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RESEARCH ARTICLE

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Metabolic Dysregulation and Male Libido: Mechanistic Insights into Diabetes-Associated Sexual Desire Suppress

Banupriya Ravichandran[1], Saravanan Govindasamy Kuppusamy[2]*, Pushkala Kammalamal[3] and Purshottam Das Gupta[4]

[1]Research scientist, Department of Biotechnology, Greensmed labs, Chennai, India

[2]Assistant Professor, Department of Biotechnology, Dwaraka Doss Goverdhan Doss Vaishnav college, Chennai, India

[3]Retired Associate Professor, Department of Zoology, SDNB Vaishnav College for women, Chennai, India

[4]Retired, Director Grade Scientist, Centre for Cellular and Molecular Biology, Hyderabad, India

ABSTRACT

Background: *Diabetes mellitus* is a chronic metabolic disorder characterized by insulin resistance, hyperglycaemia, inflammation, and hormonal dysregulation. Its global prevalence is rising rapidly in India, especially in the case of Type 2 Diabetes mellitus (T2DM). This condition predisposes individuals to multiple comorbidities and significantly impairs the quality of life. Although erectile dysfunction has been studied extensively in diabetic individuals, changes in libido remain comparatively underexplored, particularly in men. Type 2 Diabetes mellitus is associated with reduced libido in males; the underlying mechanisms need a detailed investigation and further research to be encouraged. Sexual health is a fundamental component of both mental and physical well-being. Male sexual concerns are unnoticed and underreported, which leads to insufficient screening. This condition largely results from social stigma.

Objective: Type 2 *Diabetes mellitus* (T2DM) shows significant alterations in metabolic regulation, often accompanied by comorbid conditions such as obesity and obstructive sleep apnea (OSA). These interconnected factors lead to reduced libido in males and seriously affect the psychological and overall well-being of their female partner.

Discussion: Type 2 *Diabetes mellitus* is characterized by insulin resistance and persistent hyperglycaemia, accompanied by hormonal regulation, endothelial dysfunction, and release of pro-inflammatory cytokines. These metabolic disturbances are associated with reduced testosterone levels, alteration in sexual hormone binding proteins, impaired nitric oxide and autonomic neuropathy, all of which contribute to reduced sexual desire (libido) in males. Other conditions such as obesity and obstructive sleep apnea (OSA) aggravate insulin resistance and are closely linked to hypogonadism through increased aromatase activity and visceral inflammation. In addition, disrupted sleep patterns reduce nocturnal testosterone secretion while inducing hypoxia and oxidative stress, thereby further suppressing the activity of libido. Psychological factors also interact with these biological pathways, resulting in a decreased libido and potentially contributing to dissatisfaction and emotional stress in their female partners. Collectively, these findings highlight the multifactorial activity of libido impairment in T2DM patients, involving the metabolism, hormonal, and psychological interactions.

Conclusion: Low libido activity in men with *Diabetes mellitus* shows metabolic, hormonal, sleep, and psychological disorders, which implies that beyond the men's wellbeing, it also affects the female partner also. Routine screening, mechanism-based treatment, and integrative interventions improve the sexual health and relation outcomes.

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Contact Saravanan Govindasamy Kuppusamy, Assistant Professor, Department of Biotechnology, Dwaraka Doss Goverdhan Doss Vaishnav college, Chennai, India.

Introduction

History of Diabetes

Diabetes originated from a Greek word meaning to pass through and *mellitus* is Latin word meaning sweet. The term diabetes was coined by Apollonius of Memphis around 250 to 300 BC because of the sweet nature of the urine [1]. *Diabetes mellitus* is a metabolic disorder with persistent hyperglycemia due to abnormal secretion of insulin or insulin action or both [2]. The diseases affect the metabolism of the body due to impaired utilization of glucose at cellular level [3]. The sustained and untreated hyperglycemia causes complications affecting the many organs of the body [4]. There are two major types of diabetes viz., type 1 *Diabetes mellitus* is an autoimmune disorder where pancreatic β cells are destructed resulting in the deficiency of insulin whereas the other type is, type 2 *Diabetes mellitus* is a multifactorial disorder, a combination of both insulin resistance and insulin deficiency [5].

Insulin deficiency occurs in both type 1 and type 2 diabetic patients where in type 1, there is a destruction of pancreatic β cells and type 2 is due to chronic metabolic stress causing dysfunction of β cells without sufficient insulin production, glucose uptake decreases in skeletal muscles and adipose tissue leading to hyperglycemia, increase in lipolysis and proteolysis ultimately changing the fat and protein metabolism [6]. Insulin resistance is a condition in which peripheral tissues work less in subjects compared to normal individuals. In this condition, muscle cells fail to uptake glucose, liver undergoes gluconeogenesis despite hyperglycemia, increases free fatty acids, systemic inflammation and oxidative stress increases [7].

Global Prevalence of Diabetes

Diabetes mellitus has emerged as global public health challenges of 21st century, International Diabetes Federation reported 589 million adults aged 20-79 years are currently living with diabetes across the globe and it rises due to increasing population, secondary lifestyle and obesity. Type 2 diabetes are more predominant in patients than other types and associated with metabolic risk factors. In 252 million adults with diabetes remain undiagnosed, leading to higher risk of health complications and approximately 853 million by 2050 the diabetes rate will increase to control the improved prevention, early diagnosis and effective management strategy across the globe [8].

