

Review Article**Functional Circuit Class Therapy in Type 2 Diabetes: Impact on Cardiac Autonomic Function, Fatigue, and Cognition: A Literature Review**

Sunita Kumari, Moattar Raza Rizvi

Abstract:

Type 2 diabetes mellitus (T2DM) poses a significant global health concern, affecting millions of individuals worldwide and leading to various physical and psychological complications. The escalating prevalence of T2DM is driven by factors such as urbanization, sedentary lifestyles, and rising obesity rates. Recent studies emphasize the positive impact of exercise in managing and preventing this metabolic disorder. In particular, Functional Circuit Class Therapy, a novel group-based exercise regimen, holds great promise for individuals with T2DM. However, there remains a paucity of literature investigating its effects on cardiac autonomic function, fatigue measures, and cognition in this specific population. Through a meticulous narrative review of 45 relevant articles, we aim to shed light on the potential benefits of exercise and Functional Circuit Class Therapy, offering innovative insights that may revolutionize diabetes care and enhance overall well-being. Key words: Type 2 diabetes, exercise, Functional Circuit Class Therapy, cardiac autonomic function, fatigue measures, cognition. This comprehensive review emphasizes the significant impact of Type 2 Diabetes Mellitus (T2DM) on global health and also discusses the potential benefits of exercise in its management. The introduction of Functional Circuit Class Therapy presents a promising approach for individuals with T2DM, warranting further investigation. By understanding the outcomes of exercise on cardiac autonomic function, fatigue, and cognition, this study paves the way for tailored diabetes care strategies and improved overall well-being. The significance of this research lies in its contribution to combatting the T2DM epidemic and empowering individuals to lead healthier lives.

JK-Practitioner2023;28(1-2):55-63**INTRODUCTION**

As stated by International Diabetes Foundation in 2006, as nearly 246 million individuals worldwide were affected by type 2 diabetes, and it is intended to increase to 380 million by 2025, which is a total of 7.1% of the adult population [Silink, M]. However, more recent data from the Centers for Disease Control and Prevention (CDC) in the United States show that more than 37 million Americans have diabetes, and approximately 90-95% of them have type 2 diabetes [Silink, M][Sun, H]. More of children, teenagers and young adults are developing it now which was often developed in individuals aged above 45 years. [Silink, M].

It imposes a greater effect of public health with a Type 2 diabetes is a serious public health concern with a substantial impact on human life and overall money spent on health. The cause of increase in the rising of cases of diabetes both globally and in western Europe is drastic economic development and urbanization. Both genders are equally affected with the incidence peak at around 55 years of age. It is estimated that globally 7079 individuals per 100000 will have type 2 diabetes by 2030. Lower income group pose greater chance of developing the disease.[Khan, M. A. B].

Long-lasting manifestations and symptoms of diabetes mellitus can affect both physical and mental health, many of which are crippling. The most prevalent kind of diabetes, type 2, is essentially a combination of issues with insulin release and action, either of which may predominate. Chronic hyperglycemia and microvascular pathology

Author Affiliations

Sunita Kumari, PhD Research Scholar, Department of Physiotherapy, School of Allied Health Sciences, Manav Rachna International Institute and Studies (MRIIRS), Faridabad, India

Dr Moattar Raza Rizvi, Professor & Dean, Faculty of Allied Health Sciences, Manav Rachna International Institute and Studies (MRIIRS), Faridabad, India 121001

Correspondence

Sunita Kumari, PhD Research Scholar, Department of Physiotherapy, School of Allied Health Sciences, Manav Rachna International Institute and Studies (MRIIRS), Faridabad, India 121001; sunita.fas@mriu.edu.in

Indexed

EMBASE, SCOPUS, IndMED, ESBCO, Google Scholar besides other national and International Databases

Cite This Article as

Yousuf S, Arsalan-un-Nisa, Rasool Aliya, Shafi Tufela. A cross sectional study of compliance and adherence of topical antiglaucoma medications in rural population of Kashmir..JK Pract2023;28(1-2):55-63

Full length article available at jkpractitioner.com one month after publication

Keywords

Type 2 Diabetes Mellitus, exercise, Functional Circuit Class Therapy, cardiac autonomic function, fatigue, cognition, lifestyle, well-being.

unique to diabetes that causes different types of neuropathies and nephropathies are characteristics of diabetes. The liver overproduces glucose. Because of inadequate insulin secretion caused by impaired islet beta cell function, peripheral tissues utilize glucose insufficiently. (Clemente-Suárez).

