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Review Article

Diabetes Management

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Yoga as a Holistic Approach to Diabetes Management: Addressing Stress, Metabolic Balance and Glycemic Control

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Diabetes mellitus is a chronic metabolic disorder which needs inclusive management strategies that address both physiological and psychological factors. It is such a condition that is induced by stress and uncontrolled blood glucose levels. It does require insulin but controlling the blood glucose level is necessary to reduce insulin dependence. Diabetes Management requires a holistic approach on both psychological and physiological factors. There is a strong link between insulin resistance and stress which makes the situation much worse during managing the diabetes. Yoga is a traditional practice with its deep roots in mind-body connection and has shown to be a non-invasive approach in dealing with stress and helping diabetes. It increases relaxation and restores metabolic balance by utilizing Asanas, Pranayama and meditation. This review attempts to understand the various approaches to how and why Yoga aids in stress regulation while controlling diabetes. Yoga has the ability to decrease the activity of the hypothalamic pituitary adrenal axis which decreases the amount of cortisol in the patients and allows for normal insulin regulations to follow. Practicing Yoga often makes the body more sensitive towards insulin allowing for more glucose to be absorbed in muscle cells while also reducing oxidative stress and inflammation which in turn causes diabetes. Moreover, Yoga encourages self-awareness and focus that allows people to make lifestyle changes such as better dietary choices, effective stress management and working. The literature indicates that Yoga Asanas, Pranayama, and Mudras enable people to achieve their utmost attention and concentration.

Keywords: Diabetes Mellitus, Stress Reduction, Glycemic Control, Yoga Therapy, Metabolic Health

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Introduction

Diabetes mellitus has become one of the global health problems. It affects millions of people due to its complications and morbidities.**[1]** It is prevalent non-communicable diseases worldwide, affecting over 500 million people as of 2024.**[2]** There are two primary forms of diabetes: Type 1 and Type 2, with Type 2 diabetes accounting for nearly 90% of cases. While Type 1 diabetes is an autoimmune condition that typically develops in childhood or early adulthood, Type 2 diabetes is primarily linked to lifestyle factors, including poor diet, physical inactivity, and obesity. The latter form typically manifests in adulthood but is increasingly being diagnosed in younger populations due to the rise in obesity and sedentary behaviors.**[3,4]**

Insulin, a hormone made by the pancreas, controls blood sugar by allowing the cells to take in glucose in order to produce energy in healthy people. In Type 1 diabetes, the immune system attacks by mistake the cells in the pancreas that produce insulin (known as beta cells), resulting in little or no production of insulin.**[4]** In Type 2 diabetes, cells become less responsive to insulin's effects, so the pancreas generates more insulin, leading to beta cell burn out and inadequate insulin levels.

This insulin resistance and lack of adequate insulin results in persistent hyperglycemia, which can lead to serious health complications over time.**[5,6]** Uncontrolled diabetes can give rise to a host of acute and chronic complications. Acute complications include diabetic ketoacidosis and hyperosmolar hyperglycemic state; both are life-threatening emergencies that occur due to severe hyperglycemia. Chronic complications take time to manifest and can involve many different organs and systems such as the cardiovascular system, nervous system, kidneys, eyes, and extremities. Cardiovascular disease, neuropathy, nephropathy, and retinopathy are among the most common complications associated with poorly controlled diabetes, often leading to reduced quality of life and increased mortality.**[5,7]**Stress has been identified as a significant contributing factor in both the development and progression of Type 2 diabetes. Psychological stress triggers the release of cortisol, a hormone that elevates blood glucose levels by promoting gluconeogenesis (glucose production in the liver).**[8]**

The continuous presence of stress leads to elevated levels of cortisol over a long duration, which can further exacerbate glucose intolerance as cortisol elevates insulin resistance. On flip side, stress might exacerbate pre-diabetes or diabetes-related progression because it could lead to behavioral mechanisms aimed at mitigating stress but inadvertently increasing risks or worsening health outcomes.**[8,9]** These stresses and diabetes link together, meaning that for properly managing disease, stress alleviating techniques should be adopted. Traditional treatment of diabetes encompasses medication, diet, and physical activity, but these do not consider other emotions and feelings that accompany condition. As a result, there appears to be more interest in *Yoga* as a complementary therapy since it promotes holistic health and helps alleviate stress.**[10]** *Yoga*, by promoting relaxation, mindfulness, and physical activity, may help alleviate stress and improve glycemic control, offering a valuable adjunct to traditional diabetes care. *Yoga*, a mind-body practice from ancient India, is well known in modern healthcare for its therapeutic benefits. It is rooted in a tradition of physical postures (*Asanas*), controlled breathing (*Pranayama*) and meditation (*Dhyana*) that brings balance to body, mind and spirit.**[11]** Over last few decades *Yoga* has become global in popularity not only as a form of exercise but also as a tool to manage chronic health conditions like stress and metabolic disorders like diabetes. *Yoga*'s physical benefits are deeply connected to its impact on autonomic nervous system, especially its ability to activate parasympathetic nervous system which is state of relaxation and recovery.**[12]** This counteracts body's stress response, typically mediated by sympathetic nervous system. The stress response, which triggers release of cortisol and adrenaline, can lead to negative health outcomes when prolonged, particularly in context of diabetes. By promoting relaxation and reducing cortisol levels, *Yoga* may mitigate effects of chronic stress, which is known to exacerbate insulin resistance and hyperglycemia.**[8]**