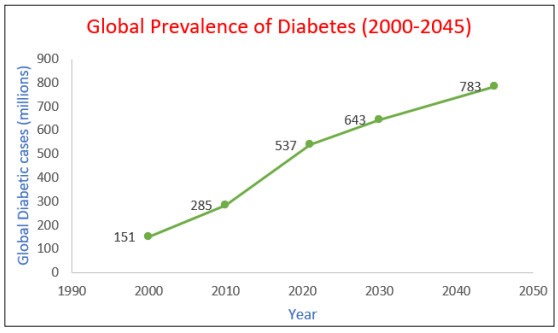

Figure 1: Global Prevalence of Diabetes from 2000 to Projected Estimates for 2045 Based on International Diabetes Federation Data.

Epidemiological Burden of Diabetes in India

India has rapid rise in diabetes and often referred as "Diabetes capital of the world" because of its largest population. The increasing burden of diabetes is linked with multi factors especially urbanization, life style, unhealthy dietary patterns, genetic susceptibility and a growing prevalence of obesity and metabolic syndrome. The diabetes rate is high in urban areas and now steadily increasing in rural areas and the prediabetic stages are increasingly placing the people at high risk of developing the disease. The disease not only affects the metabolism, but causes problem in cardiovascular function, neurological integrity, endocrine disorder and reproductive health. The growing burden of diabetes in India especially in men, affects the sexual health consequences such as libido is reduced in men and this problem is usually under reported and undiagnosed largely due to cultural stigma and lack of routine clinical screening. Thus, diabetes affects the metabolic activity, quality of life and interpersonal relationships.

Diagnostic Criteria of Glycemic Status

The diagnosis of diabetes is based on measurement of blood glucose level as per American Diabetes Association (ADA) and World Health Organization (WHO) to categorize each individual into normal glucose regulation, prediabetes and Diabetes mellitus [9]. Individuals with normal glucose metabolism through proper insulin secretion and insulin sensitivity where the blood glucose level in healthy individual is fasting glucose is around < 100 mg/dl, Postprandial glucose < 140 mg/dl and HbA1c < 5.7% [10]. Prediabetes stage people have impaired metabolism of glucose and they are more prone to type 2 diabetes where insulin is resistant, obesity, secondary lifestyle and metabolic syndrome all contribute to dysfunction of pancreatic β cells [11]. Diabetes is with persistent hyperglycemia, is present due to insulin deficiency, insulin resistance or both. Common symptoms of diabetic patients are polyuria, polydipsia, polyphagia, weight loss, fatigue and blurred vision. Persistent increase of blood glucose affects severely the reproductive and sexual health. Therefore, early diagnosis is mandatory to prevent the disease progression and avoid complications related to hormonal imbalance and libido- related disorders [12].

Sexual Health and its Overall Wellbeing

Sexual health is an important factor for physical, emotional, social and mental well-being which in turns improves the quality of life [13]. Sexual health does not imply the absence of disease or dysfunction but helps in personal satisfaction, emotional bonding and stability with intimate relationship and successful marriage [14]. Among men, libido is the biological and psychological drive for sexual activity and is influenced by multiple factors including hormonal balance, metabolic constrains, neurological signal and vascular integrity [15]. Chronic disease like diabetes disrupts the activity of the system and impair the desire for sexual thought and performance. Despite the clinical importance, sexual health is under reported and neglected aspect of medical evaluation particular in conserved families where sexual behaviour is stigmatized.

Diabetes patients neglect their sexual behaviour due to embarrassment, male sexual health thoughts, cultural stigma, lack of awareness, society and delayed diagnosis and treatment [16]. Thus, sexual health is a key quality of life marker an essential criterion for holistic management of chronic diseases.

Under Recognition of Sexual Health in Chronic Disease Management

Libido, fundamental component of sexual health reflex the complex interaction of bodily functions that regulate the sexual motivation and intimacy [17]. Despite its importance, libido is rarely considered in clinical practice especially with chronic disease like diabetes, low testosterone, estrogen imbalance, hypothyroidism, chronic stress, ageing, hyperprolactenimia, cardiovascular disease, cancer, neurotransmitter imbalance and neurological disorders are the key factors to supress libido. While these markers are focused only on disease control rather than disturbances on libido is mostly overlooked. As a result, many patients experience unnoticed reduced libido and left untreated, and thus their female partners also suffer due to lack of intimacy by the male partner.

Educated individuals, decline libido related consultancies due to sociocultural barriers and self-stigmatized due to sexual health related matters. Clinicians normally don't provide equal importance to consult in diabetic patients about the care for libido in sexual health. Consequently, libido suppression is a hidden complication in diabetes. In such conditions, mismanaged metabolism influence by the hormonal, vascular and neurological pathways to maintain the normal sexual desire [18]. However, erectile dysfunction was a focus point for the researchers and scientist but libido remain limited in scientific forum [19].

Cultural Stigma Surrounding Male Libido

In several societies, masculinity is closely associated with sexual intimacy, manliness, predetermined mind of thinking to maintain strong sexual interest. As a result, a decline in libido may be perceived as a threat to masculine identity, leading to neglect the problem or not providing the importance which prevent from seeking medical advice [20]. In many south Indian scenario, sexual topics are considered as private and avoid discussions between patients and healthcare providers. Consequently, reduced libido particularly with diabetes and the silence surrounding the male libido contributes to the delayed diagnosis, inadequate stress, negative consequences for both partners wellbeing and intimate relationships [21]. Therefore, there is a need for a more focus to observe libido changes in diabetic men and their potential consequences ultimately indispensable for marital relationships.

