EFFECTIVENESS OF HIGH INTENSITY INTERVAL TRAINING AMONG INDIVIDUALS WITH TYPE 2 DIABETES MELLITUS: A SYSTEMATIC REVIEW

Darmawati I[1], Nasution LA[1], and Fitriana LA[1].
[1]Faculty of Sports and Health Education, Universitas Pendidikan Indonesia, 40154 Bandung, Indonesia

Correspondence:
Irma Darmawati
Faculty of Sports and Health Education,
Universitas Pendidikan Indonesia,
40154 Bandung, Indonesia
Email: irmadarmawati@upi.edu

Abstract

Type 2 Diabetes Mellitus (T2DM) case management focuses on maintaining therapeutic goals and improving quality of life. Recent evidence highlights the benefits of high-intensity interval training (HIIT) as a therapeutic treatment in T2DM. However, the relationship remains unclear between the effectiveness of HIIT and T2DM. This study aimed to identify published literature that explored the effectiveness of HIIT on T2DM. We conducted a systematic review of existing literature from electronic databases: Pubmed, Proquest, and Science Direct between 2015-2020 according to PRISMA guidelines. Data were extracted based on the PICOS framework. The methodological quality of these studies was assessed using the Critical Appraisal Skills Programme (CASP) tool. Study bias was assessed using Review Manager 5.3. A total of 11 articles from 503 studies were included. Eleven randomized controlled trials found that HIIT programmes obtain a clinically relevant outcome in reducing blood glucose, improving glycemic control with a reduction in HbA1c, reducing capillary glycemia, and decreasing cardiac function. This review suggests that HIIT is effective and safe for managing T2DM. The evidence consistently demonstrates that HIIT improves health condition and reduce risk factors associated with T2DM. It is critical to encourage further research to establish medium to long-term effects and cost-effectiveness of HIIT among individuals with T2DM.

Keywords: Blood Glucose, Glycemic Control, High-Intensity Interval Training, Type 2 Diabetes Mellitus, Quality of Life

Introduction

Non-communicable diseases (NCDs) are the leading causes of death globally, killing more people each year than all other causes combined. Diabetes mellitus is a severe and chronic non-communicable disease that occurs when the pancreas does not produce enough insulin or cannot effectively use its insulin (1). Type 2 diabetes mellitus (T2DM) is a significant health problem, and its prevalence has increased at an alarming rate. Almost half a billion people in the world live with diabetes. In 2019, it was estimated that 463 million people have diabetes, and this number is expected to reach 578 million by 2030 and 700 million by 2045 (2). Increased cases year after year has made T2DM the highest cause of death in the world.

T2DM case management is focused on maintaining therapeutic goals and improving quality of life. All treatment aims to achieve and maintain optimal blood glucose, blood pressure levels, lipid level, and prevent or delay chronic complications of diabetes. T2DM can be a lifelong disease and people must be able to adapt to it and make self-care fulfilment efforts throughout their life. The primary self-care is the management of eating and exercise. Exercise is an essential component of the T2DM lifestyle as a first-line, non-pharmacological treatment. Exercise may be able to improve glycemic control, insulin sensitivity, oxidative capacity, and crucial metabolic parameters (3). High-intensity interval training (HIIT) is a healthy and beneficial exercise strategy for T2DM patients. HIIT can be characterized by a brief period of vigorous exercise followed by short periods of rest. Exercise training has been suggested to reduce vascular resistance during submaximal exercise in obese individuals with metabolic syndrome (4). However, the relationship remains unclear between the effectiveness of HIIT and individuals with T2DM.

This review aims to provide an overview of recent evidence in HIIT and its benefits to individuals with T2DM. In addition, we also provide a beneficial explanation of HIIT, its effectiveness in diabetes management, and HIIT programme recommendations to implement by individuals with T2DM. The subjects in this study studied were individuals with T2DM for at least for six months. The intervention was HIIT without any other interventions. The outcome was the effect of HIIT on an individual with T2DM.

Materials and Methods

This review used the Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) guidelines (5).

