Turkish Journal of Diabetes and Obesity / *Türkiye Diyabet ve Obezite Dergisi*
Review / *Derleme*

Impact of Dietary Factors on Obesity Management and Its Correlation with Hypothyroidism, Dyslipidaemia and Hormonal Imbalance

Ankita AWASTHI[1], Papiya BIGONIYA[2] ✉, Bhaskar GUPTA[3]

[1]Patel College of Pharmacy, Madhyanchal Professional University, Bhopal, India
[2]DSKM College of Pharmacy, RKDF University, Bhopal, India
[3]School of Pharmacy and Research, People's University, Bhopal, India

Cite this article as: Awasthi A et al. Impact of dietary factors on obesity management and its correlation with hypothyroidism, dyslipidaemia and hormonal imbalance. Turk J Diab Obes 2022;2: 177-186.

ABSTRACT

Obesity is one of the major lifestyle disorders prevalent worldwide. The increasing obesity rate is associated with the emergence of diseases like thyroid dysfunction, dyslipidaemia, hormonal imbalance, etc. Obesity is the risk factor for heart disease, atherosclerosis, insulin resistance, arthritis, musculoskeletal disorders, and cancer.

The present article portrays insights into the association of obesity with dyslipidemia, diabetes, hormonal imbalance, and hypothyroidism. Excessive or insufficient release of hormones can lead to obesity as leptin, insulin, sex hormones, and growth hormones influence appetite, metabolism, and body fat distribution. The article provides a review of the interrelationship of metabolic dysregulation with obesity and the further development of related diseases. This paper also summarizes the effects of dietary fibers and fish protein on metabolic alterations, hormonal imbalance, and hyperlipidemia associated with obesity.

This article elaborated the role of dietary intervention like fiber and dietary protein consumption useful for managing obesity-related disorders. Potential nutraceutical products are consumed as frequent food sources. Still, quality human clinical trial data are lacking, signifying the need for substantial scientific work to assess the safety and efficacy of nutraceuticals.

Keywords: *Diabetes, Dietary fibre, Dyslipidaemia, Hypothyroidism, Nutraceutical, Obesity*

Beslenme Faktörlerinin Obeziteye Bağlı Komplikasyonlar Üzerindeki Etkisi: Hipotiroidizm, Dislipidemi ve Hormonal Dengesizlik

ÖZ

Obezite, dünya çapında yaygın olan en önemli yaşam tarzı bozukluklarından biridir. Artan obezite oranı, tiroid disfonksiyonu, dislipidemi, hormonal dengesizlik vb. hastalıkların ortaya çıkması ile ilişkilidir. Obezite, kalp hastalığı, ateroskleroz, insülin direnci, artrit, kas-iskelet sistemi bozuklukları ve kanser için risk faktörüdür.

Bu makale, obezitenin dislipidemi, diyabet, hormonal dengesizlik ve hipotiroidizm ile ilişkisine dair içgörüler sunmaktadır. Leptin, insülin, seks hormonları ve büyüme hormonları iştahı, metabolizmayı ve vücut yağ dağılımını etkilediğinden hormonların aşırı veya yetersiz salınımı obeziteye yol açabilir. Makale, metabolik düzensizliğin obezite ile ilişkisi ve ilgili hastalıkların daha da geliştirilmesi hakkında bir inceleme sunmaktadır. Bu makale aynı zamanda diyet liflerinin ve balık proteininin metabolik değişiklikler, hormonal dengesizlik ve obezite ile ilişkili hiperlipidemi üzerindeki etkilerini de özetlemektedir.

Bu makale, obezite ile ilgili bozuklukları yönetmek için yararlı olan lif ve diyet protein tüketimi gibi diyet müdahalesinin rolünü detaylandırdı. Potansiyel nutrasötik ürünler sık besin kaynakları olarak tüketilmektedir. Yine de, kaliteli insan klinik deney verileri eksiktir, bu da nutrasötiklerin güvenliğini ve etkinliğini değerlendirmek için önemli bilimsel çalışmalara ihtiyaç olduğunu gösterir.