Physiology of Normal Male Libido

The physiology of healthy male libido interconnects the neuroendocrine signal, neurotransmitter pathway, vascular physiology and cognitive- emotional processes. Sexual motivation starts from central nervous system and is modulated by the hormones, metabolism and environmental stimuli. This start up initiates the libido process, followed by behavioural arousal and reproductive capacity. Disruption in any of the mechanisms leads to change or alter the libido stimuli. Understanding the mechanisms, healthy male libido provides an essential framework for examining the metabolic disability like diabetes to impair the sexual function [22].

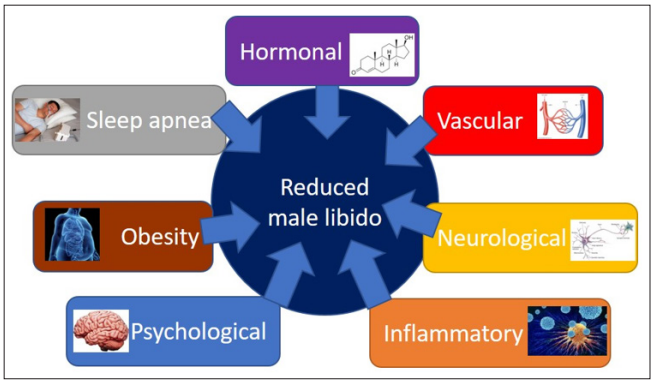

Figure 2: Multifactorial Mechanisms Linking Diabetes and Metabolic Dysfunction to Reduced Male Libido

Neuro-Endocrine Regulation

Hypothalamus Pituitary and Gonadal (HPG) Axis

The principal endocrine pathway regulating male reproduction and sexual desire is Hypothalamus pituitary and Gonadal (HPG) axis which operates by a tightly regulated hormonal cascade that starts in hypothalamus where it releases Gonadotrophin releasing hormone (GnRH) which signals the anterior pituitary to release luteinizing hormone (LH) and Follicle stimulating hormone (FSH). LH act on Leydig cells of testes, stimulating the enzymatic pathway of testosterone biosynthesis from cholesterol. FSH act on sertoli cells supporting spermatogenesis and maintain testicular function. Testosterone is responsible for libido, muscle mass, bone density and erythropoiesis.

Testosterone participate in negative feedback mechanism that regulate the HPG axis where elevated level suppresses the GnRH and intern reduce LH release and maintains hormonal homeostasis. Disruption in this mechanism by metabolic abnormality, obesity or chronic disease like diabetes reduce the testosterone production and decrease the libido [23].

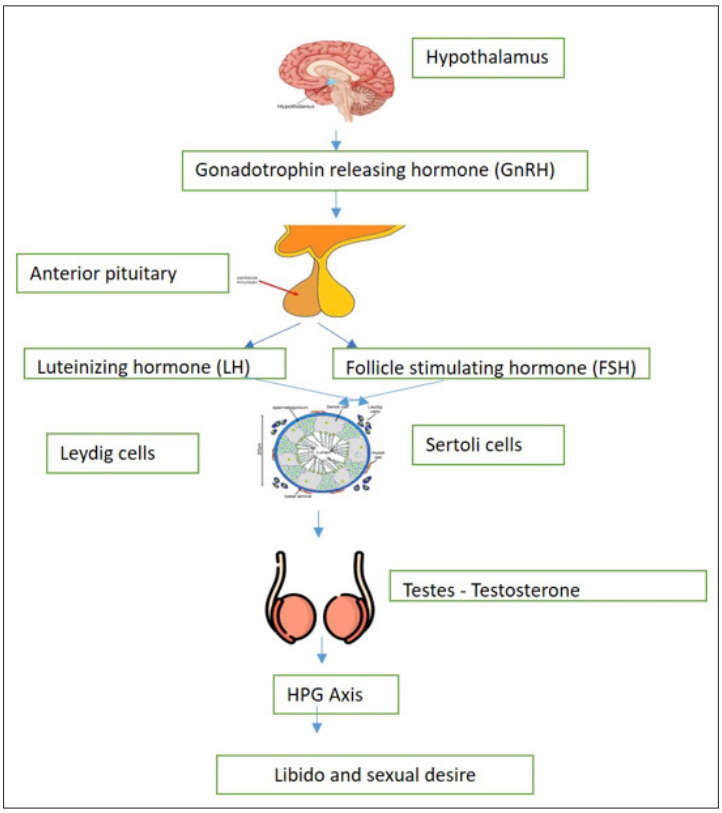

Figure 3: Physiology of Healthy Libido in Male Efficiency of Libido: Role of Testosterone

Testosterone is the important hormone responsible for male libido and reproductive behaviour. Within the central nervous system, testosterone stimulates neural activity in various parts of the brain, including the hypothalamus, amygdala, limbic system, and preoptic area, which are associated with sexual arousal. The libido activity is exerted through two major mechanisms

- direct activation of the androgen receptor.
- conversion of estradiol via aromatization.

