most relevant [7].

The U.S. Dietary Supplement Health and Education Act of 1994 deregulated the dietary supplement industry. The Office of Dietary Supplements (ODS) at the National Institutes of Health (NIH) has strengthened and enhanced understanding and knowledge of dietary supplements through the evaluation of scientific information, supporting scientific research and public education [13]. A product integrity profile is required for research projects funded by the ODS, including a collaborative approach to documentation of the commercial product. The Obesity Society believes that it is useful to conduct a qualitative analysis of non-FDA approved therapies to provide valid scientific evidence for the guidance of members [10].

Researchers have shown keen interest in the molecular and theoretical mechanisms of bioactive ingredients and the weight-loss effects of commonly used dietary supplements [7]. Table I and following paragraphs report a non-exhaustive list of dietary supplements with evidence supporting their use in weight loss.

β-Glucans

Glucans are soluble polysaccharide fibers derived from D-glucose and classified by their α or β interchain linkage. β-Glucans consist of D-glucose monomers linked together by beta-glycosidic bonds and are arranged in linear β1-3,1-4-D-glucan structure. Glucans are mostly found in cell walls of cereal grain endosperm and are also a major structural component of mushroom cell walls. As β-glucans are indigestible and readily fermented by gut microbiota in the colon and small intestine, it has been suggested that they could have a prebiotic role; they do not have significant side effect [14, 15, 52]. Their weight-loss effect is attributed to their being soluble fibers that may increase satiety due to the total time they take to move through the gastrointestinal track, and to their ability to reduce absorption of glucose. Their weight-loss effects were discovered as secondary outcomes of clinical trials designed to evaluate the effects of β-glucans on health conditions like insulin resistance, high blood pressure and dyslipidemia [14, 15].

Bitter orange

Bitter orange, *Citrus aurantium* or Seville orange, has been used in various traditional South American and Chinese folk medicines for different health conditions [53]. Bitter orange extract has been used as a supplement to treat obesity and to enhance exercise performance. It contains phytochemicals such as octopamine, alkaloids and particularly synephrine. Several studies suggest there is a positive effect of bitter orange extract on weight loss [16, 53-55]. In a clinical trial by Kaats et al., a single dose of synephrine alone or synephrine and flavonoids combined both increased the basal metabolic rate in humans. Synephrine derived from *C. aurantium* is safe and no side effects were observed when up to 98 mg/day was taken for 60 days [16].

Tab. I. Non-exhaustive list of dietary supplements with evidence supporting their use in weight loss.

Ingredient	Mechanism of action	References
β-Glucans	Reduce appetite and glucose absorption	[14, 15]
Bitter orange	Increase metabolic rate	[16]
Calcium-vitamin D	Improve metabolism, regulate triglyceride storage and adipocyte lipid metabolism	[17]
Chitosan	Reduce fat absorption	[18]
Chromium	Increase insulin sensitivity	[19, 20]
Cocoa	Stimulate thermogenesis and lipid catabolism	[21]
Coleus forskohlii	Increase lipolysis	[22, 23]
Conjugated linoleic acid	Increase lipolysis	[24, 25]
Ephedra sinica	Increase metabolic rate	[26]
Fucoxanthin	Reduce lipogenesis and increases thermogenesis	[27-31]
Garcinia cambogia	Reduce lipogenesis	[32, 33]
Glucomannan	Reduce appetite and fat absorption	[34-36]
Green coffee	Increase lipolysis	[37-40]
Green tea	Reduce appetite and increases thermogenesis	[26, 41]
Guar gum	Reduce appetite	[42]
Hoodia gordonii	Reduce appetite.	[43-45]
Irvingia gabonensis	Reduce lipogenesis	[46, 47]
Raspberry	Reduce lipogenesis and increases lipolysis	[48]
Phenylpropylamine	Reduce appetite	[49]
Pyruvate	Reduce appetite and fatigue, increases glucose uptake my skeletal muscles	[50]
White kidney bean	Reduce glucose absorption	[51]

Calcium-vitamin D supplementation

Calcium is an essential nutrient/mineral often associated with healthy teeth and bones. It is also required for muscle, heart, and nerve function and for blood clotting. Vitamin D helps the body absorb calcium after conversion to calcitriol in the kidneys. Combined supplementation of calcium and vitamin D may improve metabolic health, regulate triglyceride storage and adipocyte lipid metabolism, and reduce body weight. Three different studies have reported significant weight loss over time in adults treated with calcium, without any stated side effect [17].

