

Yoga-based Lifestyle Intervention for Prevention and Management of Type 2 Diabetes Mellitus and Associated Complications: A Clinical Research Review

HG Nadini Dewangani¹, Bimali Jayawardena², HD Sameera P Wijayagunaratne³

ABSTRACT

Type 2 diabetes mellitus (T2DM) has become a major health challenge in the 21st century. Prevention and management of this metabolic disease could be achieved by healthy lifestyle interventions. Yoga is one such lifestyle intervention practice that has been identified and proved its beneficial effects on T2DM through several studies. The purpose of this comprehensive review was to assess the available evidence from both short-term and long-term studies regarding the beneficial effects of yoga intervention on adult patients with T2DM and the significant impact on diabetes-related risk indices. According to the evidence of past literature used for this review, yoga plays a significant role in the prevention and management of T2DM through the improvement of weight, blood pressure, glycemic parameters, lipid profile, and oxidative stress. Side effects or complications due to yogic practices have not been mentioned up to date in any study conducted. To conclude, most of the findings suggest that yoga may play a vital role in the prevention and management of T2DM, but the lack of standard research studies performed in a diverse population is a big barrier to make evidence-based conclusions. Additional high-quality, long-term investigations should be performed in diverse populations to evaluate the effectiveness of yoga in the prevention and management of T2DM and its complications.

Keywords: Blood sugar, Hypertension, Lifestyle intervention, Obesity, Type 2 diabetes mellitus, Yoga.

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METHODS

Studies carried out on the beneficial effects of yoga exercise on patients with type 2 diabetes mellitus (T2DM) are sparse. Relevant articles published between 2000 and 2020 were retrieved from electronic databases (Google Scholar, PubMed, and Medline) using “yoga and type-2-diabetes mellitus” as keywords. From the article search, studies that are mainly focused on the beneficial effect of yoga intervention on T2DM-related risk indices [weight, blood pressure (BP), glycemic parameters, lipid profile, and oxidative stress] were included in this review. In addition to that, original research studies (both short-term and long-term) conducted on adults with T2DM and articles which are written in the English language were considered as other inclusion criteria. Articles without full text (abstract only) were excluded. Additional information was retrieved from annual reports of the World Health Organization (WHO), American Diabetes Association (ADA), and International Diabetes Federation (IDF).

The Burden of Diabetes Mellitus

Type 2 diabetes mellitus has become a major health challenge worldwide. Recent findings of the IDF confirm that diabetes is one of the fastest-growing global diseases.¹ According to the estimation of the WHO, 463 million people had diabetes in 2019, and it is predicted to reach 578 million by 2030 and 700 million by 2045. It is a complex metabolic disorder characterized by hyperglycemia and glucose intolerance resulting from defects in insulin secretion (cannot produce any or sufficient insulin), the action of produced insulin is not effective, or both.² There are two major types of diabetes mellitus, one is insulin-dependent diabetes (type 1 diabetes) and the other one is non-insulin-dependent diabetes (type 2 diabetes). More than 90% of the diabetic population has type 2 diabetes in developed countries, and the percentage is even higher in developing countries.³

^{1,2}Department of Chemistry, University of Kelaniya, Gampaha, Western, Sri Lanka

³Department of Physical Education, University of Kelaniya, Gampaha, Western, Sri Lanka

Corresponding Author: Bimali Jayawardena, Department of Chemistry, University of Kelaniya, Gampaha, Western, Sri Lanka, Phone: +94 (0)11 2 903 255, e-mail: bimali@kln.ac.lk

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Type 2 diabetes mellitus is one of the lifestyle-related diseases. Age, obesity, unhealthy dietary habits, sedentary lifestyle, and stress conditions have been identified as major risk factors of incidence of T2DM.^{4,5} Commonly, these conditions are linked to each other. Excessive calorie intake leads to obesity, and due to overweight, a person would likely to become physically more inactive. Obese, physically inactive behavior could create stressed conditions, and these conditions certainly promote with increasing age.