In direct activation of the androgen receptor, testosterone binds with androgen receptor which are located in the neuron of the brain. After connecting with the neuron, the testosterone-receptor complex moves into the cell nucleus and regulates gene expression. This activation enhances neuronal signals and increases libido responsiveness. In the conversion of estradiol via aromatization, in certain parts of the brain tissues, testosterone is converted into estradiol by the enzyme aromatase. It binds with the estrogen receptor in neural circuits and maintains the libido sensation in males. These pathways modulate through the neural circuits and enhance the efficiency of libido in males. The healthy secretion of testosterone is associated with increased sexual interest, sexual thoughts, sexual initiation, and improved mood and energy levels. Hypogonadism, characterized by reduced testosterone levels, is strongly associated with reduced libido, fatigue, mood swings, and lower sexual motivation [24]. Estradiol plays a crucial, balanced role in male libido, where both excessively high and very low levels can impair sexual desire and function. While testosterone is primary, optimal estradiol levels are needed for libido and sexual behavior, with imbalances-particularly a high estradiol-to-testosterone ratio-linked to erectile dysfunction and reduced drive.

Neurotransmitters in Libido

Neurotransmitters also play an important role in the modulation of male libido apart from hormonal regulation. Among the neurotransmitters, dopamine is considered as one of the important mediators of the libido or sexual desire, and this happens due to the mesolimbic reward pathway which is responsible for motivation, reward perception and behavioural responses. The pathway includes the ventral tegmental area, nucleus accumbens, hypothalamus, and prefrontal cortex. Activation of this neural circuitry stimulates in sexual anticipation, pleasure, and motivational drive, especially when dopamine is released within the nucleus accumbens, play an important role in reinforcing and enhances the libido. If depletion of dopamine, certain neurological disorders and medicines such as antipsychotic drugs that lead to reduced libido. Dopamine interacts with serotonin to act as an inhibitory factor by excessive serotonergic activity resulting in reduced libido, oxytocin is a bonding hormone for emotional intimacy and partner attachment, and norepinephrine contributes to sexual arousal, all three neurotransmitters regulate emotional bonding and behavioural responses during sexual activity [25].

Nitric Oxide and the Vascular Component

Nitric oxide is the key signalling molecule for sexual arousal and penile vascular responses. It is synthesized by endothelial cells

and nitrergic neurons through the catalytic action of enzymes nitric oxide synthase (NOS). During stimulation of sex, activation of parasympathetic nervous system triggers the release of nitric oxide from nitrergic nerve terminals and endothelial cells within penile tissue and activate the enzyme guanylate cyclase leading to increased production of cyclic guanosine monophosphate (cGMP). Elevated levels of cGMP, relaxes the smooth muscle cells in corpus cavernosum resulting in vasodilation of penile arteries, increases blood flow to penile tissue and facilitates indirectly the sexual desire [26]. The cGMP is regulated by the enzyme phosphodiesterase type 5 (PDE5) and terminates the vasodilatory signal. Impairment of nitric oxide synthesis occurs in diabetic patients and leads to reduce libido which intern reduce the sexual performances [27].

Psychological and Cognitive Arousal

Psychological factors play a vital role in initiating and sustaining the sexual desire. Libido is strongly influenced by cognitive processes within the cerebral cortex and limbic system with stimuli in emotions, sensory and interpersonal dynamics. Conditions such as chronic stress, depression, anxiety suppresses the desire by altering the neurochemical signal in the brain. Cortisol, a stress related hormone disrupts the Hypothalamus pituitary and Gonadal (HPG) axis and reduced testosterone production and diminished libido. Therefore, a male libido represents the outcome of a multidimensional interaction and disruption in these systems can impair the process and initiation of libido, highlighting the integration of physiological regulation in maintaining the healthy sexual function [28].

Mechanism of Type 2 Diabetes

Insulin Resistance

Insulin resistance is the central defect in development of Type 2 diabetes. In normal physiological conditions, insulin facilitates glucose uptake into peripheral tissues and maintains normal blood glucose levels. However, in insulin resistant states, tissues exhibit reduced responsiveness to insulin signalling. As a result, glucose uptake is reduced in tissues while hepatic glucose production continues despite of elevated blood glucose. This impaired reaction led to accumulation of more glucose in the blood, and initiated the dysregulation of the body metabolic mechanism [29].

Beta-Cell Dysfunction

As insulin resistant occurs, pancreatic β-cells stimulates the insulin secretion, leading to temporary hyperinsulinemia. However, prolonged stress impairs the β-cell function and chronic exposure lead to increased level of glucose and fatty acids damaging the β-cell to suppress the secretion of insulin. Over prolonged time, these cells become dysfunctional and lead to relative insulin deficiency which finally led to hyperglycemia [30].

Chronic Hyperglycemia

Chronic hyperglycemia is a metabolic abnormality of diabetes since, increased elevation of blood glucose disrupts the biochemical pathway resulting in oxidative stress, inflammatory response and injury in vascular systems. The altered pathways are polyol pathway, Hexosamine pathway flux and protein kinase C activation which contribute to cellular damage develops the complications in micro and macro vascular systems [31].

The major complication of chronic hyperglycemia is the formation of advanced glycation end products (AGEs). It is produced by a non-enzymatic reaction of glucose, proteins, lipids and nucleic acid which is also known as glycation. The glycation led to the change in structure of proteins, increases oxidative stresses, activation of inflammatory pathway and dysfunction in endothelium. This glycation interacts with targeted receptors known as receptor for advanced glycation end products triggers the inflammatory signalling and causes tissue and vascular damage commonly observed in diabetic patients [32].