Due to increase in rate of obesity, physical inactivity, dietary changes The incidence and prevalence of type 2 diabetes (T2DM) have indeed increased significantly due to factors such and ageing the prevalence and incidence of type 2 diabetes is increasing drastically [Ong, K. L]. Type 2 diabetes affects various organs involved in its onset, including the pancreas, liver, skeletal muscle, kidneys, brain, small intestine, heart, and adipose tissue [Gandhi, A]. Over 37 million Americans have diabetes and around 90-95% will have type to diabetes as per the reports of the Centers for Disease Control and Prevention (CDC) [Wilson, J.].

Diabetic autonomic neuropathy is a significant consequence of diabetes that is often overlooked. It is associated with other microangiopathic comorbidities and can lead to various complications such as silent myocardial ischemia, arrhythmias and sudden death. One specific manifestation of diabetic autonomic neuropathy is cardiovascular autonomic neuropathy (CAN), which is characterized by impaired autonomic regulation [Agashe, S]. A study conducted by Alberto et al. in 2014 evaluated the relationship between resting heart rate and cardiac autonomic neuropathy in 387 individuals with diabetes. The study found a correlation between elevated resting heart rate and an increased likelihood of having cardiac autonomic neuropathy. This highlights the significance of this relationship in predicting the development of this condition [Verrotti, A]. Other research supports the link between cardiac autonomic neuropathy and cardiovascular events in persons with diabetes. A meta-analysis including 87 studies confirmed the increase in resting heart rate by 10 bpm which is 1.15 for cardiovascular disease [Spallone, V]. Autonomic nervous system (ANS) imbalance, manifested as cardiac autonomic neuropathy, can be an important predictor of cardiometabolic episodes in the diabetic population [Vinik, A. I.]. It is important to recognize and diagnose cardiac autonomic neuropathy in individuals with diabetes to effectively manage and prevent complications. Autonomic dysfunction can lead to altered exercise tolerance, decrease heart rate and blood pressure response, and increases in cardiac output during workout [Karayannis, G]. Early detection and appropriate management strategies are crucial in improving outcomes for individuals with DAN.

Fatigue is a significant clinical manifestation of diabetes, particularly in individuals with Type 2 Diabetes Mellitus (T2DM), and has been connected to both depression and diabetes distress (Park H). It is a subjective experience characterized by a declining ability to perform physical or mental tasks, influenced

by a range of physiological, psychological, and lifestyle factors. These factors include fluctuations in glucose control, diabetes symptoms, emotional distress related to the condition, depression, physical inactivity, and Body Mass Index (BMI) (Hidayat, B. F). Despite its prevalence in the diabetic population, fatigue remains an underexplored aspect of the disease. Lifestyle factors, such as lack of exercise and higher BMI, contribute to the weariness experienced by individuals with T2DM (Telford, 2007). Furthermore, the diagnosis of diabetes can trigger feelings of depression, which may also contribute to feelings of fatigue (Rustad, J. K). Understanding the multifactorial nature of fatigue in diabetes is crucial for addressing its influence on patients' quality of life and overall health.

Diabetes is associated with chronic brain problems, which can manifest as impaired cognitive performance and abnormalities on brain imaging. Studies suggested that persons with T1DM and T2DM both may have experiences of cognitive and are at increased risk of developing vascular dementia, Alzheimer's disease and dementia [Zilliox, L. A] [Dove, A] [Varghese, S. M]. Glycemic control, or the management of blood glucose levels, may have an impact on the extent of cognitive dysfunction in individuals with type 2 diabetes. Research suggests that better glycemic control may help mitigate cognitive impairment in this population [Munshi, M. N.]. It is important to recognize and address cognitive impairment in individuals with diabetes as it can significantly impact their daily functioning and quality of life. Healthcare professionals should be aware of the association between diabetes and cognitive problems and adapt treatment strategies accordingly [Zilliox, L. A] [Hopkins, R].

