The Effect of Aerobic Exercise on Blood Glucose Level among Patients with Type-2 Diabetes Mellitus: Systematic Review

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Abstract: Diabetes Mellitus is the disease which causes premature mortality, and the leading cause of blindness, heart disease, and kidney failure in the world with increasing prevalance. Exercise is fundamental in Diabetes Mellitus management which functions to improve insulin sensitivity and control blood glucose level. A number of studies have been carried out to explore the effect of aerobic exercises on blood glucose level among patients with type-2 Diabetes Mellitus. The research aimed to evaluate the effect of aerobic exercise's type, frequency, intensity and duration on blood glucose level among patients with type-2 Diabetes Mellitus. This study was systematic review. The literature searches were specified from 2005-2020 through *Pubmed* and *Google Scholar*. 40 studies in total based on specific criteria was included to this study. Thirty-nine out of forty studies revealed that a variety of aerobic exercises such as walking, gymnastic (diabetic, aerobic, foot, ergonomic), step test as well as static cycling give impact on lowering blood glucose level. Seventeen out of forty studies fulfilling the criteria of frequency, duration and intensity showed that exercise helps reduce blood glucose level. In conclusion, performing aerobic exercise regularly and appropriately helps to lower blood glucose level among patients with type-2 Diabetes Mellitus.

Keywords: Aerobic Exercise, Type-2 Diabetes Mellitus, Blood Glucose Level

1. Introduction

Diabetes Mellitus (DM) is the disease which causes premature mortality worldwide. It is also a major cause of blindness, heart disease and kidney failure. The International Diabetes Federation (IDF) predicts that the prevalence of DM in the world population aged 20-79 is likely to increase, respectively, in 2030 and 2045 by 578 million and 700 million compared to 463 million in 2019. The prevalence of DM tends to increase in line with increasing age, with a prevalence of 19.9% or 111.2 million people in the age range of 65-79 years compared to the prevalence of diabetes in general in the age range of 20-79 which is 9%. Estimated death from DM and its complications is around 4.2 people aged 20–79 years or in other words every eight seconds of death in diabetics. Deaths from diabetes are 11.3% of global deaths among people in this age group. Nearly half (46.2%) of diabetes-related deaths occurred in people under the 60 years old – the working age group (International Diabetes Federation, 2019).

The three regions with the highest prevalence of DM in the population aged 20-79 years in the world are Arab-North Africa (12.2%), West Pacific (11.4%) and Southeast Asia (11.3%). The projections carried out by the IDF show that Indonesia is ranked 7th out of 10 countries in

the world and is the only country in Southeast Asia that is included in the list of 10 countries with the most DM sufferers with an estimated 10.7 million people (International Diabetes Federation, 2019). The results of the 2018 *Riset Kesehatan Dasar* (Riskesdas) showed that the prevalence of DM in Indonesian population aged ≥ 15 years has increased by 0.5% compared to the 2013 Riskesdas results, namely 1.5% (2013) and 2% (2018) and this increase occurred in almost all provinces except East Nusa Tenggara Province (Kemenkes RI, 2020).

Type-2 DM is one of the main categories of diabetes in addition to type-1 DM and gestational diabetes (International Diabetes Federation, 2019). Type-2 DM accounts for 90% of the entire population of DM sufferers in the world with characteristics of impaired insulin sensitivity and/or impaired insulin secretion. Type-2 DM is a global health problem because the prevalence and incidence of this disease continues to increase, both in industrialized and developing countries, including in Indonesia (Declori, 2019). Considering the long-term impact of suffering from DM can have serious consequences and the prevalence of type-2 DM is increasing, efforts must be made to manage diabetes, including preventive and promotive actions through education, the application of a healthy lifestyle, and combined with treatment as needed (Declori, 2019; International Diabetes Federation, 2019).

Physical exercise is one of the 5 main pillars in the management of type-2 DM apart from education, nutrition therapy, pharmacological therapy and monitoring. According to the Indonesian Endocrinology Association (PERKENI), physical exercise program should be done regularly, 3-5 days per week with a duration of 30-45 minutes each exercise, or a total of 150 minutes per week. The recommended physical exercise is aerobic exercise with moderate intensity (50%-70% maximum heart rate) (Soelistijo et al., 2019). Examples of physical exercise that fall into this category are brisk walking, leisurely cycling, jogging, swimming and group exercise or aerobic exercise (Ilyas, 2009a; Soelistijo et al., 2019). Physical exercise is not only beneficial for maintaining physical fitness, it can also lose weight and improve insulin sensitivity, so that it will improve blood glucose control (Soelistijo et al., 2019).