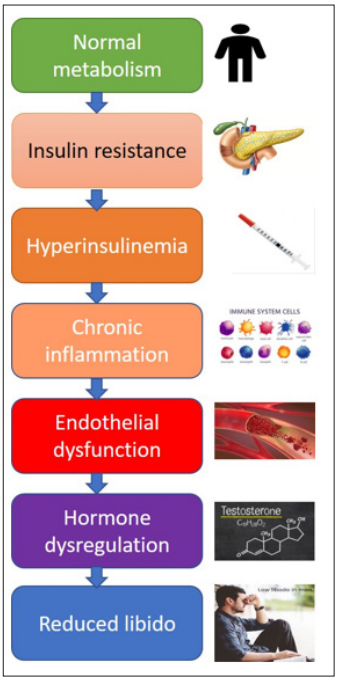

Figure 4: Metabolic transition model from normal metabolism to reduced libido

Metabolic Transition in Type 2 Diabetes

The transition occurs through metabolic disturbances and are interconnected with physiological events. In healthy individual, insulin regulates glucose in peripheral tissue and maintains the blood glucose level through proper secretion and sensitivity of insulin. Persistent resistance of insulin and expansion of adipose tissue lead to release of proinflammatory cytokines such as TNF-α and IL-6. This chronic inflammation disrupts the insulin signalling pathway and weakens the metabolism [33].

Obesity as an Amplifier of Decline in Libido

An important metabolic condition associated with type 2 diabetes is obesity which plays a vital role in reduced activity of male

libido [34]. Large population of diabetic men are overweight or obese is an important factor linking metabolic disease with sexual dysfunction. Beyond its role as energy storage tissue, adipose tissue acts as an endocrine organ, producing hormones, cytokines and other metabolic regulators influence the physiological processes [35].

Effect of Aromatization

Adipose tissue produces the enzyme aromatase where increased adipose tissue in obese patients lead to high activity of aromatase resulting in enhanced conversion of testosterone into estradiol (a form of estrogen). This hormonal shift leads to functional hypogonadism, i.e. reduced testosterone circulation and modifies the hormonal balance regulating poor libido in obese individuals [36].

Oxidative Stress Mechanism and Impairment of Leydig Cell

Hyperglycemia promotes the production of reactive oxygen species (ROS) leading to oxidative stress. The elevated level damage the cellular components including the function of Leydig cells, reducing the ability to synthesize testosterone which directly contributes to diminished libido [37].

Insulin Resistance and the Metabolic Feedback Loop

Obesity develops the insulin resistance to cause type 2 diabetes and reduces testosterone, promote fat accumulation in visceral adipose tissue. This interaction lead to vicious metabolic cycle where metabolic dysfunction occurs and contributes to progressive libido suppression [38].

Psychological and Behavioural Activity of Obese Patients

Patients with obesity experience dissatisfaction of body image, reduced confidence level and social stigma contribute to negativity of sexual self-esteem and intimate relationships. These psychological thinking led to lower sexual initiation, avoidance of intimacy and deceased sexual motivation further contributing to decline in libido [39].

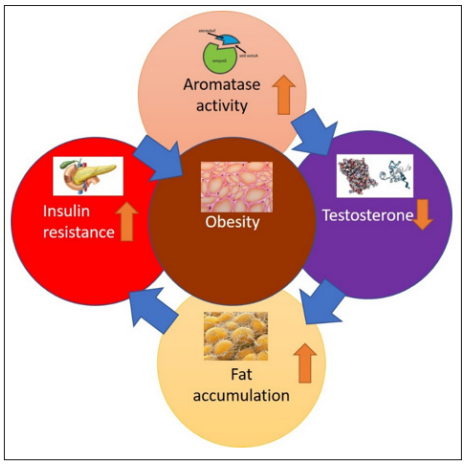

Figure 5: Obesity–testosterone feedback loop illustrating the vicious metabolic cycle

Obstructive Sleep Apnea (OSA) and its Role in Suppression of Testosterone

Obstructive sleep apnea (OSA) is a sleep related breathing problem characterized by partial or complete disruption in upper airway during sleep resulting in hypoxia and disturbed sleep pattern [40]. It is common with people of type 2 diabetes but often overlooked causal factor for reduced libido in men. Despite its clinical importance, OSA is undiagnosed in patients with chronic diseases like diabetes influence the testosterone production, vascular function and reduced sexual drive [41].

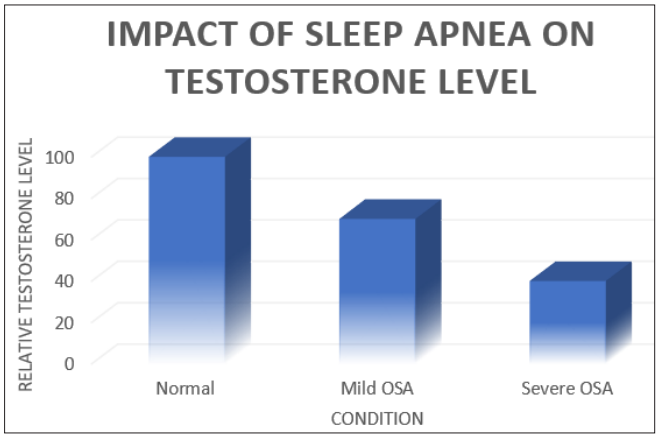

Figure 6: Relationship between obstructive sleep apnea (OSA) and testosterone levels.

Mechanisms Integrating OSA to Libido

Sleep Disturbances

Testosterone production follows a circadian rhythm, where secretion happens during deep sleep stages. It disrupts this architecture by causing repeated awakenings and fragmentation in sleep cycles. As a result, the nocturnal surge in testosterone is reduced and circadian rhythm is affected. It is a key hormonal regulator of male libido, impairment in the production of hormone disrupts the sexual desire [42].

