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MORALITY BEFORE KNOWLEDGE

The impact of sedentary behavior on blood glucose levels in type 2 diabetes mellitus patients: A literature review

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ABSTRACT

Background: Sedentary behavior, characterized by prolonged sitting or lying down, is increasingly recognized as a major health risk, particularly for individuals with type 2 diabetes mellitus (T2DM). Previous studies have shown that sedentary lifestyles can exacerbate glucose control issues, leading to poor glycemic regulation and an increased risk of complications. This study aims to explore the relationship between sedentary behavior and blood glucose levels in T2DM patients, highlighting the potential benefits of interrupting sedentary time with physical activity. **Methods**: This research utilized comprehensive literature review methodology, analyzing studies published over the past decade to assess the impact of sedentary behavior on glycemic control in T2DM patients. The review focused on both observational studies and experimental trials, employing data from clinical studies and patient monitoring. **Findings:** Prolonged sedentary behavior was found to be associated with worsening glucose control, including prolonged hyperglycemia and reduced euglycemia. Interrupting sedentary time with short bouts of physical activity (e.g., walking or light exercise) was shown to significantly improve glucose uptake in skeletal muscles, providing effects like anti-diabetic medications. Consistent and frequent interruption of sedentary behavior resulted in improved daily blood glucose control, potentially offering a non-pharmacological intervention for T2DM management. **Conclusion**: The study underscores the importance of reducing sedentary behavior in T2DM patients as a strategy to enhance blood glucose control and prevent complications. Regular physical activity interruptions can serve as a critical non-pharmacological intervention to manage and control blood glucose levels. **Novelty/Originality of this article:** This review contributes to the growing body of evidence on the health risks of sedentary behavior in T2DM patients, emphasizing the potential of simple lifestyle interventions to improve glycemic control, which has been insufficiently explored in previous literature.

KEYWORDS: sedentary behavior; type 2 diabetes mellitus; blood glucose control; physical activity interruptions; glycemic regulation.

1. Introduction

Sedentary behavior, characterized by prolonged sitting, is more commonly observed in individuals with type 2 diabetes mellitus compared to non-diabetic respondents (Paing et al., 2020). Prolonged sedentary behavior contributes to elevated blood glucose levels and insulin resistance in type 2 diabetes mellitus patients (Fritschi et al., 2016; Ajao, 2019; Paing et al., 2019; Paing et al., 2020). These adverse effects, however, can be mitigated through regular physical activity. In 2016, it was reported that 28% of adults over the age of 18 were physically inactive worldwide. In high-income countries, 26% of men and 35% of women

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were categorized as physically inactive, while in low-income countries, the prevalence was 12% among men and 24% among women (World Health Organization, 2020). Globally, the prevalence of diabetes mellitus reached 463 million cases in 2019, and it is projected to rise to 578 million in 2030 and 700 million by 2045 (International Diabetes Federation (IDF), 2019). In Indonesia, according to the 2018 Basic Health Research, the prevalence of diabetes increased from 1.5% in 2013 to 2% in 2018 (Kementerian Kesehatan Republik Indonesia, 2018). Additionally, the number of diabetes mellitus patients in Indonesia reached 10.3 million in 2017 and increased to 10.7 million in 2019, placing Indonesia seventh in global rankings (IDF, 2019). A study by Nurayati and Adriani (2017) involving 62 diabetes mellitus patients revealed that 62.9% of respondents exhibited sedentary behavior, 20.9% had moderate activity levels, and only 16.1% engaged in high levels of physical activity. Furthermore, 76.9% of respondents with sedentary behavior were found to have elevated fasting blood glucose levels.

Insulin plays a critical role in transporting glucose and amino acids to body cells, particularly muscle and fat cells. It also facilitates glycogen storage in the liver and assists in triglyceride, nucleic acid, and protein metabolism. In individuals with insulin resistance, insulin cannot perform its functions effectively, leading to elevated free fatty acid levels, increased hepatic glucose production, and enhanced fat breakdown. If left untreated, this condition can result in long-term complications, including vascular disorders, cardiovascular diseases, retinopathy, kidney failure, neuropathy, and premature death (Sommers, 2019).

Increased physical activity and reduced sedentary behavior are among the recommended interventions to help control blood glucose levels in type 2 diabetes mellitus patients (Paing et al., 2020; Nakanishi et al., 2020; ADA, 2020). Effective therapy involves diet regulation, exercise, monitoring, and education to minimize long-term complications (Smeltzer & Bare, 2010; ADA, 2020). Recommended exercises include flexibility and balance training, which improve muscle mass and metabolism. These exercises not only help regulate blood glucose levels but also reduce the risk of cardiovascular disorders, maintain healthy body weight, and enhance overall well-being (ADA, 2020).

Given these considerations, this study aims to identify the relationship between sedentary behavior and blood glucose levels in type 2 diabetes mellitus patients. The findings are expected to serve as a foundation for healthcare professionals, particularly nurses, in providing care and designing interventions to address sedentary behavior in diabetes patients. Additionally, this study seeks to contribute to academic references, support institutional research development, and enhance public awareness of the impact of sedentary behavior on blood glucose levels in type 2 diabetes mellitus patients.

