ORIGINAL ARTICLE e-ISSN: 2349-0659 p-ISSN; 2350-0964

# Varied Exercise Regimen and its Impact on Glucose Control among Type 2 Diabetes Mellitus Patients: A Systematic Review

R. Vivek, R. Kalidasan

## ABSTRACT

**Objectives:** Systematic evaluation of study varied exercise regimen impact on Hemoglobin A1C and fasting blood glucose (FG) for type 2 diabetes mellitus patients in which age ranged from 30 to 88 years. **Design:** Systematic review, qualitative aspects of analysis followed guideline as per Cochrane handbook for systematic review of intervention and Preferred Reporting Items for Systematic Review and Meta-Analysis. **Data sources:** The 23 randomized controlled trails out of 237 studies paper English language only on Web of Science and PubMed database, as where search place search term used since May 2018 and still April 2019. **Results:** The articles showed that implementation varied exercise regimen of physical exercise consisted aerobic, resistance, both combine form, walking, and endurance based as high-intensity interval training and co-intervention of low calorie diet, medicine, education counseling, and training supervision impose motivation and proper guideline could be glycosylated hemoglobin and FG reduction about type 2 diabetes mellitus patients. **Conclusion:** Varied exercise regimen of physical activity, specifically combine exercise such as endurance based aerobic and resisted exercise could be treated with pure medication to reduce glucose level in type 2 diabetes patients mellitus, managed along with lifestyle change the prolong time risk factors.

**Keywords:** Aerobic exercise, Diabetes, Diet and supervision, Resisted exercise

*Asian Pac. J. Health Sci.*, (2021); DOI: 10.21276/apjhs.2021.8.2.16

## Introduction

International diabetes federations around worldwide survey exposure (Sep 2018) reported 2 in 3 people with type 2 diabetes mellitus, and have affected cardiovascular diseases risk factors.[1] Over 350 million adults are currently at high risk of developing type 2 diabetes. These affect almost 700 million people by 2045.[2] Systematic review like a review that has been acting orderly to fixed plan, approach to minimize errors and random errors which contain in methological section. Critical evaluation in healthcare studies appraise based on inclusion and exclusion criteria and its qualitative aspects of analysis. Therefore, secondary's data are collected from reviews.[3] The complication of diabetes patients are cardiac problem, neuropathy, kidney damage, and retinopathy. Sedentary behavior is one of the most factors for developing type 2 diabetes which have major risk factors of obesity. The accumulation of fat that increased body sizes and reason to tissue and organs changing in their structure also not function normally. Type 2 diabetes is the most common type of diabetes, accounting for around 90% of all diabetes cases.[4] Physical activity is the contraction of skeletal muscle except diaphragm that requires energy to move and action, which is responsible for whole energy expenditure. In the technology world people living with too much eating, and sitting behavior such as as television watching, computer, and game using. It would be getting extra fat in human body and also physiological effect may lead chronic disease. Physical exercise is increased insulin-sensitivity and glucose uptake to show in healthy individual. The core important of exercise intervention to prevent and/or treatment, management of diabetes type 2 patients. Delivery of glucose increased and transported to myocytes, and oxidative enzyme activities. Furthermore, the capacity for glycogen synthesis increases with physical training.[5] Early intervention, ongoing support, and adherence to lifestyle changes are essential factors such as exercise and diet with treating type 2 diabetes patients. The core management strategy of diabetes patients alone with physical exercise and its suggestion from health professional for glycemic control in individuals with type 2 diabetes patients. As per reported American College of Sports Medicine, American diabetes association and joint position statement that on physical exercise have been conducted weekly 150 min exercises, 3 days training program per week but not consecutive 2 days and combined each sessions follow approximately 30–60 min.[6] The meta-analysis that demonstrated a large effect on glycosylated hemoglobin (Hba1c) reduction in type 2 diabetes mellitus patients in studies of resistance exercise consisted with relatively high number of sets per bout of exercises. The study implication could be significant for establishing an ideal exercised protocol for resistance training and prescribing tailor-made exercise programs for patients' diabetes. Authors specify that the Hba1c reduction differed according to the resistance training program was consisted such as frequency, intensity or number of sets.[7] The meta-analysis found that lifestyle intervention showed significant benefit in risk factors which are

Department of Physical Education, Bharathidasan University, Tiruchirappalli, Tamil Nadu, India

**Corresponding Author:** R. Vivek, Department of Physical Education, Bharathidasan University, Tiruchirappalli, Tamil Nadu, India. E-mail: viveknamakkalpd@gmail.com.

**How to cite this article:** Vivek R, Kalidasan R. Varied Exercise Regimen and its Impact on Glucose Control Among Type 2 Diabetes Mellitus Patients: A Systematic Review. Asian Pac. J. Health Sci., 2021; 8(2):79-89.

**Source of support:** Nil

**Conflicts of interest:** None.

**Received:** 31/01/2021 **Revised:** 03/03/2021 **Accepted:** 05/04/2021

known to be associated with the development of cardiovascular disease of type 2 diabetes mellitus. Meta-analysis included 16 trails reported that Hba1c values were significantly favored the intervention groups compared with control groups thus intervention such as exercise, diet, and education.[8] Systematic literature review showed that exercise intervention (different type of exercise) in patients with type 2 diabetes mellitus resulting improved metabolic parameter as glucose control and also in molecular adaptation that enhance cardiac function in most cases.[9] The objectives of systematic review were to study the impact of varied exercise regimen such as aerobic exercise, resistance exercise and both combine form, walking, endurance based, and strength training which can control blood glucose level and Hba1c among type 2 diabetes patients.

## Methods

### Data Sources and Study Selection

The studies searched two database names as Web of Science and PubMed. Web of Science is one of the largest international multidisciplinary which is each subject's area covering with best journal. It was stared since 1900, currently maintained by clarivate analytics. The database acquires world-wide leading citation in various disciplines. User obtain only online subscription basis, and freely available for research purpose in education institute of Bharathidasan University, Tamil Nadu, India. PubMed database opened 24 years ago, provide information about life science and clinical area by nation library of medicine at United States, Nation Institute of Health. The sources of PubMed are easily available on open access abstract and full text paper with reference through search engine. All the information of full text paper collected largest databases.

### Search Strategy

Search term; "physical activity and diabetes mellitus not yoga," "physical exercise and DM type 2," "exercise and Hba1c," "training and glucose," "aerobic exercise and fasting glucose," "strength training and DM," "walking and FBG or fasting blood glucose (FG)," "fitness and FBS," "jogging and DM," "workout and type 2 DM," "A1c and resistance exercise," "practices and FG," and DM* and training. Those which were used Boolean, phrases, and truncation search strategies.