Management of T2DM

The management of T2DM has given attention through medication and lifestyle interventions, including increasing physical activity and healthy dietary habits.

Pharmacological Treatment and Limitations

Several novel pharmacological agents are available for the treatment of diabetes. But the use of drugs for a long time has some adverse side effects and complications, such as drug dependency, and drugs may lose their effectiveness compared with the initial response with time, which would make patients develop drug resistance.^{4,6} Also, the consumption of a large volume of drugs by the population is not healthy for the economy of any country, especially in developing countries like Sri Lanka. Hence, healthy, more viable alternatives have to be invented.

Lifestyle Modification

Treatment of diabetes with the supplement of medications has been developed to maintain blood glucose, lipid profile, stress conditions, and anthropometric measures with behavior change and lifestyle modification.⁷ Lifestyle interventions include the combination of increasing physical activity and adopting healthy dietary habits with the use of recommended dosage of drugs for each individual with diabetes.^{8,9} Implementation and maintenance of physical activity is important for overall health and blood glucose management in individuals with diabetes and preventing the development of prediabetes to T2DM in high-risk individuals. Lifestyle intervention aimed at motivating individuals to maintain body energy by balancing energy gain and consumption. Reducing energy intake and increasing physical activity is a key therapy behind this.¹⁰ Hence, in recent years, several studies have been conducted to evaluate the effect of an increase in physical activity to manage T2DM and also to prevent its complications. Even moderate weight loss resulting from increased physical activity can maintain blood glucose levels by improving insulin sensitivity and other biochemical parameters in patients with T2DM and prevent the development of T2DM in high-risk individuals.¹¹ This review will provide a general overview of the important role of yoga intervention in the prevention and management of T2DM, including common health problems such as overweight, hypertension, high glucose levels, and high cholesterol.

Yoga as a Lifestyle Intervention Tool

Yoga, a form of physical activity, has been studied for several decades and has gained popularity due to its numerous health benefits. It is an efficient, cost-effective, easily performed lifestyle intervention method and has no side effects.¹² Yoga has been identified as a possible solution, and most of the studies have proven its effectiveness in preventing and managing T2DM. Yoga is a traditional Indian exercise routine consisting of various postures (Asana), breathing techniques (Pranayama), sounds, and meditation.¹³ Both short-term and long-term studies have been carried out to assess the efficacy of yoga in controlling T2DM.

Several studies have compared the effectiveness of yoga and other physical training exercises on blood glucose and other parameters.^{7,11,14} In these studies, yoga was considered as an intervention and aerobic training as a control. There is one study that suggested that yoga exercise in T2DM patients is similar to that of conventional physical training exercise because the observed responses (FBS, lipid parameters, and stress-related hormones) are similar in both groups.¹¹ Another study on women with T2DM found that yoga exercise is similar to other physical training exercises in reducing blood glucose, glycosylated hemoglobin (HbA1c), triglycerides (TG), total cholesterol (TC), and VLDL. But they concluded that yoga exercise is better than other physical training exercises in reducing the requirement of oral hypoglycemic

agents, increasing HDL, and decreasing LDL in T2DM.¹⁴ A recent randomized control trial conducted for 3 months observed a decline in fasting plasma glucose in the exercise and yoga groups. But the reduction of HbA1c was observed in the yoga group only, though not significant.⁷ A 4-week intervention study done on T2DM patients in separate groups (only walking, only yoga exercises, and alternate practice of walking with yoga) indicated that participants in all groups had a statistically significant impact on fasting blood glucose (FBG) level.¹⁵ The outcome measures of these studies suggest that yoga interventions seem to be similar to other physical exercises or superior in effects. Combined effects of yoga and physical exercises may be more effective in preventing and managing T2DM.¹⁶