A number of studies have been carried out to explore the effect of various types of aerobic exercises on blood glucose level among patients with type-2 DM. A study by Motahari-Tabari et al. (2015) found that fasting glucose levels in the intervention group doing walking exercise 3 times a week were significantly lower than the control group in patients with type-2 DM after 8 weeks . Another study by Nugraha et al. (2016) stated that diabetic gymnastic with a frequency of 3 times/week with a duration of 40 minutes had a significant effect on decreasing the average blood glucose level from 164.50 mg/dL to 145.13 mg/dL. In addition, a study by Indriyani et al. (2010) which provided an aerobic exercise intervention with a frequency of 3 times/week for 30 minutes also showed a decrease in mean blood glucose levels of 30.14 mg/dL (Indriyani et al., 2010). Based on the problems above, the purpose of this study was to determine the effect of aerobic exercise on blood glucose levels in patients with type-2 DM in terms of the aerobic exercise's type, frequency, intensity and duration.

2. Materials and Methods

This study employed a systematic review on evaluating the effect of various types and frequency, intensity and duration of physical exercise on blood glucose levels in patients with type-2 DM. Development of research questions using the PICOS format (Population, Intervention, Comparation, Outcome and Study design) (Gülpınar & Güçlü, 2013; Lockwood & Oh, 2017), include: (1) P: type-2 DM, (2) I: aerobic exercise such as walking, diabetic gymnastic, aerobic gymnastic, foot gymnastic, ergonomic gymnastic, step test and static cycling, (3) C: comparison before and after aerobic exercise and comparison between the control group and the intervention group, (4) O: decreasing blood glucose levels, and (4) S: randomized controlled trial, true experimental, quasy-experimental, and pre-experimental. So the research question is "How is the effect of aerobic exercise (I) on blood glucose levels (O) in patients with type-2 DM (P)?".

A comprehensive literature search was conducted through accessible databases or search engines, namely Pubmed and Google Scholar. Search strategy of this study was literature in Indonesian or English language, published in 2005-2020 with keyword searches on titles, content, keywords and abstracts with boolean operators. The keywords in this study were "Type-2 Diabetes Mellitus", "aerobic exercise", "blood glucose levels" and "experimental research".

The management of the obtained articles used Mendeley and Endnote as reference managers to remove duplicate studies and web-based software "Covidence" as a systematic review manager to select by screening titles, abstracts and full text. The final number of included and excluded studies was reported in the PRISMA (Preferred Reporting Items for Systematic Review and Meta-analysis) diagram (Knoll et al., 2018). The data extracted from the included articles were the details of the study, types of interventions performed, outcomes and the results of the study. "Covidence" was used to help with data extraction, and then the collected information was entered into Excel and evaluated.

3. Results and Discussion

The initial article search results from the database identified journals with a total of 876 studies published in 2005-2020. A total of 406 studies were excluded due to duplication and then 407 studies were screened for titles and abstracts. A total of 413 studies were excluded because they were not relevant to the research question. Furthermore, from the full-text screening, a total of 14 studies were excluded because the patient population was not suitable, 1 study design was not suitable, 1 full-text was not accessible, and 1 full-text was not in English or Indonesian language. Thus, a total of 40 articles that met the criteria were included in this study. PRISMA flow diagram for article selection is shown in Figure 1.

Of the 40 studies evaluated, 3 studies performed 2 types of aerobic physical exercise each so that the total intervention was 43 observations. The three most common types of aerobic physical exercise are walking (42%), diabetic gymnastic and aerobic gymnastic (21% each) as shown in Figure 2. There are 39 out of 40 studies with various types of aerobic exercise including walking, diabetic gymnastic, aerobic gymnastic, foot gymnastic, ergonomic gymnastic,

step test and static cycling showed that there was a decrease in blood glucose levels before and after physical exercise. In addition, 17 studies that met the Frequency-Intensity-Duration requirements of exercise showed a decrease in blood glucose levels in both short and long observations, as shown in Figure 3.

