

## Effects Of Taurine Supplementation on Diabetes Mellitus

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### ABSTRACT

*Taurine is a sulfur-containing, semi-essential aminosulfonic acid that is not involved in protein synthesis and is widely found in various body tissues and organs. In the human body, it can be synthesized endogenously from methionine and cysteine or obtained through diet. The best-known dietary sources are seafood and meat, while it is found in plants only in very limited amounts. Known for its antioxidant and anti-inflammatory properties in the human body, taurine plays various roles in maintaining cellular homeostasis. Diabetes mellitus is a metabolic disease characterized by chronically high blood glucose levels resulting from insulin deficiency or insulin resistance. In diabetes mellitus, persistent chronic hyperglycemia leads to the development of various complications in the long term. Some experimental studies have shown that taurine may have regulatory effects on glucose metabolism and may play a role in reducing insulin resistance. Therefore, taurine is considered a potential complementary support in diabetes mellitus management.*

**Keywords:** Diabetes mellitus, insulin, blood glucose, taurine, taurine supplementation

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## INTRODUCTION

Diabetes mellitus (DM) is a chronic metabolic disorder marked by chronic hyperglycemia due to impairments in insulin secretion, insulin sensitivity, or both (1). Type 1 and Type 2 DM are the most common forms of the disease and are associated with significant metabolic and vascular complications (2). Type 1 DM is an autoimmune disease characterized by immune-mediated damage to pancreatic  $\beta$  cells, while Type 2 DM is a multifactorial disease influenced by genetic susceptibility, dietary patterns, physical inactivity, and obesity (1). In short, Type 1 DM is characterized by insulin deficiency and hyperglycemia, while Type 2 DM is characterized by insulin resistance (3). Because both environmental and genetic factors contribute to the development of DM complications, the complications of DM develop multifactorially (4). Risk factors for the development of DM complications include poor glycemic control, dyslipidemia, hypertension, excess body weight, and elevated uric acid levels. Irregularities in each risk factor lead to complications (5). Complications of DM are divided into microvascular and macrovascular complications. Microvascular complications are characterized by conditions such as neuropathy, nephropathy, and retinopathy, whereas macrovascular complications encompass coronary artery disease, cerebrovascular disorders, and peripheral arterial disease (6).

Diabetes mellitus treatment is crucial for preventing complications from worsening or delaying their onset. While Type 1 DM is insulin-dependent, lifestyle modification, including dietary intervention and physical activity, together with oral antidiabetic agents, represents the initial approach in the management of Type 2 DM. As a result of these practices, insulin is required when effective treatment is not available in Type 2 DM (6, 7).

Taurine supplementation is being considered as a novel agent that could reduce the risk of developing DM or prevent complications in individuals who already have it, in addition to standard treatments. Taurine, also known as tauric acid or 2-aminoethylsulfonic acid, is a non-protein amino acid found in cells (2). Taurine, which is widely found in animal tissues, is found in the human body in the retina, platelets, colon, heart, and brain (8). Sources of taurine are endogenous synthesis and dietary intake, with dietary sources including meats (seafood, meat, poultry) (9). Taurine deficiency has been linked to problems with  $\beta$ -cells in the pancreas, kidney disorders, and retinal disorders (3). Taurine has roles in the body such as improving metabolic syndrome and oxidative stress (10). Taurine also functions as an antioxidant, conjugating bile acids, and modulating neurotransmitters (11). Evidence from experimental and limited human studies suggests that taurine supplementation may have beneficial effects on  $\beta$ -cell function and

insulin sensitivity (3). Taurine supplements are available commercially as capsules, tablets, or added to energy drinks (9). The relationship between taurine and DM makes it clear why taurine is considered a new treatment option. Taurine has been suggested to attenuate insulin resistance and improve glycemic control (12). In type 1 DM, its antioxidant and anti-inflammatory properties may help attenuate organ dysfunction and complications, while in type 2 DM, it helps prevent complications by maintaining glucose regulation (13). Taurine supplementation has an impact on glycemic parameters. In experimental models and individuals with Type 2 DM, taurine supplementation has been associated with increased plasma insulin levels and reduced plasma glucose concentrations (14). The aim of this review is to evaluate the effects of taurine supplementation on glucose metabolism and DM.