Routine of Yoga Sessions

Most recently published studies have described the yoga sessions in detail with the time duration allocated for each posture and breathing technique.^{4,10,15,17–25} *Surya namaskara*, *Tadasana*, *Trikonasana*, *Paschimottanasana*, *Vajrasana*, *Pavanamuktasana*, *Bujangasana*, *Dhanurasana*, *Vakrasana* as postures (asana) and *Bhastrika*, *Kapalapathi*, *Anulom-viloma*, *Bhramari*, and “Om” chanting are common breathing techniques (pranayama) have been commonly practiced in most studies and reported to significantly contribute to the outcome measures. But none of the studies evaluated the individual contribution of yogic postures on the outcomes. The impact of yogic exercises on outcome measures depends on both the duration and the frequency of yoga sessions. Yoga practice varied in type, duration, and frequency in different studies. For example, a yoga intervention was conducted for 1 week and patients received different yoga practices from morning 5:30 am to night 9:00 pm with counseling sessions,²⁶ whereas another yoga study has been conducted for 9 months.¹⁴ But in most of the studies, yoga sessions were held for 40–60 minutes per session and 3–6 days per week.^{10,11,18,21,25} Session meetings and follow-up periods varied from 7 to 24 weeks.^{11,18,19,22,24,25,27–29} The time and the duration of a yoga session are important because some of the diabetic-related parameters like HbA1c and body mass index (BMI) need to have a long period to show significant effects, while some studies have observed favorable effects in short time periods.

In a study duration of a 3-month-long yoga session, a decline in HbA1c in the yoga group was observed, but it was not significant.⁷ In a different study significantly brought down the high glycemic value after 6 months,²¹ whereas another study followed for a similar time period²⁸ reported no such significant changes in HbA1c. This may be due to the frequency and the duration of yoga sessions because in the first study sessions were held for 6 days per week for 45–60 minutes per day, and in the second study, the frequency was 3 days per week for 3 hours per day. The correct combination of the duration of the study period, time of each session, and frequency of yoga sessions might have an impact on the beneficial effects on the considered outcome measures.

Inclusion Criteria and Exclusion Criteria

Consideration of inclusion and exclusion criteria while designing the study is vital for getting reliable outcomes. Most studies have included 30–60 years old patients with T2DM for a history of 1–10 years^{11,17,23,24} and on recommended oral hypoglycemic drugs as per standard clinical practice.^{12,30} Non-smoker, non-alcoholic,^{11,19,24} and literate patients²⁴ were included. Diabetic patients treated with insulin were excluded because quick falls in FBG levels could occur during yoga sessions.²⁹ Patients not involved in any type of yogic

practice or physical exercise at the time of their inclusion were able to participate in the intervention.^{14,25,31} Most studies included patients both males and females, but several studies included either male or female patients only.^{4,7,32} A study conducted for 10 days observed that women had a higher reduction in blood glucose level than men,³³ but another study indicated that outcome measures (demographic and biochemical parameters) were not statistically significant in a gender specifically.¹¹

As exclusion criteria, most studies have excluded patients with nephropathy, retinopathy (proliferative), neuropathy, and coronary artery disease,^{20,23,30,31} cancer,^{12,19} severe osteoporosis,¹² pulmonary tuberculosis, rheumatoid arthritis, and acute macro- and microvascular complications.^{17,19} Patients without malnutrition or severe complications of diseases like cardiovascular, renal, visual, cerebral,¹¹ and patients with >200 mg/dL fasting blood glucose and 300 mg/dL or higher level of post-meal blood glucose level,¹² and having HbA1c levels between 6 and 9%^{28,34} were excluded.

Outcomes

BP

The practice of yoga is effective in reducing BP in patients with T2DM. An ample number of studies have shown yoga as an effective tool for reducing systolic and diastolic BP.^{7,10,19,22,35,36} The mean systolic and diastolic BP have reduced significantly in the yoga group after 3 months of yoga intervention compared with the control group.^{7,19,22} McDermott et al.¹⁰ observed a significant reduction of BP after 2 months of intervention. The reduction of BP gradually increases if yoga exercises are discontinued. Restarting yoga sessions leads to return BP into normal in patients.²⁹ Pranayama and Shavasana practices are recommended for patients with hypertension.¹⁶

