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Dolna 17, Warsaw,
Poland 00-773
+48 226 0 227 03
editorial_office@rsglobal.pl

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WEIGHT LOSS BUT SPICED UP? REVIEW OF CAPSAICIN AND ITS ROLE IN OVERWEIGHT AND OBESITY TREATMENT

Karol Bartecki *(Corresponding Author, Email: karolbartecki99@gmail.com)*
University Clinical Centre of the Medical University of Warsaw, ul. Banacha 1a, 02-097 Warsaw, Poland
ORCID ID: 0009-0006-1863-242X

Alicja Bury
Orlowski Hospital in Warsaw, ul. Czerniakowska 231, 00-416 Warsaw, Poland
ORCID ID: 0009-0009-2950-8741

Natalia Kraciuk
Independent Public Healthcare Establishment in Wyszków, al. Komisji Edukacji Narodowej 1, 07-200 Wyszków, Poland
ORCID ID: 0009-0007-8319-2296

Małgorzata Piekarska-Kasperska
Department of Imaging Diagnostics and Interventional Diagnostics and Interventional Radiology, Provincial Specialist Hospital of the name of Stefan Cardinal Wyszyński in Lublin, ul. Zbigniewa Herberta 21, 20-468 Lublin, Poland
ORCID ID: 0000-0001-5055-4923

Katarzyna Krupa
Wolski Hospital in Warsaw, ul. Marcina Kasprzaka 17, 01-211 Warsaw, Poland
ORCID ID: 0009-0006-3120-8631

Julia Błoniecka
Independent Public Healthcare Facility in Garwolin, ul. Lubelska 50, 08-400 Garwolin, Poland
ORCID ID: 0009-0004-0199-6230

Anna Daniel
Regional Specialist Hospital in Wrocław -Research and Development Centre, ul. H. M. Kamieńskiego 73a, 51-124 Wrocław, Poland
ORCID ID: 0009-0003-8752-6610

Jan Kamiński
Independent Public Healthcare Facility in Garwolin, ul. Lubelska 50, 08-400 Garwolin, Poland
ORCID ID: 0009-0007-2573-9986

Kacper Jankowski
Bielański Hospital named after Father Jerzy Popieluszko in Warsaw, ul. Cegłowska 80, 01-809 Warsaw, Poland
ORCID ID: 0009-0000-3722-7805

ABSTRACT

Background. Obesity has become a worldwide problem. In the last decades the population of obese adults has doubled and obese adolescents quadrupled. Currently companies focus on developing new therapeutic agents, but there are still some phytochemicals with anti-obesity properties which need to be properly evaluated.
Aim. This study reviews the current knowledge about the potential use of capsaicin and its analogues, capsinoids, in treatment of overweight and obese people.
Material and methods. The article is based on research of clinical trials and meta-analyses published on the PubMed databases in the last decade using the following keywords: capsaicin, obesity, overweight, chili pepper, TRPV1.
Results. Currently available studies demonstrate the influence of capsaicin intake on metabolism. The increase in resting energy expenditure and activity and density of brown adipose tissue show that capsaicin mobilizes metabolism in overweight and obese subjects. The positive effects require prolonged time of supplementation. Published results are incoherent mostly due to small groups of participants, different dosages of capsaicin, focus on variant parameters and short time of observation.
Conclusions. Capsaicin modulates and promotes metabolism in overweight and obese adults. To properly evaluate its role in treatment plans, more comprehensive studies are needed.

KEYWORDS

Capsaicin, Capsinoids, Overweight, Obesity, Chili Pepper, TRPV1

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Introduction.

Obesity and overweight are one of the major health problems in the modern world. According to the World Health Organization (WHO) in 2022, 2.5 billion adults aged 18 years and older were overweight, including over 890 million adults who were living with obesity. This corresponds to 43% of adults who were overweight, which is an increase from 25% assessed in 1990. About 16% of adults worldwide were obese in 2022. The worldwide prevalence of obesity has more than doubled in adults and quadrupled in adolescents between 1990 and 2022. Obesity is characterized by the expansion of adipose tissue, which contributes to systemic low-grade inflammation, insulin resistance and widespread disruption of metabolic pathways. Treatment regimens face a variety of challenges due to complex mechanisms and many underlying paths responsible for the outcome. Untreated obesity is a major risk factor for potent lethal diseases such as hypertension, stroke, non-insulin dependent diabetes mellitus, coronary heart disease, liver failure, osteoarthritis or even certain forms of cancer. (Pardali et al., 2025; Rao, 2025) Nowadays, there are new, highly effective drugs targeting weight loss and few more are on the final stages of pre-market testing. (Kokkorakis et al., 2025) Before that, researchers focused on naturally occurring chemicals with anti-obesity potency. Recent studies have provided compelling clinical evidence that supports the use of specific phytochemicals in obesity treatment. Capsaicin, green tea extract, garcinia cambogia, resveratrol or berberine have been widely studied and showed promising results in clinical trials. Current trials show that phytochemicals contribute to weight loss, BMI reduction and lipid profile improvement, which highlights their potential in managing obesity and associated comorbidities. (Alves Ferreira et al., 2017; Rao, 2025; Taghizadeh et al., 2017) Our study focuses on capsaicin and its analogues, capsinoids (a major component of chili peppers and a common kitchen ingredient in households worldwide), assessing its potential use in obesity treatment.