Exercise is a fundamental strategy for glycemic control in individuals with diabetes. It has several beneficial effects which includes increased sensitivity to insulin in tissues, improved lipid profile, reducing blood pressure, and even improving psychological well-being by alleviating symptoms of depression [Syeda, U. A] [Gulve, E. A]. The effectiveness of exercise in glycemic control can vary depending on the type of exercise. It has been reported that aerobic training is more effective than strength training in correcting glycemic control. These activities includes jogging, cycling, walking or swimming [Gulve, E. A]. Aerobic exercise has well-documented benefits in improving glucose control and retarding the progression of comorbidities associated with diabetes, such as cardiovascular disease [Gulve, E. A]. Various studies have shown the positive effect of exercise on glycemic control in individuals with diabetes. For example, a systematic review found that aerobic exercise makedly improved glycemic control in patients with type 2 diabetes mellitus [Kurniawati, Y]. Another study conducted on adults with type 1 diabetes found that physical activity, including both aerobic and resistance training, was associated with

betterment in glycemic control [Reddy, R.,]. A randomized control trial was done focusing on the individual and combined effect of both resistance and aerobic training, the result showed that there was no additional benefit of combining these type of training compared to single mode of training [Sigal, R. J]. The intensity and duration of exercise has influence on glycemic control. On comparing with continuous training high intensity interval training was found to be more effective in regulating glucose in general population [Grace, A]. However, it is essential for individuals with diabetes to consult with their healthcare providers to determine the most appropriate exercise regimen based on their specific needs and health conditions.

Embracing the power of exercise to transform the landscape of Type 2 Diabetes management and prevention is a groundbreaking approach supported by recent studies. Introducing the concept of Functional Circuit Class Therapy, a tailor-made exercise regimen designed for group engagement, represents a novel and exciting prospect for individuals with diabetes. Although extensively studied in diverse populations like stroke survivors and those with cerebral palsy, its untapped potential in Type 2 Diabetes mellitus individuals calls for further exploration. With a pioneering spirit, our current study endeavors to uncover the profound impact of Functional Circuit Class Therapy on cardiac autonomic function, fatigue measures, and cognitive well-being. This innovative investigation holds the promise of reshaping how we approach diabetes care, heralding a new era of holistic and empowering interventions.

Methodology

In pursuit of a robust and comprehensive research foundation, a meticulous methodology was employed. The initial step involved identifying pertinent literature from reputable databases like Google Scholar, PubMed, and PEDro. Using strategically chosen keywords, like "Type 2 diabetes," "cardiovascular fitness," "diabetic encephalopathy," and "fatigue," ensured the inclusion of relevant studies. Additionally, cross-referencing enabled the retrieval of additional valuable resources. A total of 32 articles were meticulously reviewed, ensuring that only full-text articles were considered for analysis. A narrative review approach was then adopted, allowing

for a cohesive and insightful synthesis of the findings. Through this rigorous methodology, our study seeks to build upon the existing knowledge and provide novel awareness about the impact of Functional Circuit Class Therapy on cardiac autonomic function, fatigue measures, and cognition in persons with Type 2 Diabetes Mellitus.

Conclusion:

Type 2 diabetes is a global health concern, with a rising prevalence predicted in the coming years. The disease is associated with several complications, including cognitive impairment, fatigue, and autonomic dysfunction, which can significantly affect the quality of life of patients. However, exercise emerges as a valuable intervention in managing diabetes and its complications. Studies have demonstrated the positive impact of exercise on glycemic control in patients with type 2 diabetes. Aerobic physical exercise has been shown to improve glycemic control significantly. Exercise has also been found to improve metabolic outcomes, including insulin sensitivity and glucose metabolism. Resistance exercise has been found to benefit insulin sensitivity in those with type 2 diabetes. High-intensity interval training has been shown to be more effective in regulating glucose than continuous training at moderate intensity. Functional circuit class therapy is a tailored exercise program that has been studied in various populations, including stroke survivors and cerebral palsy patients. However, there is a paucity of literature on the effect of circuit class therapy on individuals with type 2 diabetes. A recent study aimed to examine the effect of functional circuit class therapy on cardiac autonomic function, fatigue measures, and cognition in individuals with type 2 diabetes. The study found that circuit training is beneficial in physical function and glucose metabolism in type 2 diabetic patients. Public awareness and education about diabetes remain crucial. It is essential to understand the importance of exercise in managing diabetes and its complications. Exercise can help improve glycemic control, metabolic outcomes, and physical function in individuals with type 2 diabetes. Understanding these aspects can pave the way for effective prevention and management strategies, offering hope for improved outcomes in diabetes care