In general, 97.5% of the research revealed that there was a significant effect of changes in blood glucose levels before and after physical exercise. The results of 18 walking exercise studies, 9 diabetic gymnastic exercise studies, 9 aerobic gymnastic exercise studies, 3 foot gymnastic exercise studies, 1 step test exercise study, 1 static cycling exercise study and 1 of 2 ergonomic gymnastic exercise studies showed a significant decrease in blood glucose levels in patients with type 2 DM before and after various physical exercises, as shown in Figure 3.
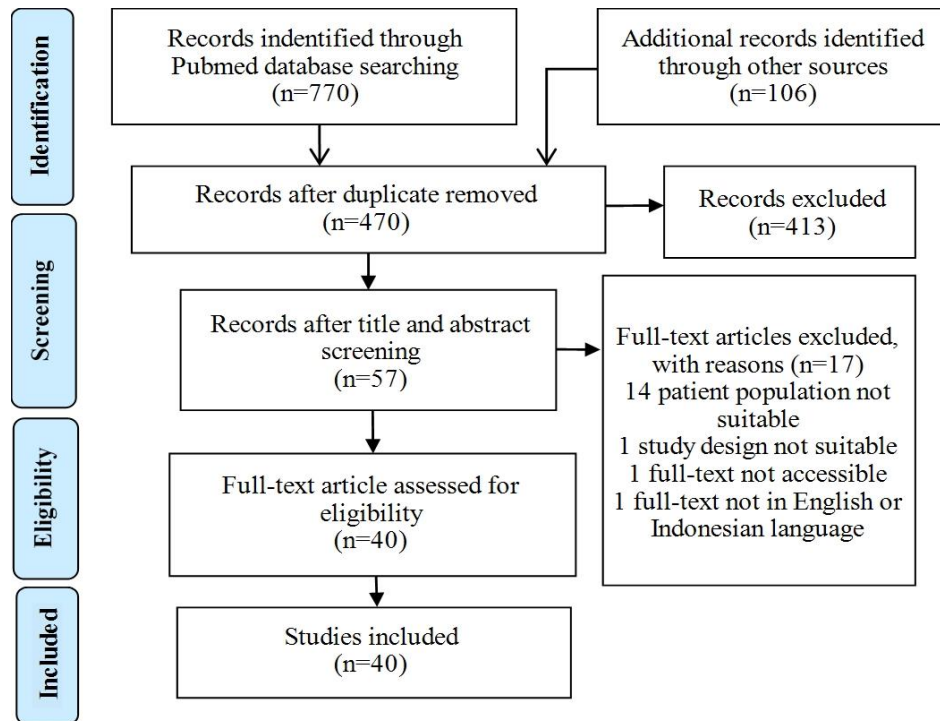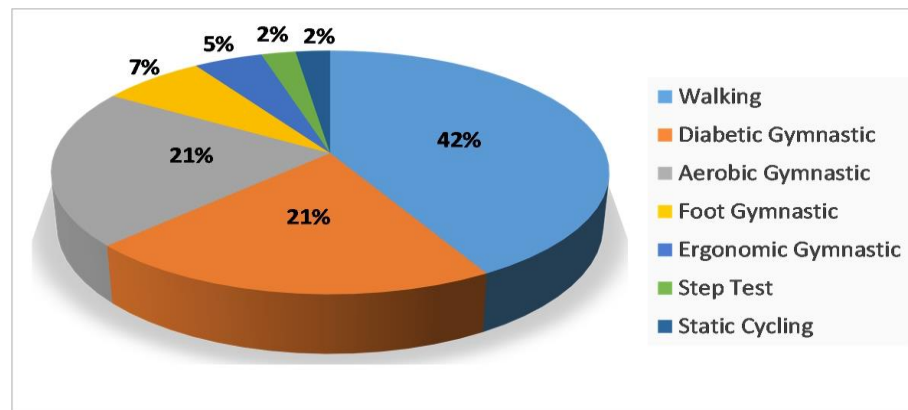