The search term used that opted 179 full text papers in Web of Science in which description, 29 papers have not pre- or post-data outcome concerned to objective of systematic review and data were presents median with inter quartile, 77 have not related to age, exercises groups-quasi experimental design, study more than 3 groups, 36 have been no variables relationship of Hba1c and fating blood glucose, 11 paper other language than English, and nine paper have non-randomized controlled trails. Eight have been cohort, case series, and case–control study. Then, nine studies finally selected. PubMed 58 full text papers follows descriptions, eight papers have not either pre- or post-data value, twenty papers not relevant to research study, 14 studies have not inclusion criteria variables, two has non- randomized controlled trails paper, and then 14 study selected meet inclusion criteria, as shown in the Figure 1. The totally setting 23 randomized controlled trails inclusion out of 237 full text papers review by

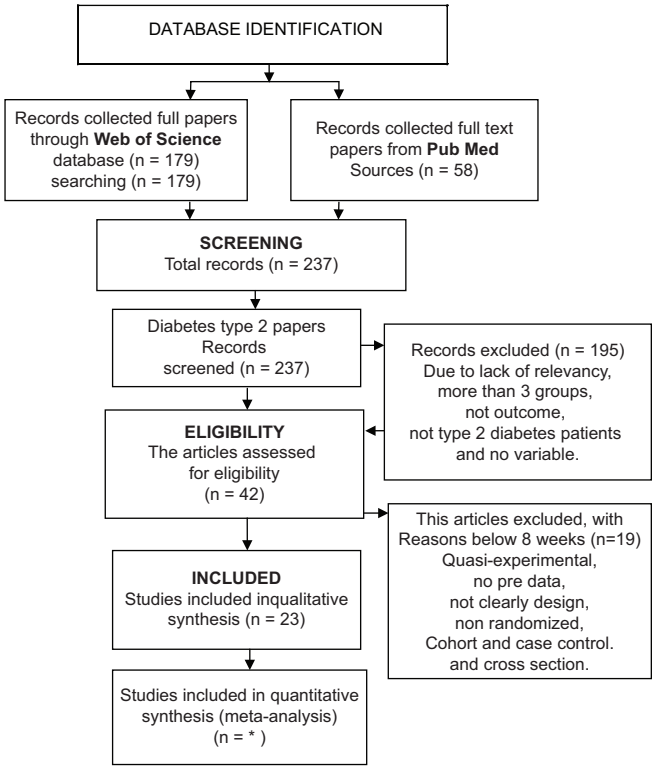


**Figure 1:** Flow chart of the result of literature search. *implies, this is not conducted meta analysis

first author and final selected second author records have among both databases about type 2 diabetes mellitus patients and those online search started since May 2018 and still April 2019 year. Inclusion criteria randomized controlled trails exercise conducted community and/or home based and/or clinical setting in various countries. Inclusion meet 23 papers published year range 1992 to current year. This study systematic review Guideline following the Preferred Repotting Items for Systematic Review and Meta-Analysis, and International database of Prospero prospectively registered our study ID No. CRD42019155268. (https://www.crd.york.ac.uk/prospero/display_record.php?ID=CRD42019155268). Further flow chart diagram that prepared hierarchy as per the study.[10]

### Eligibility Criteria

The first important in the systematic review study decision prepares questions, that well clear idea and how to seek answers. Including eligibility criteria focused address research question on specific type of studies. This study follows as participations, interventions, comparisons, and outcomes and it could be helped pre-specified criteria.

Participants: Type 2 diabetes mellitus patients included diabetes along with obesity and/or overweight, and some diabetes mellitus patients of the participants with comorbidities. Male and female (gender) are study subjects which were ranged age 30–88 criteria selected to inclusion of the study. Intervention: Physical exercise or varied exercise regimen either particular training or combine exercise consisted such as aerobic, resistance, and both combine exercise and endurance based interval training or walking exercise, that have form two or three groups:

Study cointervention diet, and/or medication and education. Comparison: Intervention against which have been compared with no treatment group or placebo group of standard care group or conventional group or active control intervention group or shame group. These all groups' intervention variation compared to physical activity and exercise groups intervention. For example, dosage, intensity, mode, frequency and duration and acting on exercise, medicine, and diet. Outcomes: Randomized controlled trails, studies depended measuring variables of outcome as FG, and hemoglobin A1c or Hba1c which contain papers opted for inclusion of the study. Training setting conducted community center, home, and hospital. Article inclusion published only English. The exclusion criteria have non-randomized controlled trails, case series, and case–control study. Yogic exercise exclusion and exercise below 8 weeks considered exclusion as age below 29 years not considered.

### Data Collection and Analysis

*Data extraction*

The data extraction by two dependent review first and second author from randomized controlled included trails and it could be reported to minimize error, information involved results of interpretation used Microsoft office-excel worksheet. The inclusion characteristics were listed such as author/year, country, study design, age in year (Mean, ±SD), and sample size/groups male/female, Co-Intervention, Treatment, and Control/Active Control groups were documented in the Table 1. Training protocol was shown author/year, exercise, control groups, intensity, and duration which included session, repetition, set and interval then follow as outcome time point and outcome measures are presented in Table 2.

### Measure of Intervention Effect

The study pre-decided outcome measure was selected variables FG and hemoglobin A1C, to which measures of intervention mostly used enzymatic colorimetric methods, glucose oxides methods, glucometer, and chromatography. Other used a few methods measured in clinical laboratory.

### Quality Assessment of Trails

A bias is a systematic error, meaning that multiple processes making replica of the same study would lead the wrong answer on average. The validity of study might have considered two dimensions, first dimension provided whether asking appropriate research question to systematic review study and lead external validity. Second dimension, purpose of the systematic review, it correct answer its research question that is frees from bias and lead internal validity. The internal validity assessment is often referred as assessment of methodological quality. Risk of bias in randomized controlled studies was methodological quality assessed by seven domain bias such as random sequence generation (selection bias), allocation sequence concealment (selection bias), blinding of participants and personal (performance bias), blinding of outcome assessment (detection bias), incomplete outcome data (attrition bias), selecting outcome reporting (reporting bias), and other potential sources bias, as shown in Table 3. Then, categories related judgments of each entry assigning which were the risk of bias as "low risk," "high risk," and 'unclear risk of biases. Assessing risk of bias in included randomized controlled studies, for guideline execution Cochrane hand book for systematic review of intervention in the chapter 8.[11]

### Methodics of Selection of Studies

In this research, type 2 diabetes patients with exercise intervention related full text articles collected from Web of science (179) and Pub-Med (58). Those 237 articles were screening totally in which 195 articles excluded due to lack of relevancy. After that 42 articles were assessing for eligibility in which excluded 19 articles that did not meet inclusion criteria. Remaining 23 articles selected for systematic review.