Mechanisms of *Yoga* in Diabetes Management

Yoga offers a multifaceted approach to managing diabetes by addressing both physiological and psychological factors. (Table 1) The mechanisms by which *Yoga* influences diabetes management can be categorized into stress reduction, improved insulin sensitivity and regulation of metabolic processes.

Table 1: Mechanisms of *Yoga* in Diabetes Management

Mechanism	Details	Benefits
Stress Reduction	-Regulates HPA axis, reducing cortisol levels. -Enhances parasympathetic activity, promoting relaxation. -Incorporates Pranayama and meditation to reduce anxiety and emotional stress.	-Lowers stress hormones that impair insulin sensitivity. -Improves mental well-being and emotional resilience. -Stabilizes blood glucose levels.
Improved Insulin Sensitivity	-Asanas improve glucose uptake in muscles by increasing blood flow and GLUT4 transporter activity.-Pranayama reduces oxidative stress, protecting insulin signaling pathways. -Enhances mitochondrial function for better glucose metabolism.	-Promotes effective insulin action. -Lowers fasting blood glucose and HbA1c levels. -Protects pancreatic beta cells from oxidative damage.
Regulation of Metabolic Processes	-Improves lipid profiles by lowering LDL and triglycerides and increasing HDL. -Lowers blood pressure by reducing vascular resistance and improving arterial compliance.-Promotes weight management through physical activity and mindful eating. -Enhances gastrointestinal health for better glucose absorption.	-Reduces cardiovascular risks associated with diabetes. -Supports stable glucose metabolism.-Encourages sustained weight loss and healthy digestion.

HPA: Hypothalamic-Pituitary-Adrenal, **LDL:** Low-Density Lipoprotein, **HDL:** High-Density Lipoprotein, **GLUT4:** Glucose Transporter Type 4, **HbA1c:** Hemoglobin A1c

Stress Reduction

Stress plays a pivotal role in the development and progression of insulin resistance, making it a significant factor in poor glycemic control among individuals with diabetes. Chronic stress activates the hypothalamic-pituitary-adrenal (HPA) axis, which triggers the release of cortisol, a stress hormone. Elevated cortisol levels increase gluconeogenesis in the liver, leading to higher blood glucose levels. Moreover, cortisol directly impairs insulin sensitivity, making it harder for cells to respond to insulin and absorb glucose efficiently. [8,13] *Yoga* provides an effective strategy for mitigating these stress-induced disruptions by regulating the HPA axis. Regular practice reduces the overactivation of this axis leading to a decrease in cortisol production and improved metabolic stability.**[14]**

In addition to modulating the HPA axis, *Yoga* enhances the parasympathetic nervous system that is known as the "rest and digest" state. This activation counter balances the effects of the sympathetic nervous system, which dominates during periods of stress and is responsible for the "fight or flight" response.**[15,16]** By shifting the autonomic balance towards parasympathetic activity, *Yoga* helps stabilize heart rate variability, lower blood pressure, and promote relaxation. This physiological shift not only improves physical health but also creates a mental state conducive to better diabetes self-management.**[17,18]** Breathing techniques, or *Pranayama*, are particularly effective in enhancing the stress-reducing benefits of *Yoga*. Practices such as alternate nostril breathing (*Anulom Vilom*) and diaphragmatic breathing improve vagal tone, Which is critical for parasympathetic activation. These techniques have been shown to lower stress markers, including cortisol and adrenaline, while promoting better oxygen delivery to cells. Slow and deep breathing regulates oxygen levels in the body, stabilizes the nervous system, and alleviates anxiety.**[18,19]** This combination of physical and psychological effects makes *Pranayama* a powerful tool for managing stress in individuals with diabetes. Meditation, an integral component of *Yoga*, complements these stress-reducing practices by fostering mindfulness and emotional resilience. Meditation techniques quiet the mind, reduce rumination, and help individuals gain greater control over their emotional responses to stress. Mindfulness, cultivated through meditation, has been shown to significantly reduce perceived stress, anxiety, and depression conditions that are particularly prevalent among individuals managing chronic diseases like diabetes.**[20]** By improving mental well-being, meditation enables individuals to adopt healthier coping mechanisms and develop a more positive outlook, which can further enhance their ability to manage their condition.**[19]**

Improved Insulin Sensitivity

One of the critical challenges in diabetes management is insulin resistance, where the body's cells fail to respond effectively to insulin, leading to elevated blood glucose levels. *Yoga* addresses this issue by directly improving glucose metabolism and enhancing the body's responsiveness to insulin through several physiological pathways. *Yoga Asanas* (physical postures) play a pivotal role in improving insulin sensitivity by stimulating blood circulation and promoting muscle activity.

