CHAPTER 18

Phytotherapy for the Management of Obesity

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SUMMARY

Obesity is a serious global health problem with complications including metabolic syndrome, chronic heart disease, diabetes, stroke, osteoarthritis and cancer. The prevalence of overweight/obesity is rising daily and currently over 300 million people have been identified to be obese all over the world. Obesity is caused by genetic, physiological, behavioral and environmental factors that increase energy intake and induce fat accumulation in adipose tissues which can lead to hyperlipidemia, cardiovascular disorders, diabetes and many other diseases. Obesity pathogenesis includes changes in the activity of different regulatory molecules such as neuropeptides, hormones, and adipokines in the brain, gut, and adipose tissue, which are treated by modifying lifestyle, antiobesity drugs and surgical procedures. The majority of antiobesity drugs have been withdrawn from the market due to serious adverse effects. Now plant-based medicines having multiple active ingredients and various mechanisms to reduce weight are readily available at an affordable cost. These plant based products are more economical as compared to synthetic medications or surgeries.

INTRODUCTION

Obesity is a disease caused by abnormal or excess fat in the body, which can cause adverse health effects (Mohajan & Mohajan, 2023). The World Health Organization (WHO) defines obesity as the abnormal or excessive accumulation of fat that may be harmful to health (Safaei et al., 2021). Obesity is multifactorial, including genetic and environmental factors interactions (Łuniewski et al.,2023), leading to imbalances between energy consumption and expenditure (Vijay et al., 2021) and affecting mechanisms that regulate energy balance homeostasis (Ramgopal et al., 2010). Excessive calorie intake, sedentary lifestyles and inadequate physical activity are the main contributors to overweight and obesity (Al Snafi et al., 2022). Concurrent medical conditions, uncontrolled accessibility to appetizing meals, genetic, social, cultural, psychological, drugs, and certain diseases (such as endocrine disorders) are additional factors that markedly raise the risk of obesity (Aziz et al., 2023).

Obesity is a complex disease in which fat increases to enlarge adipocytes, regulated by fatty acid synthase and lipoprotein lipase enzymes, and is caused by changes in two lipid metabolic functions (lipogenesis and lipolysis). Lipogenesis is the process of storing free fatty acids in the form of triglycerides (TG) while Lipolysis is the process of breaking down triglycerides into free fat and glycerol. Obesity is accompanied by hyperlipidemia, which is characterized by abnormal lipid levels in the blood. Hyperlipidemia is a major sign of obesity (Vijay et al., 2021). The signs and symptoms of obesity are high cholesterol and fatty acid levels, impaired energy metabolism, reduced insulin sensitivity, fatigue, gallbladder stones, elevated blood pressure, breathing difficulties, emotional and social issues, and excessive buildup of adipose mass with hyperplasia and hypertrophy (Gupta et al., 2011). The most widely used diagnostic test for obesity is body mass index (BMI), which divides adults into three categories: "underweight," "overweight," or "obese." BMI is calculated by dividing weight in kilograms by height in meters squared (Safaei et al., 2021; Zabbon, 2022). Extremely obese people have a BMI of more than 40 kg/m^2, whereas obese people have a BMI of more than 30 kg/m^2 (Bandara et al., 2023).

World obesity day is held annually on March 4th (Vijay et al., 2021). Obesity is labeled as a "killing disease" (Vasudeva et al., 2012), and currently, obesity is the fifth largest cause of death globally (Safaei et al., 2021). The incidence of obesity is higher in both developed and underdeveloped countries (Al Snafi et al.,2022). Life expectancy is reduced by obesity, so it is referred as "New World Syndrome" (Mohajan & Mohajan, 2023). The World Health Organization WHO (2016) estimated less than 2 billion adults as overweight worldwide. Among them, more than 600 million are thought to be obese (Vijay et al., 2021).In 2016, less than 15% of adults were obese and about 40% of adults were overweight. The worldwide epidemiology of obesity increased threefold between 1975 and

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2016. If the current pattern continues then over one billion people will be obese and one-third of the global population will be overweight by 2025 (Omer, 2020).

A global disease burden research study declared Pakistan as 9th out of 188 countries with an obese population. Pakistan Demographic and Health Survey (PDHS) (2012-13) suggested that 40% of Pakistani women of reproductive age as overweight or obese. National Nutrition Survey (NNS) (2011) declared Pakistan as an undernourished country with a high proportion of overweight adults (Satti et al., 2015). Obesity and obesity-related comorbidities include diabetes (Aziz, et al., 2023), heart disease, hypertension (Chaithanya et al., 2020), stroke, dyslipidemia, and some blood cancers [cancer, cancer, prostate and colon (Junior & Jr, 2017)], non-fatal diseases and musculoskeletal diseases such as heart disease, gallbladder disease, hepatic steatosis, hypercholesterolemia and gout, respiratory disease, asthma, obstructive insomnia, gastroesophageal acid reflux, cartilage degeneration and infertility (Mohajan & Mohajan, 2023).