## Results and Discussion

The 23 randomized controlled trails selected out of 237 full text diabetes type 2 patients. In this varied exercise regimen included studies result which would aerobic or resistance exercises and six trails both combined form, nine studies were aerobic training which is tradition or/and formal exercise including walking three studies opted. Resistance training three trails, early form of exercise keyed up with weight or without weight, resistance band used exercise. Endurance based exercise two studies of interval training. Reviewers often narrow inclusion criteria to deal with heterogeneity by including only those studies reporting a particular outcome. This was kept as guideline for this research writing.[12] In this systematic review has 23 studies but only 12 studies (29,13, 25,31,17,19,16,12,18,15,30,4) were mentioned on type 2 diabetes patients were properly diagnosed as per guideline of world health organisation and/or international diabetes federation and/or American diabetes association and other 11 studies were not mentioned clearly. Inclusion randomized controlled trails were 8 weeks and above following varied exercise regimen of training, Aerobic training[13-20,4] of nine studies were significant difference among FG and Hba1c values. Those studies only[13,16,4] were not significant that reason low intensity level trails[13,4] compare groups took low calorie but despite of low glucose level reduced among type 2 diabetes patients. The study confirms that weight reduction induced by diet that could affect glucose metabolism. Meta-analysis showed that aerobic interval training, which was at low volume and convey larger cardio-metabolic benefit than moderate intensity of continuous training of type 2 diabetes mellitus, in particular for cardio-respiratory fitness and glucose control.[21] Short time side effect could be prevented by prescribed medication but long time complication on diabetes patients delayed by regular physical activity and proper diet following that positive effect on aerobic exercise above 8 weeks.[15] Inclusion[22,23] high-intensity interval training based on endurance exercise and session per day 20 min were conducted to reduce glycemic level.[12] Unsupervised 12 weeks high-intensity interval training reduced in Hba1c of 2.8 mmol/mol (−0.20%) compared to control groups.[24] Trails of meta-analysis, a high-intensity protocol combined exercises were associated with BP reduction of type 2 diabetes mellitus and structured exercise consisted more than 150 min/week.[25] Resistance training[22,26,27] consisted such as functional and traditional exercises had no difference and not furnished session with mention already suitable glycemic level. Study 12 months progressive resistance training, power based equipment

**Table 1:** Characteristics of included study

| S. No | Author/Year | Country | Study design | Age in Year (Mean ± SD) | Sample size groups (M/F) | Co-Intervention | Treatment | Control/active con |
|---|---|---|---|---|---|---|---|---|
| 1 | Rech *et al.*, 2019[27] | Brazil | Parallel group randomized control design | ≥60 year Ex-70.5±7.4 Sham-68±6.5 | 38/Ex-18, Co-21 (m20, F18) | None | Resistance training; 12 weeks and 3 days per week | Active con; stretching workout once per week |
| 2 | Botton *et al.*, 2018[22] | Brazil | Parallel group randomized control design | 60–88 year Ex-70.6±6.7 Co-68.6±7.06 | 26/Ex-13, Co-13 | Diet | Resistance training; 12 months and 3 days per week | Stretching low intensity once per week |
| 3 | Cassidy et *al.*, 2019[24] | England | Parallel group randomized control design | 60±2 year Ex-60±3 Co-59±3 | 22/Ex-11, Co-12(M17, F6) | None | High-intensity interval training; pedal cadence and band resisted exercise 12 weeks, 3 days a week | Standard care |
| 4 | Stefano *et al.*, 2010[28] | Italy | Parallel group randomized control design | (<60 vs. ≥60) year Ex-58.8 (8.5) Co-58.8 (8.6) | 563/Ex-288, Co-275 (M329, F234) | Diet ± oral agent, life stylchange | Intensive exercise; 12 weeks and 3 days per week | Standard care alone Counseling |
| 5 | Rahbar *et al.*, 2017[17] | Iran | Parallel group randomized control design | 40–60 year Ex-48.31 (5.02) Co-48.60 (4.80) | 28/Ex-13, Co-15 | None | Aerobic exercise; treadmill 8 weeks and 3 days per week | Normal routine activity |
| 6 | Motahari-Tabari *et al.*, 2014[15] | Iran | Parallel group randomized control design | 30–65 year Ex-49.29 (1.12) Co-49.0 (1.60) | 53/Ex-27, C0-26(F53) | Diet | Aerobic exercise; stretching and flexibility 8 weeks and 3 days per week | Normal routine activity |
| 7 | Shakil-ur-Rehman *et al.*, 2018[18] | Pakistan | Parallel group randomized control design | 30–70 year Ex-(M) 59.12±05.78 (F) 51.31±5.78 Co-(m) 55.00±8.03 (F) 57.93±06.83 | 102/Ex-51, Co-51(M55, F47) | Routine medicine and diet plan | Aerobic exercise; SSAET program 25 weeks, 3 days per week | Routine medicine and diet plan |
| 8 | Praet *et al.*, 2008[16] | Netherlands | Parallel group randomized control design | 60±9 year Bric-61±9 Madi-59±9 | 37/Bric-18, Medi-19 | Diet guideline | Brisk walking; 12 months, 3 days per week | Medical fitness program; 12 months, 3 session per week |
| 9 | Karstoft *et al.*, 2013[23] | Denmark | Three group randomized control design | Iwt-57.5±2.4 Cwt-60.8±2.2 Co-57±3.0 | 32/Iwt-12, Cit-12Co-8(M20, F12) | Diet -CMG | IWT; Walking, Target energy expenditure, 4 months, 5 session per week CWT; Slow walking Target energy expenditure, 4 months, 5 session per week | Habitual routine lifestyle |
| 10 | Tudor-Locke *et al.*, 2004[29] | Canada | Parallel group randomized control design | 40–60 year Ex-52.8±5.7 Co-52.5±4.8 | 47/Ex-24, C0-23(M26, F21) | PA behaviour change, Education | First step Program; walking, 16 weeks, 3–4 days per week | Standard care |
| 11 | Snel *et al.*, 2012[19] | Netherlands | Parallel group randomized control design | Vex-53.0±2.5 Vlcd-56.1±2.4 | 27/VlcdEx-13, Vlcd-14 (M14, F13) | Diet | Aerobic exercise; cycle ergo meter, 16 weeks, 4 session per week | Very low calorie diet |
| 12 | Kadoglou *et al.*, 2012[14] | Greece | Parallel group randomized control design | 50–70 year Ex-58.4±5.7 Co-62.9±4.2 | 53/Ex-26, Co-27(M19, F34) | Diet | Aerobic exercise; treadmill 12 weeks and 4 times per week | Low intensity PA |
| 13 | Hansen *et al.*, 2009[13] | Belgium | Parallel group randomized control design | 59±8 year Hi-59±2 Li-58±1 | 37/ExHi-19, Li-18(M37) | None | Endurance type exercise program; High-intensity, 6 months, 3 session per week | Low intensity exercise |
| 14 | Kadoglou *et al.*, 2010[30] | Greece | Parallel group randomized control design | 50–65 year Ex-56.83±6.76 Co-60.32±9.28 | 47/Ex-23, Co-24(M15, F32) | None | Brisk walking; 16 weeks, 4 days per week | No exercise, maintain with usual activities |