Fig.1. PRISMA Flow Diagram

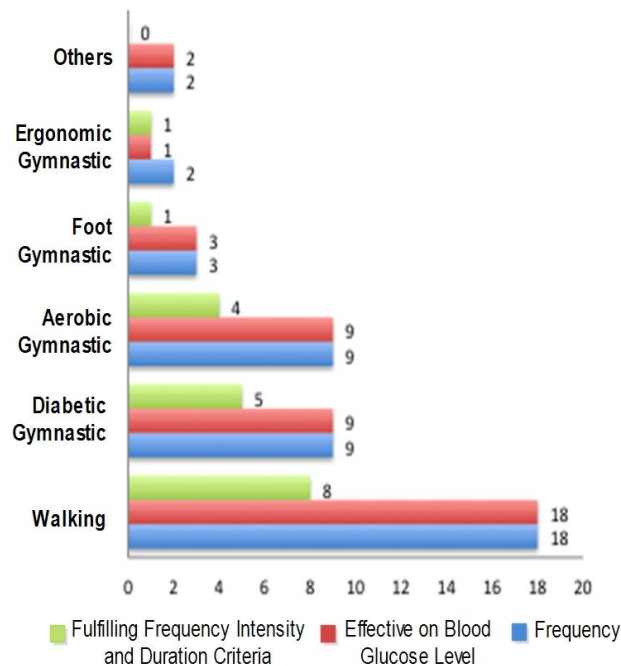**Fig.2.** Distribution of Study Frequency by The Type of Aerobic Exercise

Fig.3. Distribution of Study Frequency Based on Fulfilling Frequency-Intensity-Duration Criteria and the Effectiveness of Aerobic Exercise on Reducing Blood Glucose Levels

The evaluation results from this systematic review found that walking was the most studied type of physical exercise, namely 18 studies (42%) with all of the studies showing a significant effect of walking on decreasing blood glucose levels. As in the research conducted by Rehmaita & Tahlil (2017), Gainey et al. (2016), Hikmasari & Sari (2016), Amelia et al. (2018) and Mitranun et al. (2014). There was a decrease in blood glucose levels after the buddhist walking meditation and traditional walking groups, with mild changes in intensity from light intensity at weeks 1-6 to moderate intensity at weeks 7-12 (Gainey et al., 2016). Likewise, interval and continuous walking exercises were carried out for 12 weeks with gradual changes in intensity, from moderate in the first week and vigorous in the second and third weeks (Mitranun et al., 2014). Research by Amelia et al. (2018) found that walking exercise with a frequency of 3 times/week for 3 weeks and a duration of 30-60 minutes showed the effect of decreasing blood glucose, in the first week there was a decrease of 9.16 mg/dL, the second week of 9.51 mg/dL and the third week 12.94 mg/dL with p-value 0.000 (p-0.05). Meanwhile, in a study by Hikmasari & Sari (2016), the decrease in blood glucose levels occurred only as an acute effect, but the chronic effect did not occur significantly after 4 weeks. The walking exercise after 4 weeks showed insignificant changes of blood glucose level, this could occur because the body's metabolism had not yet reached optimal adaptation or this could occur due to many factors that affect blood sugar levels such as daily food consumption, stress levels of DM patients and other factors.

Physical exercise other than walking that can reduce blood glucose levels for people with type-2 DM is gymnastic, such as diabetic gymnastic, aerobic gymnastic, foot gymnastic and ergonomic gymnastic. Almost all studies, both the effect of diabetic gymnastic, aerobic gymnastic and foot gymnastic, showed a significant effect of decreasing blood glucose levels before and after exercise. There is only one study of ergonomic gymnastics which showed insignificant results. Research by Rehmaita & Tahlil (2017) and Afridon & Komalasari (2018) showed that diabetic gymnastic can reduce blood glucose levels in patients with type-2 DM. The average decrease in blood glucose levels is 20 mg/dL (Afridon & Komalasari, 2018). Research by Kurdanti & Khasana (2019) found that the duration of diabetes exercise for 30 minutes was more effective for lowering blood glucose levels than exercise with a duration of 60 minutes. Meanwhile in the aerobic gymnastic intervention, the average change of blood glucose levels in the intervention group was 9.07 mg/dL compared to the control group and lower blood glucose level at least 25,444 mg/dL and maximal 70.556 mg/dL from the blood glucose value (Desiani, 2019), the difference of mean blood glucose before and after aerobic exercise is 28.30 mg/dL (Dewi & Susilawaty, 2019), an average decrease of 30.14 mg/dL (Indriyani et al., 2010), in the intervention group the average change in blood glucose levels from 182.67 mg/dL to 161.61 mg/dL with a difference of 21.06 mg/dL and the mean blood glucose level in the intervention group was 161.61 mg/dL and in the control group was 188.16 mg/dL, with a difference of 26.55 mg/dL (Kurniasari et al., 2014).