Weight and Body Mass Index

Several intervention studies have shown that yoga practice is effective in reducing body weight, BMI, and waist to hip ratio.^{10,17,20,23,25} Completion of yoga intervention was associated with a 4.56–6.69% reduction of body weight, 1.2 kg/m² of BMI and the average weight reduction was 2.26 kg per person.²³ Two studies reported no significant change in body weight and BMI values compared with the baseline values,^{29,37} and in another 4-month study, patients had a mild decrease in BMI and body weight, which were not statistically significant.⁶ Poor attendance for yoga classes, limited flexibility, comorbidity, lack of basic fitness, lack of confidence, and none of the patients practiced yoga regularly at home have been identified as causes of poor results.²⁹ One study has observed beneficial effects in BMI, but there were no differences in waist circumference and waist-to-hip ratio.¹⁹ Practice of yoga exercises significantly affects in reducing body weight in obese individuals with T2DM.^{10,18} Further studies need to be conducted to prove the effectiveness of yoga in the control of T2DM-related obesity.

Oxidative Stress

Several studies have identified oxidative stress as one of the major components associated with T2DM. Breathing techniques and meditation therapies included in yoga practice may provide anti-stress effects.^{12,22,38} Improvements in some biochemical parameters related to T2DM have been obtained after paying attention to stress reduction.⁸ Malondialdehyde (MDA), protein oxidation (POX), superoxide dismutase (SOD), and phospholipase

A2 (PLA2) have been identified as oxidative stress biomarkers. Malondialdehyde forms as a result of lipid peroxidation, and serum MDA concentrations are higher in patients with T2DM. Six months of yoga practice have significantly reduced the concentration of MDA by 19.9% compared with the baseline value.¹¹ In another study, participants of the yoga group achieved significant improvement in MDA, which led to a mean 20% reduction of oxidative stress.¹⁹ A study on 20 subjects with T2DM also showed a significant reduction of serum MDA and a significant increase of SOD compared with the baseline values.³¹ Forty days of yoga practices significantly reduced the serum MDA concentration from 6.7 to 3.4 nmol/mL.²⁰ However, it is worthwhile to take into consideration, the intervention of a patient's lifestyle through yoga or any other process may create stress conditions in certain individuals and that could be more harmful than beneficial effects achieved from healthy practices.⁸

Fasting Blood Glucose and Post-prandial Blood Glucose

Most studies have examined the effect of yoga on FBG level and post-prandial blood glucose (PPBG) level. Some studies have reported a significant contribution of yogic practices for the reduction of FBG and PPBG, while some studies did not observe a significant reduction of these parameters. Study followed for 40 days has observed reduction of FBG (from 210.7 to 140.4 mg/dL) and PPBG (from 305.5 to 230.5 mg/dL).²⁴ Another study followed for the same period of time showed a significant reduction of FBG (190.1–141.5 mg/dL) and PPBG (276.5–201.7 mg/dL).³⁰ A different study conducted for a very short period found a significant reduction of FBG compared with the baseline value.⁸ Another study conducted for 6 months found a significant decrease of FBG by 29.48%, while the reduction of the control group was 7.48%.¹¹ A 3-month course of yoga exercises has observed a reduction of FBG starting from the 15th day but the fall was not statistically significant. At the end of the study period, a significant reduction of both FBG and PPBG was observed.¹² A study of 20 participants (12 males and 8 females) observed a significant reduction of FBG and PPBG.³¹ Female individuals showed a greater reduction of FBG compared with male participants. Also, the reduction of FBG in participants within the age group 50–59 years was not significant compared to the age group of 40–49 years. Reduction of FBG and PPBG was more significant in patients with poor glycemic control (FPG >126 mg/dL and PPPG >140 mg/dL) than in patients with good glycemic control (FPG <126 mg/dL and PPPG <140 mg/dL).³¹ Another 3-month study of yoga intervention showed a significant decrease in FBG and nonsignificant reduction of PPBG in the sample group while a continuation of medication in the control group has failed to reduce the FBG and PPBG levels at the end of the study period.²²