Chitosan

Chitosan is a natural marine polysaccharide fiber derived from insect exoskeletons and shells of crustaceans like lobster, shellfish etc. [10]. Although it does not occur naturally in human tissues, it appears to be biocompatible, nontoxic, biodegradable and nonimmunogenic [7]. It is used in wound dressings to stop or reduce bleeding, and orally to decrease absorption of lipids in the gastrointestinal tract and reduce body weight [18]. Its mechanism of action for weight loss may involve binding fat molecules in the intestine, preventing their absorption. Chitosan is an insoluble animal fiber that exerts a bile acid sequestration or resin effect, decreasing absorption of cholesterol. It is currently available over the counter for treatment of conditions like obesity, hypertension and hypercholesterolemia [56]. A meta-analysis by Ernst and Pittler showed a statistically significant loss of weight (2.38 kg) after chitosan supplementation for 28 days [57]. Five additional studies on the effects of chitosan supplementation on weight loss reported statistically significant changes between groups, while others reported a weight reduction (2.3 kg) after 6 weeks of supplementation [10, 58].
A Cochrane meta-analysis of 13 clinical trials on chitosan reported a statistically significant weighted mean difference in body weight (1.7 kg) between the chitosan supplement and placebo groups. However, when only higher quality trials were analyzed, the average weight loss fell to 0.6 kg, which was, however, still statistically significant [59].

Chromium

Chromium is considered an essential trace mineral, present in small amounts in different foods. It is also taken as a supplement. Chromium plays a significant role in the metabolism of amino acids, glucose, and lipids though its effects on insulin. It may directly increase the activity of serotonin and regulate its downstream impact on dopaminergic signaling on central insulin receptors. Chromium is considered to affect numerous pathways involving the central control of satiety, energy homeostasis and food intake by modulating these neurotransmitters [19, 20]. Chromium has been shown to reduce body weight while maintaining lean mass, thus it is favored by manufacturers of dietary supplements for weight loss [60].

Cocoa

The cocoa bean or cocoa seed is the dried and fermented seed from the fruit of *Theobroma cacao*. These seeds are roasted and ground to obtain cocoa. Cocoa beans contain substantial amounts of various bioactive compounds, such as methylxanthines and antioxidant polyphenols (theobromine and caffeine) that may help weight loss by converting white adipocytes into brown adipocytes and enhancing lipid catabolism and endothelial function, while reducing insulin resistance and oxidative stress [21].
A randomized controlled clinical trial proved that a combination of catechins and cocoa reduces food intake withouth any side effect in young adults [61], while a second blinded placebo-controlled study proved that cocoa by-products reduced body weight in adults [62].

Coleus forskohlii

Forskolin is a bioactive compound extracted from the root of *Coleus forskohlii,* a relative of the mint family. *Coleus forskohlii* is native to India and has been used in Ayurvedic medicine for centuries for the treatment of various health conditions, like respiratory disorders, heart disease and abdominal colic. Forskolin is a strong cAMP stimulator that activates hormone-sensitive lipase, causing release of fatty acids from adipose tissue. A few limited clinical trials have examined its effect on weight loss and found a more significant effect in males than females. A placebo-controlled, double-blind clinical trial involving 15 obese males treated with 500 mg/day forskolin extract (10%) for 12 weeks found a significant reduction in body fat in the forskolin group and an increase in lean body mass without any stated side effect, although the basal metabolic rate remained unchanged [22, 23, 63].

Conjugated linoleic acid

Conjugated linoleic acid is a natural essential omega-6 fatty acid derived from linoleic acid, found mostly in meat and dairy products. Animal studies have shown its many beneficial effects including immune enhancement, reduction of atherosclerosis biomarkers and altered body composition (lower fat mass, higher lean mass). In humans, dietary conjugated linoleic acid supplements may improve insulin sensitivity and lipid metabolism by decreasing plasma levels of triglycerides and low-density cholesterol [24, 64]. Conjugated linoleic acid proved to reduce hunger in adults, with no remarkable side effects [25].

Ephedra sinica

Ephedra sinica is a plant that occurs naturally in Asia, although it is cultivated in other parts of the world. For thousands of years, *Ephedra sinica* has been used in Chinese medicine. Ephedrine is the bioactive ingredient of *Ephedra sinica* associated with weight loss; it is mostly taken with caffeine. In clinical trials, ephedra and ephedrine demonstrate only short-term weight-loss effects. The proposed mechanism of action involves an increase in the metabolic rate and stimulation of fat burning. For these reasons, ephedrine is used in weight-loss supplements [26].