Anahtar Sözcükler: *Diyabet, Diyet lifi, Dislipidemi, Hipotiroidizm, Nutrasötik, Obezite*

ORCID: Ankita Awasthi / 0000-0002-7102-2181, Papiya Bigoniya/ 0000-0001-8673-2736, Bhaskar Gupta / 0000-0002-1329-674X

Correspondence Address / Yazışma Adresi:
Papiya BIGONIYA
DSKM College of Pharmacy, RKDF University, Bhopal, M.P., India.
Phone: +91 982 701 12 58 • E-mail: p_bigoniya2@hotmail.com

DOI: 10.25048/tudod.1027767

Received / *Geliş tarihi* : 02.12.2021
Revision / *Revizyon tarihi* : 29.06.2022
Accepted / *Kabul tarihi* : 06.08.2022

Abbreviations

WHO: World Health Organization, **BMI:** Body mass index, **TG:** Triglyceride, **HDL:** High density lipoprotein, **FFA:** Free fatty acid, **VLDL:** Very low density lipoproteins, **LPL:** Lipoprotein lipase, **ASP:** Acylation-stimulating protein, **HSL:** Hormone-sensitive lipase, **ATGL:** Adipose triglyceride lipase, **NEFA:** Non-esterified fatty acids, **HbA1c:** Glycosylated hemoglobin, **GABA:** gamma amino butyric acid, **SLR:** Soluble leptin receptors, **GH:** Growth hormone, **GHRH:** GH releasing hormone, **IGF-1:** Insulin like Growth Factor-1, **HPA:** Hypothalamic pituitary axis, **CGB:** Cortisol-Binding Globulin or transcortin, **11 HSD1:** 11 Beta-hydroxysteroid dehydrogenase-1, **SHBG:** Sex hormone-binding globulin, **PCOS:** Polycystic ovarian syndrome, **T4:** Tetraiodothyronine, **T3:** Triiodothyronine, **TBG:** Thyroxine Binding Globulin, **TSH:** Thyroid stimulating hormone.

INTRODUCTION

In the present scenario, obesity is a major public health issue to tackle for the betterment of the community. It is a serious disorder having many adverse effects on the body system. Overweight and obesity increase the risk of many health problems, including diabetes, heart disease, hormonal imbalance, osteoarthritis, musculoskeletal disorders, and certain cancers. Obesity-related cancer disease (endometrial, breast, ovarian, prostate, liver, gallbladder, kidney, and colon) is increasing at an alarming rate throughout the world. Worldwide more than 650 million people are obese, with a prevalence of 39% among adults aged 18 and over, according to World Health Organization (WHO) report (1). Risks for becoming obese include an inactive lifestyle, unhealthy food habits, familial history, hypothyroidism, diabetes, side effects from some medications, etc. Along with these, some bad practices like oversized meals with energy-dense food, lack of sleep, and lack of exercise also eventually cause obesity (2).

Obesity is assessed by the body mass index (BMI) scale. WHO defines BMI as 'a simple index of weight-for-height' that is commonly used to classify underweight, overweight, and obese adults. An individual with a BMI ranging from 25 to 30is considered 'overweight', and a BMI greater than 30 is defined as 'obese' (3). Obesity is directly associated with an increased risk of fatty liver, which can progress fibrosis and cirrhosis. The goal of obesity management is to reduce body weight in the long term in combination with a change in metabolic and hormonal imbalance, which aims to improve obesity-associated risk factors and quality of life (4). The current review focuses on dyslipidaemia, hormonal imbalances, and diabetes-related metabolic changes caused by obesity and the potential role of dietary interventions.

INTERRELATION of DYSLIPIDAEMIA and OBESITY

Lipid metabolism is highly dynamic and is affected by various factors like food intake, triglyceride (TG) rich lipoprotein concentrations, high density lipoprotein (HDL) levels and function, energy expenditure, insulin levels, and sensitivity, and adipose tissue function (5). After the ingestion of fat-containing food, the lipid content undergoes the stages of uptake, transport, and storage. Postprandial food-derived TG and free fatty acid (FFA) reach the liver, which synthesizes TG-rich lipoproteins called very low density lipoproteins (VLDL)(6). VLDL delivers FFA to the heart, skeletal muscle, and adipose tissue for energy expenditure and storage. Lipoprotein lipase (LPL) induces TG lipolysis causing FFA to release in the circulation. These liberated FFA are avidly taken up by adipocytes and utilized to re-synthesize TG in cell cytoplasm where the acylation-stimulating protein (ASP)/C3adesarg pathway plays a crucial role (7). This uptake is facilitated by FFA transporter CD36 abundantly present in muscle, adipose tissue, and the capillary endothelium. Insulin and muscle contractions facilitate FFA uptake by increasing CD36 expression (8). The postprandial release of insulin is one of the most important regulatory mechanisms for FFA metabolism, uptake, and storage. Insulin effectively inhibits hormone-sensitive lipase, which is the key enzyme for hydrolysis of intracellular lipids. HDL promotes cholesterol uptake from peripheral tissues and arterial walls, which returns it to the liver.