Search strategy

Pubmed, Proquest, and Science Direct was used in this systematic review to provide a more extensive database, with the following combination of two main keywords ('Diabetes Mellitus' OR 'Diabetes Mellitus Type 2' OR 'T2DM' OR 'Noninsulin-Dependent Diabetes Mellitus') AND ('High-Intensity Interval Training' OR 'Interval Training' OR 'High-Intensity Intermittent Exercise'). In this review, journal articles were limited to full text publications between 2015-2020, published in English. The journals must contain randomized controlled trials and participants must be individuals with T2DM for at least for six months. Exclusion criteria were studies with respondents who had other comorbidities such as hypertension and gout.

Data extraction

Three reviewers independently gave each source a code and extracted the essential information using the same standard form and quality of study assessed by Critical Appraisal Skills Programme (CASP) for the RCT tool. CASP is a high quality instrument used to assess research articles with certain designs (6). For this reason, we chose CASP to assess the quality of the articles as a whole, while the Review Manager was used to assess bias, specifically for each selected research article.

Type of study

This review included randomized controlled trial studies related to the effect of high-intensity interval training (HIIT) in Type 2 diabetes mellitus. We considered all experimental studies that used HIIT in the intervention group compared with the control group without intervention and/or other interventions for efficacy comparisons. The study outcomes were improved glycemic control, body composition, and functional capacity in individuals with diabetes.

Risk of bias assessment

Three reviewers independently assessed the quality of the study design using the standard form of the CASP tool (7). We used Review Manager (RevMan version 5.3) from the Cochrane Collaboration, a free software for assessing outcomes and risk of bias. The reviewers evaluated the quality of the selected articles using the CASP instrument and assesses the risk of bias in each article using the Review Manager. Figures 1 and 2 illustrate the findings of the bias assessment.

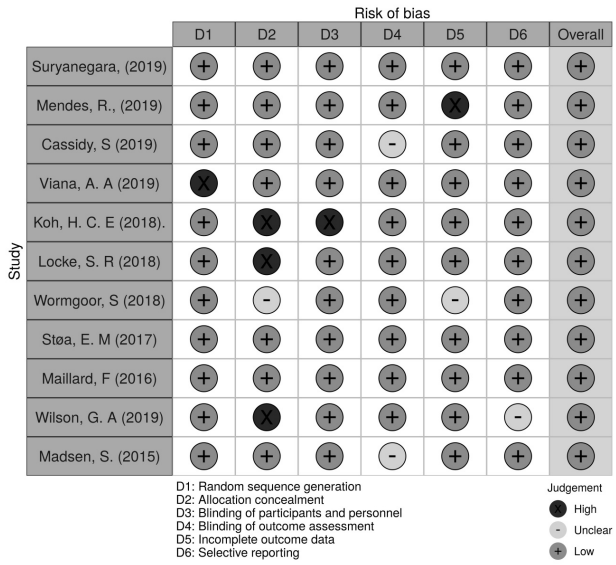

Figure 1: Risk of Bias Summary; Author's judgements about risk of bias item for each included study

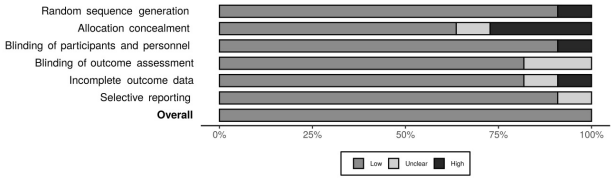

Figure 2: Risk of Bias Graph used RevMan 5.3

Data analysis

All studies included in this paper (summarized in a Table 1) contains the main characteristics and effectiveness of HIIT in T2DM. All analyses were arranged by year of publication, T2DM characteristics of patients, sample size, a protocol of HIIT intervention, and findings of the study. We reported the results that significantly correlated with improved health in individuals with T2DM.