2. Methods

2.1 Literature search strategy

The protocol and registration for this study utilized the PRISMA checklist, adapted to align with the research objectives. This literature review synthesizes findings from various studies that explore the relationship between sedentary behavior and blood glucose levels in patients with type 2 diabetes mellitus. By adhering to the PRISMA framework, the literature search process was systematically conducted to ensure transparency and reproducibility throughout all stages of the review.

Secondary data were employed in this study, sourced from previously published research articles indexed in international and national scientific databases. International journal articles were retrieved from databases such as PubMed, SpringerLink, ProQuest, ScienceDirect, Sage Journals, Google Scholar, Wiley Online Library, Oxford Academic, JAMA, PLOS ONE, Taylor & Francis Online, and Harvard Health Publishing. Meanwhile, national literature searches were conducted using databases like Google Scholar, Neliti, and the Garba Rujukan Digital (GARUDA). These platforms were selected due to their open-access availability, which facilitated efficient data retrieval. The search for relevant articles and

literature spanned from September to November 2021, ensuring the inclusion of the most recent and relevant studies available during that period.

Keywords used in the search were carefully selected based on Medical Subject Headings (MeSH) terms and Boolean operators (and, or, not) to ensure both specificity and breadth in retrieving relevant articles. In English-language databases, the primary keywords included "sedentary behavior," "blood glucose level," and "type 2 diabetes mellitus," with Boolean combinations such as ("sedentary behavior" or "sedentary") and ("blood glucose" and "blood sugar level") and ("diabetes mellitus" or "type 2 diabetes mellitus"). Similarly, Indonesian-language searches used keywords like *"perilaku sedentari," "kadar glukosa darah,"* and *"diabetes melitus tipe 2,"* with Boolean combinations like (*"perilaku sedentari"*) or (*"kadar glukosa darah"* or *"kadar gula darah"*) and (*"diabetes melitus tipe 2"* and *"diabetes melitus"*). These combinations ensured that relevant studies across both languages were adequately captured for review and analysis.

2.2 Research literature criteria

The literature search strategy in this study followed the PICOS (Population, Intervention, Comparison, Outcome, Study Design) framework, as recommended by Nursalam (2020). The *Population (P)* in this study focused on patients diagnosed with type 2 diabetes mellitus. These individuals represented the primary demographic under investigation concerning the impacts of sedentary behavior on blood glucose levels.

The *Intervention (I)* examined strategies aimed at reducing sedentary behavior among patients with type 2 diabetes mellitus. Although comparison groups (*Comparison, C) were not explicitly included, the review focused on identifying effective intervention outcomes related to physical activity and sedentary reduction. The *Outcome (O)* emphasized identifying and analyzing the relationship between sedentary behavior and blood glucose levels among type 2 diabetes patients. The *Study Design (S)* included cross-sectional studies, longitudinal studies, cohort studies, descriptive studies, randomized clinical trials, and narrative literature reviews.

Table 1. PICO research format

Criteria	Inclusion	Exclusion
Patient or problem	Type 2 diabetes mellitus patients	Non-type 2 diabetes mellitus patients
Intervention	Sedentary behavior reduction	No exclusion
Comparison	No comparison	No exclusion
Outcome	Analyzing the relationship between sedentary behavior and blood sugar levels in type 2 diabetes mellitus patients	Not relating to the relationship between sedentary behavior and blood sugar levels in type 2 diabetes mellitus patients
Research design	Cross-sectional, longitudinal study, cohort study, descriptive study, randomized clinical trial	Literature review, systematic review, meta-analysis review
Publicationn year	2011-2021	Before 2011
Language	Indonesian or English	Other than Indonesian or English
Index	SCIMAGO or SINTA	Not indexed in SCIMAGO or SINTA

Table 1. explains the PICO research format, which outlines the inclusion and exclusion criteria of the articles used in this study. The inclusion and exclusion criteria were established to ensure the relevance and quality of the selected literature. Included studies focused on patients with type 2 diabetes mellitus, evaluated the reduction of sedentary behavior, and analyzed the relationship between sedentary behavior and blood glucose levels. Only articles published between 2011 and 2021, written in either Indonesian or English, and indexed in SCIMAGO or SINTA were considered. Articles were excluded if they

did not focus on type 2 diabetes mellitus patients, did not analyze the relationship between sedentary behavior and blood glucose levels, or were not indexed in SCIMAGO or SINTA.

2.3 Study selection

The study selection process adhered to the PRISMA flowchart, which includes four main stages: identification, screening, eligibility, and inclusion (Nursalam, 2020). The *Identification* phase involved searching the specified databases using the previously mentioned keywords and Boolean operators. The search results yielded a total of 36,108 articles from PubMed (n=542), ScienceDirect (n=4,315), Sage Journals (n=750), SpringerLink (n=3,659), ProQuest (n=7,683), Wiley Online Library (n=2,449), Google Scholar (n=16,700), GARUDA (n=10), and others. Due to the unavailability of relevant articles from databases such as Neliti, Oxford Academic, JAMA, PLOS ONE, Taylor & Francis Online, and Harvard Health Publishing, these sources were excluded from further analysis.