Obesity-related typical dyslipidaemia consists of increased triglycerides, LDL-C, along with decreased HDL-C (5). Insulin resistance has a potential impact on the metabolism of TG-rich lipoproteins and FFA. Obesity condition impairs lipolysis of TG-rich lipoproteins by reducing the generation of LPL in adipose tissue and LPL activity in skeletal muscle. The development of a high LDL level in obesity is mainly due to increased TG concentrations, which have an increased affinity for arterial proteoglycans resulting in enhanced subendothelial lipoprotein retention (9). Increased postprandial lipemia leads to elevated FFA levels resulting in detachment of LPL from its endothelial surface (10). LDL receptor expression is reduced, and LDL becomes more susceptible to oxidation, causing the generation of oxidative stress, atherosclerosis, activation of leukocytes, and production of cytokines (11). HDL metabolism is also profoundly affected by obesity due to increased VLDL coupled with impaired lipolysis. Ultimately lower levels of HDL impair reversed cholesterol transport (12).

COEXISTENCE of DIABETES and OBESITY

Diabetes mellitus is a chronic lifestyle disorder caused by low insulin activity due to either the progressive inability of the pancreatic β-Langerhans islet cells to produce insulin or defective insulin uptake by the peripheral tissue. Peripheral insulin resistance is the most prominent pathology of type 2 diabetes in combination with low insulin production by pancreatic β-cells. Insulin is an anabolic hormone released by the pancreas necessary for the regulation of carbohydrates and fat metabolism. It has many functions and acts by inhibiting enzymes like hormone-sensitive lipase (HSL), and adipose triglyceride lipase (ATGL)(13). Thus, dyslipidaemia and obesity are directly related to the development of type 2 diabetes. Prevalence of both central and peripheral obesity poses a higher risk of developing diabetes. Adipocytokines like adiponectin, leptin, tumor necrosis factor, interlukin-6, resistin play an important role in adipose tissue physiology and are linked to obesity, insulin resistance, and β-cell dysfunction (14). Insulin resistance elevates FFAs in the plasma, decreases glucose transport into the muscle cells, increases fat breakdown, subsequently leads to elevated hepatic glucose production.

Obesity is defined not by the body weight alone as it is a state of developing excess adipose tissue mass. Thus, having a high percentage of body fat distributed predominantly in the abdominal region is also termed obese (15). Body fat distribution is another critical factor in determining insulin sensitivity. Individuals with peripheral fat distribution have more insulin sensitivity than those having more central (abdomen and chest) fat distribution. Adipose tissue affects metabolism by secreting hormones, glycerol, leptin, cytokines, adiponectin, pro-inflammatory substances, and non-esterified fatty acids (NEFAs). In obese individuals, the secretion of these substances is increased (16). In the case of abdominal adiposity, adipose tissue releases higher amounts of NEFAs, glycerol, hormones, pro-inflammatory cytokines contributing to insulin resistance (17).

Increased release of NEFAs is observed in both type 2 diabetes and obesity and is associated with insulin resistance in both conditions (18). Intra-abdominal fat is more lipolytic than subcutaneous fat and does not respond efficiently to the antilipolytic action of insulin, causing insulin resistance and, thus, diabetes (19). Increased lipid concentration significantly influences haemoglobin glycation with high cardiovascular disease risk, possibly due to increased insulin resistance. Hyperglycaemia promotes LDL glycation in obese type 2 diabetic persons. An increase in glycosylated haemoglobin (HbA1c) in type 2 diabetes is associated with poor insulin sensitivity and high lipid parameters (20). Interrelationship of dyslipidaemia, diabetes, and hypothyroidism with obesity has been schematically compiled in Figure 1.