Results

Search results

The PRISMA flow diagram (Figure 3) describes the process used to obtain studies using the search and screening process. The initial keyword search resulted in a total of 503 full text publications. 103 duplicates were removed. 363 full-text publications were excluded as they did not examine the effects of HIIT among T2DM patients. A total of 33 articles met all the inclusion criteria and were included in the analysis. Most of the excluded studies

Table 1: Characteristics of Included Studies (n=11)

No	Author, Year	Study Type	T2DM Age (y) Patient characteristics	Sample size (n)	HIIT Intervention	Findings
1	Suryanegara et al. (2019) (9)	RCT	59.8 ± 8.6 Confirmed T2DM for at least six months	26 patients	12 Week HIIT 36-cycle ergometry sessions at a gym. warm-up: 5 minutes from 9 (very light) to 13 (somewhat hard) HIIT: 16–17 (very hard) for five intervals 3 min recovery between interval	Cardiac function decreased Reduce cardiac stress HIIT provides a cardiac protective role during prolonged and increased metabolic demand
2	Mendes et al. (2019) (10)	RCT	60.25 ± 3.14 Confirmed T2DM for at least one year HbA1c less than 10%	15 patients	3 Weeks (Three experimental conditions: HIIT, MICT, CON) Treadmill walking HIIT: (5x (3 min x 70% Heart rate reserve) + 3 min x 30% HRR)) MICT: 30 min x 50% HRR	Blood Glucose decreased HIIT more effective than MICT
3	Cassidy et al. (2019) (11)	RCT	60 ± 2 T2DM duration: 4 ± one years	22 patients	12 weeks (3 sessions/ week) Treadmill walking Warm-up: 5 minutes from 9 (very light) to 13(somewhat hard) HIIT: 16–17 (very hard) for five intervals 3 min recovery between interval	Change in HbA 1c (%) was significant (7.13 ± 0.31 to 6.87 ± 0.29) Improves glycemic control Reduction HbA1c
4	Viana et al. (2019) (12)	RCT	52.3 ± 3 Confirmed T2DM for at least six months	11 patients	16 weeks (Four experimental conditions: HIIE HR, HIIE RPE, MICE and CON) Treadmill walking Warm-up: 4 minutes at 50% HRR HIIE HR: 21 min running at 85% HRR 2 min recovery walking at 50% HRR	Reduction in capillary glycemia and ambulatory blood pressure
5	Koh et al. (2018) (8)	RCT	57±7	16 patients	11 weeks (3 times/week) cycle ergometer 20 minutes intervention 1-minute cycling at 95% peak workload 1 min recovery cycling at 20% peak workload	Increased cardiorespiratory fitness Improved non-fasting glycemic control Increased subsarcolemmal mitochondrial volume
6	Locke et al. (2018) (13)	RCT	50.84 (10)	32 patients	24 weeks Self-selected exercise: walking or cycling treadmill or walking outdoors 75 Minute exercise/week Interval: 4x1 min to 10 x 1min interval 1 min recovery	Increased moderate to vigorous physical activity (MPVA) Increased relative VO_2peak Increased task self-efficacy Increased self-regulatory
7	Wormgoor et al. (2018) (18)	RCT	54.9 (52.3, 57.9) T2DM duration: 8.2±4.7	22 patients	12-week cycle ergometer 28 minutes, 12 repetition 1-minute bouts at 95% eWl max 1-minute recovery at 40% eWl max	Reduction in blood glucose

Table 1: Characteristics of Included Studies (n=11) (continued)

No	Author, Year	Study Type	T2DM Age (y) Patient characteristics	Sample size (n)	HIIT Intervention	Findings
8	Støa et al. (2017) (14)	RCT	53.7 (51.4, 57.0) T2DM duration: 8.0±6.0	38 patients	12-week walking or running uphill warm-up: 15 minutes from at 52% VO_2Max HIIT: 4 x 4 min at 82% VO_2Max 3 min recovery between interval at 52% VO_2Max	Increased in VO_2Max Reduction in HbA1c
9	Maillard et al. (2018) (16)	RCT	69 ±1 years T2DM duration: 14 ± 2.1 years	17 patients	16 weeks (twice a week) cycling programme HIIT: 60 × 8s at 77–85% HR max 12s recovery	Reduction central obesity
10	Wilson et al. (2019) (17)	RCT	34 - 62	16 patients	3 Months / 12 weeks Cycle ergometer 3 x 20-min per week minimum 10 min x 90% peak HR Month 1: 1 min interval, 1 min recovery Month 2: 2 min interval, 2 min recovery Month 3: 3 min interval, 2 min moderate intensity	Increased VO2 peak Increased LVEDV (P = 0.008) and LVSV (P = 0.02) at all conditions
11	Madsen et al. (2015) (15)	RCT	56 ± 2	23 patients	8 weeks, 3 times a week Cycle ergometer HIIT: 10×60 sec	Improves overall glycaemic control and pancreatic β cell function in T2D patients. Reduced in glycaemic control, glucose continuum, abdominal fat mass losses Pancreatic homeostasis ameliorated (p = 0.03 and p = 0.03, respectively). Whole-body insulin sensitivity was significantly increased (p = 0.03).