Methodology.

The article was assessed based on available clinical trials, research studies and meta-analyses published in the last decade on PubMed databases. To access valuable informations we searched using following keywords: capsaicin, casionoids, overweight, obesity, TRPV1. Particular attention was paid to literature involving overweight and obese adults.

Overview of capsaicin and capsinoids

Capsaicin (trans-8-methyl-N-vanillyl-6-nonenamide, CAP) or its non-pungent analogues, capsinoids have many properties that have led to their use in a wide variety of medical fields. Based on cellular models, the selective transient receptor vanilloid subtype 1 (TRPV1) has been found to play a key role in its metabolism. TRPV1 is an ion channel that, under physiological conditions, is activated by low (extracellular) and high (intracellular) pH, positive voltages, pungent chemicals including capsaicin, and by noxious high temperatures (>42°C) (Dhaka et al., 2009; Zhang et al., 2024). This nonselective cation (K^+, Ca^{2+}) channel is present in various regions of the body (e.g. the brain, smooth muscle of the bladder, urothelium, glial cells, liver, granulocytes, macrophages). Most TRPV1 ion channels are expressed in polymodal nociceptive afferent nerve fibres (Aghazadeh Tabrizi et al., 2017; Vennekens et al., 2008).

Capsinoids, including capsiate, dihydrocapsiate, and nordihydrocapsiate are a group of substances with a molecular structure similar to capsaicin. The only difference in the chemical structure of caspsaicin and capsite is the central linkage. Capsiate, like capsaicin, can bind to TRPV1 receptor with high affinity in the gut, but not in the oral cavity or on the skin surface, nor in the eye. This nonpungent characteristic of capsiate may be justified by its rapid hydrolysation under aqueous conditions, leading to decreased accessibility to nociceptors (e.g., in the oral cavity) (Iida et al., 2003; Iwai et al., 2003). Due to a limited application of capsaicin, because of its strong irritation, poor water solubility and unsatisfied effects, a series of derivatives (e.g. HJ-1-3, HJ-1-4, HJ-1-6) has been synthesized and is being looked forward for clinical applications. (Li et al., 2025)

To date, the precise mechanism of action of capsaicin remains to be elucidated. It has been demonstrated that the substance in question is absorbed directly in the gastrointestinal tract, subsequently entering the bloodstream via the portal vein. The metabolic effect, manifesting as thermogenesis, may be partially contingent on TRVP1 receptor stimulation. It has been hypothesized that CAP may also affect metabolism by the release of catecholamines or by stimulation of the vagus nerve. (Kawada et al., 1986; Watanabe et al., 1987)

Capsaicin attributes.

Pain management.

The mechanism by which capsaicin reduces pain transmission is through desensitization of the sensory afferent axons. This phenomenon can be attributed to the high permeability of the TRPV1 channels for calcium ions. This excess influx of calcium has been demonstrated to cause loss of mitochondrial function (as well as other cellular organelles) and thus render the afferent nerve fibre inoperant. As these nerve fibres undergo a loss of functionality, all mediators produced within these fibres will also demonstrate a marked decrease. One of these substances, substance P, is a well-known potent local pain mediator. Constant usage of topical capsaicin further promotes calcium influx into more of these nociceptive nerve fibers and depletes the neuron of substance P, and the further inoperability of the cell prevents it from forming more of this pain chemo-mediator. (Aghazadeh Tabrizi et al., 2017; Chang A, 2023) This mechanism has enabled the effective application of capsaicin in the form of 8% skin patches for the treatment of various conditions, including hemiplegic neuralgia, post-surgical neuralgia, post-traumatic neuropathy, polyneuropathy and even HIV-induced neuropathic pain. (Anand & Bley, 2011; Brown et al., 2013; Lo Vecchio et al., 2021; Sultana et al., 2021)

Antioxidative properties.

