Correlation Analysis between Daily Routine Physical Activity And Blood Glucose Control in Diabetes Mellitus Patients at The Kampung Masjid Labuhan Batu Utara Community Health Center

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***Abstract**.*

Elevated blood glucose and low physical activity represent critical health concerns in primary healthcare settings. This study aimed to analyze the correlation between daily routine physical activity and blood glucose control in patients with diabetes mellitus at Kampung Masjid Primary Health Center, North Labuhan Batu. A quantitative descriptive correlational design with cross-sectional approach was employed. Total sampling encompassed 55 diabetes patients meeting inclusion criteria. Data collection utilized the Global Physical Activity Questionnaire (GPAQ) and random blood glucose measurements from medical records. Spearman rank correlation analysis was conducted using SPSS version 25 following KolmogorovSmirnov normality testing. Results demonstrated a significant negative correlation (r = -0.615, p = 0.000) between physical activity levels and blood glucose concentration. Approximately 45.5% of patients engaged in low physical activity, while the mean blood glucose was 307.53 mg/dL, substantially exceeding therapeutic targets. Increased physical activity substantially improved glycemic control, indicating that physical activity represents a critical modifiable factor for diabetes management in primary healthcare. These findings support evidence-based physical activity promotion as essential for integrated diabetes management approaches combining pharmacological intervention with structured exercise supervision at Puskesmas facilities throughout Indonesia.

Keywords: *Blood Glucose Control; Diabetes Mellitus; Physical Activity; Primary Healthcare and Spearman Correlation.*

I. INTRODUCTION

Research Phenomenon

Elevated blood glucose levels resulting from impaired glucose metabolism constitute a defining characteristic of diabetes mellitus, a chronic metabolic disorder characterized by insulin deficiency or resistance that prevents adequate glucose uptake by cells. The global diabetes epidemic continues to expand at an alarming rate, with the World Health Organization estimating that approximately 783 million individuals worldwide are projected to have diabetes by 2045, compared to 537 million in 2021, representing a substantial increase in disease burden across all regions. Indonesia ranks among the countries most affected by this epidemic, with a prevalence estimated at 10.7 million individuals living with diabetes mellitus, positioning the nation at seventh globally. The prevalence of diabetes in Indonesia is projected to increase from 9.19% in 2020 (18.69 million cases) to 16.09% in 2045 (40.7 million cases), equivalent to a 75.1% increase over 25 years. Within Indonesian provinces, notable geographic variations exist, with Jakarta and East Nusa Tenggara demonstrating the highest and lowest prevalence rates at 2.6% and 0.5%, while North Sumatra reported 202,402 cases of diabetes mellitus in 2021, with Medan municipality accounting for the highest documented prevalence at 98.58%.

The substantial increase in diabetes mellitus incidence across populations reflects the combined influence of demographic transitions, sedentary lifestyle behaviors, and inadequate metabolic management. Sedentary lifestyles, characterized by prolonged sitting and low-energy physical activity, constitute a major modifiable risk factor for type 2 diabetes mellitus development. Recent evidence demonstrates that sedentary individuals exhibit a 77% prevalence of type 2 diabetes compared to only 16% in physically active individuals, underscoring the critical protective effect of regular physical activity. Physical inactivity has been consistently associated with adverse metabolic markers, including elevated fasting blood glucose, increased triglyceride levels, elevated cholesterol, and higher body mass index values, all of which collectively contribute to insulin resistance and impaired glucose homeostasis. The multifactorial nature of diabetes mellitus etiology necessitates a comprehensive management approach that extends beyond pharmacological interventions to encompass lifestyle modifications, particularly sustained increases in physical activity levels, which have been demonstrated to ameliorate glycemic control through multiple physiological mechanisms.

Research Problem

Despite recognition of physical activity as an essential component of diabetes mellitus management, substantial evidence indicates that patient adherence to recommended physical activity guidelines remains suboptimal at the primary healthcare level. Studies examining physical activity patterns in diabetes mellitus patients reveal that approximately 45.5% of individuals demonstrate low physical activity levels, with only 20% achieving high activity classification according to the Global Physical Activity Questionnaire, suggesting widespread difficulty in implementing sustained behavior change. Epidemiological research has established a strong inverse correlation between physical activity levels and blood glucose control, with multiple investigations demonstrating that individuals engaging in regular aerobic exercise at moderate intensity for at least 150 minutes weekly achieve significant reductions in hemoglobin A1c levels ranging from 0.5% to 0.7%, representing clinically meaningful improvements in longterm glycemic control. However, physiological evidence also indicates that the benefits of physical activity on insulin sensitivity are transient, lasting only 2 to 72 hours after each exercise bout, necessitating consistent implementation of regular physical activity to maintain sustained glucose control. Consequently, identifying barriers to physical activity adherence and developing effective intervention strategies that promote sustained behavior change remains a critical priority for primary healthcare settings.