were removed because their intervention was paired with another intervention, such as HIIT combined with resistance training, aerobic, fasting, and others (16 articles), or only included a specific population (2 papers). Eleven articles were included in this systematic review to explore new recent evidence about HIIT and T2DM.

Characteristics of included studies

Characteristics of included studies covered a wide range of population groups and geographic areas. The age of subjects ranged from 34 to 70 years old. Amongst the 11 studies, seven studies (63.63%) were conducted in European countries, two (16.67%) in America, and two (16.67%) in the southwest Pacific region. Most studies involved individuals diagnosed with T2DM for at least six months without diabetic complications, non-smokers, and did not have any exercise limitations. HIIT intervention mainly encompasses cycle ergometry and treadmill walking for 3 to 24-week interventions.

Main findings

This review explores 11 studies that implement HIIT for individuals with T2DM (as shown in Table 1). HIIT exercise programme focuses on combining active and recovery intervals to achieve maximum results for body mechanisms. We have made three classifications of HIIT-type based

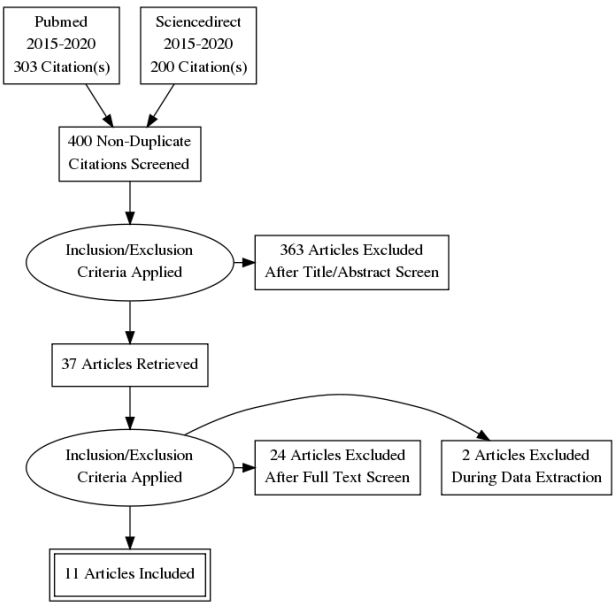

Figure 3: Results of Systematic Search in Database Related to High Intensity Interval Training on T2DM Patients

on the 11 studies: HIIT using a walking treadmill, cycle ergometry, and running outdoors. All tasks have a three-phase intervention: warm-up, interval time, and recovery time. All studies showed that HIIT is a health-beneficial exercise strategy for T2DM patients, improving glucose homeostasis, blood glucose, and functional capacity.

There were five studies using the same HIIT protocol standard. They used the same time protocol but different sports equipment. Two studies used walking treadmills, and the other studies used a cycling ergometer. They all have a similar finding that HIIT provides significant health benefits to individuals with T2DM. They reported that HIIT, in a minimum of 3 - 16 weeks, could improve the health system by decreasing blood glucose, reducing HbA1c, capillary glycemia and ambulatory blood pressure, and reducing cardiac stress. This result showed that HIIT provides a cardiac protective role during prolonged and increased metabolic demand and improves glycemic control and pancreatic β cell function in T2DM patients (8–12).

For example, the study by Locke and Stoa used an outdoor exercise in their RCT. They used cycling, walking outdoors, and running uphill to achieve their HIIT programme. They reported 12-24 weeks of HIIT exercise with four minute interval time and one to three minute recovery time can aid individuals with T2DM to increase physical activity, increase VO2Max and reduce HbA1c, with the additional benefit of increasing task self-efficacy and self-regulation (13, 14).