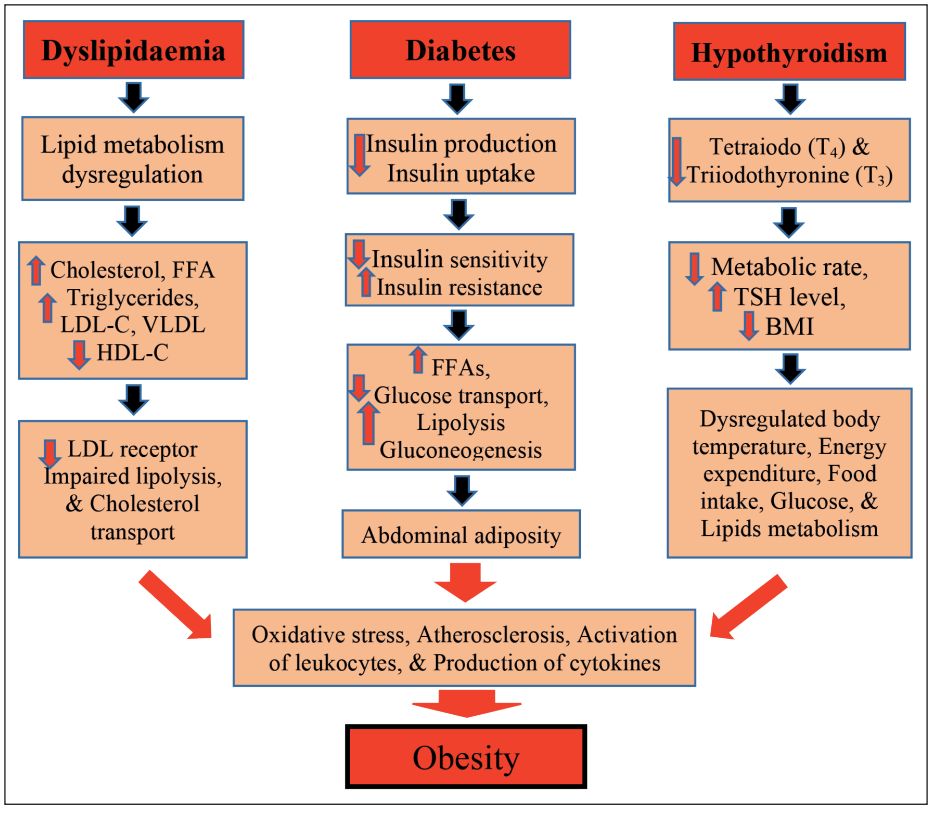

Figure 1: Interrelationship of dyslipidaemia, diabetes, and hypothyroidism with obesity.

CORRELATION of HORMONAL IMBALANCE WITH OBESITY

The endocrine hormonal system secretes hormones directly into the bloodstream, which works in fine tune with the nervous and immune systems. Excessive or insufficient release of hormones can lead to obesity and vice versa. Hormones like leptin, insulin, sex hormones, and growth hormones influence appetite, metabolism, and body fat distribution.

HORMONES of ADIPOSE TISSUE

Adipose tissue has many other important functions mediated through hormones termed adipocytokines synthesized and released by adipocytes, along with side energy storage. Adipocytokines act on the endocrine, paracrine, and autocrine course of action. The following are a few crucial adipocytokines secreted from white fat.

Leptin

Leptin produced by adipocytes or fat cells is the most powerful appetite-suppressing hormone and reduces the urge to eat by binding presynaptic GABAergic neurons (gamma amino butyric acid) of the hypothalamus. Leptin also controls body fat stores. Blood leptin levels decline during fasting, low-calorie dieting, low protein diet, or uncontrolled type 1 diabetes stimulating hunger. Serum concentrations of leptin increase in proportion with adiposity (21). But in the case of obese individuals, leptin resistance develops decreased levels of circulating soluble leptin receptors (SLR). High leptin levels with low SLR make obese individuals resistant to leptin (22). Leptin receptors are present in the liver, skeletal muscles, pancreatic beta cells, and adipose tissue implicating its endocrine, autocrine, and paracrine roles in energy regulation. Leptin signaling mediates important effects on glucose and lipid metabolism as an insulin-sensitizer (23). Leptin plays a significant role in the physiological regulation of neuroendocrine axes, i.e., hypothalamic-pituitary-gonadal, -thyroid, -growth hormone, and -adrenal axes (24).

Adiponectin

Adiponectin is a crucial adipocytokine influencing insulin sensitivity and atherogenesis. Adiponectin binds to AdipoR1 and AdipoR2 receptors, leading to activation of adenosine monophosphate dependent kinase and PPAR-α (Peroxisome proliferator-activated receptor) signaling pathways (25). Lower adiponectin levels are observed in obesity associated with insulin resistance, dyslipidaemia, and atherosclerosis in humans (26). In contrast to leptin, adiponectin is reduced in obesity and increased in response to fasting. In parallel with weight loss, plasma adiponectin level increases significantly, improving insulin sensitivity (27).