Epidemiology of Type 2 diabetes

Source	Aim	Findings
Magliano, D. J., 2022	To provide global diabetes prevalence estimates	The IDF Diabetes Atlas reports that approximately 10.5% of adults worldwide are living with diabetes, with projections indicating a rise of 643 million by 2030 and 783 million by 2045.
Ong, K. L. 2023	To provide global diabetes prevalence estimates	The global prevalence of diabetes was 8.4% and 529 million people were having diabetes throughout the world in 2021. It is projected that 783 million people will be affected by 2050.
Sun. H et al, 2022	To provide global diabetes prevalence estimates	It was reported that the global prevalence of diabetes was 10.5%, and the number of adults living with diabetes was 537 million in 2021 and by 2045, the number of adults living with diabetes is projected to rise to 783 million.
Pradeepa, R and Mohan V 2021	To discuss the burden of diabetes in India	The study suggested that the prevalence of diabetes in India is more and increasing, mainly due to the increasing rate of obesity and physical inactivity. The prevalence of diabetes in India was 8.8%, and the number of adults living with diabetes was 87 million in 2021.
Centres for Disease Control and Prevention (CDC. (2017).	To provide diabetes prevalence estimates in the United States	Data published in 2019 showed 37.3 million people suffering from diabetes in America which is equal to 11.3% of the US population. Only 28.7 million cases are diagnosed with diabetes, while 8.5 million people were undiagnosed.
Kayyali, R. et al, 2019	To establish the awareness amongst individuals about the symptoms, risk and lifestyle issues related to type 2 diabetes.	The study found that there is a need for increased public awareness and education about the symptoms, risk factors, and lifestyle choices related to Type 2 diabetes.
Gruss, S. M et al. 2019	To search for the evidence for the prevention of type 2 diabete	The study thoroughly analysed various translation studies, current research for the prevention of type 2 diabetes and educating people about the importance of changing lifestyle as prevention strategies.
Khan, M. A. B et al. 2020	To examine the global burden and forecasted trends of Type 2 diabetes	Type 2 diabetes has become topic of great concern as it has marked impact on human life and economic burden on an individual. The increase in number is of great concern in lower income countries.
Alberti, K. G, et al 2007	To present global diabetes statistics	The majority of adults with diabetes reside in low- and middle-income countries.

Diabetes and cognitive impairment

Study	Aim	Findings
Dove, A et al. 2021	To analyse the effect of diabetes on cognition and its progression to dementia	Diabetes is related to an accelerated progression of cognitive deterioration, including incident cognitive impairment and dementia.
Varghese, S. M. et al 2022	To compare the prevalence of cognitive decline in diabetic individual and the general population	It was found that cognitive impairment is higher in individuals with diabetes compared to the general population.
Hopkins, R. et al, 2016	To discuss the management of cognitive decline in adults with diabetes	The individual with diabetes often experience difficulty in performing certain task due to cognitive decline. Lifestyle modification, glycemic control and medication can be used as management strategies for the same.
Luchsinger, J et al., 2007	To review epidemiologic studies of the link between diabetes and cognitive impairment	Diabetes is associated with cognitive impairment, including executive function, working memory, psychomotor and attentional functions. Diabetes treatment may alter the trajectory to cognitive impairment, and interventions that prevent diabetes could prevent cognitive impairment.
Alkethiri, K et al, 2021	To investigate the connection between type 2 diabetes and cognitive functions	Type 2 diabetes is linked to impairment of cognitive functions, with executive function, attention/concentration, visual memory, and verbal memory.
Zilliox, L. A et al., 2016	To find out the evidence suggesting that diabetes leads to cognitive decline and eventually to dementia	Type 1 and 2 diabetes individual showed cognitive decline leading to dementia in both human as well as animal.