The other four studies in this systematic review assessed HIIT using a cycle ergometer for 8-16 weeks. Research by Wilson et al. modifies the HIIT protocol with different interval times every month. The result of this study is similar to another study in this review that HIIT can improve all glycemic control and pancreatic β cell function in T2DM patients. The other results showed that HIIT could also decrease abdominal fat mass known as central obesity (15–18). Most studies were deemed to be of good quality and low bias, based on critical appraisal and bias evaluation (Figures 1 and 2).

Discussion

This systematic review aims to review in depth the findings of the effectiveness of HIIT therapy in patients with T2DM. This study is required because similar research still uses specific parameters such as glycemic control and cardiorespiratory fitness (19, 20). Our systematic review is a more general discussion of the effects of HIIT therapy in T2DM patients.

HIIT modification of body endurance exercises can be performed in intervals by combining anaerobic exercises with resting intervals. The implementation of HIIT combines both aerobic and anaerobic energy source from the body. Bompa & Buzzichelli stated that HIIT is an intermittent exercise characterized by a period of practice interspersed with rest periods. The rest period used is an active rest, which can be street, relaxed jogging, and gymnastics (21). Several factors that must be met in stacking HIIT are the duration of exercise, exercise intensity, rehearsal, and the rest period after each training.

Training duration is defined as the distance to be taken. Exercise intensity can be interpreted as time for space. The workout replay is the number of times the exercise should be repeated. The rest period is an active resting period between each training time. HIIT consists of slow-type and fast-type activities. Slowly training interval training can be done with an extended consideration of training for 60 seconds up to 3 minutes, with an exercise intensity of 60-75% maximum heart rate, repetition schemes of 15-30 times, and a rest period of 3-5 minutes. The recovery period in an exercise is as essential as the training period. Determination of the exercise-to-rest ratios can be seen from the aerobic capacity of an activity. The better the aerobic capacity, the faster the recovery process (21).

Physical activity, including HIIT, can improve glucose homeostasis regulation in both T2DM patients and healthy individuals. HIIT has recently assumed a prominent role in the scope of physical activity and health due to the cardiovascular and metabolic benefits that it appears to induce in populations with risk factors and chronic diseases, including T2DM (10).

All studies in this review showed that respondents are given a physical exercise for a minimum of three weeks and a maximum of 16 weeks, sufficient to provide noteworthy results in managing individuals with T2DM. The most significant result in T2DM patients was increased whole body sensitivity to insulin, characterized by decreased blood sugar, reduction of HbA1c, and improved overall glycemic control and pancreatic β cell function (15).

Other indirect benefits of HIIT application in individuals with T2DM were decreased cardiac function, reduced cardiac stress, reduced capillary glycemia, ambulatory blood pressure, and provides cardiac protective role during contractility. Increased metabolic demand also prevents further complications associated with hypertensive disease (9). Additional benefits also include improved physical fitness characterized by increased cardiorespiratory fitness, increased moderate to vigorous physical activity (MPVA; which also has a good impact on reducing central obesity), increased task self-efficacy, and increased self-regulatory support efforts to achieve optimal quality of life for individuals with T2DM.

The biochemical mechanism driving these alterations is enhanced activation of peroxisome proliferator-activated receptor gamma coactivator 1-alpha (PGC-1), a modulator of numerous mitochondrial genes expression (11, 13). This results in enhanced glucose absorption and oxidation capacity, as well as higher insulin sensitivity. These activities result in a drop in blood sugar levels after 40-90 minutes of HIIT training. This reduction in blood sugar levels is naturally associated with the synergistic action of oral hypoglycemic medications prior to HIIT activity (12, 16).