Fucoxanthin

Fucoxanthin is a marine carotenoid widespread in nature and mostly isolated from diatoms and seaweeds. Several preclinical trials have investigated a mechanism of action of fucoxanthin in the treatment of obesity and associated cardiometabolic alterations. Fucoxanthin decreases plasma and hepatic concentrations of triglycerides. It also reduces expression of acetyl-CoA carboxylase, thus decreasing malonyl-CoA formation, fatty acid synthase expression and saturated long-chain fatty acid synthesis [27-29].

Research studies have reported that fucoxanthin may downregulate low density lipoprotein receptor expression in the liver [28]. It also downregulates expression of the *C/EBP*α (CCAAT/enhancer-binding protein-alpha), *PPAR*-γ (peroxisome proliferator-activated receptor gamma) and *SREBP-1c* (sterol regulatory element-binding protein 1c) genes during intermediate to late adipocyte differentiation stages, whereas during the initial adipocyte differentiation stages, fucoxanthin enhances expression of the proteins *C/EBP*α, *PPAR*-γ, A-FABP (adipocyte fatty acid-binding protein), *SREBP-1c* (sterol-regulatory element binding protein-1C), glucose transporter 4 (GLUT4) and lipoprotein lipase [30]. Similarly fucoxanthin has been known to stimulate UCP-1 (uncoupling protein1) expression in white adipocytes, thereby increasing energy expenditure and thermogenesis [31].

In a study of 151 obese premenopausal women who were given supplements containing fucoxanthin from brown seaweed and pomegranate seed oil extracts at various doses for almost 16 weeks, the group receiving 300 mg pomegranate seed oil and 300 mg seaweed extract (2.4 mg fucoxanthin) had a statistically significant decrease in waist circumference, body weight and body fat, without any side effects. Moreover, the group that received more than 2.4mg fucoxanthin showed an increase in resting energy expenditure compared to the placebo [65].

Garcinia cambogia

Garcinia cambogia is a plant native to Asia, Polynesia, Africa, and Australia. It has various significant anti-inflammatory, antineoplastic, hypolipidemic and antidiabetic effects on the body, and its extracts have anorexigenic effects. *Garcinia* has also been analyzed for weight management. Its rind is high in hydroxycitric acid, believed to be a bioactive component that causes weight loss by inhibiting extra-mitochondrial citrate lyase or ATP-citralyase that influences the synthesis of cholesterol and fatty acids. As ATP-citralyase is the major enzyme involved in the synthesis and storage of fatty acid in cells, hydroxycitric acid may inhibit lipogenesis [10, 32, 33].

Glucomannan

Glucomannan is a water-soluble polysaccharide dietary fiber that is easily extracted in large amounts from softwoods, tubers, plant bulbs and roots. Most glucomannan is extracted from the tuber of konjac (*Amorphophallus konjac*), an Asian plant for use as an herbal remedy. Glucomannan high molecular weight polysaccharide is composed of β-(1-4)–linked D-mannose and D-glucose monomers and is considered a soluble fiber. This highly viscous dietary fiber can absorb 50 times its weight in water. Since human salivary and pancreatic amylase cannot break β-1,4 glycosidic bonds, glucomannan reaches the colon almost unchanged and is fermented by gut microbiota. Glucomannan is lately being analyzed for its beneficial effects on weight loss, blood glucose, and dyslipidemia, amongst other uses [34, 35]. Some clinical trials question its effectiveness in weight loss [35, 66]. Thus, new studies will be needed to confirm glucomannan positive action on weight reduction.

Various mechanisms of action could explain the effects of glucomannan on weight loss: it may cause satiety through greater mastication effort, by prolonging gastric emptying, and by shortening the time food remains in the small intestine. Fecal energy loss may be another mechanism of action, as soluble fiber decreases absorption of fats and protein. Sood et al. reported statistically significant weight loss (-0.79 kg) after almost 5.2 weeks in humans taking glucomannan [36].

Green coffee

Green coffee extract is obtained from unroasted green coffee beans and marketed in caffeinated and decaffeinated forms. The bioactive ingredients of green coffee extract include chlorogenic acid, a polyphenol of the phenolic acid subfamily [67]. Different mechanisms of action of green coffee extract on weight loss may be caused by a reduction in pancreatic lipase activity, a lipolytic effect on adipocytes, inhibition of hydroxymethylglutaryl-CoA (HMG-CoA) reductase, acyl-CoA- cholesterol acyltransferase (ACAT) and fatty acid synthase (FASN), an increase in β-oxidation and increased expression of PPAR-α in liver, a nutrient sensor that regulates genes important in peroxisomal and mitochondrial β-oxidation, and fatty acid transport. A meta-analysis

reported statistically significant weight loss after green coffee extract supplementation (180-200 mg/day) for a period of 4-12 weeks, with no side effects [37-40].