Fatigue and Reduced Sexual Desire

Individuals with untreated OSA experience excessive daytime sleepiness and chronic fatigue due to poor sleep quality. It can significantly reduce physical energy levels and motivation of sexual activity with lower frequency of intimate interactions [43].

Mood Swings and Psychological Issues

OSA is also associated with neuropsychological disturbances which makes the individual irritable, mood swings, sudden depression. This arises due to chronic sleep deprivation, hypoxia related neuronal stress and imbalance in the hormones. These brings conflict between the partners, lack sexual desire, emotional intimacy and poor satisfaction of the relationship contributing to suppression of libido [44].

Screening and Assessment

Early screening of libido suppression in men with diabetes requires a clinical evaluation. Although diabetes management routinely screens metabolic monitoring, sexual health remains under screened. As a result, many patients experience reduced libido and remain uncared, undiagnosed and untreated [45].

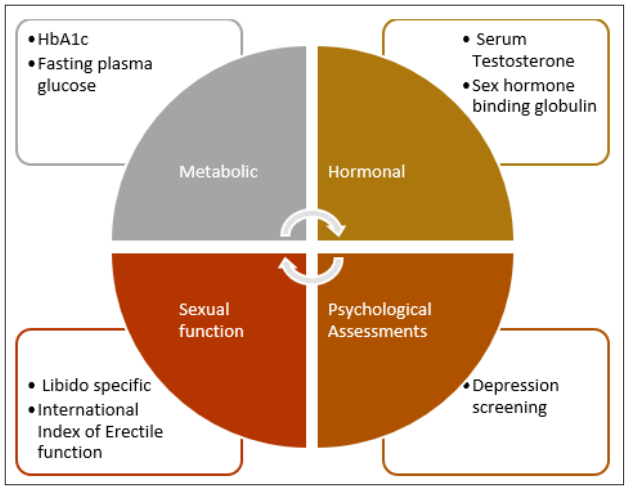

Figure 7: Screening and assessment of libido in Type II *Diabetes mellitus* patients.

Metabolic Screening

The glycemic status is an important parameter to be evaluated, as hyperglycemia and metabolic dysregulation are primary contributors to hormonal and vascular disturbances that affect the process of libido.

HbA1c (Glycated Hemoglobin)

HbA1c is screened for the average glucose level of the past 3 months and widely used to assess the glycemic control. Poor glycemic index is strongly associated with vascular damage, neuropathy, and endocrine disturbances that influence libido.

Fasting Plasma Glucose

Measurement of fasting glucose in blood determines the baseline glycemic status and detects hyperglycemia. Elevated fasting glucose level indicates impaired regulation of glucose and suggests metabolic stress contributing to sexual dysfunction.

Hormonal Screening

It is a crucial test for identifying the abnormalities of the endocrine system associated with the decline in libido [46].

Screening of Serum Testosterone

Measurement of both total and free testosterone provides insight into the status of androgens. Low testosterone is frequently observed in men with diabetes and obesity, which are strongly associated with reduced libido and hypogonadism.

Sex Hormone Binding Globulin (SHBG)

SHBG regulates the availability of circulating testosterone by binding with sex hormones in the bloodstream. Alterations in SHBG levels are commonly seen in metabolic disorder patients, where the SHBG affects the free testosterone and thereby influences libido.

Sexual Function Assessments

Clinical questionnaires help to evaluate sexual health and screen for dysfunction [47].

International Index of Erectile Function

It is a questionnaire to assess several aspects of male sexual function and is primarily designed for erectile dysfunction, and provides useful information regarding sexual drive.

Libido-specific Questionnaires

Libido is still under consideration, but that is the root cause for erectile dysfunction, and a specific questionnaire for libido has to be framed for earlier detection cases, and this can prevent early identification and will not lead to more complex problems like erectile dysfunction. These tools help clinicians to distinguish between reduced sexual desire and other forms of sexual dysfunction.

Psychological Screening

It is closely linked to the motivation of sexual health and relationship dynamics.

Depression Screening

Patient Health Questionnaire-9 (PHQ-9) to screen for depressive symptoms, because these depressions reduce the libido by altering the neurotransmitter balance and reducing motivation for pleasurable activities, including sexual intimacy [48].

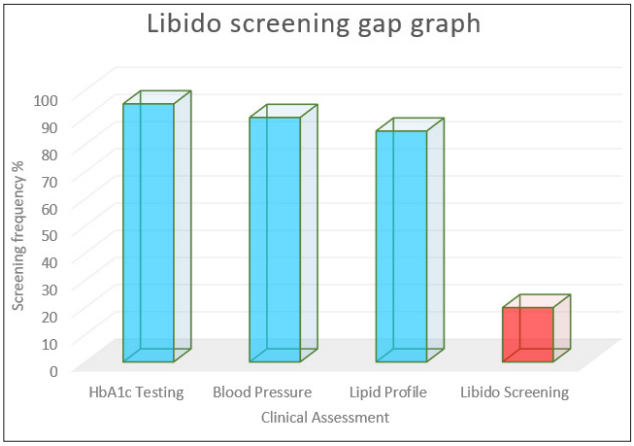

Figure 8: Disparity between metabolic screening and sexual health evaluation in diabetes care

Treatment Methods for Libido Suppression in Diabetic Men

A multidimensional therapeutic approach is needed to address libido suppression in diabetic men. Treatment strategy included are conventional medical therapies, lifestyle interventions, psychological counselling and other complementary approaches. This type of treatment not only increases libido activity but also overall problems discussed will be restored and regain back the metabolic and psychological health [49].