Diabetes and fatigue

Author/Study	Aim	Findings
Bi, Y., Zhang et al., 2021	To identify and prevent fatigue in patients with type 2 diabetes	There is strong evidence suggesting the relation between type 2 diabetes (T2DM) and fatigue.
Singh, R et al., 2016	To evaluate the connection between quality of life, functional status and fatigue in type 2 diabetes	Fatigue is prevalent in patients with type 2 diabetes and is associated with lower quality of life. The contributing factors are both physiological(disease and its complication) as well psychological. (depression and anxiety)
Goedendorp, M. M et al., 2014	To examine the impact, prevalence, and potential determinants of chronic fatigue in type 1 diabetes	Though the fatigue cannot be explained only by hyperglycemia or glucose variability but is prevalent in type 1 diabetic individuals.
Jain, A et al., 2015	To study the prevalence of depression and fatigue in type 2 diabetes mellitus in industry workers	Fatigue and depression are more prevalent in diabetes patients compared to nondiabetic participants.
Widyanthari, D. M et al., 2020	To explore the possible connections between diabetes and fatigue	Blood glucose fluctuation is often thought of as a cause of fatigue in diabetes, but there may be other factors involved, such as inflammatory markers. Other related factors that can contribute to fatigue in diabetes include obesity and comorbidities associated with complications.

Diabetes and autonomic function

Author/Study	Aim	Findings
American Diabetes Association. (2023).	To provide guidelines for diagnosing and treating diabetes	Autonomic neuropathy is common complication in diabetes, which increases the chance of exercise-induced injury or adverse events through decreased autonomic control.
Autonomic control of energy balance and glucose homeostasis [Hyun, U., & Sohn]	To discuss the function of the autonomic nervous system (ANS) in energy balance and glucose homeostasis	Energy balance and glucose homeostasis are majorly regulated by ANS. Sympathetic nervous system increases thermogenesis and hepatic gluconeogenesis, while parasympathetic nervous system promotes insulin secretion.

Diabetes and circuit class therapy

Study	Aim	Findings
Park, S. Y., & Lee et al., 2015	To assess the effects of circuit training on physical function and glucose metabolism in type 2 diabetes	Circuit training improved the physical function index and glucose metabolism in type 2 diabetic patients.
Arazi, H et al.,2020	To investigate the efficacy of circuit resistance training on insulin resistance, serum glucose and physical health in type 2 diabetic elderly males.	Study showed the positive effect of circuit resistance training on serum glucose, insulin resistance, and health-related physical fitness in elderly men with type 2 diabetes.
Gretebeck, K. A. et al., 2019	Aim of the study was to compare the effects of functional circuit training on mobility performance in older individuals with type 2 diabetes	Functional circuit training improved mobility in type 2 diabetic older adult.
Verrotti, A.] et al., 2019	To review the complications of diabetic autonomic neuropathy	There is significant increment in morbidity and mortality in individuals with type 2 diabetes as it affects the autonomic nervous system wherein it leads to autonomic neuropathy which can affect any circuit/tract of the autonomic nervous system.
Bönhof, G. J. et al., 2019	To review the clinical sequels of diabetic neuropathy and its association with autonomic dysfunction	Neuropathic pain, foot ulcers and autonomic dysfunctions are major clinical symptoms following diabetes leads to significant morbidity and mortality.

Exercise and diabetes

Study	Aim	Findings
Reddy, R et al., 2019	To investigate whether there is any effects on glycemic control of resistance exercise and aerobic exercises in adults with type 1 diabetes	Both type of exercises can improve glycemic control in adults with type 1 diabetes.
Kirwan, J. P. et al., 2017	Whether the exercise can be used as management strategy in type 2 diabetes	Both aerobic and resistance training has positive impact on glucose regulation whether implemented individually or in combination.High-intensity interval training may also be effective.
Kurniawati, Y et al., 2019	To review the effectiveness of physical exercise on glycemic control in individuals with type 2 diabetes	Aerobic physical exercise is effective in improving glycemic control in individuals with type 2 diabetes.