Improved circulation ensures a more efficient delivery of glucose and insulin to muscle cells, enhancing their uptake and utilization of glucose for energy production.**[21]** Dynamic poses such as Surya Namaskar (Sun Salutation) mimic the effects of moderate physical exercise by activating muscle contractions that increase the expression of glucose transporters (GLUT4) on cell membranes.**[22]** This facilitates the transport of glucose from the bloodstream into cells, thereby lowering blood sugar levels. Additionally, *Asanas* are known to reduce low-grade systemic inflammation, which is a significant contributor to insulin resistance. Chronic inflammation disrupts insulin signaling pathways, and by alleviating this condition, *Yoga* helps restore metabolic balance.**[23]**

Controlled breathing practices, or *Pranayama*, further enhance insulin sensitivity by reducing oxidative stress. Oxidative stress, caused by an imbalance between free radicals and antioxidants, is a major factor that impairs insulin signaling and glucose homeostasis. *Yoga* breathing techniques stimulate the activity of antioxidant enzymes, neutralizing free radicals and protecting cells from oxidative damage. By improving the cellular environment, *Pranayama* optimizes insulin signaling pathways, allowing for better glucose uptake and utilization.**[24]**

Yoga also impacts mitochondrial efficiency, which is vital for maintaining proper energy metabolism. Mitochondria, the energy-producing organelles in cells, play a crucial role in glucose metabolism. *Yoga* practices improve mitochondrial function by enhancing their capacity to generate energy efficiently. This leads to better utilization of glucose and reduced accumulation of excess sugar in the bloodstream. Improved mitochondrial activity also minimizes the generation of free radicals, further reducing oxidative stress. Additionally, by protecting pancreatic beta cells from free radical damage, *Yoga* helps preserve their ability to produce insulin, ensuring sustained metabolic function.**[24,25]**

Regulation of Metabolic Processes

Yoga plays a significant role in optimizing overall metabolic health, which is essential for effective diabetes management. By influencing multiple physiological processes, *Yoga* contributes to better lipid profiles, blood pressure regulation, weight management, appetite control, and gastrointestinal health.

One of the key benefits of *Yoga* is its ability to improve lipid profiles. Studies have shown that regular *Yoga* practice lowers levels of low-density lipoprotein (LDL) often referred to as "bad cholesterol," and triglycerides, while simultaneously increasing levels of high-density lipoprotein (HDL), or "good cholesterol." This modulation of lipid levels helps reduce the risk of cardiovascular complications, which are a common and severe consequence of poorly managed diabetes. Lower LDL and triglyceride levels reduce arterial plaque buildup, improving overall vascular health and reducing the likelihood of heart attacks and strokes.**[26]** In addition to improving lipid profiles, *Yoga* is effective in regulating blood pressure. Regular practice has been shown to lower both systolic and diastolic blood pressure by enhancing arterial compliance and reducing stress-induced vascular tension. *Yoga*'s ability to activate the parasympathetic nervous system, coupled with its stress-reducing effects, helps maintain a healthy blood pressure range. Lower blood pressure not only minimizes the risk of cardiovascular issues but also protects against kidney damage, a common complication of long-term diabetes.**[27]**

Yoga also supports weight management, a critical factor in improving insulin sensitivity and glycemic control. The physical activity involved in *Yoga* promotes gradual weight loss by increasing energy expenditure and improving digestion. Certain *Yoga* poses stimulate the abdominal organs, enhancing digestive efficiency and reducing bloating. By targeting abdominal fat specifically, *Yoga* helps lower insulin resistance, leading to better glucose metabolism.**[28]**

Mindfulness, cultivated through *Yoga* practice, is another essential aspect of metabolic regulation. *Yoga* encourages individuals to become more aware of their hunger and satiety cues, fostering healthier eating behaviors. This heightened awareness reduces overeating and emotional eating, which are common contributors to weight gain and glycemic fluctuations. By promoting mindful eating, *Yoga* helps individuals make more balanced dietary choices, which are essential for maintaining stable blood sugar levels.**[29]** *Yoga* enhances gastrointestinal health which plays a pivotal role in glucose absorption and metabolism. By stimulating the parasympathetic nervous system, *Yoga* improves gut motility and digestion.**[30]**