*(Contd...)*

**Table 1:** *(Continued)*

| S. No | Author/Year | Country | Study design | Age in Year (Mean ± SD) | Sample size groups (M/F) | Co-Intervention | Treatment | Control/active con |
|---|---|---|---|---|---|---|---|---|
| 15 | Kang *et al*., 2016[31] | South Korea | Vgroup randomized control design | Ex-56.0±7.4 Co-57.5±4.6 | 16/Ex-8, C0-8(F16) | None | Aerobic exercise; walking and resistance exercise, 12 weeks, 3 times per week | Standard care |
| 16 | De Lade *et al*., 2016[32] | Brazil | Parallel group randomized control design | St-57±12 At-54±9 | 11/ExSt-5, Aero-6(M5, F6) | None | Aerobic training; 20 weeks, 3 weekly session | Strength training given after aerobic exercise |
| 17 | Mavros *et al*., 2013[26] | Australia | Parallel group randomized control design | Older than 60 year | 84/Ex-36, Sham-48 | None | PRT; high-intensity exercise, 12 months, 3 days per week | Sham exercise; low intensity usual care |
| 18 | Annibalini *et al*., 2017[33] | Italy | Parallel group randomized control design | 55–70 year Ex-57±9.1 Co-60±6.8 | 16/Ex-8, C0-8(M16) | None | Aerobic and strength exercise; 16 weeks, 2-3 times a week | Usual care |
| 19 | Taghizadeh *et al*., 2018[20] | Iran | Parallel group randomized control design | 62.25±3.81 Yr | 20/Ex-10, Co-10(F20) | None | Endurance training; treadmill, 8 weeks, 3 session per week | Not involve any kinds of exercise training |
| 20 | Liu *et al*., 2015[34] | China | Parallel group randomized control design | Ex-52.59±11.43 Co-51.20±11.34 | 42/Ex-22, Co-20(M19, F23) | None | Aerobic and resistance training; 12 weeks, 2-3 session per week | Conventional and drug therapy and psychological counseling |
| 21 | Winding *et al*., 2018[12] | Denmark | Three group randomized control design | Hiit-54±6Yr End-58±8Yr Co-57±7 | 32/Hiit-13, End-12, Co-7(M19, F13) | Diet | HIIT; cycling, 11 weeks, 3 session per week Endurance training; cycling, do same week and session | Energy intake low compare with 2 groups |
| 22 | Yang *et al*., 2017[35] | Canada | Three group randomized control design | 52±1.2 year RT1-52.2±1.2 RT2-49.8±1.4 RT3-54.6±1.2 | 51/RT1-16, RT2-17, RT3-18(M30.F21) | Diet | Resistance and Aerobic training; RT2-High-intensity, 6 months, 5 days a week RT3-Endurance, low intensity, do same above | RT1-usual care |
| 23 | Vanninen *et al*., 1992[4] | Finland | Parallel group randomized control design | 40–60 year male-53±7 Female-54±6 | 78/Ex-38, Co-40(M45, F33) | Diet | Aerobic exercise; walking, jogging, 12 months, 3–4 times week | Conventional treatment |

Ex: Exercise group, Co: Control group, SD: Standard deviation, M/F: Male/Female, SSAET: Supervised structured aerobic exercise training, CGM: Continuous glucose monitor, IWT: Interval walking training, CWT: Continuous walking training, PRT: Progressive resistance training, PA: Physical activity, HIIT: High-intensity interval training

**Table 2:** Training protocol of included study

| *S. No* | *Autor/Year* | *exercise* | *Control/active control* | *Supervision* | *Intensity* | *Duration/session/ Repetitions/Sets/ intervals* | *Outcome time point* | *Outcome measures* |
|---|---|---|---|---|---|---|---|---|
| 1 | Rech *et al.*, 2019[27] | RT program included Function ex and tradition ex squat and bench stepping, knee flex and extension and abdominal crunches | Stretching workout with low intensity-static move for large muscle groups | Yes | F.c- Omni Scale R.E-15 repetition maximum | 12 weeks, 3 days a week, (R) F.Ex 10-15 T.Ex 10-12, (s) F.Ex and T.Ex 2-3, (I) 1–1.30 min | 0 and 12 weeks | Hba1c, FG, Cholesterol |
| 2 | Botton *et al.*, 2018[22] | RT program; strength ex on Tradition machine, free weight and F.Ex squat and steps up and down | Joint mobilization and static stretching for large muscle groups, perform low intensity | NR | F.c- Omni Scale (0 to 10) | 12 weeks, 3 days a week, (R) F.Ex 10–15 T.Ex 10-12,(s) F.Ex and T.Ex 2-3, (I) 1–1.30 min | 0 and 12 months | hba1c, FG, Cholesterol, muscle strength, sit-to-stand, timed up and go RTD 50&200 |
| 3 | Cassidy *et al.*, 2019[24] | High-intensity interval training; the rating exertion (RPE) increased forms 9–13 comfortable Cadence. And resistance band upper body exercise was light | Standard care and routine normal, not change their medicine, PA, diet | Yes | Borg Scale (9–17) RPE | 12 weeks, 3 days a week, (I) 3 min | 0 and 12 weeks | Hba1c, weight, BMI, BP, Sv, Co, Heart rate variability |
| 4 | Stefano *et al.*, 2010[28] | Intensive ex; 150 min/Weeks 2 supervised session of progressive mixed (aerobic and resistance) training-treadmill, cycle ergo-meter | Standard care alone counseling | Yes | 11.25 MET-h/ wk (vo2 max) | 12 months, weekly twice, (5–8) | 0 and 12 months | Hba1c, FG, Upper and lower body Strength, homa-IR, Bp, cholesterol, wc, BMI, OHAS, insulin, Antihypertensive agents, lipid |
| 5 | Rahbar *et al.*, 2017[17] | Aerobic ex; treadmill with no slope. bruce protocol and its increased gradually | Normal routine activity | Yes | 50–70% max heart rate | 8 weeks, 30 min session, 3 days per week | 0 and 8 weeks | Hba1c, FG, ht, wt, BMI, Ef%, cholesterol, BP, micro albumin |
| 6 | Motahari-Tabari *et al.*, 2014[15] | Aerobic ex; stretching and flexibility ex 50 min daily exercise (Brick walking 30 min) | Standard care (normal routine activity) | Yes | 60% max heart rat | 8 weeks, 50 min per session, 3 times a week | 0 and 8 weeks | FG, Plasma insulin, hip.c, wait.c, BMI, wt |
| 7 | Shakil-ur-Rehman *et al.*, 2018[18] | Aerobic ex; supervised structured aerobic ex treadmill training inclination (0–3) divided 5 phases with 5 week duration | Keep routine medication and diet plan | NR | Borg Scale, vo2 max by the resting heart rate | 25 weeks, 20–50 min per session, 3 days a week, | 0 and 25 weeks | Hba1c, FG, plasma insulin level, Insulin resistance, HDL, LDL, Interleukin-6, nitric oxide, cyclooxygenase, RPE, dyspnea level, BMI, Vo2 max |
| 8 | Praet *et al.*, 2008[16] | Brick walking; the endurance type ex consisted of 5–6 Km/h and resistance ex, floor ex own body weight or elastic bands | Medical fitness ex; endurance type ex consisted of interval ex on home trainer and 8 difference ex target upper& lower body | NR | brick- 75 ± 5% MF-73 ± 2% max heart rate | 12 months, 60 min per session, 3 days a weekly | 0 and 12 months | Hba1c, FG, BMI, HOMA, resting heart rate, Bp |