Green tea

Green tea is made from the steamed and pan-fried unfermented (unoxidized) leaves of *Camellia sinensis*. Green tea has caffeine that is thought to contribute to the suppression of appetite and stimulation of thermogenesis. Antioxidants in green tea like the catechin orepigallocatechin-3-gallate, inhibit norepinephrine breakdown that in turn causes an increase in calories burned [26, 41]. A randomized, double-blind, placebo-controlled clinical trial reported that green tea extract reduces body weight without side effects on more than 100 women [68].

Guar gum

Guar gum, a dietary fiber obtained from seeds of the plant *Cyamopsis tetragonolobus,* is used in various food products particularly as a thickener and emulsifier in baked items [10]. It consists of high molecular weight galactomannan polysaccharides in linear, β-1,4–linked D-mannopyranosyl chains with α-1,6 D-galactopyranosyl side chains [69]. Guar gum may cause weight loss by virtue of its bulking characteristics in the gut which delay gastric emptying [7, 70]. Guar gum supplements have therefore been used to reduce food intake and to increase satiety, but a meta-analysis did not sustain its effectiveness, and side effects were reported including diarrhea, flatulence, and cramps [42, 70].

Hoodia gordonii

Hoodia gordonii, also known as Bushman's hat, is a leafless succulent plant with medicinal properties occurring naturally in Namibia, Botswana, and South Africa. Researchers have studied *Hoodia gordonii* as a weight-loss adjuvant due to its appetite suppressing properties, although its use was questioned due to several adverse effects, among which were nausea and skin reactions [45]. Metabolites such as pregnane glycosides that contain 6-deoxy and 2,6-dideoxy sugars have been isolated from *Hoodia gordonii*. While the active compound causing the anorexigenic effect of *Hoodia gordonii* is not yet clear, P57AS3 (P57), an oxypregnane steroidal glycoside, is commonly considered to be the metabolite responsible for these effects [43-45].
Research into the effects of P57 in vivo have shown that intraventricular injection of purified P57 in rats decreases food intake and significantly increases hypothalamic ATP production, which may decrease the appetite response. According to an in-vitro study, P57 stimulates cholecystokinin secretion in human enteroendocrine cells, while cholecystokinin has been studied for insights into its appetite-suppressing effect through the vagus nerve. However, since oral administration of *Hoodia gordonii* is known to cause gastric breakdown of P57, the extract must be taken in high doses to obtain significant clinical effects [45, 69, 71], or easy to absorb derivatives developed.

Irvingia gabonensis

Irvingia gabonensis, also known as African wild mango, is a native to western and central Africa. Its seed is high in saturated fatty acids and its flesh is rich in polyphenols, specifically flavonoids. Oben et al. treated adipocyte cultures with *Irvingia gabonensis* extract and observed inhibition of PPAR-γ (peroxisome proliferator-activated receptor gamma) expression, a decrease in leptin protein levels and upregulation of adiponectin expression, thus inhibiting lipogenesis [46, 47]. Other randomized double-blind clinical trials analyzed the weight loss effects of *Irvingia gabonensis* extracts [72, 73]. Most of these studies were systematically reviewed by Onakpoya et al., who reported that administration of 200-3150 mg/day *Irvingia gabonensis* extract for 4-10 weeks could lead to statistically and clinically significant weight loss and decreased waist circumference compared to a placebo group. Side effects of the extract included headache and sleep difficulty [74].
Irvingia gabonensis emerged from these studies as a useful adjuvant dietary supplement in weight reduction management. However, many of these clinical studies were conducted on relatively small samples of black people from Africa. The research should be extended to larger and more diverse populations [72].