This enhanced digestive efficiency ensures a steady and balanced absorption of glucose, preventing sudden spikes or drops in blood sugar levels. Better gastrointestinal health also supports the microbiome, which has been linked to improved metabolic and immune function.**[31]**

Evidence Supporting *Yoga*'s Role in Diabetes Management

Research has shown that regular *Yoga* practice can significantly improve glycemic outcomes. Clinical studies have reported reductions in fasting blood glucose levels, improvements in hemoglobin A1c (HbA1c) and enhanced insulin sensitivity among individuals with Type 2 diabetes who engage in *Yoga*.**[32]** Additionally, *Yoga* has been shown to positively influence lipid profiles, blood pressure, and body mass index (BMI), all of which are critical factors in the comprehensive management of diabetes.**[33]**

Effective management is critical to prevent long-term damage to organs. Stress, characterized by increased cortisol levels, directly impacts blood glucose levels, making it an essential focus for intervention. *Yoga*, a practice that includes *Asanas* (physical postures), *Pranayama* (breathing exercises), and meditation, has been increasingly recognized for its ability to alleviate stress.**[11,12]** This review delves into the potential of *Yoga* as a therapeutic intervention to address the stress-diabetes axis, enhancing patients' quality of life. Clinical studies have demonstrated that regular *Yoga* practice can significantly improve glycemic control. *Asanas*, involving gentle movements and stretching, enhance glucose uptake in muscle cells, thereby reducing blood glucose levels. *Pranayama* practices, by promoting better oxygenation, can enhance mitochondrial function and insulin sensitivity.**[34,35]** Several trials have reported reductions in fasting blood glucose levels and HbA1c values in diabetic patients following consistent *Yoga* practice. A growing body of evidence supports the role of *Yoga* in managing diabetes-related stress and improving metabolic outcomes. The role of *Yoga* in improving glycemic control and reducing stress was highlighted in a study by Amita *et al.* (2008), which investigated the effect of *Yoga*-Nidra on blood glucose levels in diabetic patients. (Table 2) The findings revealed a significant reduction in fasting blood glucose levels and improved emotional well-being among participants, Emphasizing the relaxation-induced benefits of *Yoga*-Nidra on stress and metabolic regulation.**[36]** Adding a unique dimension to the therapeutic potential of *Yoga*, a recent study by Nayak *et al.* (2023) examined the effects of laughter *Yoga* (Table 2) on glycemic control in patients with type 2 diabetes. This randomized controlled trial found that incorporating laughter *Yoga* as part of the intervention not only improved blood glucose regulation but also elevated patients' mood and reduced stress markers, presenting a novel, enjoyable approach to diabetes management.**[37]** *Kundalini Yoga* integrates dynamic postures, breathing exercises, meditation, and chanting, focusing on awakening the body's energy and balancing the endocrine system. A study investigating the *Effect of Simplified Kundalini Yoga with and without Varma Therapy on Blood Sugar Fasting and Blood Sugar Post Prandial Among Diabetes Men* demonstrated significant improvements in fasting and postprandial blood glucose levels. Simplified *Kundalini Yoga* when practiced consistently, was found to reduce stress and enhance insulin sensitivity, attributed to its combination of mindfulness and physical engagement.**[38]** *Hatha Yoga*, characterized by gentle postures combined with controlled breathing, has shown promise in improving diabetes outcomes. In a pilot study by Vizcaino (2013) *Hatha Yoga Practice for Type 2 Diabetes Mellitus Patients,* participants demonstrated improved glycemic control and enhanced physical fitness. The study noted reductions in fasting blood glucose and improved flexibility and strength which support overall metabolic health. By promoting relaxation and reducing cortisol levels Hatha *Yoga* addresses stress-related impacts on glycemic control further emphasizing its role in diabetes management.**[39]** *Ashtanga Yoga* is a physically intensive style of *Yoga* involving a fixed sequence of postures performed in a dynamic flow. Its benefits for diabetic patients were highlighted in the study *Impact of Ashtanga Yoga Practices and Music Therapy on Selected Biochemical Variables Among Gestational Diabetic Women* by Bismi and Duraisami (2024). The findings revealed significant reductions in fasting glucose and HbA1c levels among participants. *Ashtanga Yoga*'s emphasis on physical exertion and synchronized breathing increases energy expenditure, enhances insulin sensitivity, and promotes weight management.