Improve the blood glucose level by therapeutic strategy in diabetic patients by regular monitoring and antidiabetic medications like metformin. HbA1c levels are checked periodically and reduce metabolic stress which improves overall sexual and metabolic health [50]. Physical activity like walking, jogging, weight reduction, balanced diet and adequate sleep supports the healthy individual by improving the insulin sensitivity and testosterone levels, reduces visceral adiposity, proteins and other diet makes the metabolism to promote insulin secretion, hormonal regulation increase sleep and reduce or cessation of smoking and intake of alcohols [51]. Testosterone replacement therapy is considered to patients with hypogonadism and low testosterone secretion under proper guidance of the practitioner to restore the androgen levels, improve sexual desire, mood and overall well-being. However, careful observation is needed to assess the contraindications and to monitor long-term safety. Psychosexual therapy and couple-based screenings by professionals can help patients for emotional and behavioural barriers in sexual intimacy [52].

Symptom Based vs Mechanism Based Treatment Methods

Men with reduced libido in diabetic condition are till today treated based on symptomatic interventions. However, libido suppression associates with metabolic disorders arises from multifactorial physiological disturbances. Therefore, these therapeutic approaches are important for developing effective and sustainable strategies [53].

Symptom-Based Treatment

It primarily focuses on managing the clinical manifestation of sexual desire without addressing the metabolic or hormonal cause. one common therapy involves the use of phosphodiesterase type 5 (PDE 5) inhibitors, which enhance nitric oxide mediated vasodilation and increase the flow of blood in penile tissues [54]. They do not directly involve to improve the reduced libido condition but focused only on erectile dysfunction. As a result, symptom-based treatments provide temporary functional improvement but not resolve the endocrine and metabolic factors for the suppression of libido.

Mechanism-Based Treatment

It focuses on understanding the biological processes responsible for decline in libido and it targets metabolic, hormonal, inflammatory and psychological contributors of libido suppression. The treatment should be provided to improve insulin sensitivity, through the management of lifestyle, weight and diabetes control, restore normal testosterone levels and reduce systemic inflammation and oxidative stress which can impair the endocrine and vascular functions which addresses the psychological and relational factors within intimate relationships. Thus, mechanism-based approaches improve the libido and metabolic health of diabetic patients. But the symptom-based approaches bring short-term relief whereas mechanism-based therapies provide sustainable improvement in libido and overall sexual well-being [55].

Partner Impact and Female Well-being

Reduced libido in men with diabetes do not affect only the men or the individual but also its female partner. It affects emotional and psychological wellbeing of both partners because sexual relationship is an important component of intimate partnerships, persistant avoidance of sex will lead to think female to avoid communications, stress, constant argument between the relationship, irritability, complete avoidance, and finally results in divorce [56]. Females in this society still hesitate to talk about the male libido and their own hormonal needs manifest in thinking of their own personal characters. It is therefore important to consider the libido as serious effect due to diabetic patients when evaluating the clinical manifestations. Libido and physical intimacy if reduced in long-term will lead to change in routines and expectations of females and are not openly discussed. Consistent rejection of sexual intimacy by male leads to loss of attraction to female may be due to physiological and metabolic process gets decreased and proper medical evaluation of libido at earliest will not allow the diabetic or patients to suffer from erectile dysfunction and emotional security [57].

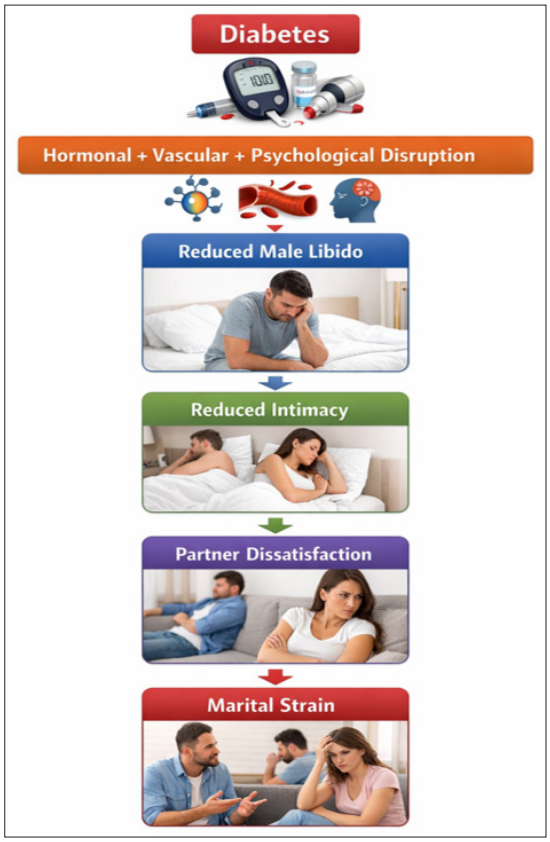

Figure 9: Conceptual Model Illustrating the Relationship Between Diabetes, Reduced Male Libido, and Relationship Outcomes