Dieting and physical activity are the main treatments for obesity. When these are ineffective then anti-obesity medications are used that act by reducing appetite or fat absorption inhibition through peripheral or central pathways. In extremely obese cases, the stomach's volume and/or bowel's length are lowered by performing bariatric surgery or the implantation of an intragastric balloon, which results in an early state of satiation and a decreased capacity to absorb nutrients from food and ultimately increases the life expectancy of obese individuals (Gupta et al., 2011; Bandara et al., 2023).

GLOBAL PREVALENCE

Obesity is a prevalent medical issue that affects people of all ages and genders in developed as well as developing countries. Since 1980, the global incidence of obesity has doubled with a third of the overweight or obese world's population. Currently 30% of the global population or two billion people over 18 years of age are overweight or obese. Annually more than 3.4 million deaths occur due to obesity(Henning, 2021; Fruh, 2017).

BURDEN OF OBESITY IN PAKISTAN

Pakistan also has a high prevalence of obesity, where 21% are overweight, 9% are obese, and 30% of adults have more BMI. According to 26 research findings, women are more likely to be overweight than men (32% vs. 26%) due to less physical exercise and more stay at home while men go out to work. Middle aged adults are more prone to being overweight. Due to sedentary lifestyles, overweight and obesity are more common in urban areas than in rural areas. In Khyber Pakhtunkhwa (KPK) 56% are overweight while 29% are in Punjab and Baluchistan. Punjab has a high prevalence of obesity while Baluchistan has a more overweight population. In Sindh, the prevalence of overweight is 19% as compared to other provinces (Satti et al., 2015).

CLASSIFICATION OF OBESITY BASED ON BMI

Body mass index (BMI), which is computed by dividing body mass by the square of height, is used to measure obesity (Gupta et al., 2011). The following is the BMI formula:

$BMI = mass_{kg/}$ height m^2.

RISK FACTORS OF OBESITY

Abnormal high fat levels cause weight gain and ultimately lead to obesity. There are multiple factors responsible for obesity. The obesity risk factors can be either non-modifiable and modifiable factors (Masood & Moorthy, 2023).

Modifiable Risk Factors

Epigenetic, Physical inactivity, Drugs such as antidepressants (citalopram, amitriptyline, nortriptyline, phenelzine), steroids (prednisone, hydrocortisone), antipsychotics (haloperidol, clozapine, lithium, quetiapine), antidiabetics (insulin, pioglitazone, glimepiride, glipizide, glyburide). Medical conditions (insulinoma, metabolic syndrome, hypothyroidism, Cushing syndrome, congestive heart failure, hypoproteinemia, polycystic ovary syndrome), Age, Pregnancy, Endocrine-disrupting chemicals (EDCs) Tributylin, BPA (Bisphenol A), DDT (Dichlorodiphenyltrichloroethane), DES (Diethylstilbesterol), DDE (Dichlorodiphenyl dichloroethylene), PCBs (Polychlorinated biphenyls), phthalates, PBDEs (Polybrominated diphenyl ethers), polybrominated biphenyls, Parabens (alkyl esters of p-hydroxybenzoic acid), Phyto-estrogens (Sahu et al., 2019; Masood & Moorthy, 2023). Environmental and Lifestyle factors like smoking cessation (Chaithanya et al., 2020), insufficient sleep, sedentary lifestyle (Kansra et al., 2021), overeating habits and extended working hours (Omer, 2020).

Non-Modifiable Risk Factors

Genetic obesity is classified into syndromic, polygenic, and monogenic. Monogenic obesity examples are Melanocortin 4 MC4 receptor deficiency (Henning, 2021), POMC (Pro-opiomelanocortin neuropeptide) mutations, SIM1 (Single-minded 1 transcription factor) deficiency, NTRK2 (Neurotrophic tyrosine receptor kinase 2) mutations, BDNF (Brain-derived neurotrophic factor) mutations, SH2B1 (SH2B adaptor protein 1) mutations, PC1/2 (Proconvertase) deficiency, KSR2 (Kinase suppressor of Ras 2 protein) mutations, ADCY3 (Adenylyl cyclase 3) mutations (Omer, 2020; Masood & Moorthy, 2023). Pradera Willi syndrome (PWS), Bardet Biedl syndrome, Laurence-moona Biedl syndrome, Albright's hereditary osteodystrophy, Cohen syndrome, and Borjeson Forssman Lehmann are syndromic obesity examples (Omer, 2020; Masood & Moorthy, 2023). Polygenic obesity includes PWS (Prader-Willi Syndrome), brachydactyly mental retardation syndrome; BDMR, (1p36) monosomy 1p36 syndrome, (9q34) Kleefstra syndrome, (6q16) PWS-like syndrome, (17p11) Smith Magenis syndrome; SMS, and (11p13) WAGR syndrome (Lin & Li, 2021; Vijay et al., 2021).