Omentin

Visceral adipose tissue produces another adipokine called omentin that exerts insulin-sensitizing actions. Its expression is reduced in type 2 diabetes, insulin resistance, obesity, increased waist circumference, high triglycerides, and leptin levels (28).

GROWTH HORMONE

Growth hormone (GH) secreted by the pituitary gland mediates effects through Insulin like Growth Factor-1 (IGF-1) produced mostly by the liver. GH and IGF-1 together influence lipids, protein, and glucose metabolism by inhibiting fat accumulation, promoting protein accretion, altering energy expenditure, and body fat/muscle composition. Normally, a postprandial increase in insulin suppresses GH secretion to promote glycogenesis and adipogenesis. GH secretion is modulated by the hypothalamic GH releasing hormone (GHRH) that follows a pulsatile pattern influenced by age, sex, sleep, food, physical activity, and body weight. Decreased GH and increased GHBP levels are typically observed in obesity (29).

Adrenal hormones

Dysregulation of the hypothalamic pituitary axis (HPA) in the form of 'functional hypercortisolism' could potentially cause abdominal obesity along with different metabolic consequences (30). About 90% of the adrenal gland hormone cortisol mainly binds to Cortisol-Binding Globulin (CGB or transcortin). The free or unbound 10% of circulating cortisol is bioactive. Usually, serum concentrations of cortisol are normal in obesity due to cortisol's local production in the fat tissue. Adipose tissue has 11 Beta-hydroxysteroid dehydrogenase-1 (11HSD1) enzymes, which convert cortisone (inactive corticoid) to cortisol (active corticoid). High-normal Adrenocorticotropic hormone (ACTH) and cortisol levels in obesity is associated with cardiovascular risk factors, insulin resistance, and dyslipidaemia (31).

High cortisol in obesity is derived from cortisone due to increased activity of 11HSD1 and increased visceral fat mass. Visceral fat cells populate higher numbers of glucocorticoid receptors and mineralocorticoid receptors. Mineralocorticoid receptor activation mediates inflammation and dysregulation of adipokines, causing insulin resistance and the development of metabolic disorder (32).

Sex hormones

Sex hormone levels are altered in obesity and influencing the expression of different obesity phenotypes. There is a strong relationship between obesity and androgen levels, sex hormone-binding globulin (SHBG), and gonadotropins. Most

circulating testosterone and estrogen bind to transport proteins SHBG and albumin has only about 2% off in the unbound or free bioactive form. SHGB increases and bioactive testosterone decreases with aging.

Androgens

Testosterone deficiency induces adiposity in men and, which further can induce hypogonadism. Obesity in men is also associated with SHBG levels due to decreased testosterone levels (33). Male obesity has been associated mostly with secondary hypogonadism (hypogonadotropic) related to obstructive sleep apnoea, type 2 diabetes, hypertension, and increased body fat mass (34,35).

It is reported that long-term obesity can lower testosterone-producing Leydig cells and promote the destruction of existing ones. Hypogonadism can itself worsen obesity and promote increased fat mass, which in turn may exacerbate the hypogonadal state like a vicious cycle of 'hypogonadal-obesity cycle'. Low testosterone levels lead to muscle mass reduction and an increased adipose tissue in abdominal depots, which further increases the preferential deposition of fat in the abdomen region (36).

Sex steroid level abnormalities in premenopausal and postmenopausal women cause an increase in body weight and fat tissue. Obese women have higher levels of testosterone and lower androstenedione and SHBG levels (37). Though genetic factors control the timing of menarche, age at menarche in females has been declining since the last 30 years, particularly due to changes in nutritional status (38). The risk of developing obesity is higher with earlier menarche and comorbidities in adult life, such as breast cancer, cardiovascular disease, cerebrovascular disease, and type 2 diabetes (39).

Leptin receptors are predominamtly expressed in the human ovaries and testes, indicating their regulatory role. Evidence supports that leptin is a mediator of infertility at the level of the ovary in obese women. Exposure of human granulosa-lutein cells to increasing concentrations of leptin caused a moderate but consistent decrease of E2 concentrations, leptin is able to suppress LH-induced estradiol production by human granulosa lutein cells (40). Polycystic ovarian syndrome (PCOS) is a condition associated with elevated androgen levels and infertility in women. Obese women with PCOS were found to have higher leptin and lower SLR level (41). Obesity was also reported to lower intra testicular testosterone levels in men via leptin.