## **TAURINE**

### **Biochemistry of Taurine**

Taurine is chemically defined as a  $\beta$ -amino acid, characterized by the presence of an amino group ( $\text{NH}_2$ ) and a sulfonic acid group ( $\text{SO}_3\text{H}$ ) attached to the  $\beta$ -carbon atom (9). It is a non-protein amino acid that serves as an intracellular amino acid in many animal tissues (15). Taurine, which is not involved in protein synthesis and is not incorporated into muscle proteins, is sulfur-containing amino sulfonic acid and is considered conditionally essential in humans under certain physiological or pathological conditions (2). Widely distributed across animal tissues, it plays multiple roles in human physiology. It participates in several cellular functions, including antioxidant activity, neurotransmitter modulation, and bile acid conjugation (11) and also contributes to human health through its blood pressure-regulating and anti-inflammatory effects (9).

Experimental and clinical studies have also suggested that taurine may exert beneficial or potentially therapeutic effects on metabolic syndrome (10). Impaired glucose regulation, a key component of metabolic syndrome, may be improved through taurine's potential hypoglycemic and insulin-sensitizing effects (16). Thus, beyond its basic physiological functions, taurine may serve as a promising adjunct for regulating metabolic syndrome-related parameters (17).

Taurine deficiency, although uncommon in healthy adults, has been associated with cardiomyopathy, renal dysfunction, pancreatic  $\beta$ -cell damage, and loss of retinal photoreceptors (3). Taurine is distributed widely throughout the human body and is present at particularly high concentrations in excitable tissues such as the heart, brain, and retina, as well as in platelets, and various glandular tissues (18).

Taurine levels are maintained through both exogenous dietary intake and endogenous synthesis (19). Endogenous synthesis occurs primarily in the liver from the amino acids cysteine and methionine (15), although other tissues—including the kidneys, brain, and adipose tissue—also contribute to its production (19). Because the biosynthetic capacity of humans is relatively limited, taurine is obtained primarily through dietary sources, including meats and seafood, or supplementation (15, 16). Foods rich in taurine include mussels, oysters, shellfish, chicken, and turkey, with seafood and meat constituting the primary dietary contributors; plant-based foods contain only trace amounts (2, 20). Importantly, studies have not reported any genotoxic, carcinogenic, or teratogenic effects associated with taurine intake (3).

### **Taurine Supplementation**

Taurine supplementation has been suggested to exert protective effects against several health conditions, including aging, metabolic syndrome, certain cancers, cardiovascular disease, neurological disorders, and mitochondrial dysfunction (21). It may also improve insulin resistance—a component of metabolic syndrome—by enhancing glucose regulation (3). Reduced serum taurine levels are associated with various oxidative stress-related disorders, and supplementation has been reported to alleviate some of these abnormalities (2).

Intracellular concentrations typically range from 5–50 mM, whereas plasma levels average around 100  $\mu$ M. Following oral supplementation, plasma taurine peaks within approximately 1 to 2.5 hours (21). Taurine is commonly administered in capsule form or as a component of taurine-rich beverages (12). The recommended dosage varies depending on the intended use but generally ranges between 500 and 2000 mg (9). In mammalian models, long-term taurine supplementation has been shown to suppress endogenous taurine synthesis (10). Furthermore, intake exceeding recommended levels may lead to mild gastrointestinal or neurological side effects in some individuals. The appropriate dose of taurine supplements depends on several individual factors, including age, weight, sex, and overall health status (9).

### **PATHOPHYSIOLOGY OF DM**

Diabetes mellitus is a combination of various metabolic disorders rather than a single disease entity (4). It is defined by chronic hyperglycemia and abnormalities in carbohydrate, lipid, and protein metabolism that arise from impairments in insulin secretion, insulin sensitivity, or a combination of both (8).

Diabetes mellitus is commonly classified into two major types: Type 1 DM and Type 2 DM (2). Type 1 DM is characterized by autoimmune destruction of pancreatic  $\beta$ -cells, leading to

absolute insulin deficiency and subsequent hyperglycemia, whereas Type 2 DM is primarily characterized by insulin resistance accompanied by a progressive decline in  $\beta$ -cell function (3). Additional clinically recognized types include latent autoimmune DM in adults (LADA), monogenic DM syndromes, and gestational DM (4).