*(Contd...)*

**Table 2:** *(Continued)*

| *S. No* | *Autor/Year* | *exercise* | *Control/active control* | *Supervision* | *Intensity* | *Duration/session/ Repetitions/Sets/ intervals* | *Outcome time point* | *Outcome measures* |
|---|---|---|---|---|---|---|---|---|
| 9 | Karstoft *et al.*, 2013[23] | Interval walking training; JD Mate, used as a pedometer, group had the target energy expenditure rate set for 70% with speed walking. Continuous walking training; target energy expenditure rate set at 55% with slow walking | Habitual life style and JD mate pedometer data uploaded monthly | Yes | IWT: Peak energy ex 70% low to high CWT; 55% peak energy ex moderate intensity | 4 months, 60 min per session, 5 days a week, | 0 and 4 months | Hba1c, FG, vo2 max, Body com, lipids, Bp, CGM glucose |
| 10 | Tudor-Locke *et al.*, 2004[29] | First step programs; pedometer use walking hour while energy used activities goal setting self-monitoring | Group received post card for their participation | NR | PA by approximately 3000-12000 step/ day | 16 weeks, 30 min session, 3–4 days a week | 0 and 16 weeks | Hba1c, FG, cholesterol, 2-h glucose, w.c, h.c, Heart rate, Bp |
| 11 | Snel *et al.*, 2012[19] | Adding ex; training at home for 30 min and a 1 h hospital training aerobic exercise + low calorie diet | Very low calorie diet approximately 450 Kcal/ day | Yes | 70% max capacity cycloergometer | 16 weeks, 30 min session, 4 days a week | 0 and 16 weeks | Hba1c, FG, Bp, cholesterol, average insulin, BMI, Waist cm |
| 12 | Kadoglou *et al.*, 2012[14] | Aerobic exercise; walking or running on treadmill, cycling, calisthenics of upper and lower limps | Walking 3–5 times per week with low intensity | Yes | 60–75% max heart rate | 12 weeks, 45–50 min per session, 4 times a week | 0 and 12 weeks | Hba1c, FG, Bp, cholesterol, BMI, Waist cm |
| 13 | Hansen *et al.*, 2009[13] | Endurance type exercise; walking, cycling, cross-country and sky type exercise. High-intensity exercise 40 min, 118 ± 3 beat per min | Low intensity 55 min, 105 ± 3 heart beat | Yes | HI-75% vo2 Peak moderate to high LI-50% vo2 Peak low to moderate | 6 months, 40–55 min session, 3 session per week | 0, 2 and 6 months | Hba1c, FG, Blood lipid, body com, vo2 max |
| 14 | Kadoglou *et al.*, 2010[30] | Brick walking; goal 150 min/ week of self controlled moderate intensity | No exercise instruction maintain usual habitual activities | Yes | 50–70% | 16 weeks, 30–60 Min per session, 4 days a week | 0 and 16 weeks | Hba1c, FG, Bp, W/H ratio, insulin, cholesterol, vo2 peak |
| 15 | Kang *et al.*, 2016[31] | aerobic = resistance ex; treadmill 30 min, and resistance use weight machine (upper and lower body) | Standard care | NR | Aerobic 60% HRR Resista-60–80% | 12 weeks, 60 min per session, 3 times a week, (R ) 7-12)(S) 2 | 0 and 12 weeks | Hba1c, FG, Wc, insulin cholesterol, Bp, c-reactive protein, HOMA_IR, C peptide |
| 16 | De Lade *et al.*, 2016[32] | Aerobic ex; treadmill ex, bikes, elliptical and upper body cycle ergometer | Strength training; rowing squat, bench press, rowing with dumb, bells, shoulder ex, dumbbells and circuit exercise | Yes | 50–70% | 20 weeks, 50–60 min per session, 3 times weekly, (R) 12–15 (S) 2-3 | 0, 10 and weeks | Hba1c, FG, PP glycemic, cholesterol, seric insulin, HOMA-IR |
| 17 | Mavros *et al.*, 2013[26] | Progressive resistance training; High-intensity, pneumatic resis Equipment power training was concentric and eccentric for 4 s | Low intensity with usual care | Yes | 80% Bore scale rate (15–18) | 12 months, 3 days a week, R-8, S-3 | 0 and 12 months | Hba1c, HOMA2-IR, body com, skeletal muscle mass, Vat, mid thigh muscle attenuation |
| 18 | Annibalini *et al.*, 2017[33] | Aerobic ex; treadmill (walking) & strength ex- horizontal, leg puss & pull down, lat machine, chest press | Usual diabetics care | Yes | aerobic 85% vo2 max Resistance – 45–65% Hr | 16 weeks, A 5–10 min, Resis 30–60 min, 2–3 times a week, R 15–20, S 2–4 | 0 and 16 weeks | Hba1c, FG, BMI, hc, 1-RM, Bp, cholesterol |

*(Contd...)*

**Table 2:** *(Continued)*

| *S. No* | *Autor/Year* | *exercise* | *Control/active control* | *Supervision* | *Intensity* | *Duration/session/ Repetitions/Sets/ intervals* | *Outcome time point* | *Outcome measures* |
|---|---|---|---|---|---|---|---|---|
| 19 | Taghizadeh *et al*., 2018[20] | Endurance type exercise; moderate intensity treadmill walking or running | Not involve any kinds of training | NR | 60–75% | 8 weeks, 35–50 min per session, 3 session a week | 0 and 8 weeks | Hba1c, FG, HOMA -IR, vo2 max, body fat, BMI |
| 20 | Liu *et al*., 2015[34] | Aerobic ex; home based ex start with slow and low intensity, Resis ex elastic band (borg scale 11–14) | Convention and drug therapy, psychological counseling | Yes | A 40–60% R 50–60% | 12 weeks, 3 session per week, R-2-5 times a week, Re 8–10, S-2 | 0 and 12 weeks | Hba1c, FG, cholesterol, HOMA-IR, Fin, Pbg |
| 21 | Winding *et al*., 2018[12] | High-intensity interval training; 11 week bicycle intervention consisting of 20 min/session and 95% of W peak Endurance training; 11 week bicycle intervention consisting of 40 min/session and 50% of W peak | Energy intake low Compare to both groups | NR | HIIT- cycling of 1 min at 95% W peak ENDU-cycling at 50% W peak | 11 weeks, 3 session per week, In-1 min | 0 and 11 weeks | Hba1c, FG, vo2 max, Body com, lipids, CGM |
| 22 | Yang *et al*., 2017[35] | RT2; High-intensity RT low repetition 75% of 1 RM RT3; Endurance RT low intensity high repetition 50% of 1 RM | RT1; low intensity, high repetition lowest ex volume 50% of 1 RM | Yes | R2-High-intensity (7-RM) R3-Low Intensity (15-RM) | 6 months, 5 days a week, R2-(Re) 7, R3-(Re) 15, S 2–3 | 0 and 6 Months | Hba1c, FG, cholesterol, vo2 max, BMI, hc, body fat, lean mass |
| 23 | Vanninen *et al*. 1992[4] | Aerobic ex; walking, jogging, cycling, cross-country, occupation and recreational activity | Standard care | Yes | 30-60% | 12 months, 3–4 times a week, 30–60 min per session, | 3, 0, 12 months | Hba1c, FG, FP insulin, cholesterol, max oxygen uptake, serum triglycerides |