Several studies observed a significant reduction of FBG^{7,25,26,38,39} or both FBS and PPBG at the end of the study period,^{4,6,10,14,17–20,23,34} and several other studies have also observed a nonsignificant reduction of FBG after the study period.²⁸

HbA1c

Most of the yogic interventions had a significant effect of lowering the HbA1c value in patients with T2DM. One study observed better glycemic control (HbA1c from 9.03 to 7.83) after 40 days of yoga intervention.³⁰ A significant decrease in HbA1c observed in several studies,^{17–19,21,24,40,41} while some recent studies have observed nonsignificant changes in HbA1c at the end of the yoga intervention study period.^{5,28,37}

Lipid Profile

There are several evidence about the beneficial effects of yoga intervention in improving blood cholesterol levels in patients with T2DM. A study conducted for 10 days showed that the concentrations of serum TC, LDL cholesterol, VLDL cholesterol, TC/HDL ratio, and TG were significantly lower, and HDL cholesterol significantly higher compared with the baseline values.⁸ In another study that compared yoga and other physical exercises found a significant reduction in serum TC in both groups at the end of the study period. No significant differences were observed in the concentration of serum TG, VLDL, LDL, and HDL levels in the yoga and conventional exercise groups.¹¹ A significant improvement in lipid profiles was observed in a study followed for 45 days of yoga intervention, but the improvement was not similar in all participants of the study. As a percentage, only 13.66% of patients showed an increase in the concentration of HDL. 25.80%, 20.91%, and 18.18% of patients had a reduction of VLDL, LDL, and TC, respectively.²³ Another study has observed a significant reduction in TG and LDL, but HDL concentration change is not statistically significant.¹⁷ Twelve weeks of yoga intervention has observed that the yoga group had statistically significant changes in TC, TG, HDL, and LDL levels.²⁵ Another comparison study of yoga and other physical activities showed that HDL was increased and the concentration of LDL was reduced with a significant difference in the yoga intervention group. Triglycerides, TC, and VLDL have reduced significantly in both groups.¹⁴ A study conducted a residential yoga program for 6 weeks and followed at home for 12 weeks found that a significant decrease in TC and TG and a nonsignificant reduction in the concentrations of LDL, VLDL, and HDL.⁵ Finally, several other studies have observed a significant effect of lipid profile at the end of the study period.^{20,32}

Adherence to the Yoga Program

Beneficial effects on outcomes would directly rely on continuous attendance to the yoga sessions and regular practice at home. However, continuous adherence to yoga practice is a challenge. The attendance percentage varies from study to study. Several studies have monitored and included the attendance data of each yoga session. One study has shown to have 95.25% of overall attendance for classes.²⁷ In another study, participants were encouraged to do group discussions to enhance the adherence and retention of participants in the study, and all participants completed the yoga program with an average attendance of 81.3%.²⁵ A study followed for 12 weeks of yoga classes reported having an overall 50% attendance, and none of the participants had practiced yoga regularly at home.²⁹ In another study, >80% of attendance for the yoga classes were considered as regular,⁷ and it was indicated that most of the participants had undergone classes regularly. In a different study, patients who did not attend the complete study were excluded from the final analysis.⁴ One study indicated that participants in the yoga group (70%) had higher overall attendance than the control group (63%).¹⁰ In most of the interventions, participants were asked to continue the home practice and maintain a daily log.^{7,8,11,14}

Possible Mechanism of Yoga in the Management of T2DM

The exact mechanism of action of yoga in the management of T2DM is still unknown. Several hypotheses are describing the science behind yoga can link the benefits of doing yoga with diabetes management. Most studies hypothesize that the postures (asana)

might have a beneficial effect on every bone, joints, tissue, and organ in the body. Stretching and relaxation processes happening in tissues during each posture may boost the direct regeneration of beta cells of the pancreas. As a result, the sensitivity of insulin at target tissues may increase and, consequently which may increase the uptake of insulin, and eventually, it may reduce the blood sugar. Improved sensitivity or increased production of liver enzymes could enhance the metabolism of lipids and lipoproteins, which may increase the uptake of TG by adipose tissues.^{17,24,30} Breathing exercises may be involved in the metabolic rate and stress relaxation processes. Combined beneficial effects resulting from postures, breathing techniques, and meditation along with conventional medicine may offer a better feeling of general well-being.¹⁷