Estrogens

Estrogens play an important role in females controlling body weight, fat distribution, energy expenditure, and metabolism. Gonadotropins releasing hormones from the pituitary gland regulates ovarian estrogens synthesis in premenopausal women. In post-menopausal women and men, estrogens are produced in the adipocytes in proportion to the total body adiposity (42). Metabolic effects of estrogens are mediated through the estrogen receptor, whereas gynaecologic actions are exerted through estrogen receptor β. Estrogens act as an insulin sensitizer in skeletal muscle, liver, and adipocytes, positively affecting glucose homeostasis (43). Estrogen deficiency promotes metabolic dysfunction, which lately predisposes to obesity, metabolic syndrome, and type 2 diabetes. On the contrary, obesity is associated with elevated estrogen levels due to increased production in adipocytes (44), giving rise to risk factors for breast cancer development and cardiovascular disease. Figure 2 explains correlation of hormonal imbalance with obesity.

LINKAGE of HYPOTHYROIDISM WITH OBESITY

Thyroid hormones, Tetraiodothyronine (T_4) and Triiodothyronine (T_3) regulate basal metabolism, thermogenesis and play an important role in lipid and glucose metabolism and fat oxidation. Thyroid dysfunction is associated with body weight and composition changes, body temperature, energy expenditure, food intake, glucose, and lipids metabolism. T_4 and T_3 circulate bound to Thyroxine Binding Globulin (TBG) with less than 1%, unbound, and biologically active. Hypothyroidism has a well-established link to weight gain and decreased metabolic rate having a direct association with thyroid stimulating hormone (TSH) serum level and BMI. Fat accumulation increases in parallel with an increase in serum TSH and free T_3 levels independent of insulin sensitivity and other metabolic parameters.

Free T_3 to T_4 ratio has a positive association with BMI and waist circumference (45). Body mass index is directly correlated to thyroid volume and the incidence of thyroid nodules. Thyroid Receptor α mediates effects of T_4 in bone, skeletal muscle, brain, and heart, whereas Thyroid Receptor β regulates TSH secretion and the metabolic effects of T_3 in the liver (46). Being overweight or obese is the fifth most vulnerable risk of death. Most of the threat comes from thyroid hormone dysfunction and the increased risk of cancer associated with obesity. Thyroid dysfunction-related obesity impacts the body related to low back pain, knee pain, osteoarthritis, depression, and anxiety (47).

MANAGEMENT of OBESITY THROUGH NATURAL DIETARY INTERVENTION

According to WHO, obesity is growing like an epidemic, and if immediate action is not taken, millions of people will suffer from weight-related severe disorders (48). Central body fat distribution has an essential effect on metabolic