This dynamic practice also improves cardiovascular health, further reducing the risk of diabetes-related complications.**[40]**

Table 2: Types of *Yoga* and their potential benefits for diabetes management

Types of Yoga	Potential benefits for diabetes management
Asanas (Physical Postures)	Enhances blood circulation and glucose uptake by muscle cells.
	Improves insulin sensitivity.
	Reduces inflammation, which contributes to insulin resistance.
Yoga-Nidra (Deep Relaxation)	Reduces stress and lowers cortisol levels, which helps in better glycemic control.
	Improves emotional well-being, contributing to overall health.
Pranayama (Breathing Techniques)	Reduces oxidative stress and enhances insulin sensitivity.
	Improves oxygenation and energy levels, benefiting overall metabolic function.
Laughter Yoga	Reduces stress and enhances mood, which indirectly improves glycemic control.
	Lowers cortisol levels, improving insulin sensitivity.
Kundalini Yoga	Balances the endocrine system, which helps regulate blood sugar.
	Reduces stress and improves emotional health, contributing to better diabetes management.
Hatha Yoga	Improves flexibility, reduces body fat, and enhances insulin sensitivity.
	Helps manage blood pressure and blood glucose levels.
Ashtanga Yoga	Increases energy expenditure, supports weight loss, and enhances metabolic rate.
	Improves insulin sensitivity and glucose metabolism.

Integration of *Yoga* into Diabetes Care

Integrating *Yoga* into conventional diabetes management offers a holistic approach that addresses both mental and physical aspects of health. Diabetes care traditionally relies on pharmacological treatments, dietary modifications and physical exercise to control blood glucose levels and prevent complications.**[41]** However, these strategies often fail to consider the mental and emotional burden of living with a chronic illness which can significantly affect treatment adherence and outcomes. *Yoga*, with its emphasis on mindfulness, relaxation, and physical activity provides a complementary tool that enhances overall diabetes management.**[33]** *Yoga* can complement dietary changes and pharmacological treatments providing patients with a sense of empowerment over their condition.**[28]**

One of the primary benefits of integrating *Yoga* into diabetes care is its accessibility and adaptability. *Yoga* can be practiced by individuals of all ages and fitness levels, making it an inclusive intervention. It does not require expensive equipment or facilities, which makes it particularly beneficial in resource-limited settings.**[42]** Additionally, *Yoga* can be tailored to suit individual needs, with practices ranging from gentle stretches and breathing exercises for those with limited mobility to dynamic poses and sequences for more active individuals. This flexibility allows healthcare providers to personalize *Yoga* routines for their patients, ensuring that the practice aligns with their physical abilities and medical conditions.**[12]** *Yoga* also complements traditional diabetes management strategies by addressing key risk factors such as stress, obesity, and cardiovascular health.**[43]**

For healthcare providers, integrating *Yoga* into diabetes care involves several practical considerations. Educating patients about the benefits of *Yoga* and how it complements their existing treatment plans is essential to ensure engagement and adherence. Providers can collaborate with certified *Yoga* instructors who have experience working with individuals with chronic conditions, ensuring that patients receive safe and effective guidance. Establishing *Yoga* classes in clinics, community centers, or online platforms can make the practice more accessible to patients. Healthcare teams can also develop written or video-based resources to help patients incorporate *Yoga* into their daily routines.**[44]** Another important aspect of integration is monitoring the outcomes of *Yoga* practice. Regular assessments of glycemic control, lipid profiles, blood pressure and weight can help quantify the benefits of *Yoga* in diabetes management.**[45]** Encouraging patients to track their progress and share their experiences can provide valuable feedback for refining *Yoga* protocols and enhancing patient engagement.

Conclusion

Diabetes is a multifaceted metabolic disorder that requires an integrated approach to management, addressing both physical and psychological factors. *Yoga*, with its unique combination of physical postures, controlled breathing techniques and meditation, offers a holistic method to support diabetes control.

It directly influences blood glucose regulation by enhancing insulin sensitivity, improving glucose uptake and reducing inflammation and oxidative stress. Moreover, *Yoga* alleviates stress a critical factor in diabetes progression by regulating cortisol levels and promoting relaxation through activation of the parasympathetic nervous system. *Yoga* is a valuable adjunct to conventional diabetes care addressing both the physiological and psychological dimensions of the disease. Its affordability, accessibility and minimal risk make it a suitable intervention for diverse populations. Further research is warranted to refine *Yoga* protocols tailored for diabetes and evaluate its long-term benefits. By integrating *Yoga* into diabetes management strategies, healthcare providers can offer patients a comprehensive tool to enhance their quality of life and achieve better glycemic control.