Sigal, R. J. et al., 2007	To investigate the efficiency of resistance training, aerobic training, or both on glycemic control in individuals with type 2 diabetes	Combining the type of exercise may not be very effective when compared to individual protocol hence it can be concluded that if implemented individually both aerobic and resistance training can be effective for glycemic control.
Grace, A. et al. 2017	To investigate the effects of different aerobic exercise training intensities on glycemic control in individuals with type 2 diabetes	The study highlighted the effectiveness of high-intensity interval training over continuous training to improve glycemic control in individuals with type 2 diabetes.

REFERENCES

- Agashe, S., & Petak, S. (2018). Cardiac autonomic neuropathy in diabetes mellitus. *Methodist DeBakey cardiovascular journal*, 14(4), 251.
- Alberti, K. G. M. M., Zimmet, P., & Shaw, J. (2007). International Diabetes Federation: a consensus on Type 2 diabetes prevention. *Diabetic Medicine*, 24(5), 451-463.
- Alkethiri, K., Almtoudi, T., bin Jurays, A., Abanumay, F., Aldammas, M., AlKhadheer, M., ... & Bashir, S. (2021). The relationship between type 2 diabetes mellitus with cognitive functions. *Heliyon*, 7(3).
- American Diabetes Association. (2023). Standards of care in diabetes—2023 abridged for primary care providers. *Clinical Diabetes*, 41(1), 4-31.
- Arazi, H., Gholizadeh, R., Sohbatazadeh, A., & Eghbali, E. (2020). The impact of circuit resistance training on serum glucose, insulin resistance and health related physical fitness in elderly men with type 2 diabetes. *Baltic Journal of Health and Physical Activity*, 12(3), 6.
- Bi, Y., Zhang, L., Li, X., Kan, Y., Li, S., Zou, Y., ... & Zhang, Y. (2021). Contributing factors of fatigue in patients with type 2 diabetes: A systematic review. *Psychoneuroendocrinology*, 130, 105280.
- Bjornstad, P., Chao, L. C., Cree-Green, M., Dart, A. B., King, M., Looker, H. C., ... & Nelson, R. G. (2023). Youth-onset type 2 diabetes mellitus: an urgent challenge. *Nature Reviews Nephrology*, 19(3), 168-184.
- Bönhof, G. J., Herder, C., Strom, A., Papanas, N., Roden, M., & Ziegler, D. (2019). Emerging biomarkers, tools, and treatments for diabetic polyneuropathy. *Endocrine reviews*, 40(1), 153-192.
- Centers for Disease Control and Prevention (CDC). (2017). National Diabetes Statistics Report, 2017-Estimates of Diabetes and Its Burden in the United States Background.
- Clemente-Suárez, V. J., Martín-Rodríguez, A., Redondo-Flórez, L., López-Mora, C., Yáñez-Sepúlveda, R., & Tornero-Aguilera, J. F. (2023). New Insights and Potential Therapeutic Interventions in Metabolic Diseases. *International Journal of Molecular Sciences*, 24(13), 10672.
- Dove, A., Shang, Y., Xu, W., Grande, G., Laukka, E. J., Fratiglioni, L., & Marseglia, A. (2021). The impact of diabetes on cognitive impairment and its progression to dementia. *Alzheimer's & Dementia*, 17(11), 1769-1778.
- Gandhi, A., Tang, R., Seo, Y., & Bhargava, A. (2022). Organ-Specific Glucose Uptake: Does Sex Matter?. *Cells*, 11(14), 2217.
- Goedendorp, M. M., Tack, C. J., Stegink, E., Bloot, L., Bazelmans, E., & Knoop, H. (2014). Chronic fatigue in type 1 diabetes: highly prevalent but not explained by hyperglycemia or glucose variability. *Diabetes care*, 37(1), 73-80.
- Goran, M. I., Ball, G. D., & Cruz, M. L. (2003). Obesity and risk of type 2 diabetes and cardiovascular disease in children and adolescents. *The Journal of Clinical Endocrinology & Metabolism*, 88(4), 1417-1427.
- Grace, A., Chan, E., Giallauria, F., Graham, P. L., & Smart, N. A. (2017). Clinical outcomes and glycaemic responses to different aerobic exercise training intensities in type II diabetes: a systematic review and meta-analysis. *Cardiovascular diabetology*, 16, 1-10.
- Gretebeck, K. A., Blaum, C. S., Moore, T., Brown, R., Galecki, A., Strasburg, D., ... & Alexander, N. B. (2019). Functional exercise improves mobility performance in older adults with type 2 diabetes: a randomized controlled trial. *Journal of Physical Activity and Health*, 16(6), 461-469.
- Gruss, S. M., Nhim, K., Gregg, E., Bell, M., Luman, E., & Albright, A. (2019). Public health approaches to type 2 diabetes prevention: the US National Diabetes Prevention Program and beyond. *Current diabetes reports*, 19, 1-11.
- Gulve, E. A. (2008). Exercise and glycemic control in diabetes: benefits, challenges, and adjustments to pharmacotherapy. *Physical Therapy*, 88(11), 1297-1321.
- Hidayat, B. F., Sukartini, T., & Kusumaningrum, T. (2020). A systematic review of fatigue in type 2 diabetes. *Jurnal Ners*, 15(2), 513-517.
- Hopkins, R., Shaver, K., & Weinstock, R. S. (2016). Management of adults with diabetes and cognitive problems. *Diabetes Spectrum*, 29(4), 224-237.
- Hyun, U., & Sohn, J. W. (2022). Autonomic control of energy balance and glucose homeostasis. *Experimental & Molecular Medicine*, 54(4), 370-376.
- Jain, A., Sharma, R., Choudhary, P. K., Yadav, N., Jain, G., & Maanju, M. (2015). Study of fatigue, depression, and associated factors in type 2 diabetes mellitus in industrial workers. *Industrial Psychiatry Journal*, 24(2), 179.