In the *Screening* phase, initial filtering was performed based on inclusion and exclusion criteria, resulting in a refined set of 24,525 articles. Further screening based on the relevance of titles and abstracts reduced this number to 41 articles. Duplicate entries were manually removed, leaving 36 articles. Subsequent abstract analysis excluded studies that did not focus on sedentary behavior, blood glucose levels, or type 2 diabetes, leaving 27 articles. A final full-text review, guided by the inclusion and exclusion criteria, resulted in the selection of 12 articles for analysis.

The *Eligibility* phase involved a thorough review of the selected articles to ensure they met all predefined criteria. Studies that failed to directly address the relationship between sedentary behavior and blood glucose levels in type 2 diabetes mellitus patients were excluded. Articles that passed this stage proceeded to the final *Inclusion* phase, where 12 articles were confirmed for data extraction and analysis.

2.4 Data analysis

The data analysis technique employed in this study was comparative analysis, as described by Nursalam (2020). This method involves identifying similarities and patterns across multiple studies concerning variables such as research methods, outcomes, interventions, and conclusions. Comparative analysis facilitates the synthesis of key findings and enhances the reliability of the study results.The analysis was carried out by systematically comparing variables from the selected articles retrieved from databases such as PubMed, ProQuest, GARUDA, Google Scholar, and Wiley Online Library. Each article was analyzed based on author details, publication year, study title, research design, sample size, instruments used, analysis methods, key findings, and overall conclusions. The findings were then synthesized to provide a comprehensive overview of the relationship between sedentary behavior and blood glucose levels in type 2 diabetes mellitus patients, offering valuable insights for healthcare professionals and future researchers.

3. Results and Discussion

3.1 Study characteristics

Based on the search results, 12 relevant articles were identified for use as literature in this study, providing a comprehensive range of insights. The research designs employed in these articles varied significantly, which contributes to the strength and diversity of the findings. Seven of the studies were cross-sectional, offering a snapshot of data at one point in time, while three were longitudinal studies, tracking changes over time to provide deeper insights into the phenomena being examined. Additionally, two randomized controlled trials were included, which offer the highest level of evidence in terms of establishing causality.

The literature sources came from both international and national origins, further diversifying the scope of the research. Six of the articles were from countries such as the

United Kingdom, Portugal, and the United States, adding a global perspective to the study. The remaining articles originated from domestic regions such as Surabaya, Surakarta, Karangasem, and Riau, reflecting the relevance and applicability of the research in local settings. The geographic and methodological diversity of these studies enhances the reliability of the findings and supports the generalizability of the conclusions drawn from the research.

3.2 Characteristics of study respondents

The characteristics of the respondents described in the selected articles predominantly focused on patients with type 2 diabetes mellitus, offering valuable insights into this population. Across the 12 studies reviewed, the sample sizes varied, with the average number of participants exceeding 45. The largest sample size in a study consisted of 86 respondents, while the smallest sample involved just 12 participants. This range highlights the variety in the scope of research conducted on this topic. The research also reveals a notable gender disparity, as the majority of participants were female. This trend may suggest that women are more likely to participate in diabetes-related research, potentially due to different health-seeking behaviors or greater awareness of diabetes risks.

The age range of participants in the studies varied significantly, with respondents spanning from over 18 years to 85 years old. This broad age range allows for a more comprehensive understanding of how sedentary behavior affects individuals with type 2 diabetes across different stages of life. The duration of diabetes diagnosis also varied, with participants diagnosed anywhere from one to ten years prior to the study. This diversity in both age and the length of time since diagnosis provides a well-rounded representation of individuals living with type 2 diabetes and allows researchers to examine the effects of sedentary behavior in varying contexts, from newly diagnosed patients to those with long-standing conditions. The diverse demographic profiles within these studies contribute to a better understanding of how sedentary behavior influences the management of type 2 diabetes across different patient groups.

3.3 Study findings

This literature review analyzed 12 relevant studies to extract findings regarding sedentary behavior and glycemic control in patients with type 2 diabetes mellitus. The analysis revealed consistent associations between sedentary behavior patterns, interruptions in sedentary time, and glycemic outcomes.

Table 2. Study findings

No	Author/Year	Title/Volume/Journal Name	H-Index (SCIMAGO)	Demographic Characteristics: Place (P), Age (A), Gender (G)	Methodology: Design (D), Sample (S), Instrument (I), and Analysis (A)	Results	Summary of Results
1	Paing et al. (2018)	Dose-response between frequenct of interruption of sedentary time and fasting glucose, the dawn phenomenon and night-time glucose Type 2 Results/Diabetic Medicine	H-145	P: England A: Average age 60 years G: Not specified	D: Randomized three-treatment S: 12 people I: ActivPAL 3 for measuring sedentary behavior; FreeStyle Libre for continuous glucose monitoring A: Multilevel mixed-effect linear regression to assess changes in glucose levels between conditions for the same individuals.	1. Participants were divided into three groups with three treatments: Group 1 interrupted sedentary behavior every 60 minutes, Group 2 every 30 minutes, and Group 3 every 15 minutes. Group 3 showed reductions in fasting glucose, the dawn phenomenon, and glycemic variability compared to Groups 1. 2. Fasting glucose and the duration of the dawn phenomenon were better controlled in Group 3 compared to Groups 2 and 1.	The interruption of sedentary behavior every 15 minutes improves glucose control in individuals with type 2 diabetes mellitus.
2	Sardinha et al. (2017)	Sedentary patterns, Physical Activity, and Cardiorespiratory Fitness in Association to Glycemic control in Type 2 Diabetes Patients/Frontiers in Physiology/8/262	H-102	P: Portugal A: Average age 58.9 years G: 29 females, 37 males	D: Cross-sectional S: 66 respondents I: Accelerometry to measure sedentary behavior, mixed meal tolerance test for glucose and insulin measurements. A: Independent sample test/Mann-Whitney-	1. In this study, women were more physically active than men, with no difference in sedentary behavior between sexes. Sedentary behavior negatively affected fasting glucose levels (β= 0.32, p=0.037). Reducing/interruption of sedentary behavior had beneficial effects on HOMA-IR (β=0.28, p=0.047) and fasting glucose (β=0.25, p=0.046).	Sedentary behavior is detrimental to the metabolic health of patients with type 2 diabetes mellitus and is associated with HOMA-IR, Matsuda index, and fasting glucose.