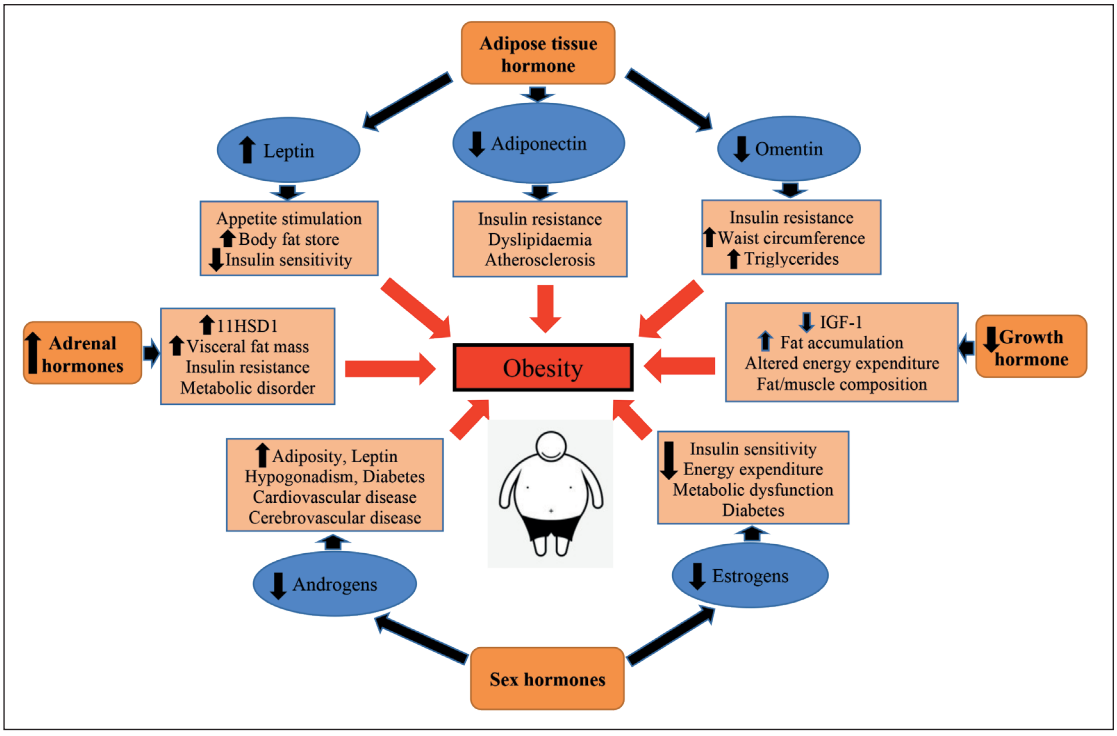

Figure 2: Correlation of hormonal imbalance with obesity.

and heart risk factors. Increased visceral fat accumulation is a risk factor for coronary artery disease, dyslipidaemia, hypertension, stroke, and type 2 diabetes. The quantity of fat ingested and total calories are the two most important dietary factors inducing obesity and lipidemia. High LDL cholesterol level is the single most strong predictor of cardiac disease risk in women below 60 years. An increase in blood total cholesterol, VLDL, and triglycerides have also been observed postmenopause (49). Nowadays, people do less physical work, and their diet mostly includes more carbohydrates and fat, contributing to obesity. Some countries have meager obesity rates, in Japan obesity rate is 3.7%, the diabetes rate is 7.6%, and in American obesity rate is about 30%. The people of Japan and other Asian countries have less tendency to get fat because they have less storage space for fat and have the habit of taking a low calorie and low carbohydrate diet. The average working western population mostly consumes high-fat, high-sugar, high-salt, energy-dense, and micronutrient-poor foods, which tend to be lower in cost but obviously have lower nutrient quality.

Obesity-related dyslipidaemia can be treated following lifestyle changes, including weight loss, physical exercise, and a healthy diet. Lifestyle changes synergistically improve insulin resistance and dyslipidaemia (50). Physical exercise is reported to increase the LPL and hepatic lipase activity, which stimulates triglycerides lipolysis, decreasing serum LDL, and triglyceride levels (51). Exercise alone is usually not sufficient to induce significant weight loss, but it can facilitate significant weight loss and maintain weight (52). Diet intervention weight loss has a direct effect on the serum lipid profile. The type of dietary fat also affects postprandial lipemia (53). A decrease in LDL is more pronounced with a low-fat diet, whereas the increase in HDL and the decrease in triglycerides is greater with the high-fat diet (54). Low carbohydrate diet decreases triglycerides to a greater extent compared to the low-fat diet, which is more effective in lowering LDL levels, whereas both increase HDL (55). Diet having high protein and less carbohydrate can help to improve metabolism and hormonal imbalance (56). A high protein vs. low protein diet has a similar weight loss profile with no differences in LDL or HDL levels, but the high protein diet results in a much greater decrease in triglyceride levels (57). Diet high in soluble fibers can lower LDL levels. Decreased intake of saturated and trans fats along with high soluble fiber favourably decreases LDL levels. The glycaemic index of foods is a marker for glucose's rapid absorption and appearance in the blood during meal consumption. High glycemic index foods (sugary food, potato, white rice, and bread) results in greater glucose and insulin excursions, causing blood sugar level to rise and fall quickly. Low glycemic index foods like whole grains, fruit, vegetables, beans, and lentils help feel fuller for a longer controlling appetite and are useful for weight loss.

Nutraceuticals are known as functional foods with higher nutritional value. Substances isolated from whole food, such as isolated nutrients, processed food, and dietary supplements, are considered nutraceuticals. Administration of nutraceuticals helps in the management of obesity and protects from oxidative stress and inflammation (58). There is an increase in demand for nutraceutical foods, dietary supplements, and pharmaceuticals containing peptides. It has also been found that intake of nutraceuticals products, physical activity, and high dietary fiber intake is very useful for controlling obesity, smoking, and increased dietary fat intake (59). A variety of products from fish is utilized as medicinal products in edibles collectively called Fish by-products (head, skin, scales, and whole body). The use of these by-products, which are rich in protein (collagen, chitin), lipids, and amino acids, minimizes the problem in metabolic disorder as if used as a crude supplement (60). Bioactive peptides are well recognized for their possible role in reducing cardiovascular risk, inflammatory diseases, and metabolic changes (61). The fish meal also provides vitamins, minerals, and other growth factors, contributing to productivity and higher yields. Despite the physicochemical characterization challenges associated with fish proteins, their nutritional value and functional properties give potential opportunities to be used as food and medicinal products (62). Nutraceuticals comprising herbal actives are rapidly growing across the global market. Animal products as nutraceuticals have not gained much importance, while this can be a significant segment catering to the highly evolving global market. This also reiterates the need for standardization for ensuring the efficacy, stability, and overall quality of products.