References

1. Van Dieren S, Beulens JW, van der Schouw YT, Grobbee DE, Neal B. The global burden of diabetes and its complications: an emerging pandemic. Eur J Cardiovasc Prev Rehabil. 2010 May;17 Suppl 1:S3-8. *doi: 10.1097/01.hjr.0000368191.86614.5a. PMID: 20489418 [Crossref][PubMed][Google Scholar]*

2. Budreviciute A, Damiati S, Sabir DK, Onder K, Schuller-Goetzburg P, Plakys G, Katileviciute A, Khoja S and Kodzius R (2020) Management and Prevention Strategies for Non-communicable Diseases (NCDs) and Their Risk Factors. Front. Public Health 8:574111. doi: 10. *3389/fpubh.2020.574111 [Crossref][PubMed] [Google Scholar]*

3. Magliano DJ, Boyko EJ; IDF Diabetes Atlas 10th edition scientific committee. IDF DIABETES ATLAS [Internet]. 10th edition. Brussels: International Diabetes Federation; 2021. *Chapter 1, What is diabetes? Available from: [Article][Crossref] [PubMed][Google Scholar]*

4. Echeverri AF, Tobón GJ. Autoimmune diabetes mellitus (Type 1A) In: Anaya JM, Shoenfeld Y, Rojas-Villarraga A, et al. , editors. Autoimmunity: From Bench to Bedside [Internet]. *Bogota (Colombia): El Rosario University Press; 2013 Jul 18. Chapter 29. Available from: [Article][Crossref] [PubMed][Google Scholar]*

5. Dludla PV, Mabhida SE, Ziqubu K, Nkambule BB, Mazibuko-Mbeje SE, Hanser S, Basson AK, Pheiffer C, Kengne AP. Pancreatic β-cell dysfunction in type 2 diabetes: Implications of inflammation and oxidative stress. World J Diabetes. 2023 Mar 15;14(3):130-146. *doi: 10.4239/wjd.v14.i3.130. PMID: 37035220; PMCID: PMC10075035 [Crossref] [PubMed][Google Scholar]*

6. Khin PP, Lee JH, Jun H-S. Pancreatic Beta-cell Dysfunction in Type 2 Diabetes. European Journal of Inflammation. 2023;21. *doi:10.1177/1721727X231154152 [Crossref] [PubMed][Google Scholar]*

7. Hassan EM, Mushtaq H, Mahmoud EE, Chhibber S, Saleem S, Issa A, Nitesh J, Jama AB, Khedr A, Boike S, Mir M, Attallah N, Surani S, Khan SA. Overlap of diabetic ketoacidosis and hyperosmolar hyperglycemic state. World J Clin Cases. 2022 Nov 16;10(32):11702-11711. *doi: 10.12998/wjcc.v10.i32.11702. PMID: 36405291; PMCID: PMC9669841 [Crossref][PubMed][Google Scholar]*

8. Sharma K, Akre S, Chakole S, Wanjari MB. Stress-Induced Diabetes: A Review. Cureus. 2022 Sep 13;14(9):e29142. *doi: 10.7759/cureus.29142. PMID: 36258973; PMCID: PMC9561544 [Crossref] [PubMed][Google Scholar]*

9. Surwit RS, Schneider MS, Feinglos MN. Stress and diabetes mellitus. Diabetes Care. 1992 Oct;15(10):1413-22. *doi: 10.2337/diacare.15.10.1413. PMID: 1425110 [Crossref][PubMed][Google Scholar]*

10. Gianotti L, Belcastro S, D'Agnano S, Tassone F. The Stress Axis in Obesity and Diabetes Mellitus: An Update. Endocrines. 2021; 2(3):334-347. *[Article] [Crossref][PubMed][Google Scholar]*

11. Sengupta P. Health Impacts of Yoga and Pranayama: A State-of-the-Art Review. Int J Prev Med. 2012 Jul;3(7):444-58. *PMID: 22891145; PMCID: PMC3415184 [Crossref][PubMed][Google Scholar]*

12. Woodyard C. Exploring the therapeutic effects of Yoga and its ability to increase quality of life. Int J Yoga 2011;4:49-54. . *[Crossref][PubMed][Google Scholar]*

13. Merabet N, Lucassen PJ, Crielaard L, Stronks K, Quax R, Sloot PMA, Fleur SEL, Nicolaou M, How exposure to chronic stress contributes to the development of type 2 diabetes: A complexity science approach, Frontiers in Neuroendocrinology,2022;65:100972. https://doi. org/10. 1016/j. *yfrne.2021.100972 [Crossref] [PubMed][Google Scholar]*

14. Aggarwal A. Hypothalamo-pituitary-adrenal axis and brain during stress, Yoga and meditation: a review. Intl J Health Clin Res. (2020) 3:96–103. *[Crossref][PubMed][Google Scholar]*

15. Kankanamge S. Effects of Stress on the Nervous System. https://www. senwellnesssanctuary. *com/effects-of-stress-on-the-nervous-system. POSTED July 28, 2021 [Crossref][PubMed][Google Scholar]*

16. Malpas S, Sympathetic Nervous System Overactivity and Its Role in the Development of Cardiovascular Disease, Physiol Rev 90: 513–557, 2010; doi:10. 1152/physrev. 00007. 2009. *[Crossref][PubMed][Google Scholar]*