					Wilcoxon non-parametric for sex comparison and QQ plot normalization. Multiple regression analysis to understand the relationship between sedentary time, sedentary breaks, physical activity, and cardiorespiratory fitness with metabolic variables.	After adjusting for gender and cardiorespiratory fitness, total sedentary time negatively affected HbA1C (β=0.25, p=0.044), while interruption of sedentary behavior had beneficial effects on HOMA-IR (β=0.25, p=0.036), Matsuda index (β=0.26, p=0.036), and fasting glucose (β=0.22, p=0.038).	
3	Paing et al. (2019)	Dose- Respons between frequency of breaks in sedentary time and glucose control in type 2 diabetes; a proof of concept study/ Journal of science and medicine in sport/	H-99	P: English A: ≥35 years G: 4 females /8 males	D: Randomized three-treatment S: 12 participants I: activPAL (recording energy expenditure, sitting time, standing time, and lying time) CGM (monitoring glucose levels over two weeks) A: IBM SPSS Statistics version 24.0 Differences in glucose variables between treatment conditions were analyzed using multilevel mixed-effect linear regression with repeated measures. Differences in sitting time, standing time, walking time, energy expenditure, and energy intake were	Among the 12 participants, three interventions were performed after seven hours of sitting, with breaks of three minutes for moderate-intensity walking. In group 1, breaks occurred every 60 minutes; in group 2, every 30 minutes; and in group 3, every 15 minutes. The study demonstrated that breaking sedentary behavior every 15 minutes improved post-breakfast glucose (48%), cumulative glucose (62%), and 24-hour glucose (34%) compared to breaks every 60 minutes. Interrupting sedentary behavior every 15 minutes, combined with antidiabetic medication, was effective in reducing HbA1c and diabetes-related complications.	Interrupting sedentary behavior every 15 minutes is more effective in controlling daily blood glucose levels, while the combination of 15-minute breaks and antidiabetic medication is effective in reducing HbA1c levels and diabetes-related complications.

					analyzed using multilevel mixed-effect linear regression. Pairwise comparisons between treatment conditions were conducted using Fisher's LSD post-hoc test.		
4	Paing et al. (2018)	The association of sedentary time and breaks in sedentary time with 24 hour glycemic control in type 2 diabetes/ Preventive medicine reports/12	H-31	P: English A: ≥18 years G: 23 female respondents, 14 male respondents	D: Cross-sectional S: 37 respondents I: Freestyle Libre (measuring glucose every 15 minutes for two weeks), activPAL3 (monitoring sedentary behavior) A: Analysis was conducted using G*Power 3.1.9.2 to assess the strength of the relationship between sedentary behavior, sedentary breaks, and glucose control.	After adjusting for age, sex, BMI, carbohydrate intake, energy expenditure, and antidiabetic medication, sedentary time was significantly associated with a reduction in euglycemic periods (normal blood glucose levels) (β=0.44, 95% CI 0.86; 0.03, p=0.04). Statistically, there was also a significant association between sedentary time and prolonged hyperglycemia duration (β=0.36, 95% CI 0.05; 0.78, p=0.08). Reducing sedentary behavior significantly increased time spent in euglycemia (β=0.38, 95% CI 0.00; 0.75, p=0.04). Post-hoc power analysis revealed that there was a 97% probability of detecting a significant association between sedentary time and reduced euglycemic duration, and an 88% probability of detecting a significant association between sedentary breaks and increased euglycemic duration.	Duration of sedentary behavior was associated with poor glucose control, as evidenced by shorter euglycemic periods and increased hyperglycemic time. Interrupting sedentary behavior has a beneficial effect on improving daily glucose control.
5	Paing et al. (2020)	Impact of free living patern of sedentary	H-133	P: English	D: Longitudinal study	After adjusting for age, sex, sleep duration, carbohydrate intake, and	In conclusion, this study highlights that