It has been demonstrated that capsaicin exerts a significant inhibitory effect on lipid peroxidation in red blood cell membranes, as well as in the liver and mitochondria of mice. It also modulates the immune system response through the exertion of inhibitory effects on pro-inflammatory cytokines. It has been demonstrated that the process of nitric oxide (NO) production is reduced, thereby weakening the inflammatory process. In human subjects, it has been observed that capsaicin contributes to lower levels of serum lipoprotein oxidation after a period of four weeks of supplementation. It has been hypothesized that the process may result in a reduction of lipid peroxidation, consequently leading to a decrease in oxidative stress. (Azlan et al., 2022; Thongin et al., 2022)

Gut microbiota alternations.

Numerous studies associate the profile of gut microbiota with the development of obesity. The interaction between dietary components and intestinal microflora influences gut microbiota composition and modulates metabolism. The altered balance of gut flora has been associated with high risk of autoimmune and allergic diseases, obesity, metabolic syndrome and even cancer. Capsaicin recently drew considerable attention due to the positive effect on gut microbiota. It alters the flora by eliminating the disease-causing enteric pathogens, encouraging growth of beneficial bacteria. The potential mechanism engages TRPV1 channel activation, which may induce local release of neuropeptides and modulate gut microbiota composition by modifying the inflammatory and immune conditions. It is hypothesized that capsaicin also reduces intestinal permeability and influences the regulation of the microbiome-gut-brain axis. Provided evidence establishes new perspective on capsaicin and encourages to further research. (Kang et al., 2016; Rosca et al., 2020; Wang et al., 2021)

Satiety and hunger.

Satiety is a complex and highly regulated process that involves several centers of the brain (e.g. hypothalamus and dorsal vagal region). It also engages multiple circulating factors and hormones which are influenced by meal composition and frequency. Ghrelin, leptin and insulin determine most of the energy homeostasis. The defect or deficiency in these hormones has been associated with the promotion of obesity, therefore hormones modulation may counteract this effect. It has been noted that capsaicin may increase satiety and therefore reduce appetite, without affecting plasma concentrations of glucagon-like peptide-1 (GLP-1) and peptide YY (PYY). (van Avesaat et al., 2016) TRPV1 channel activation influences glucose metabolism and modulates the leptin response on hypothalamus. Addition of capsaicin may increase the sensation of fullness and may decrease desire to eat after negative energy balance meal. (Elmas & Gezer, 2022; Gannon et al., 2016; Zheng et al., 2017)

Anti-obesity properties.

Cell models.

The anti-obesity activity of capsaicin has been widely studied in laboratory conditions using 3T3-L1 cells, Caco-2 cells and HepG2 cells.

3T3-L1 cell line is derived from mouse 3T3 cells with a fibroblast-like morphology, which has been used in biological research to understand metabolic disorders in adipose tissue. Researchers revealed that capsaicin can suppress the differentiation of adipocytes, inducing the browning of white adipose cells, as well as increase thermogenesis and decrease the intracellular lipid content by enhancing lipid metabolism.

HepG2 human cancer cell line has been applied to study the process of lipid metabolism, digestion and transport, and to analyze the mechanisms of anti-obesity, hypolipidemic and anti-diabetic effects of different phytochemicals. Having a structure and activity similar to liver cells, HepG2 cells are used to understand mechanisms of insulin-resistance, fat accumulation and obesity-related metabolic changes. Researchers noted that capsaicin can inhibit lipid accumulation and modulate fatty acid catabolism through stimulating the TRPV1 receptor. Capsaicin was also found to accelerate the glucose uptake/consumption and the ATP production of hepatocytes. Potentially, intracellular increase of calcium ions causes alternations in expressing different genes, which may be associated with glucose and amino acid metabolism. (Zeng et al., 2023)

Mature Caco-2 cells have the same polarity as normal small intestinal epithelial cells. Caco-2 cell models were used by various researchers to stimulate the penetration and absorption processes of bioactive substances and to study the effects of different dietary components on cell proliferation. It has been noticed that capsaicin can induce energy metabolism by activating intracellular ATP production and accumulation by up-regulating specific enzymes. Capsaicin was also proven to reduce fatty acid uptake and, consequently, to increase endogenous fatty acid biosynthesis, suggesting the hypolipidemic effects of CAP in Caco-2 cells. (Li et al., 2020)

Animal models.