CLINICAL MANIFESTATION OF OBESITY

Obesity is presented by signs and symptoms of excessive body fat, extremely large waistline, sleep apnea, heavy sweating, fatigue, Gastroesophageal Reflux Disease (GERD), abdominal pain, pain and soreness in the joints or muscles,skin rashes and abrasion, varicose veins especially in the lower extremities, irregular menstrual cycle(Chaithanya et al., 2020).

Pathogenesis of Obesity

The pathology of obesity involves certain abnormalities such as increased appetite and reduced calorie expenditure that alters physical activity and cellular functioning, leading to stimulation of adipogenesis that provokes the production and release of cytokines causing serious cardiovascular complications like atherosclerosis and hyperlipidemia as shown in Fig. 1 (Bhardwaj et al., 2021). Adipose tissue is found throughout the human body and is classified into two types: brown and white. Brown adipose tissue is mostly located in small, distinct areas of newborns where it produces heat whereas white adipose tissue is the most common form of fatty tissue in adults in which fat stores. Previously, it was believed that fat tissue serves mainly as a storehouse where excess triglycerides can be stored or broken down into free fatty acids and glycerol in response to the body's metabolic requirement. Recently, it has been found that adipose tissue is metabolically active and has the ability to make a communication network between different body organs (Henning, 2021). Generally, fats are of two types: subcutaneous and visceral. Visceral fat, also known as active fat, is deposited over organs like the heart, abdomen, kidney, liver, intestines, and pancreas, affecting hormone expression for regulating metabolic rate, distribution of body fat, and appetite. Furthermore, subcutaneous fat is beneath the skin's outer layer in the legs and underarms. More visceral fat deposition is linked with high blood levels of LDL-cholesterol which could result in hypertension, diabetes, heart disease, and stroke (Lokuruka, 2013; Kumar et al., 2022). A sedentary lifestyle along with excessive calorie intake causes energy imbalance and increases the body's subcutaneous fat tissue. Excessive caloric intake increases adipocytes size > 100-120 µmand stores fatty acids in visceral adipocytes in the mesentery and omentin as well as in the liver, pancreas, kidneys, pericardium, and epicardium. There are two types of body shapes on the basis of fat deposition: apple and pear. An apple shape (Android) accumulates visceral fat in the upper waist, abdomen, neck, arms, and shoulders, increasing the likelihood of type 2 diabetes. Pear shape deposits fat on the legs and hips have minimal abdominal fat, and less chance of weight-related diseases (Henning, 2021; Kumar et al., 2022).

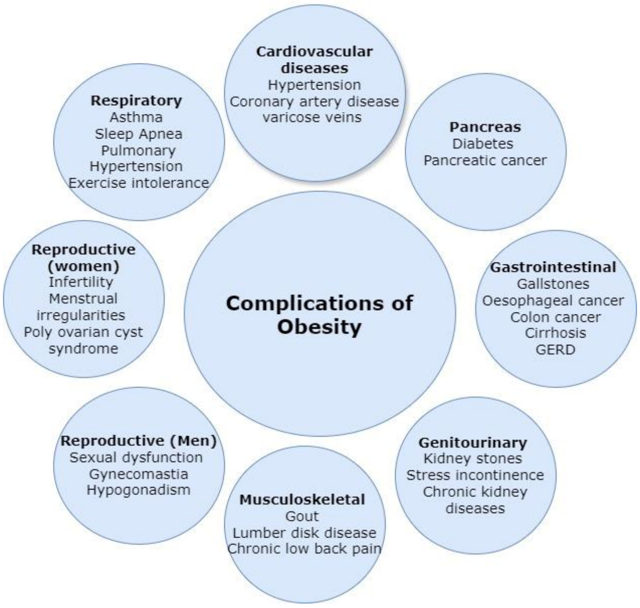

Fig 1. Multiple metabolic and vascular complications related to obesity

Complications of Obesity

The co-morbidities of the metabolic syndrome, including hypertension, diabetes mellitus (type 2), high blood cholesterol level, and high triglyceride level., are more likely to occur in obese people. The health consequences of obesity can be broadly categorized into two groups: those resulting from excess fat mass including obstructive insomnia, osteoarthritis, and social dismissal, and those resulting from a larger number of fat cells such as cancer, diabetes, and heart disease, and non-alcoholic fatty liver syndrome. Insulin resistance is the result of the body's altered response to insulin caused by an abnormal increase in body fat mass in humans (Gupta et al., 2011).