	behavior on intra-day glucose regulation in type 2 diabetes/ europan journal of applie physiology/120	A: 60 years G: 23 females, 14 males	S: 12 participants I: ActivPAL (measuring energy expenditure, recording time spent sitting, standing, and lying down); CGM (monitoring glucose levels over two weeks) A: IBM SPSS Statistics version 24.0 A multiple regression model with Generalized Estimating Equations (GEEs) was used to examine the relationship between sedentary time and breaks in sedentary behavior with glucose levels before and after breakfast, lunch, dinner, and during the dawn phenomenon. Sensitivity analysis was performed to assess the relationship between sedentary behavior and breaks in sedentary behavior with glucose variables influenced by walking time and moderate-to-vigorous physical activity.	walking time (Model 1), sedentary behavior was significantly associated with elevated glucose levels before breakfast (0.18 mmol/L/hour, 95% CI 0.07; 0.28), after lunch (0.15 mmol/L/hour, 95% CI 0.04; 0.26), before dinner (0.21 mmol/L/hour, 95% CI 0.11; 0.32), after dinner (0.10 mmol/L/hour, 95% CI 0.02; 0.17), and during the dawn phenomenon (0.16 mmol/L/hour, 95% CI 0.11; 0.21). After further adjustment with BMI and diabetes duration in addition to Model 1, sedentary behavior remained associated with glucose levels before breakfast (0.19 mmol/L/hour, 95% CI 0.07; 0.29), after lunch (0.17 mmol/L/hour, 95% CI 0.06; 0.28), before dinner (0.17 mmol/L/hour, 95% CI 0.07; 0.28), after dinner (0.15 mmol/L/hour, 95% CI 0.04; 0.26), and during the dawn phenomenon (0.06 mmol/L/hour, 95% CI 0.00; 0.12). Long-term monitoring demonstrated that sedentary behavior significantly affects glycemic control throughout the day. The findings indicate that reducing sedentary behavior can clinically lower glucose levels before	sedentary behavior has a detrimental effect on glucose levels, particularly glucose levels before breakfast, lunch, and both before and after dinner. Reducing sedentary time can be an effective strategy for improving glycemic control.

						breakfast, lunch, and dinner by approximately 1 mmol/L.	
6	Paing et al. (2020)	Diurnal patterns of objectively measured sedentary time and interruptions to sedentary time are associated with glycaemic indices in type 2 diabetes/ journal of science and medicine in sport/	H-99	P: United Kingdom A: 62.8 years G: 14 males, 23 females	D: Longitudinal study S: 37 respondents I: ActivPAL3 (to measure sedentary behavior); Freestyle Libre (to measure glucose levels) A: Linear regression was used to identify the relationship between sedentary behavior and breaks in sedentary time during the morning, afternoon, and evening with glucose percentages and glucose range differences.	Sedentary behavior was higher in the evening compared to the morning and afternoon. Breaks in sedentary behavior were less frequent in the evening and most frequent in the morning. The absence of breaks in sedentary behavior during the morning and afternoon was associated with elevated glucose levels before dinner in the evening. There was a beneficial relationship between breaks in sedentary behavior during the evening and morning with achieving glucose targets before dinner, after breakfast, and after dinner, as well as with the duration of hyperglycemia and euglycemia.	In conclusion, the diurnal patterns of sedentary time and interruptions in sedentary behavior are significantly associated with glycemic indices in individuals with type 2 diabetes mellitus.
7	Fritschi et al. (2016)	Association Beetwen Daily Time Spent in Sedentary Behavior and Duration of Hyperglikemia in Type 2 Diabetes/ Biological Research for Nursing/18/2	H-46	P: United States (Midwestern) A: 58 years G: 42 females, 44 males	D: Descriptive longitudinal study S: 86 respondents I: A1CNow (to measure HbA1C) A: SPSS version 22 and STATA version 13. Generalized Estimating Equations (GEE) were used to examine the relationship between sedentary time and the	Based on the use of Actiwatch and Continuous Glucose Monitoring System (CGMS) over 2–5 days, the average time spent in sedentary behavior was 511 minutes per day during waking hours. Time spent in low-to-moderate physical activity was less than six minutes per day, with an average blood glucose level of 160 mg/dL sustained for 549 minutes per day. Prolonged sedentary behavior was associated with an extended period of hyperglycemia.	In conclusion, prolonged sedentary behavior contributes to extended hyperglycemic duration in patients with type 2 diabetes mellitus. Regular breaks in sedentary behavior should be promoted as part of physical activity guidelines for diabetes management and prevention.