RT: Resistance training, F.Ex: Functional exercise, T.Ex: Traditional exercise, Hba1c: Glycosylated hemoglobin, FG: Fasting blood glucose, RPE: Rating of perceived exertion, NR: Not report, Sv: Stroke volume, Co: Cardiac output, Bp: Blood pressure, PR: Peripheral resistance, Ex: Exercise, PA: Physical activity, HOMA-IR: Homeostasis model assessment, OHAS: Oral hypoglycemic agents, BMI: Body mass index, HT: Height, WT: Weight, EF: Max, ejection fraction, Hip.C: Hip circumference, Wait. C: Waist circumference, HDL: High-density lipoprotein, LDL: Low-density lipoprotein, CGM: Continuous glucose monitor, HRR: Heart rate reserve, 1RM: Maximum repetition, FIN: Fasting insulin

**Table 3:** Risk of bias assessment in included study as per Cochrane bias tool

| S. No | List of studies | Random sequence generation bias | Allocation concealment bias | Blinding of participants and performance bias | Blinding of outcome assessment bias | Incomplete Outcome Data bias | Selecting reporting bias | Other sources of bias |
|---|---|---|---|---|---|---|---|---|
| 1 | Rech *et al*., 2019[27] | Low | Low | Low | Low | Unclear | Low | Low |
| 2 | Botton *et al*., 2018[22] | Low | Unclear | Unclear | Low | Unclear | Low | Low |
| 3 | Cassidy *et al*., 2019[24] | Low | Unclear | Unclear | Low | Low | Low | Low |
| 4 | Stefano *et al*., 2010[28] | Low | Low | Low | Low | Low | Low | Low |
| 5 | Rahbar *et al*., 2017[17] | Low | Unclear | High | Low | Low | Low | Low |
| 6 | Motahari-Tabari *et al*., 2014[15] | Low | Unclear | Unclear | Unclear | Low | Low | Low |
| 7 | Shakil-ur-Rehman *et al*., 2018[18 | Low | Unclear | High | Unclear | Low | Low | Low |
| 8 | Praet *et al*., 2008[16] | Low | Low | Low | Low | Low | Low | Low |
| 9 | Karstoft *et al*., 2013[23] | Low | Unclear | Low | Low | Low | Low | Low |
| 10 | Tudor-Locke *et al*., 2004[29] | Low | Unclear | Low | Unclear | Low | Low | Low |
| 11 | Snel *et al*., 2012[19] | Low | Unclear | Low | Low | unclear | Low | Low |
| 12 | Kadoglou *et al*., 2012[14] | Low | Unclear | High | Unclear | Low | Low | Low |
| 13 | Hansen *et al*., 2009[13] | Low | Unclear | High | Unclear | Low | Low | Low |
| 14 | Kadoglou *et al*., 2010[30] | Low | Unclear | High | Unclear | Low | Low | Low |
| 15 | Kang *et al*., 2016[31] | Low | Unclear | Unclear | Unclear | Low | Low | Low |
| 16 | De Lade *et al*., 2016[32] | Low | Unclear | High | Unclear | Low | Low | Low |
| 17 | Mavros *et al*., 2013[26] | Low | Unclear | Low | Low | Low | Low | Low |
| 18 | Annibalini *et al*., 2017[33] | Low | Unclear | High | Unclear | Low | Low | Low |
| 19 | Taghizadeh *et al*., 2018[20] | Low | Unclear | Unclear | Unclear | Low | Low | Low |
| 20 | Liu *et al*., 2015[34] | Low | Unclear | Unclear | Unclear | Low | Low | Low |
| 21 | Winding *et al*., 2018[12] | Low | Unclear | Unclear | Unclear | Low | Low | Low |
| 22 | Yang *et al*., 2017[35] | Low | Unclear | Low | Low | Unclear | Low | Low |
| 23 | Vanninen *et al*., 1992[4] | Low | Unclear | Low | Low | Unclear | Low | Low |

used high-intensity of 80% could have significant difference with compare groups. Meta-analysis trails showed that resistance band smaller effect on Hba1c and found in meta-analysis in participants with type 2 diabetes mellitus. The resistance band studies were training period 12–16 weeks in duration, with a little reduction glucose, but free weight or weight machine used duration of 3 and 6 months have showed significant reduction. The resistance band training was not assessing resistance precisely to ensure optimal progression to higher loads. However, free weight or weight machine exact quantities of weight were assessed. However, resistance band training was not important effect, there is reason to key difference at studies used free weight and weight machine, and has contributed to this lesser reduction in Hba1c.[36] Endurance based interval training [24,12] exercise, this reviews based 12 weeks training high-intensity interval exercise well difference compared groups on Hba1c and FG, but minimum improvement in cardiac function. Therefore, intensity 50–60%, three sessions weekly with 40–60 min and considered exercise supervision. The walking training three studies[30,23,29] nine and ten were showed that first step program is an effect physiological adaptation to type 2 diabetes mellitus patients with cardiac problem. Karstoft study was three groups, one had interval walking training reduced hyperglycemic level but there were no significance different and post-intervention parameter was measured at least 48 h after and up 7 days. Measures would have to lead under estimation of benefits and three groups exercise pre-post values of Hba1c and FG were almost reduced, but difference had not compared two intervention groups except conventional group. Clinical messages that walking training frequency should be fairly high on average 3–5 times per week, in session lasting from 20 to 60 min, to be effective in improving walking performance.[37] Walking exercise patients had persistent motive to goal follow supervised sessions and strictly diet control would be significant. The capacity for glycogen synthesis increases with physical training.[5] Type 2 diabetes patients' two group comparisons which have larger effect size associated with exercise prescription, fitness testing, supervised exercise, group session, and recommendations for longer duration exercise session.[38] The aim of Italian diabetes and exercise study was assessed whether a strategy combining prescribed and supervision mixed (aerobic and resistance) training program alone with structured exercise counseling impact lead to Hba1c level and cardiovascular risk to reduce.[28] American diabetes association as per 150 min/week of moderate intensity activity corresponding to MET- h/wk and new information, this study highly intensive exercise combine form (aerobic and resistance training) strategy effective Hba1c with lifestyle change which was supervised that superior continuous reinforcement counseling. The study found that combined resistance and aerobic regimens improved glycemia control to greater extent than either aerobic or resistance alone.[39] The study 6 months longer training of combines both aerobic and resistance training impact was feasible weekly supervised intensity 50–75% (1-RM) and volume 2–3 sets and 7–15 repetitions advantage an AT routine before initiating RT.[35] The review shown that the implementation of physical activity programs (aerobic, resistance, flexibility, and combined exercise), based on nutrition with low glycemia index, calorie restriction, and education session about type 2 diabetes mellitus patients improve blood glucose level.[40] The clinical favorable impact of diabetes self-management education on reduction in glycogenic control is critical important because glycemic control is among the strongest predictors of disease.[41] Aerobics and resistance both combine[31-35,28] form exercises above 8 weeks of exercise with 80% intensity, 40–60 per session and 3 days a week that might be significant difference in hemoglobin a1c among compared group. However, 8 weeks low to moderate intensity or weekly twice, 30–40 min exercises were not significant difference in compared group although within pre-post FG to reduce minimum. Authors' statement that systematic review indicates the evidence the effectiveness of resistance exercise compared to aerobic exercise was no difference in values of Hba1c and cholesterol; however, it

was increase in $vo_{2\ max}$ favoring of type 2 diabetes mellitus.[42] In the systematic review, core study analysis might be combine exercise possible with prescribed medicine, diet, and supervision. The meta-analysis found that lifestyle intervention showed significant benefit in risk factors to which associated with development of cardiovascular disease of type 2 diabetes mellitus. Meta-analysis included 16 trails reported data were Hba1c significantly favored the intervention groups compared with control groups thus intervention such as exercise, diet, and education.[8]