DIAGNOSIS / ASSESSMENT OF OBESITY

Body mass index (Vijay et al., 2021) and anthropometric parameters such as skinfold thickness, waist circumference, and waist-to-hip ratio (Chaithanya et al., 2020) are used to assess the degree and extent of obesity.

Body Mass Index (BMI)

Adolphe Quetelet (1796–1874), a Belgian astronomer, mathematician, statistician, and sociologist, is known for inventing the Body Mass Index (BMI). In 1972, Ancel Keys, a scientist from the United States, and his collaborators introduced the Body Mass Index (BMI) (Mohajan & Mohajan, 2023). Obesity is mostly estimated using body mass index (BMI), which is calculated as follows: BMI = Mass (kg) / Height (m^2). Obesity is classified on the basis of BMI as shown in Table 1. A person is considered obese if body mass index (BMI) is 30 or higher (Vijay et al., 2021). BMI can also be calculated as follows in pounds and inches: [weight (pounds)/height (inches) 2] x 703 (Chaithanya et al., 2020).

Table 1. BMI based classification of obesity

Category	BMI
Underweight	< 18.5
Normal weight	18.5–24.9
Overweight	25.0–29.9
ClassIobesity	30.0–34.9
Class II obesity	35.0–39.9
Class III obesity	≥ 40.0
Extremely obese	≥ 40- 50

Table 2. Anti-obesity potential of medicinal plants with their possible mechanism of action