17. Vinay AV, Venkatesh D, Ambarish V. Impact of short-term practice of Yoga on heart rate variability. Int J Yoga. 2016;9(1):62-66. *doi:10.4103/0973-6131.171714 [Crossref][PubMed][Google Scholar]*

18. Catela D, Santos J, Oliveira J, Franco S, Mercê C. Heart Rate Variability, Blood Pressure and Peripheral Oxygen Saturation during Yoga Adham and Mahat Breathing Techniques without Retention in Adult Practitioners. Journal of Functional Morphology and Kinesiology. 2024; 9(4):184. *[Article][Crossref][PubMed][Google Scholar]*

19. Bentley TGK, D'Andrea-Penna G, Rakic M, et al. Breathing Practices for Stress and Anxiety Reduction: Conceptual Framework of Implementation Guidelines Based on a Systematic Review of the Published Literature. Brain Sci. 2023;13(12):1612. *Published 2023 Nov 21. doi:10.3390/brainsci13121612 [Crossref][PubMed] [Google Scholar]*

20. Keng SL, Smoski MJ, Robins CJ. Effects of mindfulness on psychological health: a review of empirical studies. Clin Psychol Rev. 2011;31(6):1041-1056. *doi:10.1016/j.cpr.2011.04.006 [Crossref][PubMed] [Google Scholar]*

21. Mangala Gowri M, Rajendran J, Srinivasan AR, Bhavanani AB, Meena R. Impact of an Integrated Yoga Therapy Protocol on Insulin Resistance and Glycemic Control in Patients with Type 2 Diabetes Mellitus. Rambam Maimonides Med J. 2022;13(1):e0005. *Published 2022 Jan 27. doi:10.5041/RMMJ.10462 [Crossref][PubMed] [Google Scholar]*

22. Richter EA. Is GLUT4 translocation the answer to exercise-stimulated muscle glucose uptake?. Am J Physiol Endocrinol Metab. 2021;320(2):E240-E243. *doi:10.1152/ajpendo.00503.2020 [Crossref] [PubMed][Google Scholar]*

23. Prasanna Venkatesh L, Vandhana S. Insights on Surya namaskar from its origin to application towards health. J Ayurveda Integr Med. 2022;13(2):100530. *doi:10.1016/j.jaim.2021.10.002 [Crossref][PubMed] [Google Scholar]*

24. Tangvarasittichai S. Oxidative stress, insulin resistance, dyslipidemia and type 2 diabetes mellitus. World J Diabetes. 2015;6(3):456-480. *doi:10.4239/wjd.v6.i3.456 [Crossref][PubMed] [Google Scholar]*

25. Gautam S, Kumar U, Kumar M, Rana D, Dada R. Yoga improves mitochondrial health and reduces severity of autoimmune inflammatory arthritis: A randomized controlled trial. Mitochondrion. 2021 May;58:147-159. *doi: 10.1016/j.mito.2021.03.004. Epub 2021 Mar 17. PMID: 33741520 [Crossref] [PubMed][Google Scholar]*

26. Nagarathna R, Usharani MR, Rao AR, Chaku R, Kulkarni R, Nagendra HR. Efficacy of Yoga based life style modification program on Medication score and lipid profile in type 2 diabetes – A randomized control study. Int J Diabetes Dev Ctries 2012;32:122 30. . *[Crossref][PubMed][Google Scholar]*

27. Hagins M, States R, Selfe T, Innes K. Effectiveness of Yoga for hypertension: systematic review and meta-analysis. Evid Based Complement Alternat Med. 2013;2013:649836. *doi:10.1155/2013/649836 [Crossref][PubMed] [Google Scholar]*

28. Raveendran AV, Deshpandae A, Joshi SR. Therapeutic Role of Yoga in Type 2 Diabetes. Endocrinol Metab (Seoul). 2018 Sep;33(3):307-317. *doi: 10.3803/EnM.2018.33.3.307. Epub 2018 Aug 14. PMID: 30112866; PMCID: PMC6145966 [Crossref][PubMed][Google Scholar]*

29. Watts, AW, Rydell S. A, Eisenberg ME, Laska MN,Sztainer DN, Yoga's potential for promoting healthy eating and physical activity behaviors among young adults: a mixed-methods study. Int J Behav Nutr Phys Act 15, 42 (2018). https://doi. *org/10.1186/s12966-018-0674-4 [Crossref] [PubMed][Google Scholar]*

30. Dalton A, Mermier C, Zuhl M. Exercise influence on the microbiome-gut-brain axis. Gut Microbes. 2019;10(5):555-568. *doi:10.1080/19490976.2018.1562268 [Crossref] [PubMed][Google Scholar]*