23. Karayannis, G., Giamouzis, G., Cokkinos, D. V., Skoularigis, J., & Triposkiadis, F. (2012). Diabetic cardiovascular autonomic neuropathy: clinical implications. *Expert review of cardiovascular therapy*, 10(6), 747-765.
24. Kayyali, R., Slater, N., Sahi, A., Mepani, D., Lalji, K., & Abdallah, A. (2019). Type 2 Diabetes: how informed are the general public? A cross-sectional study investigating disease awareness and barriers to communicating knowledge in high-risk populations in London. *BMC Public Health*, 19(1), 1-11.
25. Khan, M. A. B., Hashim, M. J., King, J. K., Govender, R. D., Mustafa, H., & Al Kaabi, J. (2020). Epidemiology of type 2 diabetes—global burden of disease and forecasted trends. *Journal of epidemiology and global health*, 10(1), 107.
26. Kirwan, J. P., Sacks, J., & Nieuwoudt, S. (2017). The essential role of exercise in the management of type 2 diabetes. *Cleveland Clinic journal of medicine*, 84(7 Suppl 1), S15.
27. Kurniawati, Y., Baridah, H. I. A., Kusumawati, M. D., & Wabul, I. (2019). Effectiveness of physical exercise on the glycemic control of type 2 diabetes mellitus patients: a systematic review.
28. Luchsinger, J., & Florez, H. (2007). Diabetes mellitus and cognitive impairment. *Psychiatric Disorders and Diabetes Mellitus*, 41-52.
29. Magliano, D. J., Boyko, E. J., & Atlas, I. D. (2021). What is diabetes?. In *IDF DIABETES ATLAS* [Internet]. 10th edition. International Diabetes Federation.
30. Munshi, M. N. (2017). Cognitive dysfunction in older adults with diabetes: what a clinician needs to know. *Diabetes Care*, 40(4), 461-467.
31. Ong, K. L., Stafford, L. K., McLaughlin, S. A., Boyko, E. J., Vollset, S. E., Smith, A. E., ... & Brauer, M. (2023). Global, regional, and national burden of diabetes from 1990 to 2021, with projections of prevalence to 2050: a systematic analysis for the Global Burden of Disease Study 2021. *The Lancet*.
32. Park, H., Park, C., Quinn, L., & Fritschi, C. (2015). Glucose control and fatigue in type 2 diabetes: the mediating roles of diabetes symptoms and distress. *Journal of advanced nursing*, 71(7), 1650-1660.
33. Park, S. Y., & Lee, I. H. (2015). Effects on training and detraining on physical function, control of diabetes and anthropometrics in type 2 diabetes; a randomized controlled trial. *Physiotherapy theory and practice*, 31(2), 83-88.
34. Pradeepa, R., & Mohan, V. (2021). Epidemiology of type 2 diabetes in India. *Indian journal of ophthalmology*, 69(11), 2932.
35. Reddy, R., Wittenberg, A., Castle, J. R., El Youssef, J., Winters-Stone, K., Gillingham, M., & Jacobs, P. G. (2019). Effect of aerobic and resistance exercise on glycemic control in adults with type 1 diabetes. *Canadian journal of diabetes*, 43(6), 406-414.
36. Rustad, J. K., Musselman, D. L., & Nemeroff, C. B. (2011). The relationship of depression and diabetes: pathophysiological and treatment implications. *Psychoneuroendocrinology*, 36(9), 1276-1286.