Medicinal Plant	Probable Mechanism	Reference
Achyranthes aspera Linn	It raises HDL cholesterol while lowering total cholesterol, total triglyceride, and LDL cholesterol levels.	Rani et al., 2012
Acorus calamus Linn	It induces weight loss by inhibiting α-glucosidase activity.	Avadhani et al., 2013
Allium sativum Linn	It prevents glutathione depletion and lipid peroxidation in hepatic tissue while also raising antioxidant enzyme levels. It inhibits the following enzymes: sterol regulatory element binding protein-1c, 3-hydroxy-3-methylglutaryl-coenzyme A reductase, fatty acid synthase, and acetyl CoA carboxylase.	Kim et al., 2013; Lai et al., 2014
Alpinia galanga Linn	The active component galangin reduces liver weight, lipid peroxidation, and the accumulation of hepatic triglycerides.	Kumar & Alagawadi, 2013
Argyreia nervosa Bojer	It lowers serum levels of triglycerides, LDL, total cholesterol, and leptin.	Kumar et al., 2011
Avena sativa	The complex relationship between hunger and energy regulation is influenced by β-glucan's effects on gut hormones, satiety perception, stomach emptying, and short-chain fatty acids.	Lin et al., 2013; Al-Snafi, 2015
Bauhinia variegata Linn	It decreases appetite by lowering total cholesterol, triglycerides, and low-density lipoprotein levels. It increases serotonin levels in the brain.	Balamurugan & Muralidharan, 2010; Al-Snafi, 2013
Boehmeria nivea (L.) Gaudich	It decreases the activities of lactate dehydrogenase and serum alkaline aminotransferase in adipose tissue weight. The circulating HDL cholesterol levels rise while reducing serum levels of LDL- cholesterol, serum triglyceride, total cholesterol, atherogenic index, and cardiac risk factors.	Lee et al., 2011
Brassica rapa L.	It stimulates the synthesis of genes that are associated with lipolysis in white adipocytes, including uncoupling protein, hormone-sensitive lipase, adipose triglyceride lipase, and β_3-adrenergic receptor.	An et al., 2010
Brassica campestris	It raised the expression of genes linked to lipolysis, including uncoupling protein 2, adipose triglyceride lipase, β_3-adrenergic receptor, and hormone-sensitive lipase (HSL).	An et al., 2010; Al-Snafi , 2015
Bursera grandiflora (Schltdl.) Engl	It reduces weight by lowering plasma triglyceride levels.	Santamaría et al., 2012
Camellia sinensis	It decreases LDL, and triglyceride levels by increasing Leptin concentration, lipogenesis inhibition, and lipolysis stimulation. It induces lipid oxidation and facilitates lipolysis.	Aziz et al., 2023; Ghai et al., 2023
Camellia oleifera Abel	It raises high-density lipoprotein cholesterol while lowering levels of triacylglycerides and total cholesterol. In animal liver, it also reduces fatty acid activity.	Chen, 2014
Capsicum annuum	It reduces the levels of LPL mRNA expression in 3T3-L1 cells.	Baek et al., 2013; Al-Snafi, 2015
*Cheilanthes albomarginata*C.B. Clarke	It reduces plasma triglyceride activity and decreases the weight of fat tissue.	Lamichhane et al., 2014
Citrus aurantifolia	It decreases body weight by inducing anorexia and lowering the consumption of food.	Asnaashari et al., 2010; Al-Snafi, 2016
Citrus sunki (Hayata) Yu.Tanaka	It lowers acetyl-CoA carboxylase and AMPK phosphorylation levels.	Kang et al., 2012
Clerodendrum phlomidis L. f.	It prevents the activity of pancreatic lipase.	Chidrawar et al., 2012
Curcuma longa L.	It decreases weight gain by promoting the consumption of carbohydrates and enhancing glucose uptake by GLUT4 (glucose transport type 4) in adipose tissue via the phosphoinositide phospholipase C-phosphoinositide 3-kinase (PLC-PI3K) pathway.	Ghai et al., 2023
Dioscoreae tokoronis Linn	It reduces the levels of triglycerides, total plasma cholesterol, and low-density lipoprotein cholesterol. It decreases the expression of SREBP-1 and fatty acid synthase in liver and adipose tissues.	Song et al., 2009
Foeniculum vulgare	It prevents lipase activity.	Garg et al., 2011; Al-Snafi, 2018
Fraxinus excelsior L.	It prevents fat accumulation, limits adipocyte differentiation throughout animal growth, and increases fat metabolism by β-oxidation, which minimizes fat storage.	Ibarraa et al., 2011
Garcinia cowa Roxb. ex Choisy	It prevents the ATP-dependent citrate lyase enzyme from cleaving citrate into oxaloacetate and acetyl-CoA. It increases serum total cholesterol and serum apo A1 levels.	Altiner et al., 2012; Márquez et al., 2012
Gymnema sylvestre (Retz.) R.Br. ex Sm	It raises the levels of antioxidant enzymes, HDL-cholesterol, and apolipoprotein A1, and decreases the levels of serum lipids, leptin, insulin, glucose, LDH, and apolipoprotein B.	Kumar et al., 2012; Reddya et al., 2012; Kumar et al.,2013
Helianthus annuus	It reduces food intake	Islam, 2015; Al-Snafi, 2018
Hibiscus cannabinus L.	It decreases SGOT and SGPT activity, LDL-C, serum cholesterol, and triglyceride levels.	Mohan & Gayathri, 2013
Holoptelea integrifolia (Roxb.) Planch.	It decreases HMG-CoA reductase activity, inhibits cholesterol biosynthesis and stimulates the activity of cholesterol acyltransferase, lecithin.	Subash & Augustine, 2013
Hypericum silenoides Juss.	It reduces body weight and serum glucose levels. Also affected triglycerides, total cholesterol, and high-density lipoprotein cholesterol levels.	Cruza et al., 2013
Ipomoea batatas (L.) Lam	It alters the expression of HMG-CoA Reductase, SREBP-l, Acyl-CoA Synthase, Fatty Acid Synthase, and Glycerol-3-Phosphate Acyltransferase in liver tissue.	Ju et al., 2011
Jasminum sambac	It inhibits pancreatic lipase activity	Yuniarto et al., 2015; Al-Snafi, 2018
Kochia scoparia	It inhibits pancreatic lipase activity	Han et al., 2006; Al-Snafi, 2018)