A decrease in blood glucose levels was also shown after foot gymnastic exercise in a study conducted by Hikmasari & Sari (2016), Priyoto & Widyaningrum (2020) and Ruben et al. (2016). The difference in blood glucose levels before and after the foot gymnastic intervention was 182.80 mg/dL decreased to 143.13 mg/dL, and there was a decrease in the average blood glucose value of 39.67 mg/dL (Priyoto & Widyaningrum, 2020). A research by Ariani et al. (2015) showed that ergonomic gymnastic was effective in reducing blood glucose levels. Meanwhile, research conducted by Fahmi & Widyatmoko (2016) showed that there was no significant difference between the ergonomic gymnastic intervention group and the control group in reducing blood glucose levels. Ergonomic gymnastics exercise carried out for 1 session did not show a significant effect because the duration or frequency had not been met so that the response from ergonomic gymnastic showed a decrease of only 1 mg/dL (Fahmi & Widyatmoko, 2016). Other interventions, such as step test and static cycling also showed a significant effect on blood glucose levels (Fathoni, 2005; Surasta et al., 2013).

The various studies' results above show changes in blood glucose levels after doing various aerobic exercises which can be explained that under normal conditions, insulin regulates glucose levels within normal limits, both in the fasting state and after eating, but in DM patients there is a decrease in insulin levels that work well so that glucose level regulation becomes problematic (Waspadji, 2009). Physical exercise activities will cause (1) the use of glucose by active muscles, (2) an increase in insulin receptors that are more active due to increased blood flow. Physical movement/work of actively contracting muscles causes muscle fibers to be more permeable and increases insulin sensitivity, in other words, there is an increase in the use of large

amounts of glucose. This condition will affect the decrease in blood glucose levels, especially in DM patients (Soegondo et al., 2009). Increased insulin sensitivity is a response to physical exercise. This response will not last in the long term, so to maintain blood glucose levels in a stable condition, physical exercise must be carried out continuously and regularly (Ilyas, 2009b).

The provisions for the implementation of physical exercise according to PERKENI stated that physical exercise program should be done regularly, with a frequency of 3-5 times/week, a duration of 30-45 minutes/physical exercise, or a total duration of 150 minutes in one week, and no more than 2 consecutive days of pause between physical exercise (Soelistijo et al., 2019). Physical exercise for people with DM must adhere to the CRIPE principle (Continues, Rhythmical, Interval, Progressive, Endurance Training) which is physical exercise must (1) be carried out continuously, (2) have a regular tempo, (3) performed alternately, (4) gradually from light to high intensity and adapted to individual abilities, and (5) exercise endurance by involving large muscles (Alvarez et al., 2016). The results of the systematic review of 40 studies included in this study with various types of aerobic exercise found that the most widely practiced physical exercise and effective on decreasing blood glucose levels was physical exercise with a frequency of 3 times/week, duration of 30-45 minutes/exercise and moderate intensity. Observations made in the studies included in this study showed that most physical exercise lasted more than 1 week. This shows that physical exercise should be done regularly and appropriately with the provisions of its implementation so that blood glucose levels in type-2 DM patients can be well controlled (Ilyas, 2009b).

4. Conclusion

The results from several studies included in this systematic review concluded that various types of aerobic exercise in lowering blood glucose levels among patients with type-2 DM. The most performed aerobic exercise is walking (42%), followed by diabetic and aerobic gymnastic (21% each). It can be concluded that people with type-2 DM can do aerobic exercise regularly with a frequency of 3 times/week, moderate intensity and duration of 30-45 minutes to control blood glucose levels.

Conflict of Interest

All Authors declare no conflict of interest and agree with the content of the manuscript.

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