### Strength and Limitation

The systematic review, impact of intervention such as aerobic exercise, resistance exercise, and combine form (strength and endurance based) of exercises, Hba1c, and FG control among type 2 diabetes mellitus patients. Therefore, combine basis exercises were significant difference on glucose reduced than the resistance exercise no reduction appropriated glucose level and co-intervention of diet, medication, and education counseling. Supervision and exercise proper guideline gave motivation on diabetes patients to additional impose training program. Exercise before resistance exercise, began with endurance based exercise. All the exercises program various duration from 8 weeks to 12 months to which vary age groups from 30 to 88 years. This systematic review, study conducted. and based on Web of Science and PubMed database obtained paper only and varied country place where as different geographical setting. Some of the randomized controlled trails adverse affect among type 2 diabetes mellitus patients, who were absent following training program. The study has 25% to loss the follow-up of training program.[28]

## Conclusion

The worldwide burden of diabetes mellitus is highly and growing that which contributors to morbidity and mortality. The study conclusion that high-intensity interval exercise were conducted 12 weeks programs following 3–4 session for more than 30 min weekly and 3 days per week training was significance reduction in Hba1c and FG. High-intensity exercise sufficient duration for post-exercise energy expenditure, aerobic exercise of moderate to vigorous intensity (60–80% max heart rate). Resistance training result was less significant energy expenditure than aerobic exercise. Combine training of aerobic and resistance exercise, the intensity of at least 60% of $HR_{peak}/HR_{max}$ or 55% of $vo_{2\ max}$ for aerobic exercise and 50% of 1RM for resistance training generally showed, session must followed 40–60 min statistically significant result. This study suggestion starting aerobic exercises before resisted exercise would be significant benefits. Study can be combine (endurance and strength) form best result for diabetes type 2 patients with proper regular guideline exercise, supervision, diet following by dietician and education counseling might be occurred Hba1c and FG reduced significantly. It could minimize the risk of cardiovascular disease.

## Acknowledgment

I graceful thanks to Dr. VinodKumar, BAMS, MD (Research Officer, National Institute of Mental Health & Neurosciences, INDIA) as well as Dr. Sudhaselvi, MBBS., MD (General medicine, Govt. Hospital, Salem [Dt], INDIA) who gave us wonderful research idea about systematic review on type 2 diabetes mellitus patients. Area clarified with specialists' person emerging answer on varied exercise regimen impact on glucose control for type 2 diabetes mellitus patients.

## References

1. International Diabetes Federation. IDF News. Brussels, Belgium: International Diabetes Federation; 2018. Available from: https://www.idf.org/news/156:idf-global-survey-reveals-2-in-3-people-with-type-2-diabeteshave-cvd-risk- factors.html.
2. International Diabetes Federation. IDF Atlas. 8th ed. Brussels, Belgium: International Diabetes Federation; 2017. Available from: https://www.idf.org/search.html?searchword=diabetes%20type%202&searchphrase=all.
3. Egger M, Davey-Smith G, Altman D. Systematic Reviews in Health Care: Meta-Analysis in Context. 2nd ed. London: BMJ Books; 2001.
4. Vanninen E, Uusitupa M, Siitonen O, Laitinen J, Länsimies E. Habitual physical activity, aerobic capacity and metabolic control in patients with newly-diagnosed Type 2 (non-insulin-dependent) diabetes mellitus: Effect of 1-year diet and exercise intervention. Diabetologia 1992;35:340-6.
5. Goedecke J, Ojuka E. Diabetes and Physical Activity. Vol. 60. Sydney: Karger Medical and Scientific Publishers; 2014.
6. Colberg SR, Albright AL, Blissmer BJ, Braun B, Chasan-Taber L, Fernhall B, *et al*. Exercise and Type 2 diabetes: American college of sports medicine and the American diabetes association, joint position statement. Med Sci Sports Exerc2010;42:2282-303.
7. Ishiguro H, Kodama S, Horikawa C, Fujihara K, Hirose AS, Hirasawa R, *et al*. In search of the ideal resistance training program to improve glycemic control and its indicationfor patients with Type 2 diabetes mellitus: A systematic review and meta-analysis. Sports Med 2016;46:67-77.
8. Chen L, Pei JH, Kuang J, Chen HM, Chen Z, Li ZW, *et al*. Effect of lifestyle intervention in patients with Type 2 diabetes: A meta-analysis. Metabolism 2015;64:338-47.
9. Verboven M, Van Ryckeghem L, Belkhouribchia J, Dendale P, Eijnde BO, Hansen D, Bito V. Effect of exercise intervention on cardiac function in Type 2 diabetes mellitus: A systematic review. Sports Med 2019;49:255-68.
10. Richars L, Polk C. PRISMA Preferred Reporting Items for Systematic Review and Meta-Analysis; 2017. Available from: http://www.prisma-statement.org/PRISMAStatement/Checklist.aspx.
11. Higgins JP, Altman DG. Assessing risk of bias in included studies. In: Sterne JA, editor. Cochrane Handbook for Systematic Review of Intervention. Ch. 8. United Kingdom: Cochrane Collaboration; 2011.
12. Winding KM, Munch GW, Iepsen UW, Van Hall G, Pedersen BK, Mortensen SP. The effect on glycaemic control of low-volume high-intensity interval training versus endurance training in individuals with Type 2 diabetes. Diabetes Obesity Metab 2018;20:1131-9.
13. Hansen D, Dendale P, Jonkers RA, Beelen M, Manders RJ, Corluy L, *et al*. Continuous low to moderate-intensity exercise training is as effective as moderate- to high-intensity exercise training at lowering blood HbA1c in obese Type 2 diabetes patients. Diabetologia 2009;52:1789-97.
14. Kadoglou NP, Vrabas IS, Kapelouzou A, Lampropoulos S, Sailer N, Kostakis A, *et al*. The impact of aerobic exercise training on novel adipokines, apelin and ghrelin, in patients with Type 2 diabetes. Med Sci Monit 2012;18:CR290-5.
15. Motahari-Tabari N, Shirvani MA, Shirzad-e-Ahoodashty M, Yousefi-Abdolmaleki E, Teimourzadeh M. The effect of 8 weeks aerobic exercise on insulin resistance in Type 2 diabetes: A randomized clinical trial. Glob J Health Sci 2014;7:115-21.
16. Praet SF, Van Rooij ES, Wijtvliet A, Boonman-De Winter LJ, Enneking T, Kuipers H, *et al*. Brisk walking compared with an individualised medical fitness programme for patients with Type 2 diabetes: A randomised controlled trial. Diabetologia 2008;51:736-46.