Medicinal Plant	Probable Mechanism	Reference
Ocimum basilicum	It lowers the activity of the enzyme pancreatic lipase.	Irondi et al., 2016; Al-Snafi, 2021
Larix laricina (Du Roi) K.Koch	It promotes uptake of glucose, stimulate adipogenesis, AMPK activator, and mitochondrial uncoupler/ inhibitor (on normal isolated mitochondria).	Harbilas et al., 2012
Ligularia fischeri (Ledeb.) Turcz.	It inhibits pancreatic lipase activity.	Cha et al., 2012
Mangifera indica	It reduces the expression of adipogenesis-related transcription factors and enzymes.	Ramíreza et al., 2017; Al-Snafi et al., 2021
Morinda citrifolia L.	It decreases plasma triglyceride levels and increases glucose tolerance, which reduces body weight and fat mass.	Saminathan et al., 2013
Morus australis Poir	It lowers insulin resistance related to leptin.	Wu et al., 2013
Murraya koenigii (L.) Spreng.	It prevents weight gain by decreasing the plasma levels of triglycerides, total cholesterol.	Birari et al., 2010
Myrciaria dubia (Kunth) McVaugh	It lowers blood levels of insulin, LDL-c, glucose, triglycerides, total cholesterol, and fat in white adipose tissues in animals. It also increases HDL-c values.	Nascimento et al.,2013
Nitraria retusa (Forssk.) Asch.	The extract exerts anti-obesity effects by reducing blood levels of triglycerides and LDL cholesterol, inhibiting the increase of body weight and fat mass, and upregulating the expression of genes related to liver lipid homeostasis.	Kalai et al., 2014
Olea europaea	It reduces the expression of molecules linked to adipogenesis and thermogenesis.	Jung et al.,2019
Panax ginseng C.A.Mey.	Ginsam phosphorylates AMP-activated protein kinase and promotes PPAR-Î³ expression in the liver and muscle. Through Protein Kinase A, the extract significantly stimulates the particular hormone Lipase.	Lima et al., 2009; Park et al., 2013
Plantago lanceolata	It enhances the metabolism of adipose tissue by inducing lipolysis, accelerating fatty acid oxidation, and inhibiting fatty acid synthase.	Reza et al., 2021; Yoshidaa et al., 2012
Polygonum aviculare L.	P. aviculare extract reduces high levels of mRNA expression of fatty acid synthase, adipocyte protein 2, sterol regulatory element-binding protein-1c, and peroxisome PPAR- γ in the white adipose tissue of obese mice.	Sung et al., 2013
Rheum palmatum L.	Rhein acts as a PPARγ antagonist by suppressing peroxisome PPAR-γ transactivity and target genes expression related to peroxisome PPAR-γ.	Shin et al., 2012; Zhang et al., 2012; Oh et al., 2015
Sapindus emarginatus Vahl	Along with body weight and BMI, the methanolic extract lowers blood sugar, total cholesterol, LDL-cholesterol, HDL-cholesterol, triglycerides, SGOT, and SGPT levels.	Suneetha et al., 2013
Tamarindus indica L.	It reduces the levels of total plasma cholesterol, low-density lipoprotein, and triglycerides. It produces a rise in high-density lipoprotein levels and a corresponding decrease in body mass.	Jindal et al., 2011; Azman et al., 2012; Sasidharan et al., 2014
Veratrum nigrum L.	It lowers body weight and fat pad weight in mice given an extremely fatty diet.	Park et al., 2013
Vigna angularis (Willd.) Ohwi & H. Ohashi	It decreases lipid release into the stool as well as prevents hepatic lipid deposition. When adipocytes are incubated with extract then causes a dramatic reduction in triglyceride formation, the activity of glycerol phosphate dehydrogenase, and inflammatory responses without harming the viability of the cells.	Kitano-Okada et al., 2012

Table 3. Anti-obesity plants with phytochemicals

Plant	Phytoconstituent	Reference
Allium cepa L.	Quercetin	Yu et al., 2021
Aloebarbadensismiller	Quercetin, Gallic acid	Rahouiet al., 2018
Capsicum annuum	Capsaicin	Soifoini et al.,2021
Carica papaya L.	Saponins, Tannins, Alkaloids, Anthocyanidins, Anthraquinones	Moro & Basile, 2000
Cinnamomum zeylanicum	Cinnamaldehyde	Camacho et al., 2015
Coriandrum sativum	Quercetin	González-Castejón & Rodriguez-Casado, 2011
Curcuma longa	Curcumin	Lone et al., 2016; García-Barrado et al., 2020
Emblica officinalis	Terpenoids	Faizal et al., 2009
Litchi chinensis	Flavonoids	Qi et al., 2015
Ocimum sanctum	Rutin, Gallate, Ellagic acid, Epigallocatechin	Pérez-Ramírez et al., 2017.
Piper nigrum L.	Flavonoids, Tannins, Saponins, Alkaloids	Nahak & Sahu, 2011; Naidu et al., 2014
Syzygium aromaticum	β-caryophyllene, Eugenol	Ding et al., 2017
Vitis vinifera L.	Flavonoids, Stilbenoids, Resveratrol, Proanthocyanins	Di Pietro et al., 2023.
Zingiber officinale	6-Gingerol	Kim et al., 2018.

Waist Circumference (WC)

The waist circumference technique is directly related to abdominal fat content and measures the waist circumference of obese people before and after weight reduction treatment. The American Heart Association suggested 102 cm (40 in.) for men and 88 cm (35 in.) for women as the acceptable WC standards (Chaithanya et al., 2020).