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					duration of hyperglycemia over five days.	Sedentary behavior throughout the day was found to predict hyperglycemic duration at levels exceeding 8.9 mmol/mol (160 mg/dL) over five days. The findings indicate that each additional minute of sedentary behavior increases hyperglycemic duration by 0.12 minutes. If sedentary behavior is prolonged by 60 minutes, the duration of hyperglycemia is expected to increase by 7.4 minutes.	
8	Sam et al. (2017)	Analysis of the relationship between activities of daily living (ADL), physical activity, and dietary compliance with blood glucose levels in diabetes mellitus patients in the working area of Poasia Public Health Center in 2017. Student Scientific Journal of Public Health, 2.	S-5 H-17	P: Poasia A: 30–65 years G: 46 females, 17 males	D: Cross-sectional S: 63 respondents I: Glucotest was used to measure blood glucose levels, supported by interviews and questionnaires. A: Chi-Square test was used to evaluate the association between physical activity and blood glucose levels.	Out of the 63 respondents, 30 individuals (47.6%) with low levels of physical activity had uncontrolled blood glucose levels. Meanwhile, among the 33 respondents with moderate physical activity levels, 90.9% had controlled blood glucose levels, while only 9.1% exhibited uncontrolled blood glucose levels. The results of the Pearson correlation test demonstrated a significant relationship between physical activity and blood glucose levels in patients with type 2 diabetes mellitus.	There is a significant association between physical activity and the control of blood glucose levels in patients with type 2 diabetes mellitus. Adequate physical activity plays an essential role in achieving better glycemic control in diabetic patients.
9	Nurayati & Adriani (2017)	Hubungan aktivitas fisik dengan kadar gula darah puasa penderita diabetes melitus tipe 2. *Amerta Nutrition*, 1(1), 80–87.	S2 h-22	P: Surabaya A: 30–80 years G: 27 males, 35 females	D: Cross sectional S: 62 I: The Physical activity questionnaire (PAQ)	Among the 62 respondents, 36 individuals experienced elevated fasting blood glucose levels exceeding 160 mg/dL. Respondents with type 2 diabetes mellitus exhibited low physical activity levels and tended to	There is a clear association between low physical activity levels and increased fasting blood glucose levels in patients with type 2 diabetes mellitus.

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					A: Spearman's rho was employed to examine the relationship between physical activity and fasting blood glucose levels in type 2 diabetes mellitus patients.	engage in sedentary behavior. Many reported reduced physical activity after being diagnosed, as they stopped working and spent more time sitting. Respondents with low physical activity levels demonstrated high fasting blood glucose levels, with a prevalence rate of 76.9%. This finding indicates a significant relationship between low physical activity and elevated fasting blood glucose levels in type 2 diabetes mellitus patients.	Promoting regular physical activity is essential for improving glycemic control and preventing complications associated with diabetes.
10	Alza et al. (2020)	Physical Activity, Disease Duration, and Blood Glucose Levels In Type 2 Diabetes Mellitus Patients/ Gizido/12/ 1	S5 H-13	P: Riau A: 30–80 years G: 22 females, 2 males	D: Cross-sectional S: 24 respondents I: Easy Touch GCU for measuring blood glucose levels; physical activity assessed through interviews . A: Univariable analysis was used to examine blood glucose levels and physical activity.	Among the 24 respondents, 16 individuals (66.77%) exhibited low physical activity levels, while 8 individuals engaged in moderate physical activity. Regular exercise, performed 3-4 times a week, was found to improve insulin sensitivity and help control blood glucose levels. Respondents with low physical activity levels exhibited uncontrolled blood glucose levels, whereas those with moderate physical activity showed better glycemic control.	Regular physical exercise, at least 3-4 times a week, is an effective approach to controlling blood glucose levels in patients with type 2 diabetes mellitus. Promoting physical activity in diabetic patients is crucial for improving insulin sensitivity and preventing complications.
11.	Mujabi, & Yuniartika. (2018)	The relationship between blood sugar levels and depression and physical activity in people with diabetes mellitus.	S3 H- 14	P: Surakarta A : 40–75 years G: 16 males, 39 females	D: Cross-sectional S: 55 respondents I: BDI II (Beck Depression Inventory-II) and IPAQ	Among the 55 respondents, 33 individuals (60%) exhibited low levels of physical activity. The study found a significant relationship between physical	Physical activity levels significantly influence blood glucose control in patients with type 2 diabetes mellitus. Encouraging higher

		Journal of Nursing Science News, 11(2), 153–159.			(International Physical Activity Questionnaire) A: Descriptive correlational analysis to assess the relationship between blood glucose levels, depression levels, and physical activity in type 2 diabetes mellitus patients.	activity levels and blood glucose levels in diabetes mellitus patients.	levels of physical activity may improve glycemic control and reduce associated complications, including depression.
12	Pawana et al. 2013	Activity Levels a nd Their Impact On Blood Glucose In Diabetes Mellitus Patients In The Working Area Of Puskesmas Karangasem I (September-October 2013)	S3 H-11	Research Location: Karangasem Age Range: 35–85 years Gender Distribution: 32 males, 23 females	Study Design: Cross-sectional Sample Size: 55 respondents Instruments: Glucometer for blood glucose measurement and an unspecified questionnaire Data Analysis: Univariate and bivariate analysis	Among the 55 respondents, 21 individuals had low levels of physical activity. Of the 21 respondents with low physical activity, 11 (52.4%) had uncontrolled blood glucose levels.	Low physical activity levels are associated with poor blood glucose control in diabetes mellitus patients, highlighting the importance of increasing physical activity for better glycemic management.

Paing et al. (2018) found that interrupting sedentary behavior every 15 minutes resulted in better fasting glucose levels and glycemic variability compared to interruptions every 30 or 60 minutes. Another study by Sardinha et al. (2017) demonstrated that sedentary behavior adversely affected fasting glucose levels and insulin resistance (HOMA-IR), with interruptions showing beneficial effects on metabolic health indicators. Similarly, Paing et al. (2019) reported that breaking sedentary time every 15 minutes was more effective in improving daily glucose control and reducing HbA1c levels compared to less frequent interruptions.