31. Moghetti P, Balducci S, Guidetti L, Mazzuca P, Rossi E, Schena F, Walking for subjects with type 2 diabetes: A systematic review and joint AMD/SID/SISMES evidence-based practical guideline, Nutrition, Metabolism and Cardiovascular Diseases,2020;30(11):1882-1898. https://doi. org/10. 1016/j. *numecd.2020.08.021 [Crossref] [PubMed][Google Scholar]*

32. Cui J, Yan JH, Yan LM, Pan L, Le JJ, Guo YZ. Effects of Yoga in adults with type 2 diabetes mellitus: A meta-analysis. J Diabetes Investig. 2017;8(2):201-209. *doi:10.1111/jdi.12548 [Crossref][PubMed][Google Scholar]*

33. Thind H, Lantini R, Balletto BL, Donahue ML, Salmoirago-Blotcher E, Bock BC, Scott-Sheldon LA. The effects of Yoga among adults with type 2 diabetes. A systematic review and meta-analysis. Preventive Medicine,2017;105:116-126. *[Crossref] [PubMed][Google Scholar]*

34. Balaji PA, Varne SR, Ali SS. Physiological effects of yogic practices and transcendental meditation in health and disease. N Am J Med Sci. 2012;4(10):442-448. *doi:10.4103/1947-2714.101980 [Crossref][PubMed][Google Scholar]*

35. Mondal S. Proposed physiological mechanisms of Pranayama. A discussion, Journal of Ayurveda and Integrative Medicine. 2024;15(1):100877. *[Crossref][PubMed][Google Scholar]*

36. Amita S, Prabhakar S, Manoj I, Harminder S, Pavan T. , Effect of Yoga-Nidra on blood glucose level in diabetic patients. Indian Journal of Physiology and Pharmacology,2008; 53(1): 97–101. . *[Crossref][PubMed][Google Scholar]*

37. Hirosaki M, Ohira T, Wu Y, Eguchi E, Shirai K, Imano H, Funakubo N, Nishizawa H, Katakami N, Shimomura I, Iso H. Laughter Yoga as an enjoyable therapeutic approach for glycemic control in individuals with type 2 diabetes: A randomized controlled trial. Front Endocrinol (Lausanne). 2023 Mar 31;14:1148468. *doi: 10.3389/fendo.2023.1148468. PMID: 37065750; PMCID: PMC10102335 [Crossref][PubMed][Google Scholar]*

38. Selvalakshmi S. Effect of Simplified Kundalini Yoga with and without Varma Therapy on Blood Sugar Fasting and Blood Sugar Post Prandial among Diabetes Men. Journal of Xi'an University of Architecture & Technology, 2019; XI(IX):62-69. . *[Crossref][PubMed][Google Scholar]*

39. Vizcaino M. Hatha Yoga practice for type 2 diabetes mellitus patients: a pilot study. Int J Yoga Therap. 2013;(23):59-65. *PMID: 24165524 [Crossref][PubMed][Google Scholar]*

40. Bismi V, Duraisami V. Impact of Ashtanga Yoga Practices and Music Therapy on Selected Biochemical Variable among Gestational Diabetic Women. ShodhKosh: Journal of Visual and Performing Arts. 2024;5. *doi:10.29121/shodhkosh.v5.i3.2024.1992 [Crossref][PubMed][Google Scholar]*

41. Ahmad F, Joshi SH. Self-Care Practices and Their Role in the Control of Diabetes: A Narrative Review. Cureus. 2023;15(7):e41409. *Published 2023 Jul 5. doi:10.7759/cureus.41409 [Crossref][PubMed] [Google Scholar]*

42. Ferreira-Vorkapic C, Feitoza JM, Marchioro M, Simões J, Kozasa E, Telles S. Are There Benefits from Teaching Yoga at Schools? A Systematic Review of Randomized Control Trials of Yoga-Based Interventions. Evid Based Complement Alternat Med. 2015;2015:345835. *doi:10.1155/2015/345835 [Crossref][PubMed] [Google Scholar]*

43. McDermott KA, Rao MR, Nagarathna, R. Murphy EJ,Burke A,Nagendra RH,Hecht FM, A Yoga intervention for type 2 diabetes risk reduction: a pilot randomized controlled trial. BMC Complement Altern Med. 2014;14: 212. *[Article][Crossref] [PubMed][Google Scholar]*

44. Yatham P, Chintamaneni S, Stumbar S. Lessons From India: A Narrative Review of Integrating Yoga Within the US Healthcare System. Cureus. 2023;15(8):e43466. *Published 2023 Aug 14. doi:10.7759/cureus.43466 [Crossref][PubMed] [Google Scholar]*

45. Bilagi A, Kurian J, Bilagi S. Intensive integrated Yoga therapy on lipid profile, body composition and insulin resistance among Type 2 diabetes mellitus. Yoga Mimamsa 2022;54(2): 70-77. DOI: 10. *4103/ym.ym_108_22 [Crossref][PubMed][Google Scholar]*