Discussion

Comparison Between Diabetic and Non-diabetic Libido in Individuals

In non-diabetic individuals, libido happens in systematic and coordinated fashion, by normal functioning of the hypothalamic-pituitary-gonadal axis, endothelial signalling, neurotransmitter activity and psychological well-being. In contrast men with diabetes exhibit a multifactorial hormonal imbalance which impairs the activity of libido by chronic hyperglycemia, insulin resistance and metabolic abnormalities. Diabetic men have reduced circulating testosterone level and results in hypogonadisms along with change in sex hormone binding globulin which directly affects the libido sensation. Vascular dysfunction, exacerbates this condition more leading to damage endothelial function and less production of nitric oxide which impairs the blood flow in genital parts and psychological arousal mechanisms. Additionally, diabetic neuropathy diminishes the genital sensation and leads to reduced responses in libido activity. Low grade inflammation with elevated cytokines suppresses Leydig cell and testosterone synthesis. Collectively, these changes in diabetic men experience a profound and multidimensional effect in suppressing the libido activity compared to non-diabetic individuals.

Gender Differences in Regulation of Libido

The role of libido significantly differs between male and female due to change in hormone, neurobiological pathway and psychosocial influences. In male, libido occurs by hormone testosterone, which work by obeying the pathways of central nervous system associated by providing motivation and reward towards a sexual desire. Dopaminergic signalling with mesolimbic reward system is responsible for initiating and maintaining the sexual interest whereas in diabetic men reduced hormone level directly shows its impact on male libido.

In female libido occurs by more complex and multifactorial parameter as it is not only influenced by hormonal factors, but also emotional intimacy, quality relationship and psychological context. Fluctuations occur in every stage of menstrual cycles, pregnancy and menopause it modulates the level of sexual drive-in women. Compared to men, women have a strong integration of emotional and relational factors in the context of libido. Diabetes affects libido in both sexes but through different pathways. Men libido affects by hormone testosterone and vascular impairment whereas in women leads to reduced lubrication, discomfort and psychological stress which influences the libido. Thus, gender specific differences highlight the need for a detailed and inclusive approach to sexual health in metabolic disorder.

Impact of Ageing and Sexual Hormones on Libido

Aging is a key factor in libido, where it is highly influenced by the level of hormones. Women generally live longer than men, but a rapid decline in reproductive hormones is due to menopause. The reduction in estrogen levels leads to decreased libido, dryness in the vagina, and other genitourinary symptoms, which together accelerate the sexual aging.

In men, a gradual decline in testosterone with age occurs, and it is much slower; this activity is exacerbated by chronic problems such as diabetes, obesity, and obstructive sleep apnea, leading to reduced libido or sexual activity. Thus, men experience progressive hormonal aging, and women encounter a more abrupt transition that impacts libido. These changes are the root cause of a mismatch in sexual expectations, and when it is combined with diabetes, it further suppresses the activity of libido in men and reduces coitus within couples. This missed interaction underscores the importance of both partners in the evaluation of sexual health, particularly with aging populations affected by chronic metabolic diseases.

Clinical and Relationship Implications

The diabetes associated libido suppresses not only individual health, but also affects interpersonal relationships and quality of life. In diabetes management, sexual health is always under considered as a criteria with clinical focus toward glycemic control and macrovascular complications. The undiagnosed libido leads to missed opportunities for early interventions and comprehensive care.

From a relationship point of view, reduced libido in men leads to reduced intimacy, which is perceived by partners as rejection or emotional withdrawal. Over time, it leads to dissatisfaction, communication gaps, and psychological stress in the relationship. Thus, it is important to emphasize that these problems are not exclusive to individuals but affect both partners through biological and psychosocial interactions.

Thus, a mechanism-based disease management is essential for today's scenario rather than symptom-based management. Addressing erectile dysfunction without evaluating metabolic, hormonal, and psychological factors provides a temporary solution but not a permanent benefit. Thus, a holistic approach strategy are needed to incorporate glycemic control, hormonal assessment, lifestyle modification, mental health, and couple-centered counselling, which helps in more sustainable outcomes. Integrating sexual health, like libido, with chronic diseases like diabetes manages both the underlying causes and improves the well-being and relationship satisfaction of the patients by reinforcing the libido as a key component of health.

Conclusion

Diabetes mellitus is a metabolic disorder with systemic consequences that extend beyond classical complications such as cardiovascular disease, neuropathy and nephropathy. Reduced libido in men is important but overlooked parameter especially in diabetic patients and it is a cause of metabolic dysregulation. This integrated mechanism involved in multifactorial approach where chronic hyperglycemia, insulin resistance and metabolic inflammation disrupt the normal physiological process affecting HPG axis, endothelial functioning and neural signalling pathways. These disturbances reduce the secretion of testosterone impairs nitric oxide mediated vascular responses and alters the neurotransmitter pathway which leads to reduced or absence of libido. In addition, obesity, aromatase

mediated hormonal alterations and obstructive sleep apnea further suppresses the testosterone and prominent imbalance in metabolism, creating a self-reinforcing cycle that promotes libido decline. Despite these complications, diabetes care is monitored only by metabolic activity while sexual health remains neglected.

Overall, this review suggests that diabetes act as a central driver for libido suppression through integrated pathways. Therefore, rather than symptom-based treatment as a clinician we need to adapt a mechanism-based approach that controls glycemic secretion, lifestyle factors, hormone synthesis and psychological supports to both partners. Routine screening and awareness improve sexual health, quality of life and relationship well-being, highlighting the importance of libido suppression as an under screened complication of diabetes.

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