Limitations of Studies on Yoga

The findings of studies limit the generalizability of results because of their limitations. Major limitations include small sample size,^{5,17,26,31,34,37} nonrandomized allocation of participants into groups,^{19,21,27} poor collection of data,^{14,17} participant selection,³¹ intervention,^{22,34} the absence of a control group to compare the outcomes,^{5,22,26} adherence of participants to the study.¹⁰ Short duration of the intervention^{26,27} and selecting the patients from the same locality.²¹

SUMMARY AND CONCLUSION

Obese, physically inactive persons are at a high risk of having T2DM. Prevention or management of this epidemic disease could be achieved through education, adopting a healthy lifestyle with the required medications, and continuation of healthy living. Yoga is one such lifestyle intervention practice that has been identified and proved for its beneficial effects on T2DM and associated complications. According to the evidence of past literature used for this review, yoga plays a significant role in the prevention and management of T2DM through the improvement of weight, BP, glycemic parameters, lipid profile, and oxidative stress. Side effects or complications due to yogic practices have not been mentioned up to date in any study conducted. Further studies are much needed with standard study designs considering adequate sample size, appropriate control group, study duration, and course content (right combination of frequency and duration). Most of the studies have been conducted in India, and more studies should be conducted to evaluate the effectiveness of yoga in different populations with different lifestyles.

REFERENCES

1. International Diabetes Federation (2019). IDF DIABETES ATLAS 9th ed, Available from https://www.diabetesatlas.org/upload/resources/material/20200302_133351_IDFATLAS9e-final-web.pdf.
2. American Diabetes Association. 4. Comprehensive medical evaluation and assessment of comorbidities: standards of medical care in diabetes-2020. *Diabetes Care* 2020;43(Suppl 1):S37–S47. DOI: 10.2337/dc20-S004.
3. World Health Organization. Global Report on Diabetes. Geneva: WHO; 2016. Available at: <https://apps.who.int/iris/handle/10665/204871>.
4. Chimkode S, Kumaran SD, Kanhere VV, et al. Effect of yoga on blood glucose levels in patients with type 2 diabetes mellitus. *J clin diagnostic res* 2015;09(4):1–3. DOI: 10.7860/JCDR/2015/12666.5744.
5. Vaibhavi B, Satyam T, Sanjibkumar P, et al. Effect of Holistic module of yoga and ayurvedic panchakarma in type 2 diabetes mellitus—a pilot study. *J Endocrin and Metab Diseases* 2013;03(01):90–98. DOI: 10.4236/ojemd.2013.31014.