The anti-obesity properties of capsaicin have also been deeply studied in animal model experiments using rats and mice in which obesity was induced by diet. These researchers focused on the influence of capsaicin on obesity and its comorbidities such as insulin resistance, type 2 diabetes, dyslipidemia, hypertension, cardiovascular and cerebrovascular diseases. According to observations, capsaicin can increase satiety, enhance lipid and glucose metabolism, suppress diet-induced steatosis and diabetes and modulate the composition of gut microbiota. It was found that CAP can improve glucose homeostasis and reduce obesity-induced insulin resistance in diabetic rats. Researchers also described that capsaicin treatment combined with moderate exercise were effective in reducing the caloric intake, body weight gain, abdominal fat, oxidative stress and hepatic steatosis in hypoestrogenic female rats. (Li et al., 2020; Zheng et al., 2017)

Human trials.

There are limited clinical trials focusing on weight loss potential of capsaicin in overweight and obese people. Current studies demonstrate that CAP can modulate metabolism by increasing resting energy expenditure and mobilization of brown adipose tissue. It has been also reported that CAP intake can affect bone metabolism and increase bone mineral density in overweight subjects. The available data is not conclusive since most of the studies include small groups of subjects, focus on different parameters and the duration of the intervention doesn't exceed 8 weeks. The results of eligible studies included in this review are summarized in Table 1.

Table 1. Characteristics and findings of the studies included in the analysis.

Reference	Type of study	Participants	Dosage	Duration	Results
(Rigamonti et al., 2018)	single-blind, randomized, placebo-controlled and cross-over design trial	10 obese adolescents and young adults (4 women and 6 men, age: 21.0±5.8 yrs; BMI: 41.5±4.3 kg/m2)	2 mg capsaicin	6 hours*	↑ Resting energy expenditure No changes in: Energy intake, appetite, and circulating levels of some orexigenic and anorexigenic peptides
(Osuna-Prieto et al., 2022)	randomized, triple-blinded, placebo-controlled, crossover trial	24 sedentary men (age = 40.2 ± 9.2 years-old; BMI = 31.6 ± 4.5 kg/m2 [n = 11 overweight, n = 13 obese])	12 mg of dihydrocapsiate	60 minutes of steady-state exercise bout	No differences in the EE and FATox during exercise. no changes in glucose, triglycerides, or NEFAs serum levels, neither in the skin temperature nor thermal perception across conditions. Heart rate and perceived fatigue did not differ between conditions.
(Salvio et al., 2023)	randomized, double-blind, placebo-controlled study	18 slightly overweight women (BMI: NA)	9 mg/day of capsinoids	8 weeks	No changes in weight or waist circumference. ↑ in BMD values measured at the spine ↑ adipose tissue (9.1%) ↓ in lean mass (8.5%)
(Han et al., 2022)	randomized, double-blind clinical trial	48 participants BMI of ≥23 kg/m2	19 g/d as Kochujang powder	6 weeks	↓ total cholesterol, LDL, HDL, triglyceride levels ↓ waist circumference ↓ visceral fat
(Nirengi et al., 2016)	randomized, double-blind, placebo-controlled study	20 volunteers (10 male, 10 female)	9mg/day capsinoids	8 weeks	↑ BAT density (during treatment) ↓ BAT density (in the 8-week follow-up period)
(Fuse et al., 2020)	randomized, double-blind, placebo-controlled study	40 subjects [age, 43.8 (mean) years; BMI, 25.4 kg/m2]	9mg/day (capsinoid)	6 weeks	↑ BAT density ↑ in resting energy expenditure/kg (overweight subgroup)

Abbreviations used: BMI - body mass index, BMD - bone mass density, BAT- brown adipose tissue, EE- energy expenditure, FATox - fat oxidation, LDL - low-density lipoprotein, HDL - high-density lipoprotein, NEFAs - non-esterified fatty acids, NA – not acquired; Other symbols: ↑- up regulation, ↓- down-regulation

* This study has a complex method of collecting data, the last data was assessed in the sixth hour after ingestion of capsaicin.