The inconsistent implementation of structured physical activity interventions in primary healthcare facilities further compounds suboptimal diabetes management outcomes. While international guidelines from the American College of Sports Medicine and World Health Organization recommend specific physical activity prescriptions, including 150 to 300 minutes weekly of moderate-intensity aerobic activity or equivalent vigorous-intensity exercise combined with resistance training, primary healthcare centers often lack systematic mechanisms for delivering personalized, structured physical activity programs, resulting in missed opportunities for meaningful glycemic improvement. Research examining diabetes management in community health centers indicates that existing approaches frequently prioritize pharmacological management and glucose monitoring while inadequately addressing behavioral components necessary for optimal disease control, such as supervised exercise prescription, activity monitoring, and ongoing behavioral support. Furthermore, the relationship between daily routine physical activity and blood glucose control remains understudied in many primary healthcare settings, particularly regarding whether modest increases in habitual physical activity, distinct from structured exercise programs, produce meaningful glycemic improvements in real-world clinical contexts.

The epidemiological and clinical gap regarding the correlation between daily physical activity patterns and glycemic control at the primary healthcare level prompted investigation into this relationship within a specific Indonesian healthcare setting. Preliminary observations in Medan municipality, where diabetes mellitus represents a significant health burden with 98.58% case documentation rate among municipalities and districts in 2021, suggest that many patients struggle to maintain recommended physical activity levels despite receiving standard diabetes education and pharmacological management. The absence of quantitative local data characterizing the magnitude and direction of the relationship between daily physical activity and blood glucose control in this specific population represents a significant evidence gap that impairs clinical decision-making regarding resource allocation, intervention prioritization, and patient education strategies at the primary healthcare level.

Research Objective, Research Urgency, and Research Novelty

This study aimed to analyze the correlation between daily routine physical activity and blood glucose control in patients with diabetes mellitus attending Kampung Masjid Primary Health Center in North Labuhan Batu. The research holds considerable urgency given the escalating prevalence of diabetes mellitus in Indonesia and the insufficient physical activity levels demonstrated by affected populations, necessitating evidencebased interventions that address modifiable risk factors at primary healthcare settings where the majority of Indonesian diabetes patients receive care. The novelty of this investigation resides in its quantitative characterization of the relationship between objectively measured physical activity using the Global Physical Activity Questionnaire and biochemically verified blood glucose control, providing locally applicable evidence that can inform the development of structured physical activity programs tailored to the economic and cultural context of Indonesian primary healthcare settings, thereby contributing to the evidence base for integrated diabetes management approaches that successfully bridge the gap between guideline recommendations and real-world clinical implementation.

II. METHODS

Research Design and Types of Research

This research employed a quantitative descriptive correlational design with a cross-sectional approach. According to Sugiyono (2021), quantitative research methodology relies on numeric data and statistical techniques to measure and understand natural and social phenomena, using structured instruments such as questionnaires and scales analyzed through statistical methods including regression analysis, analysis of variance, and path analysis. The fundamental objective of quantitative research is to establish generalizations or predict future events based on patterns identified in historical data. The descriptive correlational method, as outlined by Creswell and Creswell (2022), aims to describe the relationship between two or more variables at a single point in time without establishing causal relationships, thereby providing comprehensive understanding of natural associations within a given population. The cross-sectional approach permitted simultaneous collection of data on daily physical activity and blood glucose levels from study participants at a specific time point, eliminating the need for longitudinal follow-up and enabling efficient investigation of the association between variables in the primary healthcare context.

Research Variables

The research framework incorporated two primary variables in the analytical structure. The independent variable consists of daily routine physical activity levels measured through validated instruments. The dependent variable (dependent variable) comprised blood glucose control outcomes assessed through laboratory measurements. According to Sudaryono (2023), identification and precise operationalization of variables constitute essential preliminary steps in quantitative research design, ensuring consistency between conceptual definitions and measurement procedures employed in data collection. Independent and dependent variables were clearly defined operationally to facilitate accurate measurement and meaningful analysis of their relationships.