### **Current Therapeutic Approaches to DM**

Early attempts to manage DM relied on herbal remedies and dietary regulation (22). Today, treatment strategies differ between Type 1 and Type 2 DM. Management of Type 1 DM requires lifelong insulin therapy, supported by daily lifestyle practices such as regular exercise, adequate sleep, and balanced nutrition. Insulin regimens typically include basal insulin and bolus insulin administered according to nutritional intake (23). Type 2 DM, which is characterized by insulin resistance and progressive  $\beta$ -cell dysfunction, is closely associated with oxidative stress and inflammation; therefore, reducing these factors is an important component of treatment (24). First-line therapy for Type 2 DM includes lifestyle modification and oral antidiabetic medications. Insulin therapy is initiated when adequate glycemic control cannot be achieved with diet, exercise, or oral agents (6).

Advances in DM technology have significantly improved disease management. Automated insulin delivery systems, continuous subcutaneous insulin infusion pumps, and continuous glucose monitoring devices help maintain glucose levels within the target range and reduce the risk of severe hypoglycemia and hyperglycemia (25). Beyond established therapeutic approaches, interest in adjunctive options has increased, with taurine being considered a potentially beneficial agent.

### **PHYSIOLOGICAL INTERACTIONS BETWEEN TAURINE AND GLUCOSE METABOLISM**

Taurine plays several physiological roles, one of which is the regulation of blood glucose homeostasis (18). It contributes to glucose homeostasis by modulating insulin secretion from pancreatic  $\beta$ -cells and influencing insulin signaling pathways. Taurine enhances insulin sensitivity in part by increasing adiponectin mRNA expression. In line with this, a recent systematic review and meta-analysis of RCTs demonstrated that taurine supplementation significantly reduced waist circumference, triglyceride levels, and fasting blood glucose, and lowered the overall risk of metabolic syndrome (17). In conditions of mitochondrial oxidative stress, the impaired mitochondrial functions involved in glucose and lipid metabolism further exacerbate metabolic dysregulation. Acting as an antioxidant, taurine protects mitochondria by

reducing oxidative stress and thereby supports normal glucose and fat metabolism (21). In addition, taurine has been suggested to modulate insulin secretion through  $\beta$ -cell signaling mechanisms, partly via the inhibition of ATP-sensitive potassium channels, facilitating insulin release and supporting glucose regulation (26). Taurine improves complications in Type 1 DM with its antioxidant and anti-inflammatory effects in the body, while it plays a role in glucose regulation in Type 2 DM and has a hypoglycemic effect (13).

### **Taurine Supplementation on Type 1 DM**

Taurine supplementation has been suggested to exert beneficial effects in Type 1 DM primarily through its antioxidant and anti-inflammatory properties, rather than through direct glycemic control. Experimental evidence indicates that taurine may reduce oxidative damage, attenuate inflammatory responses, and help preserve residual  $\beta$ -cell function, particularly in the early stages of the disease, thereby contributing to metabolic homeostasis (13).

Mitochondrial oxidative stress plays a key role in the pathogenesis of metabolic disturbances and DM-related complications. By acting as an antioxidant, taurine protects mitochondrial function, thereby supporting glucose and lipid metabolism and reducing oxidative stress-induced cellular damage (21).

Animal studies provide stronger evidence regarding the role of taurine in preventing DM-related complications (11). Diabetic nephropathy, a common microvascular complication of Type 1 DM, has been shown to improve following taurine supplementation in experimental models. In diabetic rats, taurine administration reduced urinary protein excretion and oxidative stress—key markers of nephropathy—and attenuated cellular hypertrophy and fibrosis induced by advanced glycation end products in renal tissue (11). Beyond nephropathy, taurine has demonstrated protective effects against other DM-related complications in Type 1 animal models. In streptozotocin-induced diabetic rats, taurine supplementation attenuated oxidative stress and improved left ventricular function, suggesting a cardioprotective role in diabetic cardiomyopathy (27). Additionally, taurine has been shown to reduce vascular endothelial dysfunction in Type 1 diabetic rats by suppressing oxidative stress and downregulating pro-inflammatory endothelial markers (28).