Rigamenti et al. conducted a randomized clinical trial assessing intake of 2mg of capsaicin in a group of obese young adults (age: 21.0±5.8 years; BMI: 41.5±4.3 kg/m2). This study didn't reveal significant changes in energy intake, feeling of satiety or hunger. The levels of hormones such as ghrelin, glucagon-like peptide 1 (GLP-1) or Peptyd-YY didn't differ statistically 3 hours after meal. However, a significant increase in resting energy expenditure, assessed by indirect computerized calorimetry, was noted in the capsaicin subgroup. Therefore, in this study the hypophagic effect of capsaicin was not confirmed, but these preliminary data demonstrate its ability as a metabolic activator in young obese adults.(Rigamonti et al., 2018)

Osuna-Pietro et al. contradicted the claim that capsaicin has an impact on energy expenditure shortly after digestion. This randomized study focused on assessing the effects of dihydrocapsiate intake in a group of 24 subjects with overweight and obesity. The participants performed physical tests examining their energy expenditure and fat oxidation during 60 minutes after the administration of 12mg dihydrocapsiate. No significant change in measured parameters was noticed. Similarly, no significant changes were observed in glucose, triglycerides, or NEFAs serum levels, neither in skin temperature nor in thermal perception across conditions. (Osuna-Prieto et al., 2022)

Salvio et al performed a study on a group of 18 mildly overweight women. Patients had their weight, waist circumference, body composition and mineral bone density (via dual-energy X-ray absorptiometry (DXA)) measured at the beginning and the end of the study. The study group was given 9mg of capsaite for 8 weeks. After this period, no significant differences were seen between the groups in terms of body weight and waist circumference measurements. However, a significant difference was noted in the capsaite-treated patients in BMD measured in spinal bones. Similarly, a statistically significant increase in body fat and reduction in lean mass was noted in the study group, where no statistically significant changes were seen in the placebo group. This study demonstrates that capsaicin may influence bone metabolism in addition to minor changes in body composition. (Salvio et al., 2023)

There is also a recent study published in 2022 by A Lum Han et al., mainly focusing on Kochujang and its anti-obesity properties. Kochujang is a fermented soy paste which has a 20-30% component red hot chilli peppers powder, rich in capsaicin. (Shin et al., 2016) This research compared different types of Kochujang based on their microbiota components. Major decrease in total cholesterol, low-density lipoprotein cholesterol, high-density lipoprotein cholesterol and triglyceride levels were documented in groups with high and low dose of beneficial microbes. The waist circumference has significantly decreased in a group with high dose of microbes and those who received commercial Kochujang. Visceral fat has significantly reduced in the high dose group and the population of beneficial microorganisms in stool samples increased in all groups. This study shows that consumption of Kochujang reduces visceral fat content and improves the lipid profile. That outcome may be assigned to microbiotal components, but the role of capsaicin cannot be ruled out. (Han et al., 2022).

Brown Adipose Tissue.

Obesity develops when an excessive energy intake exceeds energy expenditure over a long period of time. White adipose tissue (WAT) stores excess energy intake, while brown adipose tissue (BAT) is an energy-consuming adipose tissue storing thermal energy. When comparing to white adipocytes on a cellular level, brown adipocytes have more lipid droplets that are smaller in size and have more mitochondria. Due to thermoregulatory dependency in early life, BAT is present in large quantities in infants and children. In adults, the presence of BAT at the scapula is almost residual, but there are some active sites at the clavicle, pericarotid artery and pericardium. (Cypess et al., 2009) BAT activity can be assessed through ^{18}F-fluorodeoxyglucose positron emission tomography combined with computed tomography (18-FDG-PET/CT). In recent decades, different studies revealed that BAT is activated and recruited by exposure to cold, that is mediated by transient receptor potential (TRP) channels and the sympathetic nervous system (SNS). This results in increased energy expenditure and decreased body fat volume. Capsaicin and capsinoids mimic the effects of exposure to cold by activating TRPV1, thus leading to recruitment and activation of BAT and then to a decrease in total body fat. (Liu et al., 2022; Nirengi et al., 2015) Novel studies suggest that activating BAT and inducing the browning of WAT can accelerate the intake of glycolipids and reduce insulin secretion, which may be a new strategy to improve glycolipids' metabolism and insulin resistance of patinets with obesity and type 2 diabetes mellitus (T2DM). (Cheng et al., 2021)