6. Mohammed R, Banu A, Imran S, et al. Importance of yoga in diabetes and dyslipidemia. *Int J Res Med Sci* 2016; 3504–3508. DOI: 10.18203/2320-6012.ijrms20162320.
7. Sreedevi A, Gopalakrishnan UA, Ramaiyer SK, et al. A randomized controlled trial of the effect of yoga and peer support on glycaemic outcomes in women with type 2 diabetes mellitus: a feasibility study. *BMC Complement Altern Med* 2017;17(1):100. DOI: 10.1186/s12906-017-1574-x.
8. Bijlani RL, Vempati RP, Yadav RK, et al. A brief but comprehensive lifestyle education program based on yoga reduces risk factors for cardiovascular disease and diabetes mellitus. *J Altern Complementary Med* 2005;11(2):267–274. DOI: 10.1089/acm.2005.11.267.
9. Ramamoorthi R, Gahreman D, Skinner T, et al. The effect of yoga practice on glycemic control and other health parameters in the prediabetic state: a systematic review and meta-analysis. *PLoS ONE* 2019;14(10):e0221067. DOI: 10.1371/journal.pone.0221067.
10. McDermott KA, Rao MR, Nagarathna R, et al. A yoga intervention for type 2 diabetes risk reduction: a pilot randomized controlled trial. *BMC* 2014;14(1):212. DOI: 10.1186/1472-6882-14-212.
11. Gordon LA, Morrison EY, McGrowder DA, et al. Effect of exercise therapy on lipid profile and oxidative stress indicators in patients with type 2 diabetes. *BMC* 2008;8(1):21. DOI: 10.1186/1472-6882-8-21.
12. Amita S, Prabhakar S, Manoj I, et al. Effect of yoga-nidra on blood glucose level in diabetic patients. *Ind J Physiol Pharmacol* 2009;53(1):97–101.
13. Tundwala V, Gupta RP, Kumar S, et al. A study on effect of yoga and various asanas on obesity, hypertension and dyslipidemia. *Int J Basic and Applied Med Sci* 2012;2(1):93–98.
14. Nagarathna R, Usharani MR, Rao AR, et al. Efficacy of yoga based life style modification program on medication score and lipid profile in type 2 diabetes—a randomized control study. *Int J Diab in Developing Countries* 2012;32(3):122–130. DOI: 10.1007/s13410-012-0078-y.
15. Esha K, Prajakta S, Ashok S, et al. Effect of alternate walking and yoga on blood sugar levels in type 2 diabetes. *Ind J Physiol Pharmacol* 2019;63(1):16–20.
16. Sahay BK, Sahay RK. Lifestyle modification in management of diabetes mellitus. *J Ind Med Assoc* 2002;100(3):178–180.
17. Balaji PA, Varne SR, Ali SS. Effects of yoga - pranayama practices on metabolic parameters and anthropometry in type 2 diabetes. *Int Multidiscip Res J* 2011;1(10):01–04.
18. Dash S, Thakur AK. Effect of yoga in patient's with type-II diabetes mellitus. *J Evolution of Med Dental Sci* 2014;3(7):1642–1655. DOI: 10.14260/jemds/2014/2038.
19. Hegde SV, Adhikari P, Kotian S, et al. Effect of 3-Month yoga on oxidative stress in type 2 diabetes with or without complications: a controlled clinical trial. *Diabetes Care* 2008;34(10):2208–2210. DOI: 10.2337/dc10-2430.
20. Malhotra V, Singh S, Sharma SB, et al. The status of NIDDM patients after yoga asanas: assessment of important parameters. *J Clin Diag Res* 2010;4:2652–2667.
21. Nagothu RS, Rajagopalan A, Indla YR, et al. Beneficial effects of yogasanas and pranayama in limiting the cognitive decline in type 2 diabetes. *Natl J Physiol Pharm Pharmacol* 2016;7(3):232–235.
22. Shantakumari N, Sequeira S, Eldeeb R. Effect of a yoga intervention on hypertensive diabetic patients. *J Adv Intern Med* 2012;01(02):60–63. DOI: 10.3126/jaim.v1i2.6526.
23. Singh S, Kyzom T, Singh KP, et al. Influence of pranayamas and yoga-asanas on serum insulin, blood glucose and lipid profile in type 2 diabetes. *Ind J Clin Biochem* 2008;23(4):365–368. DOI: 10.1007/s12291-008-0080-9.
24. Singh S, Malhotra V, Singh KP, et al. A preliminary report on the role of yoga asanas on oxidative stress in non-insulin dependent diabetes mellitus. *Ind J Clin Biochem* 2001;16(2):216–220. DOI: 10.1007/BF02864866.