37. Shin YL, Yoo H, Hong JY, Kim J, Lee KN, Kim YH. Glucose Control in Korean Patients with Type 2 Diabetes Mellitus according to Body Mass Index. *Journal of Obesity & Metabolic Syndrome*. 2023 Mar 3;32(1):55.
38. Sigal, R. J., Alberga, A. S., Goldfield, G. S., Prud'homme, D., Hadjiyannakis, S., Gougeon, R., ... & Kenny, G. P. (2014). Effects of aerobic training, resistance training, or both on percentage body fat and cardiometabolic risk markers in obese adolescents: the healthy eating aerobic and resistance training in youth randomized clinical trial. *JAMA pediatrics*, 168(11), 1006-1014.
39. Sigal, R. J., Kenny, G. P., Boulé, N. G., Wells, G. A., Prud'homme, D., Fortier, M., ... & Jaffey, J. (2007). Effects of aerobic training, resistance training, or both on glycemic control in type 2 diabetes: a randomized trial. *Annals of internal medicine*, 147(6), 357-369.
40. Silink, M. Mobilising The Resources To Address The Diabetes Epidemic. *Diabetes in Asia Study Group (DASG) acknowledges the generous support of*, 1.
41. Singh, R., Teel, C., Sabus, C., McGinnis, P., & Kluding, P. (2016). Fatigue in type 2 diabetes: impact on quality of life and predictors. *PloS one*, 11(11), e0165652.
42. Spallone, V. (2019). Update on the impact, diagnosis and management of cardiovascular autonomic neuropathy in diabetes: what is defined, what is new, and what is unmet. *Diabetes & metabolism journal*, 43(1), 3-30.
43. Sun, H., Saeedi, P., Karuranga, S., Pinkepank, M., Ogurtsova, K., Duncan, B. B., ... & Magliano, D. J. (2022). *IDF Diabetes Atlas: Global, regional and country-level diabetes prevalence estimates for 2021 and projections for 2045*. *Diabetes research and clinical practice*, 183, 109119.
44. Syeda, U. A., Battillo, D., Visaria, A., & Malin, S. K. (2023). The importance of exercise for glycemic control in type 2 diabetes. *American Journal of Medicine Open*, 9, 100031.
45. Varghese, S. M., Joy, N., John, A. M., George, G., Chandy, G. M., & Benjamin, A. I. (2022). Sweet Memories or Not? A Comparative Study on Cognitive Impairment in Diabetes Mellitus. *Frontiers in Public Health*, 10, 822062.
46. Verrotti, A., Prezioso, G., Scattoni, R., & Chiarelli, F. (2014). Autonomic neuropathy in diabetes mellitus. *Frontiers in endocrinology*, 5, 205.
47. Vinik, A. I., Casellini, C., Parson, H. K., Colberg, S. R., & Nevoret, M. L. (2018). Cardiac autonomic neuropathy in diabetes: a predictor of cardiometabolic events. *Frontiers in neuroscience*, 12, 591.
48. Widyantari, D. M., Jawi, I. M., Antari, G. A. A., & Widyantini, D. N. (2020). Fatigue among diabetic patients: A descriptive study. *Enfermería Clínica*, 30, 131-134.

49. Wilson, J. (2023). The Impact of County Level Characteristics on Type 2 Diabetes Related ED Utilization.
50. Zilliox, L. A., Chadrsekaran, K., Kwan, J. Y., & Russell, J. W. (2016). Diabetes and cognitive impairment. *Current diabetes reports*, 16, 1-11.