Waist to Hip Ratio (WHR)

WHR indicates cardiovascular risk, obesity, and accumulated abdominal fat content (Chaithanya et al., 2020). World Health Organization defines abdominal obesity as represented by a waist-hip ratio of more than 0.85 for women and 0.90 for men. Because of the uneven distribution of fat,

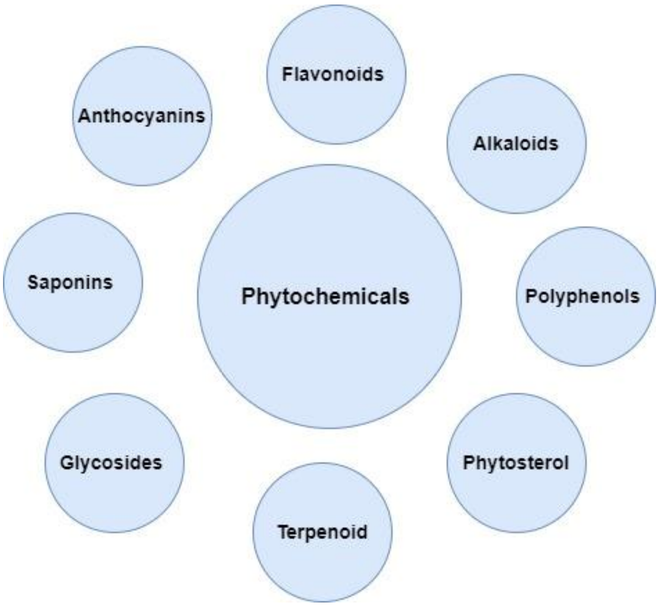

Fig 2. Phytochemicals in obesity management

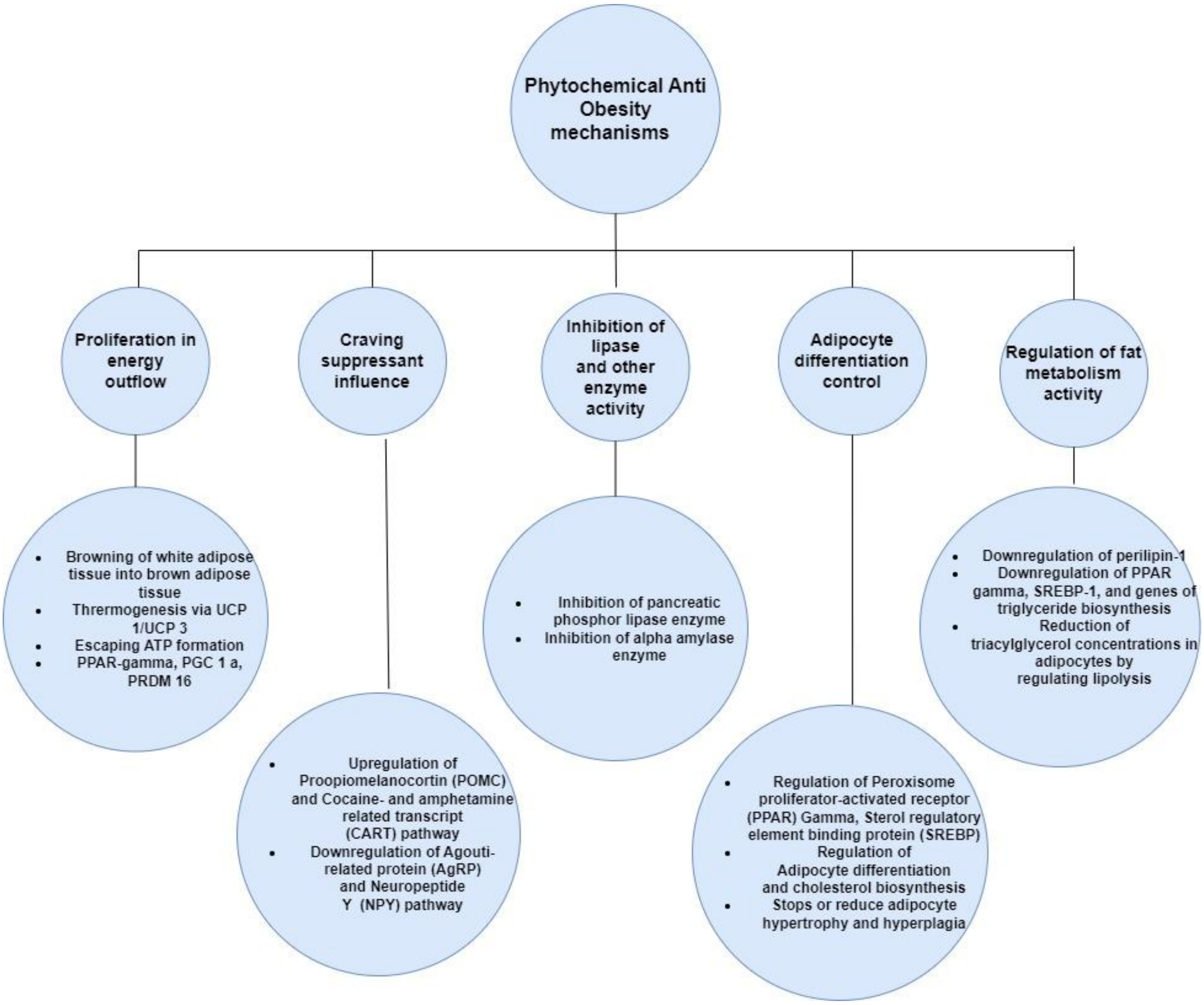

Fig 3. Phytochemicals having obesity regulatory mechanisms

than 0.8 are more likely to suffer from serious health problems respectively. The formula for calculating WHR is: WHR =Waist Circumference / Hip circumference (Vijay et al., 2021).