Population and Sample Selection

The target population encompassed all patients with diabetes mellitus receiving care at Kampung Masjid Primary Health Center (Puskesmas Kampung Masjid) in North Labuhan Batu. Sudaryono (2023) defines population as the complete collection of units that share common characteristics and represent the focus of research inquiry. The research employed a total sampling methodology, incorporating all diabetes mellitus patients who fulfilled established inclusion and exclusion criteria. Inclusion criteria included patients who provided informed written consent, had received treatment at Kampung Masjid Primary Health Center, possessed documented blood glucose measurements within the health center's medical records, and were aged 18 years or older. Exclusion criteria encompassed patients who declined participation, were attending the health center for initial consultation only, presented with serious complications requiring hospitalization, were pregnant or lactating, or had incomplete medical records. This sampling strategy ensured comprehensive inclusion of the accessible population, facilitating analysis of the complete cohort served by the primary healthcare facility.

Research Instruments and Data Collection Techniques

Two primary instruments were employed for comprehensive data collection. The first instrument consisted of a structured demographic questionnaire capturing personal information including age, sex, occupational status, educational level, marital status, body height, body weight, and duration of diabetes mellitus diagnosis. The questionnaire also collected clinical information from medical records including recent blood glucose measurements and relevant medical history. The second instrument comprised the

Global Physical Activity Questionnaire (GPAQ) version translated into Indonesian, a validated instrument recommended by the World Health Organization (2012) for measuring physical activity across populations aged 15 to 89 years. This questionnaire contains 16 items organized into four domains addressing occupational physical activity, transportation-related physical activity, leisure-time recreational physical activity, and sedentary behavior patterns. According to Emzir (2023), instrument selection in quantitative research requires ensuring validity, reliability, and applicability to the target population. The GPAQ domains specifically assess intensity and duration of physical activities performed during each week, permitting calculation of activity levels expressed in metabolic equivalent of task (MET) values per minute per week.

Activity intensity assignments utilize 4 MET for moderateintensity activities and 8 MET for vigorous-intensity activities according to World Health Organization classifications. Categorical classification of physical activity levels follows WHO standards categorizing activities as low (less than 600 MET-minutes per week), moderate (600 to 3000 MET-minutes per week), or high (3000 or more METminutes per week). Blood glucose data were collected from patient medical records at Kampung Masjid Primary Health Center using random blood glucose (RBG) measurements recorded through laboratory examinations. Data extraction involved documenting the most recent valid blood glucose measurements available in each patient's medical record. According to Sudaryono (2023), data collection in quantitative research requires systematic procedures ensuring accuracy, completeness, and integrity of information from identified sources. Questionnaires were completed through direct administration with researcher assistance when required, ensuring respondent comprehension and accurate response documentation. The data collection process occurs over a specified timeframe to incorporate all eligible participants meeting selection criteria.

Research Procedures

The research procedure comprised three sequential phases. The preliminary phase involved obtaining administrative authorization from Kampung Masjid Primary Health Center leadership, conducting preliminary investigation to identify the research population and relevant clinical issues, collecting relevant literature resources, and preparing questionnaire instruments according to ethical standards. Documentation requirements included securing informed consent forms and ensuring compliance with institutional research protocols established by the primary healthcare facility. The implementation phase involved systematic questionnaire distribution to patient meeting inclusion criteria, with researcher presence to provide clarification when respondents required assistance. Researchers reviewed completed questionnaires for completeness before finalizing data collection. Simultaneously, researchers extracted blood glucose data from institutional medical records, ensuring documentation of dates and measurement circumstances. Data collection progressed systematically to maintain consistency and completeness across all participants.The concluding phase encompasses data organization, coding, and entry into statistical analysis software. Researchers verified data accuracy through review of questionnaires and medical records, established a comprehensive database incorporating all variables, and prepared data for subsequent statistical analysis according to predetermined analytical procedures.

Data Analysis Techniques

Data analysis proceeds through two complementary approaches addressing both descriptive characteristics and relational hypotheses. Univariate analysis characterizes the distribution and features of each research variable independently. Frequency distributions and descriptive statistics including minimum values, maximum values, means, and standard deviations were calculated for blood glucose levels, physical activity scores, and respondent characteristics such as age and sex. Descriptive statistics provided comprehensive summary information about the study population and variable distributions, facilitating identification of data patterns and anomalies. Bivariate analysis examined associations between physical activity levels and blood glucose control. According to Creswell and Creswell (2022), bivariate analysis in quantitative correlational designs enables investigation of relationships between two variables through appropriate statistical tests selected based on data characteristics. Prior to correlation analysis, normality testing was performed using the Kolmogorov-Smirnov test at a 0.05 significance level to determine whether data followed normal distribution patterns. Data with p-values exceeding 0.05 were interpreted as normally distributed, while data with p-values below 0.05 were classified as non-normally distributed. The normality test results determined the appropriate correlation coefficient calculation method. For data following normal distribution patterns, the Pearson product-moment correlation coefficient (r) was calculated to quantify linear relationships between variables.