Evidence from human studies remains limited. In a small clinical study, taurine was administered at a dose of 0.5 g/day to patients with Type 1 DM for 30 days, and its effects on carbohydrate and lipid metabolism were evaluated. The findings indicated improvements in

lipid metabolism, suggesting potential metabolic benefits of taurine supplementation in individuals with Type 1 DM, although the small sample size limits definitive conclusions (13).

Although a recent systematic review and meta-analysis reported significant reductions in HbA1c, fasting blood glucose, and HOMA-IR with taurine supplementation in diabetic patients, the majority of included trials enrolled individuals with Type 2 DM; only one study specifically examined patients with Type 1 DM, underscoring the limited availability of high-quality human evidence in this population (3). Overall, taurine appears to act through multiple interconnected pathways, including antioxidant defense, modulation of insulin signaling, and attenuation of inflammatory processes.

### **Taurine Supplementation on Type 2 DM/Insulin Resistance**

Taurine supplementation has been suggested to influence glucose homeostasis in Type 2 DM primarily through improvements in insulin sensitivity and modulation of insulin signaling pathways. Reduced taurine levels have been associated with DM and its related complications, highlighting a potential role for taurine in metabolic regulation (20).

Experimental studies indicate that taurine may exert protective effects in Type 2 DM by reducing oxidative stress, modulating insulin signaling, and attenuating insulin resistance (13, 29, 30). In animal models, taurine supplementation has been shown to influence insulin secretion and glucose handling, although these effects appear to be mediated predominantly through improvements in insulin sensitivity rather than direct hypoglycemic action (11, 31).

Evidence from animal studies supports a role for taurine in pancreatic and peripheral insulin-related mechanisms. In a study using non-obese diabetic pregnant mice, maternal taurine supplementation enhanced pancreatic islet development in offspring, which was associated with a delayed onset of DM (11). In another experimental model, insulin resistance was induced in mice through intralipid and heparin administration, leading to hepatic insulin resistance via serine phosphorylation. Taurine supplementation was suggested to attenuate insulin resistance by modulating pathways involved in serine phosphorylation and insulin signaling (31).

Human clinical evidence further supports these findings, although results remain heterogeneous. In a randomized controlled study involving 120 participants, taurine supplementation (1000 mg, three times daily for 8 weeks) resulted in significant reductions in serum insulin levels and HOMA-IR compared with the control group, indicating an improvement in insulin resistance. However, no significant changes were observed in fasting blood glucose or HbA1c levels, suggesting that taurine's primary effect may be related to

insulin sensitivity rather than direct glycemic control (26). The absence of significant changes in fasting blood glucose and HbA1c in this study, despite improvements in insulin resistance, may be attributable to several factors, including differences in baseline glycemic control among participants, the relatively short intervention duration, or the possibility that taurine's effects on glycemic indices require a longer period to manifest. These discrepancies highlight the need for longer-term trials with standardized protocols.

A systematic review and meta-analysis synthesizing data from multiple randomized controlled trials (RCTs) reported that taurine supplementation significantly reduced fasting blood glucose and HbA1c levels in individuals with DM, providing pooled evidence in support of its glycemic benefits (3). Similarly, in another randomized study involving patients with Type 2 DM, daily supplementation with 3 g of taurine for 8 weeks led to significant reductions in fasting blood glucose, insulin levels, and insulin resistance compared with controls (25). Supporting these individual trials, a systematic review and meta-analysis of five RCTs involving 209 diabetic patients demonstrated that taurine supplementation significantly reduced HbA1c (SMD  $-0.41$ ; 95% CI:  $-0.74, -0.09$ ), fasting blood glucose (SMD  $-1.28$ ; 95% CI:  $-2.42, -0.14$ ), and HOMA-IR (SMD  $-0.86$ ; 95% CI:  $-1.30, -0.42$ ) compared with controls, providing pooled evidence for its beneficial effects on glycemic indices in diabetic patients (3). Collectively, these findings suggest that taurine supplementation may improve insulin resistance and metabolic parameters in individuals with Type 2 DM, although its effects on long-term glycemic control require further investigation.