Glucose is a critical fuel source for contracting skeletal muscles during HIIT. HIIT employs a more significant proportion of fast-twitch muscle fibers that require carbohydrates (glucose) as the preferred substrate for adenosine-triphosphate (ATP) regeneration (8, 18). Additionally, the regulation of glucose uptake into skeletal muscle cells is dependent on several physiological factors, including glucose delivery (increased skeletal muscle blood flow and capillary recruitment), glucose transport protein (GLUT4) expression and translocation into cell membranes, and glucose metabolism (mitochondrial capacity). These factors vary among individuals as they are dependent on ages, T2DM durations, and baseline fitness (18). Following a hard workout, the balance between elevated catecholamine levels (which promote glycogenolysis) and enhanced peripheral glucose uptake (which replenishes reserves) leads to increased insulin sensitivity and lower blood sugar levels (15, 18).

Research with walking and cycling protocols can significantly impact clinical practice in populations since both are the most popular exercise choice for public health promotion and T2DM control (10). Walking and cycling are low-cost, low-impact, and low-risk activities that can be practiced outdoors, not only using a treadmill and cycle ergometer. Walking and cycling with a HIIT structure require few resources and has greater acute metabolic effect on glycemic control (22).

On the other hand, brisk walking, an activity type of moderate intensity (23), can also be manipulated to achieve vigorous intensity by adjusting the treadmill to a higher incline. HIIT protocols can be replicated in outdoor conditions if walking is combined with stair climbing, uphill walking, walking with external loads, or with very brisk walking. This modification was implemented in studies by Støa et al. (14) and Darmawati et al. (24) via implementing HIIT in three phases: warm up, interval exercise, and recovery time. This HIIT intervention combines brisk walking (77-85% HRR) as interval training and walking as a recovery time with 50% HRR.

Of the 11 studies, eight had a control group that was given a similar intervention, namely moderate-intensity continuous training (MICT). The results of these eight studies varied depending on the focus of each study. Some obtained similar results when patients performed HIIT or MICT exercises, which includes energy expenditure, peak systolic and diastolic blood pressure, reductions in capillary glycaemia, increased relative VO2 peak, and raised self-regulation and task self-efficacy. However, it can be concluded that HIIT was more effective than MICT. The former was more effective in increasing peak heart rate, peak RPE, workload and perceived exertion. It also significantly reduced BG levels and was more effective in reducing abdominal fat mass (body weight and Body Mass Index).

The results of this review have the potential to impact exercise promotion among individuals with T2DM. Our findings can aid individuals with T2DM to evaluate the advantages of HIIT as a safe and effective exercise strategy in controlling T2DM. A limitation of this review is its small sample size. Improvement in sample size will strengthen the findings that HIIT enables maintenance of blood glucose and insulin sensitivity in an individual with T2DM.

Conclusion

This review determined that individuals with T2DM could benefit from HIIT. HIIT is a safe and effective way to improve insulin sensitivity, aerobic fitness, blood glucose control, and reduce risk factors associated with T2DM, all of which contribute to an improved quality of life for those with T2DM. Public health centers should manage T2DM patients in their communities through sporting activities that incorporate effective and simple interval training approaches to improve their quality of life.

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Competing interests

All authors declare that there is no conflict of interest.

References

1. World Health Organization (WHO). Global Report on Diabetes. 2016. Available at: https://www.who.int/publications/i/item/9789241565257. Accessed 7 December 2021.