OBESITY TREATMENT

The mainstay treatment of obesity includes Lifestyle modifications, anti-obesity medications and bariatric procedures (Zabbon, 2022).

Physical Activity in Obesity

The most important components of weight reduction therapy are increasing physical activity increasing energy expenditure and reducing food intake in obese people. Regular physical activity for 60-90 minutes every day is the most effective way to lose weight. Regular physical activity helps people maintain a healthy weight and reduces their overall likelihood of risk of coronary heart disease (CHD). Physical activity regulates Diabetes and can reduce mean HbA1c levels by 0.6%. Aerobic physical activity should be done every day for a minimum of 30 minutes each day and 150 minutes each week (Chaithanya et al., 2020; Łuniewski et al., 2023). Moderate aerobic physical exercise/work should be done for at least 150-300 minutes/ week by fast walking, water aerobics, tennis doubles, and dancing whereas intense aerobic physical activity such as swimming, fast cycling, jogging, soccer games, walking up the stairs, skipping, and tennis singles, are recommended for at least 75- 150 minutes/ week (Mohajan & Mohajan, 2023).

Anti-Obesity Drugs

Antiobesity drugs are prescribed to persons with a BMI of more than 30 kg/m^2, patients with a BMI of more than 27 kg/m^2 along with more than one weight-related risk factor like diabetes, hypertension, or hypercholesterolemia or associated disease (Chaithanya et al., 2020; Zabbon, 2022). At present, the US Food and Drug Administration (FDA) approved six important anti-obesity drugs (Gjermeni et al., 2021). Four drugs have been approved for long-term treatment of obesity: Orlistat (Xenical, Alli), Liraglutide (Saxenda), Phentermine-Topiramate (Qsymia), and Naltrexone-Bupropion (Contrave). Setmelanotide, an FDA-approved MC4R agonist, is used to treat extremely obese patients who have POMC, PCSK1 (proprotein convertase subtilisin/kexin type 1), or LEPR (leptin receptor) deficiency (Lin & Li, 2021).

Anti-Obesity Medicinal Plants

Antiobesity drugs are no longer used for reducing weight because of the high cost and serious adverse effects associated with them. So, there is a need to explore new natural products that could be used as alternative therapy in treating obesity. Moro & Basil (2020) documented a number of recognized medicinal plants that are supposed to be effective in obesity treatment (Patra et al., 2015). Different medicinal plants have anti-obesity effects like *Zingiber officinale* reduces intestinal fat absorption by inhibiting pancreatic lipase enzyme (Table 2). Secondary metabolites phytochemicals such as alkaloids, flavonoids, tannins, saponins, and polyphenols (Fig. 2) present in medicinal plants are responsible for weight loss. Coffee (*Coffea arabica*) has active phytoconstituent caffeine that causes weight loss by reducing BMI. Some important phytochemicals of plants are given in Table 3. These phytochemicals act through several signaling pathways such as the browning of white adipose tissue into brown adipose tissue, Upregulation of Proopiomelanocortin (POMC) and Cocaine- and amphetamine-related transcript (CART), Inhibition of lipase enzyme, Regulation of adipogenesis by PPARgamma, inhibit lipogenesis and increase lipolysis, reduce triglycerides accumulation in adipocytes (Fig. 3).

CONCLUSION

Obesity and overweight are the most prevalent health problems with various life-threatening complications. The current chapter highlighted the therapeutic potential of plants to treat obesity and its consequences. Phytotherapy are more advantageous in treating multiple disorders from ancient times and using plant-based products to treat obesity is rising rapidly. Plant-based medicines used for weight reduction include Ginger, Green tea, Coffee, Turmeric, Chili pepper, Blueberry, Soybean, Lotus leaf with taurine, *Hibiscus sabdariffa*, and Coptis root. Plants contain several phytochemicals with anti-obesity effects that target pathomechanisms of obesity. The most commonly found phytochemicals are flavonoids, alkaloids, tannins, saponins, and polyphenols that improve insulin sensitivity, and control appetite by regulating adipocyte formation and lipid metabolism. The anti-obesity actions of these phytochemicals define the effectiveness and safety of traditional medicinal plants in obesity management. Further study is required to determine the pharmacokinetics, pharmacodynamics and safety of medicinal plants' phytochemicals that would support their role in obesity treatment.

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