CONCLUSION

This article emphasizes the deleterious role of different related disorders and abnormalities in inducing obesity. People with obesity generally have an unhealthy lifestyle and eats a lot of carbohydrate and fat-rich products with comparatively less protein in diet. This review focused on complications of obesity-related thyroid disorder, hormonal imbalance, and dyslipidaemia. Dyslipidaemia related to obesity is characterized by higher serum levels of triglycerides and low density lipoproteins. Insulin inflicts its anti-obesity effect by inhibiting hormone-sensitive lipase, the key enzyme causing hydrolysis of intracellular lipids. Dyslipidaemia and obesity are directly correlated to type 2 diabetes as the prevalence of obesity pose a higher risk of developing diabetes. This is further related to insulin resistance, which elevates plasma fatty acid levels and decreases glucose transport into the muscle cells leading to elevated liver glucose production. Obesity is defined not alone by body weight, and abdominal adiposity is also a significant risk factor for being obese.

Disproportionate body fat distribution is a critical factor contributing to insulin resistance. As commonly observed, increased level of HbA1c depicts poor insulin sensitivity and high lipid levels in diabetic patients. Combined effect of leptin, insulin, sex hormones, and growth hormones influence our appetite, metabolism, and body fat distribution. Leptin is produced by fat cells, which in turn controls body fat stores. Serum concentrations of leptin increase in proportion with adiposity, whereas in contrast, adiponectin is reduced in obesity. High ACTH and cortisol levels are associated with obesity. Long-term obesity causes hypogonadism that further worsens obesity, and promotes fat deposition. Leptin receptors are found in ovaries and testes, which is a mediator of infertility in obese women. Estrogens play an important role in controlling female body weight, fat distribution, and metabolism. Thyroid hormones, T_4 and T_3 regulate basal metabolic rate and thermogenesis regulating lipid and glucose metabolism. Hypothyroidism has a well established link with decreased metabolism and weight gain. Thyroid hormone dysfunction imposes an increased risk of obesity. Obesity in adult life has direct correlation with higher risk of breast cancer, cardiovascular disease, cerebrovascular disease, and type 2 diabetes.

Obesity and associated disorders can be prevented naturally by the regular consumption of nutraceuticals. Several epidemiological studies have confirmed that the consumption of functional foods/nutraceuticals could considerably lower the risk of various chronic diseases associated with obesity. The nutraceuticals discussed in this article are commonly consumed as a staple diet by many ethnic populations. Nutraceutical products contain minerals, vitamins, fibers and are also rich in protein content. Vitamins and antioxidants levels are found to be lower in obese persons compared to the non-obese, which is responsible for the development of inflammation diseases in obese individuals. Research has found that Nutraceuticals can modulate adipocyte cells' activity and other related aspects of pathogenic obesity though the ability to weight loss is variable. Nutraceuticals like natural fibers and fish protein have a greater potential to reverse weight gain and obesity-related comorbidities. This field still requires greater research efforts especially utilizing well-designed study protocol in animal models.

In the present day, the world's need for weight management emphasizes the importance of healthy eating patterns, including a variety of nutrient and protein-dense food in a regular diet. A diet containing higher amount of fiber and protein-rich foods can help enhance satiety, improve health, and help decrease body weight. The inclusion of nutraceuticals in a regular diet will enable common people to be able to control obesity along with a significant decrease in the burden on the countries health system. This will, in turn,

help to achieve a physically, socially, and psychologically better population of citizens. Further research should focus on the cellular level effect of fibers and fish proteins on adipocyte expansion, adipogenesis inhibition, and adipocyte apoptosis promotion.

Acknowledgment

None.

Author Contributions

The article content was conceptualized and designed by **Papiya Bigoniya.** The literature search was conducted by **Ankita Awasthi** under the supervision of **Papiya Bigoniya, Ankita Awasthi** has contributed actively in writing manuscript. Content analysis and interpretation was done by **Papiya Bigoniya** with critical review of content.

Conflicts of Interest

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Financial Disclosure

None.

Ethical Approval

None

Peer Review Process

Extremely peer-reviewed and accepted.

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