2. International Diabetes Federation. IDF Diabetes Atlas 9th Edition. 2019. Available at: https://diabetesatlas.org/atlas/ninth-edition/ Accessed 7 December 2021.
3. Kirwan JP, Sacks J, Nieuwoudt S. The essential role of exercise in the management of type 2 diabetes. Cleve Clin J Med. 2017;84(7):S15–21.
4. Mora-Rodriguez R, Fernandez-Elias VE, Morales-Palomo F, Pallares JG, Ramirez-Jimenez M, Ortega JF. Aerobic interval training reduces vascular resistances during submaximal exercise in obese metabolic syndrome individuals. Eur J Appl Physiol. 2017;117(10):2065–73.
5. Moher D, Liberati A, Tetzlaff J, Altman DG, Altman D, Antes G, *et al.* Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. PLoS Med. 2009;6(7):e1000097.
6. Long HA, French DP, Brooks JM. Optimising the value of the critical appraisal skills programme (CASP) tool for quality appraisal in qualitative evidence synthesis. Res Methods Med Heal Sci. 2020;1(1):31–42.
7. Critical Appraisal Skills Programme. 2018. Available at: https://casp-uk.net/. Accessed 7 December 2021.
8. Koh HCE, Ørtenblad N, Winding KM, Hellsten Y, Mortensen SP, Nielsen J. High-intensity interval, but not endurance, training induces muscle fiber type-specific subsarcolemmal lipid droplet size reduction in type 2 diabetic patients. Am J Physiol Endocrinol Metab. 2018;315(5):872-84.
9. Suryanegara J, Cassidy S, Ninkovic V, Popovic D, Grbovic M, Okwose N, *et al.* High intensity interval training protects the heart during increased metabolic demand in patients with type 2 diabetes: A randomised controlled trial. Acta Diabetol. 2019;56(3):321–9.
10. Mendes R, Sousa N, Themudo-Barata JL, Reis VM. High-intensity interval training versus moderate-intensity continuous training in middle-aged and older patients with type 2 diabetes: A randomized controlled crossover trial of the acute effects of treadmill walking on glycemic control. Int J Environ Res Public Health. 2019;16(21):1–14.
11. 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 Dis Res. 2019;16(1):69–76.
12. Viana AA, Fernandes B, Alvarez C, Guimarães GV, Ciolac EG. Prescribing high-intensity interval exercise by rpe in individuals with type 2 diabetes: Metabolic and hemodynamic responses. Appl Physiol Nutr Metab. 2019;44(4):348–56.
13. Locke SR, Bourne JE, Beauchamp MR, Little JP, Barry J, Singer J, *et al.* High-intensity interval or continuous moderate exercise: A 24-week pilot trial. Med Sci Sports Exerc. 2018;50(10):2067–75.
14. Støa EM, Meling S, Nyhus LK, Glenn Strømstad, Mangerud KM, Helgerud J, *et al*. High-intensity aerobic interval training improves aerobic fitness and HbA1c among persons diagnosed with type 2 diabetes. Eur J Appl Physiol. 2017;117(3):455–67.
15. Madsen SM, Thorup AC, Overgaard K, Jeppesen PB. High intensity interval training improves glycaemic control and pancreatic β cell function of type 2 diabetes patients. PLoS One. 2015;10(8):1–24.
16. Maillard F, Rousset S, Pereira B, Boirie Y, Duclos M, Boisseau N. High-intensity interval training is more effective than moderate-intensity continuous training in reducing abdominal fat mass in postmenopausal women with type 2 diabetes: A randomized crossover study. Diabetes Metab. 2018;44(6):516–7.
17. Wilson GA, Wilkins GT, Cotter JD, Lamberts RR, Lal S, Baldi JC. HIIT improves left ventricular exercise response in adults with type 2 diabetes. Med Sci Sports Exerc. 2019;51(6):1099–105.
18. Wormgoor SG, Dalleck LC, Zinn C, Harris NK. Acute blood glucose, cardiovascular and exaggerated responses to HIIT and moderate-intensity continuous training in men with type 2 diabetes mellitus. J Sports Med Phys Fitness. 2018;58(7–8):1116–26.
19. Francois ME, Little JP. Effectiveness and safety of high-intensity interval training in patients with type 2 diabetes. Diabetes J. 2015;(11):39–44.
20. Liu J, Zhu L, Li P, Li N, Xu Y. Effectiveness of high-intensity interval training on glycemic control and cardiorespiratory fitness in patients with type 2 diabetes: A systematic review and meta-analysis. Aging Clin Exp Res. 2019;31(5):575–93.
21. Bompa T, Buzzichelli C. Periodization: Theory and methodology of training. 6th Ed. Illinois, USA: Human Kinetics. 2019.
22. 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(2):228–36.
23. Kato M, Goto A, Tanaka T, Sasaki S, Igata A, Noda M. Effects of walking on medical cost: A quantitative evaluation by simulation focusing on diabetes. J Diabetes Investig. 2013;4(6):667–72.
24. Darmawati I, Setiawan A, Permatasari H. Reducing body mass index of adult female who has excessive weight and obesity through physical exercise of interval training. Indones Nurs J. 2015;18(2):88–94.