## **CONCLUSION AND RECOMMENDATIONS**

Overall, current evidence suggests that taurine may play a beneficial role in DM by supporting antioxidant and anti-inflammatory defenses, enhancing insulin sensitivity, and protecting  $\beta$ -cells. Taurine supplementation has been associated with improvements in several DM-related metabolic parameters and may help attenuate the progression of chronic complications such as neuropathy, nephropathy, retinopathy, and cardiovascular disease. Based on current evidence, taurine supplementation appears to be well tolerated in adults and may represent a potential complementary strategy rather than a routine clinical recommendation; nevertheless, the absence of an established upper intake level and the limited long-term safety data warrant cautious interpretation. Future studies should focus on clarifying the therapeutic potential of taurine by employing well-designed randomized controlled trials that consider dose, duration, sample size, and participant characteristics. More rigorous evidence is needed to determine whether taurine can effectively prevent DM or delay its complications. Comprehensive clinical

research will ultimately define the role of taurine supplementation as an adjunctive option in DM management.

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## REFERENCES

1. Demir S, Nawroth PP, Herzig S, Ekim Üstünel B. Emerging Targets in Type 2 Diabetes and Diabetic Complications. *Adv Sci (Weinh)*. 2021;8(18):e2100275.
2. Sirdah MM. Protective and therapeutic effectiveness of taurine in diabetes mellitus: a rationale for antioxidant supplementation. *Diabetes Metab Syndr*. 2015;9(1):55-64.
3. Tao X, Zhang Z, Yang Z, Rao B. The effects of taurine supplementation on diabetes mellitus in humans: A systematic review and meta-analysis. *Food Chem (Oxf)*. 2022;4:100106.
4. Cole JB, Florez JC. Genetics of diabetes mellitus and diabetes complications. *Nat Rev Nephrol*. 2020;16(7):377-90.
5. Ceriello A, Prattichizzo F. Variability of risk factors and diabetes complications. *Cardiovasc Diabetol*. 2021;20(1):101.
6. Wu Y, Ding Y, Tanaka Y, Zhang W. Risk factors contributing to type 2 diabetes and recent advances in the treatment and prevention. *Int J Med Sci*. 2014;11(11):1185-200.
7. Maleki V, Mahdavi R, Hajizadeh-Sharafabad F, Alizadeh M. The effects of taurine supplementation on oxidative stress indices and inflammation biomarkers in patients with type 2 diabetes: a randomized, double-blind, placebo-controlled trial. *Diabetology & Metabolic Syndrome*. 2020;12(1):9.
8. Sarkar P, Basak P, Ghosh S, Kundu M, Sil PC. Prophylactic role of taurine and its derivatives against diabetes mellitus and its related complications. *Food Chem Toxicol*. 2017;110:109-21.
9. Santulli G, Kansakar U, Varzideh F, Mone P, Jankauskas SS, Lombardi A. Functional Role of Taurine in Aging and Cardiovascular Health: An Updated Overview. *Nutrients*. 2023;15(19).
10. Neuwirth LS, Gökhan N, Kaye S, Meehan EF. Taurine Supplementation for 48-Months Improved Glucose Tolerance and Changed ATP-Related Enzymes in Avians. *Pharmacology*. 2023;108(6):599-606.
11. Ito T, Schaffer SW, Azuma J. The potential usefulness of taurine on diabetes mellitus and its complications. *Amino Acids*. 2012;42(5):1529-39.
12. Kurtz JA, VanDusseldorp TA, Doyle JA, Otis JS. Taurine in sports and exercise. *J Int Soc Sports Nutr*. 2021;18(1):39.
13. Baliou S, Adamaki M, Ioannou P, Pappa A, Panayiotidis MI, Christodoulou I, et al. Ameliorative effect of taurine against diabetes and renal-associated disorders (Review). *Med Int (Lond)*. 2021;1(2):3.
14. L'Amoreaux WJ, Cuttitta C, Santora A, Blaize JF, Tachjadi J, El Idrissi A. Taurine regulates insulin release from pancreatic beta cell lines. *J Biomed Sci*. 2010;17 Suppl 1(Suppl 1):S11.