25. Vaishali K, Kumar KV, Adhikari P, et al. Effects of yoga-based program on glycosylated hemoglobin level serum lipid profile in community dwelling elderly subjects with chronic type 2 diabetes mellitus—a randomized controlled trial. *Phys Occupat Thera Geriat* 2012;30(1):22–30. DOI: 10.3109/02703181.2012.656835.
26. Vinutha HT, Raghavendra BR, Manjunath NK. Effect of integrated approach of yoga therapy on autonomic functions in patients with type 2 diabetes. *Ind J Endocrin Metab* 2015;19(5):653–657. DOI: 10.4103/2230-8210.163194.
27. Dasappa H, Fathima FN, Prabhakar R. Effectiveness of yoga program in the management of diabetes using community health workers in the urban slums of Bangalore city: a nonrandomized controlled trial. *J Family Med Prim Care* 2016;5(3):619–624. DOI: 10.4103/2249-4863.197323.
28. Jyotsna V, Ambekar S, Singla R, et al. Cardiac autonomic function in patients with diabetes improves with practice of comprehensive yogic breathing program. *Indian J Endocr Metab* 2013;17(3):480–485. DOI: 10.4103/2230-8210.111645.
29. Skoro-Kondza L, Tai SS, Gadelrab R, et al. Community based yoga classes for type 2 diabetes: an exploratory randomized controlled trial. *BMC* 2009;9(1):33. DOI: 10.1186/1472-6963-9-33.
30. Singh S, Malhotra V, Singh KP, et al. Role of yoga in modifying certain cardiovascular functions in type 2 diabetic patients. *J Assoc Physicians India* 2004;52:203–206.
31. Duraiswamy V, Balasubramaniam G, Subbiah S, et al. Role of yoga in the management of type 2 diabetes mellitus. *Ind J Student Res* 2011(3):80–84. DOI: 10.5549/IJSR.1.3.80-84.
32. Mondal S, Kundu B, Saha S. Yoga as a therapeutic intervention for the management of type 2 diabetes mellitus. *Int J Yoga* 2018;11(2):129–138. DOI: 10.4103/ijoy.IJOY_74_16.
33. Vijayakumar V, Mooventhan A, Raghuram N. Influence of time of yoga practice and gender differences on blood glucose levels in type 2 diabetes mellitus and normal healthy adults. *Explore (New York)* 2018;14(4):283–288. DOI: 10.1016/j.explore.2017.11.003.
34. Jyotsna VP, Joshi A, Ambekar S, et al. Comprehensive yogic breathing program improves quality of life in patients with diabetes. *Ind J Endocr Metab* 2012;16(3):423–428. DOI: 10.4103/2230-8210.95692.
35. Agte VV, Jahagirdar MU, Tarwadi KV. The effects of sudarshan kriya yoga on some physiological and biochemical parameters in mild hypertensive patients. *Ind J Physiol Pharmacol* 2011;55(2):183–187.
36. Gadham J, Sajja S, Rooha V. Effect of yoga on obesity, hypertension and lipid profile. *Int J Res Med Sci* 2015;3(5):1061–1065. DOI: 10.5455/2320-6012.ijrms20150506.
37. Mullur RS, Ames D. Impact of a 10-minute seated yoga practice in the management of diabetes. *J Yoga Physical Ther* 2016;06(01):224–228. DOI: 10.4172/2157-7595.1000224.
38. Bindra M, Nair S, Darotiya S. Influence of pranayamas and yoga-asanas on blood glucose, lipid profile and hba1c in type 2 diabetes. *Int J Pharm Bio Sci* 2013;4(1):169–172.
39. Vijayakumar V, Mooventhan A, Raghuram N. Effect of short-term yoga-based lifestyle intervention on plasma glucose levels in individuals with diabetes and pre-diabetes in the community. *Diabetes Metabol Syndr* 2017;11(2):597–599. DOI: 10.1016/j.dsx.2017.03.002.
40. Angadi P, Jagannathan A, Thulasi A, et al. Adherence to yoga and its resultant effects on blood glucose in type 2 diabetes: a community-based follow-up study. *Int J Yoga* 2017;10(1):29–36. DOI: 10.4103/0973-6131.186159.
41. Bairy S, Rao MR, Edla SR, et al. Effect of an integrated naturopathy and yoga program on long-term glycaemic control in type 2 diabetes mellitus patients: a prospective cohort study. *Int J Yoga* 2020;13(1):42–49. DOI: 10.4103/ijoy.IJOY_32_19.