Raspberry

Raspberry ketones [4-(4-hydroxyphenyl)-2-butanone] are natural aromatic substances found, for example, in red raspberries and rhubarb. Extracted from raspberries, they are used as flavoring in the food industry. Several *in-vitro* studies on the effect of these ketones on adipocytes have reported increased fatty acid oxidation, reduced lipid accumulation and enhanced secretion of adiponectin [48]. Molecular studies have established that raspberry ketones downregulate expression of various genes associated with adipogenesis, such as C/EBPα, PPAR-γ, ACC1 (acetyl-CoA carboxylase1), SCD1 (steroyl-CoA desaturase1), A-FABP 2 (adipocyte fatty acid–binding protein 2) and FAS (fatty acid synthase), whereas it increased the mRNA levels of genes involved in the process of fatty acid oxidation, such as HSL (hormone-sensitive lipase), CPT (carnitine palmitoyl transferase) and ATGL (adipose triglyceride lipase) was observed [75]. Moreover, in-vivo studies on rodents fed a high-fat diet have shown that raspberry ketones prevented any increase in body weight or visceral adipose tissue. The mechanism of this effect presumably involves stimulation of brown and white adipose tissue and inhibition of pancreatic lipase activity [76].

These properties suggest that raspberry ketone supplementation could be an alternative weight-loss measure, but sufficient clinical evidence is lacking and certain teratogenic and cardiotoxic effects of raspberry ketones identified by in-silico research, indicate the need for further detailed study [77].

Phenylpropylamine

Phenylpropylamine (PPA) is a sympathomimetic agent that has structural similarity to ephedrine and amphetamine. It may act as a decongestant and appetite suppressant and induce significant weight loss. It is used as an over-the-counter supplement for weight loss. Researchers believe that PPA acts through the α-1 adrenergic receptor (α1-AR) [49]. In a double-blind placebo-controlled study, Schteingart administered a 1200 kcal diet and 75 mg/day PPA to 101 overweight subjects for 6 to 20 weeks and reported greater weight loss (2.59 kg) in the PPA-supplemented group than in the placebo group, without untoward side effects [78].

Pyruvate

Pyruvate is the simplest alpha-keto acid having a carboxylic and a ketone functional group. It is the end product of glycolysis but is also obtained from other sources. It breaks down glucose and produces energy and is also a key intermediate in several cell metabolic pathways. Pyruvate helps lipid metabolism by reversible conversion to phosphoenolpyruvate, increasing glucose uptake by skeletal muscle. It may therefore promote weight loss [50]. By virtue of these properties, pyruvate has been used to promote weight loss in subjects with obesity, to improve athletic performance, and in the treatment of cataracts, high cholesterol and cancer. A meta-analysis which analyzed six clinical trials concluded that pyruvate is effective in reducing body weight, and that adverse effects include gas, bloating and diarrhea [79]. Pyruvate should be administered with thiamine, a cofactor of pyruvate dehydrogenase, an essential enzyme that allows pyruvate to enter the Kreb's cycle [80].

White kidney bean

Extract of white kidney bean (*Phaseolus vulgaris* L.) contains alpha-amylase inhibitor (phaseolamin) that inhibits pancreatic amylase activity, lowering glycemia and calorie absorption by delaying or preventing complex carbohydrate digestion. It is therefore used as an over-the-counter dietary supplement for weight loss [51]. Several proof-of-concept clinical trials have established a dose-dependent reduction in glucose absorption after supplementation with white kidney bean. However, weight-loss effects were more prominent in some relatively small, short-term studies that used 1.5-6 g/day of white kidney bean extract. For instance, a clinical trial involving 60 subjects with obesity reported greater reductions in fat mass, body weight and thigh, hip and waist circumference in the group taking white kidney bean extract than in the placebo group, without any side effect [81, 82].

Conclusions

Obesity is a prevalent nutritional disease and a significant public health issue in industrialized countries. Due to their low toxicity profile, dietary supplements are considered an attractive alternative to traditional therapy, which usually comprise surgical and pharmacological treatments. Dietary supplements for weight loss or obesity managements may act through several mechanisms, among which are reduction of lipogenesis, appetite, and nutrient absorption, or increasing lipolysis and energy expenditure. Among the many ingredients presented in this study, chitosan and green tea showed promising results with limited side effects. Weight loss and absence of side effects were reported for both ingredients by meta-analysis. More clinical studies on chitosan and green tea, as well as other promising ingredients, will be needed to increase our knowledge on the efficacy and on the mode of actions of dietary supplements for weight loss and obesity management.

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Conflicts of interest statement

Authors declare no conflict of interest.

Author's contributions

Gabriele Bonetti, Karen L. Herbst: These authors contributed equally to this work.
MB: study conception, editing and critical revision of the manuscript; GB, KLH, Kevin D, Kristjana D, AKK, BA, VV, GM, AI: literature search, editing and critical revision of the manuscript. All authors have read and approved the final manuscript.

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