15. Inam UL, Piao F, Aadil RM, Suleman R, Li K, Zhang M, et al. Ameliorative effects of taurine against diabetes: a review. *Amino Acids*. 2018;50(5):487-502.
16. Caletti G, Cardoso MV, Scheffel RS, Schaan BD, Gomez R, Bock PM. Effect of taurine on glycaemic, lipid and inflammatory profile in individuals with type 2 diabetes: study protocol of a randomised trial. *Br J Nutr*. 2023;129(11):1871-6.
17. Tzang CC, Chi LY, Lin LH, Lin TY, Chang KV, Wu WT, et al. Taurine reduces the risk for metabolic syndrome: a systematic review and meta-analysis of randomized controlled trials. *Nutr Diabetes*. 2024;14(1):29.
18. Sak D, Erdenen F, Müderrisoğlu C, Altunoglu E, Sozer V, Gungel H, et al. The Relationship between Plasma Taurine Levels and Diabetic Complications in Patients with Type 2 Diabetes Mellitus. *Biomolecules*. 2019;9(3).
19. Miyazaki T. Identification of a novel enzyme and the regulation of key enzymes in mammalian taurine synthesis. *Journal of Pharmacological Sciences*. 2024;154(1):9-17.
20. Bae M, Ahmed K, Yim JE. Beneficial Effects of Taurine on Metabolic Parameters in Animals and Humans. *J Obes Metab Syndr*. 2022;31(2):134-46.
21. Jong CJ, Sandal P, Schaffer SW. The Role of Taurine in Mitochondria Health: More Than Just an Antioxidant. *Molecules*. 2021;26(16).
22. Looker HC, Chang DC, Baier LJ, Hanson RL, Nelson RG. Diagnostic criteria and etiopathogenesis of type 2 diabetes and its complications: Lessons from the Pima Indians. *Presse Med*. 2023;52(1):104176.
23. Powers AC. Type 1 diabetes mellitus: much progress, many opportunities. *J Clin Invest*. 2021;131(8).
24. Attia MS, Ayman F, Attia MS, Yahya G, Zahra MH, Khalil MMI, et al. Mitigating diabetes-related complications: Empowering metformin with cholecalciferol and taurine supplementation in type 2 diabetic rats. *World J Diabetes*. 2024;15(8):1778-92.
25. Esmaeili F, Maleki V, Kheirouri S, Alizadeh M. The Effects of Taurine Supplementation on Metabolic Profiles, Pentosidine, Soluble Receptor of Advanced Glycation End Products and Methylglyoxal in Adults With Type 2 Diabetes: A Randomized, Double-Blind, Placebo-Controlled Trial. *Can J Diabetes*. 2021;45(1):39-46.
26. Moludi J, Qaisar SA, Kadhim MM, Ahmadi Y, Davari M. Protective and therapeutic effectiveness of taurine supplementation plus low calorie diet on metabolic parameters and endothelial markers in patients with diabetes mellitus: a randomized, clinical trial. *Nutr Metab (Lond)*. 2022;19(1):49.
27. Wang GG, Li W, Lu XH, Zhao X, Xu L. Taurine attenuates oxidative stress and alleviates cardiac failure in type I diabetic rats. *Croatian medical journal*. 2013;54(2):171-179.
28. Wang LJ, Yu YH, Zhang LG, Wang Y, Niu N, Li Q, et al. Taurine rescues vascular endothelial dysfunction in streptozocin-induced diabetic rats: correlated with downregulation of LOX-1 and ICAM-1 expression on aortas. *European journal of pharmacology*. 2008;597(1-3), 75-80.
29. Wu N, Lu Y, He B, Zhang Y, Lin J, Zhao S, et al. Taurine prevents free fatty acid-induced hepatic insulin resistance in association with inhibiting JNK1 activation and improving insulin signaling in vivo. *Diabetes research and clinical practice*. 2010;90(3), 288-296.
30. Kim KS, Oh DH, Kim JY, Lee BG, You JS, Chang KJ, et al. Taurine ameliorates hyperglycemia and dyslipidemia by reducing insulin resistance and leptin level in Otsuka Long-Evans Tokushima fatty (OLETF) rats with long-term diabetes. *Experimental & molecular medicine*. 2012;44(11), 665-673.
31. Ahmed K, Choi HN, Yim JE. The Impact of Taurine on Obesity-Induced Diabetes Mellitus: Mechanisms Underlying Its Effect. *Endocrinol Metab (Seoul)*. 2023;38(5):482-92.