17. Rahbar S, Naimi SS, Soltani AR, Rahimi A, Baghban AA, Rashedi V, *et al*. Improvement in biochemical parameters in patients with Type 2 diabetes after twenty-four sessions of aerobic exercise: A randomized controlled trial. Iran Red Crescent Med J 2017;19:e13931.
18. Shakil-ur-Rehman S, Karimi H, Gillani SA, Amjad I, Ahmad S, Yaseen A. Response to a supervised structured aerobic exercise training program in patients with Type 2 diabetes mellitus does gender make a difference? A randomized controlled clinical trial. J Natl Med Assoc 2018;110:431-9.
19. Snel M, Gastaldelli A, Ouwens DM, Hesselink MK, Schaart G, Buzzigoli E, Jazet IM. Effects of adding exercise to a 16-week very low-calorie diet in obese, insulin-dependent Type 2 diabetesmellitus patients. J Clin Endocrinol Metab 2012;97:2512-20.
20. Taghizadeh M, Ahmadizad S, Naderi M. Effects of endurance training on hsa-miR-223, P2RY nd platelet function in Type 2 diabetic patients. Clin Hemorheol Microcirc 2018;68:383-9.
21. Qiu S, Cai X, Sun Z, Zügel M, Steinacker JM, Schumann U. Aerobic interval training and cardiometabolic health in patients with Type 2 diabetes: A meta-analysis. Front Physiol 2017;8:957.
22. Botton CE, Umpierre D, Rech A, Pfeifer LO, Machado CL, Teodoro JL, *et al*. Effects of resistance training on neuromuscular parameters in elderly with Type 2 diabetes mellitus: A randomized clinical trial. Exp Gerontol 2018;113:141-9.
23. Karstoft K, Winding K, Knudsen SH, Nielsen JS, Thomsen C, Pedersen BK, *et al*. The effects of free-living interval-walking training on glycemic control, body composition, and physical fitness in Type 2 diabetic patients: A randomized, controlled trial. Diabetes Care 2013;36:228-36.
24. Cassidy S, Vaidya V, Houghton D, Zalewski P, Seferovic JP, Hallsworth K, *et al*. Unsupervised high-intensity interval training improves glycaemic control but not cardiovascular autonomic function in Type 2 diabetes patients: A randomised controlled trial. Diabetes Vasc Res 2019;16:69-76.
25. Figueira FR, Umpierre D, Cureau FV, Zucatti AT, Dalzochio MB, Leitão CB, *et al*. Association between physical activity advice only or structured exercise training with blood pressure levels in patients with Type 2 diabetes: A systematic review and meta-analysis. Sports Med 2014;44:1557-72.
26. Mavros Y, Kay S, Anderberg KA, Baker MK, Wang Y, Zhao R, *et al*. Changes in insulin resistance and HbA1c are related to exercise-mediated changes in body composition in older adults with Type 2 diabetes: Interim outcomes from the GREAT2DO trial. Diabetes Care 2013;36:2372-9.
27. Rech A, Botton CE, Lopez P, Quincozes-Santos A, Umpierre D, Pinto RS. Effects of short-term resistance training on endothelial function and inflammation markers in elderly patients with Type 2 diabetes: A randomized controlled trial. Exp Gerontol 2019;118:19-25.
28. Stefano B, Silvano Z, Antonio N, Pierpaolo DF, Stefano C, Patrizia C, *et al*. Effect of an intensive exercise intervention strategy on modifiable cardiovascular risk factors in subjects with Type 2 diabetes mellitus: A randomized controlled trial: The Italian diabetes and exercise study (IDES). Arch Intern Med 170:1794-803.
29. Tudor-Locke C, Bell RC, Myers AM, Harris SB, Ecclestone NA, Lauzon N, *et al*. Controlled outcome evaluation of the first step program: A daily physical activity intervention for individuals with Type II diabetes. Int J Obes 2004;28:113-9.
30. Kadoglou NP, Vrabas IS, Sailer N, Kapelouzou A, Fotiadis G, Noussios G, *et al*. Exercise ameliorates serum MMP 9 and TIMP 2 levels in patients with Type 2 diabetes. Diabetes Metab 2010;36:144-51.
31. Kang SJ, Ko KJ, Baek UH. Effects of 12 weeks combined aerobic and resistance exercise on heartrate variability in Type 2 diabetes mellitus patients. J Phys Ther Sci 2016;28:2088-93.
32. De Lade CG, Marins JC, Lima LM, De Carvalho CJ, Teixeira RB, Albuquerque MR, *et al*. Effects of different exercise programs and minimal detectable changes in hemoglobin A1c in patients with Type 2 diabetes. Diabetol Metab Syndr 2016;8:1-9.
33. Annibalini G, Lucertini F, Agostini D, Vallorani L, Gioacchini A, Barbieri E, *et al*. Concurrent aerobic and resistance training has anti-inflammatory effects and increases both plasma and leukocyte levels of IGF-1 in late middle-aged Type 2 diabetic patients. Oxid Med Cell Longev 2017;2017:3937842.
34. Liu Y, Liu S, Cai Y, Xie K, Zhang W, Zheng F. Effects of combined aerobic and resistance training on the glycolipid metabolism and inflammation levels in Type 2 diabetes mellitus. J Phys Ther Sci 2015;27:2365-71.
35. Yang P, Swardfager W, Fernandes D, Laredo S, Tomlinson G, Oh PI, *et al*.Finding the optimal volume and intensity of resistance training exercise for Type 2 diabetes: The forte study, a randomized trial. Diabetes Res Clin Pract 2017;130:98-107.
36. McGinley SK, Armstrong MJ, Boulé NG, Sigal RJ. Effects of exercise training using resistance bands on glycaemic control and strength in Type 2 diabetes mellitus: A meta-analysis of randomised controlled trials. Acta Diabetol 2014;52:221-30.
37. Peurala S, Karttunen A, Sjogren T, Paltamaa J, Heinonen A. Evidence for the effectiveness of walking training on walking and self-care after stroke: A systematic review and meta-analysis of randomized controlled trials. J Rehabil Med 2014;46:387-99.
38. Nielsen PJ, Hafdahl AR, Conn VS, LeMaster JW, Brown SA. Meta-analysis of the effect of exercise interventions on fitness outcomes among adults with Type 1 and Type 2 diabetes. Diabetes Res Clin Pract 2006;74:111120.
39. Oliveira C, Simões M, Carvalho J, Ribeiro J. Combined exercise for people with Type 2 diabetes mellitus: A systematic review. Diabetes Res Clin Pract 2012;98:187-98.
40. Barreira E, Novo A, Vaz JA, Pereira AM. Dietary program and physical activity impact on biochemical markers in patients with Type 2 diabetes: A systematic review. Atencion Primaria 2018;50:590-610.
41. Chrvala CA, Sherr D, Lipman RD. Diabetes self-management education for adults with type diabetes mellitus: A systematic review of the effect on glycemic control. Patient Educ Counseling 2016;99:926-43.
42. Nery C, De Moraes SR, Novaes KA, Bezerra MA, Silveira PV, Lemos A. Effectiveness of resistance exercise compared to aerobic exercise without insulin therapy in patients with Type 2 diabetes mellitus: A meta-analysis. Braz J Phys Ther 2017;21:400-15.