Nirengi et al. demonstrated significant changes in brown adipose tissue density in subjects who supplemented thermogenic capsinoids. His study focused on a method of assessing BAT using total hemoglobin concentration ([total-Hb]) evaluated by near-infrared time-resolved spectroscopy (NIRTRS). Recently, his team demonstrated that this method, under thermoneutral conditions (i.e., without cold exposure),

is positively correlated with (18-FDG-PET/CT) indices only in the supraclavicular region, which potentially contains BAT deposits. (Nirengi et al., 2015) To confirm his assumptions, he performed two studies evaluating changes in BAT density in subjects taking oral capsaicin. The first study involved 3 subjects who received 1.5mg of capsinoids daily for a period of 6 weeks. Before the start of the study as well as after 6 weeks, BAT activity was assessed using FDG-PET/CT. The calculated maximum standardized uptake valve (SUVmax) on both sides increased by 48.8%. The second double-blind study included 20 patients, half of whom took 9mg of capsinoids for 8 weeks. BAT density was assessed using NIRTRS. After 8 weeks, a 46.4% increase in BAT density was observed in the study group. After 8 weeks, the participants were examined again and a 12.5% decrease in BAT density was observed in the group that took capsinoids. Although the study focused on evaluating a new diagnostic approach that assesses BAT, it also showed that oral intake of capsinoids significantly affects BAT activation and thus fat oxidation in the body. (Nirengi et al., 2016)

Fuse et al. determined the effect of taking capsionids on BAT density and resting energy expenditure in normal-weight and overweight healthy subjects. Similarly to Nirengi et al., BAT density was assessed using [total-Hb] evaluated by NIRTRS in the supraclavicular regions and resting energy expenditure was estimated using a respiratory gas analyzer. Participants in the study group took 9mg capsinoids daily for 6 weeks. The study showed that BAT activity significantly increased in the group taking capsinoids and demonstrated a close relationship between BAT density and Resting Energy Expenditure. The overweight subgroup supplementing capsinoids showed a significant increase in resting energy expenditure. The findings of this study suggest that prolonged consumption of capsinoids could be beneficial in maintaining and enhancing metabolic health in middle-aged, normal to overweight populations through the enhancement of BAT. (Fuse et al., 2020)

Recent meta-analyses.

Meta-analysis conducted in 2017 by Zsiboras et al. demonstrated that subjects with the Body Mass Index (BMI) over 25kg/m2 supplementing capsaicin, tend to increase their energy expenditure and decrease their respiratory quotient. In the subgroup with the BMI less than 25 kg/m2, no statistical changes in these parameters were observed between the control and the study group. It leads to the conclusion that capsaicin supports negative energy balance and accelerates body fat oxidation, thus potentially supporting the treatment of overweight individuals. (Zsiborás et al., 2018)

Different meta-analysis executed by Sheikhhossein et al. revealed that only in the subgroup of overweight subjects, which supplemented capsinoids for over 12 weeks, a significant change in body weight was noted. However, no significant non-linear associations were found between capsinoids supplementation dosage and study duration with both body weight and body-mass index. (Sheikhhossein et al., 2022)

In the meta-analysis from 2023 conducted by Zhang et al. the effects of capsaicin on the physical parameters were summarized in the group of overweight and obese individuals. From the available data, they observed that BMI, body weight and waist circumference changed statistically when patients supplemented capsaicin. In contrast, no significant change in waist to hip ratio has been noted. Therefore, Zhang et al. demonstrate that capsaicin supplementation has rather modest effects in reducing body weight, waist circumference and BMI. (Zhang et al., 2023)

Conclusions.

Capsaicin and capsinoids can modulate metabolism by the activation and recruitment of brown adipose tissue and by increasing energy expenditure, leading to reducing body weight in a population of overweight and obese people. Recent studies suggest that it has rather modest anti-obesity properties and potential influence on bone metabolism. Inconclusive evidence in the referenced studies may accord due to the small groups of participants, relatively short observation and lack of proper follow-ups. Also, the amounts of supplemented capsaicin or capsinoids differ among the studies. Further longitudinal and randomized clinical trials are needed to explain the effects of capsaicin and capsinoids on body weight control and to accurately assess their usefulness in obesity treatment plans.

Disclosure.
Authors' contributions:
Conceptualization: Karol Bartecki, Alicja Bury
Methodology: Karol Bartecki, Alicja Bury, Natalia Kraciuk
Software: n/a
Check: Małgorzata Piekarska-Kasperska, Anna Daniel
Formal analysis: Małgorzata Piekarska-Kasperska
Investigation: Karol Bartecki, Alicja Bury
Resources: Katarzyna Krupa, Julia Błoniecka
Data curation: Natalia Kraciuk, Jan Kamiński
Writing -rough preparation: Alicja Bury, Karol Bartecki, Anna Daniel
Writing -review and editing: Jan Kamiński, Katarzyna Krupa
Visualization: Julia Błoniecka, Anna Daniel, Kacper Jankowski
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Project administration: Karol Bartecki

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