In longitudinal studies, such as those by Fritschi et al. (2016) and Paing et al. (2020), prolonged sedentary behavior was associated with extended hyperglycemia durations and poorer glucose control. Fritschi et al. (2016) specifically highlighted that each additional minute of sedentary time increased hyperglycemia duration by 0.12 minutes. Moreover, the study by Sam et al. (2017) indicated a significant relationship between physical activity levels and controlled blood glucose levels, suggesting that reduced sedentary time and increased physical activity are essential components of diabetes management. These findings emphasize that reducing sedentary time and incorporating frequent breaks or physical activities play a crucial role in improving glycemic control. The collective evidence supports the integration of structured sedentary time interventions into diabetes care plans to optimize health outcomes.

3.4 The relationship between sedentary behavior and blood glucose levels in patients with type 2 diabetes mellitus

Patients with type 2 diabetes mellitus are prone to sedentary behavior (Nurayati, 2017). Measurements using actiwatch and Continuous Glucose Monitoring System (CGMS) over 2–5 days revealed that respondents spent an average of 511 minutes per day engaging in sedentary activities (Fritschi, 2016). Similarly, a study by Paing et al. (2018) indicated that diabetes mellitus patients spent an average of 9.8 ± 1.8 hours per day in sedentary behavior. This finding aligns with Sardinha et al. (2017), who reported that diabetes patients spent approximately 582 minutes or 9.7 hours per day in sedentary activities. Prolonged sedentary behavior has been associated with reduced euglycemic periods and prolonged hyperglycemia duration (Paing, 2018). Furthermore, sedentary behavior adversely affects glycemic outcomes (Sardinha, 2017; Sam, 2017).

Patients with type 2 diabetes mellitus often exhibit increased sedentary behavior after being diagnosed. Nurayati (2017) reported that 36 out of 62 respondents with type 2 diabetes had low physical activity levels, with 76.9% experiencing elevated blood glucose levels. Supporting this, Sam (2017) found that 30 out of 63 respondents (47.6%) exhibited low physical activity levels and poor blood glucose control. Similarly, Alza (2020) noted that 66.7% of respondents, or 16 out of 24 participants, had low physical activity levels. Mujabi (2018) found that 60% of respondents (33 out of 55) displayed sedentary habits. Additionally, Pawana (2013) reported that 21 out of 55 respondents had low physical activity levels, and 11 of them (52.4%) experienced uncontrolled blood glucose levels.

Prolonged sedentary behavior has been shown to increase hyperglycemic duration and shorten euglycemic periods (Fritschi, 2016). A post-hoc power analysis revealed that 97% of findings significantly detected a relationship between sedentary behavior and reduced euglycemic duration, while 88% identified a significant relationship between interrupting sedentary behavior and increased euglycemic duration (Paing, 2018). In a study by Paing et al. (2019), interrupting sedentary behavior every 15 minutes with 3 minutes of light walking improved post-breakfast glucose (48%), cumulative postprandial glucose (62%), and 24-hour glucose levels (34%) compared to breaks every 60 minutes.

Paing (2018) further reported that interrupting sedentary behavior every 15 minutes resulted in better fasting glucose control, improved dawn phenomenon, and enhanced glycemic outcomes compared to interruptions every 30 or 60 minutes. Interruptions during

morning and evening periods were found to be beneficial for achieving pre-breakfast, post-breakfast, and post-dinner glucose targets, as well as for improving hyperglycemic and hypoglycemic durations (Paing, 2020). The frequent and consistent interruption of sedentary behavior produces effects comparable to antidiabetic medications, significantly enhancing daily glucose control (Paing, 2019).

3.5 Discussion

Sedentary behavior refers to a state where energy expenditure is ≤1.5 Metabolic Equivalents (METs) while sitting or lying down during waking hours (Tremblay, 2017). Activities such as sitting, lying down, watching television, using a computer, playing video games, driving, and reading fall into this category (Sedentary Behavior Research Network, SRBN). According to Oshima et al. (2016), sedentary behavior, combined with insufficient physical activity during leisure time, contributes to health problems, including obesity, metabolic syndrome, cardiometabolic diseases, type 2 diabetes, and premature mortality. This behavior has detrimental effects on patients with type 2 diabetes mellitus as it is associated with poor glucose control, characterized by reduced euglycemic periods and prolonged hyperglycemia duration (Paing et al., 2018; Sardinha et al., 2017; Fritschi et al., 2016; Paing, 2020; Sam, 2017).

Studies measuring sedentary behavior duration, such as those conducted by Nicolo et al. (2019), Honda et al. (2019), Paing et al. (2018), and Fritschi et al. (2016), consistently show that respondents with type 2 diabetes mellitus spend between 8 and ≥10 hours per day engaging in sedentary behavior. This finding aligns with the NHANES 2001–2016 survey, which reported persistently high and stable sedentary behavior durations across adolescents, adults, and older individuals (Yang, 2019). Furthermore, Oshima et al. (2016) observed through accelerometer measurements that adults spend an average of 9 hours per day in sedentary behavior, with individuals aged ≥60 years averaging 10 hours daily, exceeding the levels observed in children and adolescents. Several studies have reported that between 38% and 66.7% of patients with type 2 diabetes mellitus have low physical activity levels. Sam (2017) found that 30 out of 63 respondents exhibited low physical activity, while Sardinha (2017) reported 36 out of 62 respondents. Alza (2020) identified 16 out of 24 individuals with low physical activity levels, while Mujabi (2018) reported 33 out of 55 respondents, and Pawana (2013) noted 21 out of 55 participants demonstrating sedentary habits. These findings emphasize that low physical activity among patients with type 2 diabetes mellitus increases the risk of poor blood glucose control.

Patients with diabetes mellitus are recommended to reduce sedentary behavior and increase physical activity to lower mortality risk and prevent cardiovascular diseases. According to the World Health Organization (World Health Organization, 2020), adults with chronic conditions should engage in moderate-intensity aerobic physical activity for at least 150–300 minutes per week or vigorous-intensity physical activity for 75–150 minutes per week. Additionally, they should include muscle-strengthening exercises, balance training, and resistance exercises of moderate-to-high intensity to improve functional capacity and prevent falls. Regular interruptions in sedentary behavior through exercise have been shown to improve glycemic control in type 2 diabetes patients (Alza, 2020). Prolonged sedentary habits, if left unchecked, can worsen daily glucose control and increase the risk of diabetes complications. Therefore, glucose management strategies should include periodic breaks from sedentary behavior, as recommended.

Although the mechanisms linking sedentary behavior with blood glucose levels require further research (Honda, 2019; Sardinha, 2017), it is hypothesized that prolonged physical inactivity leads to muscle atrophy and shifts in muscle fiber type, contributing to insulin resistance (Honda, 2019). Atrophied muscles exhibit impaired glucose uptake (Bergouignan, 2016). Light-intensity activities replacing sedentary behavior can enhance glucose control independently of insulin (Bergouignan, 2016).

To mitigate the negative impacts of sedentary behavior, adults with chronic diseases are encouraged to replace sedentary time with moderate-to-vigorous physical activity (WHO, 2020). Effective diabetes management involves a combination of a healthy diet, regular physical exercise, smoking cessation, and weight management (IDF, 2020). Longitudinal intensive monitoring has demonstrated that sedentary behavior modifies glycemic control throughout the day. Interventions targeting sedentary behavior can optimize glycemic control during morning, daytime, and nighttime periods (Paing, 2020). Studies by Henzon (2016) and Nurayati (2017) conclude that consistent interruption of sedentary behavior through light ambulation improves glucose regulation. Frequent and consistent sedentary breaks can serve as a strategic intervention to manage blood glucose levels and prevent diabetes-related complications.

During the COVID-19 pandemic, restrictions such as social distancing, quarantine, and mobility limitations increased stress levels, unhealthy snacking habits, and reduced physical activity, leading to weight gain and poor HbA1c control (Ruissen, 2021). Physical inactivity levels rose significantly during the pandemic compared to pre-pandemic levels, particularly among individuals aged ≥40 years (42.9% before the pandemic versus 57.3% during the pandemic) and among diabetes patients (43.2% before versus 57.7% during the pandemic) (Marcal, 2020). Prolonged sedentary behavior and insufficient physical activity increased hospitalization risks for diabetes patients during the pandemic. Patients with uncontrolled diabetes mellitus (blood glucose levels >180 mg/dL) infected with COVID-19 faced higher risks of severe complications and mortality (Marcal, 2020).

Interrupting sedentary behavior stimulates muscle contraction, causing GLUT-4 translocation and increasing glucose uptake by skeletal muscles without insulin involvement (Holt, 2010). Physical exercise enhances GLUT-4 expression, promoting glucose uptake even in type 2 diabetes patients (Dugan, 2016). Aerobic and resistance exercises improve insulin sensitivity for up to 72 hours post-exercise while reducing glucose concentrations for 2–48 hours (Dugan, 2016). Therefore, regular exercise and consistent sedentary breaks are essential strategies for managing blood glucose levels and preventing complications in type 2 diabetes patients.

In conclusion, patients with type 2 diabetes mellitus typically spend 8–10 hours daily in sedentary behavior. Prolonged sedentary habits without periodic breaks can exacerbate glucose control and prolong hyperglycemic episodes. Regular interruptions in sedentary time, combined with adherence to physical activity recommendations, are crucial strategies for improving glucose control, reducing diabetes complications, and enhancing overall health outcomes. Public health campaigns should emphasize the importance of these interventions for diabetes management.

4. Conclusions

The findings from the literature review suggest that prolonged sedentary behavior negatively impacts glucose control in patients with type 2 diabetes mellitus, leading to reduced euglycemic durations and prolonged hyperglycemic states. Interrupting sedentary behavior with regular physical activity can improve glucose uptake in skeletal muscles and help enhance daily glucose control, with effects comparable to anti-diabetic medications. Therefore, individuals with type 2 diabetes should increase their physical activity and reduce sedentary behavior to better manage their condition.

Future research should further investigate the link between sedentary behavior and insulin resistance, with a focus on underlying mechanisms. Healthcare providers can use these insights to educate patients on the risks of sedentary behavior and the benefits of physical activity in managing blood glucose levels. This information should be integrated into nursing education, ensuring future healthcare professionals are well-equipped to manage type 2 diabetes and prevent its complications.

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