However, when data did not follow normal distribution, the Spearman rank correlation coefficient (rho) was employed as a non-parametric alternative providing valid assessment of monotonic relationships between variables without assuming normal distribution requirements. The Spearman correlation test particularly suited this study's requirements, as preliminary normality testing indicated non-normal distribution of both physical activity and blood glucose variables. Correlation coefficients were interpreted using standardized conventions where values approaching 1.0 or negative 1.0 represented strong relationships, values near 0.5 or negative 0.5 represented moderate associations, and values approaching 0.0 represented weak or absent relationships. Statistical significance was determined through examination of p-values, with values below 0.05 indicating statistically significant associations in this investigation. All quantitative data processing utilized Statistical Package for Social Sciences (SPSS) software, version 25 or later, consistent with contemporary research standards for managing and analyzing health sciences data. Confidence intervals were set at 95%, corresponding throughout to the standard alpha level of 0.05 used statistical testing. Results were organized into tables displaying frequency distributions, descriptive statistics, normality test results, and correlation analysis findings, facilitating comprehensive visualization and interpretation of research outcomes.

Operational Definitions

Physical activity encompasses all body movements using skeletal muscles that increase energy expenditure above baseline rest levels, measured through the Global Physical Activity Questionnaire expressed in MET-minutes per week following World Health Organization conversion protocols. Blood glucose control was operationalized as random blood glucose concentration measured through laboratory analysis expressed in milligrams per deciliter, reflecting current metabolic status at the time of measurement. Diabetes mellitus was defined as a chronic metabolic disorder characterized by persistently elevated blood glucose levels resulting from impaired insulin secretion, insulin action, or both, with diagnosis confirmed through medical records at Kampung Masjid Primary Health Center. Daily routine physical activity referred specifically to habitual movement patterns integrated into ordinary daily life, distinct from formal structured exercise programs, including occupational activities, transportation-related movement, and leisure-time physical pursuits measured according to GPAQ assessment domains.

III. RESULT AND DISCUSSION

Results Respondent Characteristics

Gender and age are two determining factors in this study.

Table 1. CharacteristicsRespondents

Karakteristik Responden	Frekuensi	Presentase (%)
Jenis Kelamin		
Laki-laki	18	32.7
Perempuan	37	67.3
Usia		
≤45 tahun	8	14.5
46-55 tahun	27	49.1
>55 tahun	20	36.4

Based on the data in the table, 37 out of 100 respondents were female (67.3% of the total), while 18 out of 100 respondents were male (32.7%). Based on the data, there were more women than men living with Diabetes Mellitus around the Kampung Masjid Community Health Center in North Labuhan Batu Village. The majority of participants were in the 46-55 years age range, with 27 people (49.1%), with 20 people (36.4%) falling into the 55 years and above age group, and 8 people (14.5%) in the 45 years and below age group. The majority of Diabetes Mellitus sufferers were middle-aged or older, according to these findings.

Physical Activity Overview

This study used the World Health Organization's (WHO) Global Physical Activity Questionnaire (GPAQ) to assess participants' physical activity levels. To get a better idea of how active each person was, we translated their scores into METs/minutes/week. In Table 2, you can see the lowest (Min), highest (Max), and average (Mean) values of the GPAQ scores given by respondents.

Table 1. Respondents' GPAQ Scores

GPAQ Score	
Min	0
Max	5600
Mean	1471.93

Based on the table above, it is known that the respondents' physical activity scores varied between 0 and 5600 METs/min/week, with an average value of 1471.93 METs/min/week. Next, the distribution of respondents based on physical activity level categories (low, medium, high) is presented in Table 3 below.

Table 2. Frequency Distribution of Respondents' Physical Activities

Physical Activity	Frequency	Percentage (%)
Low	25	45.5
Currently	19	34.5
Tall	11	20
Total	**55**	**100**

The majority of respondents (25 out of 100 or 45.5% of the total) were included in the "low" physical activity category, as seen in the table above, while 19 people (34.5%) had moderate physical activity, and 11 people (20.0%) were classified as having high physical activity.

Blood Glucose Level Overview

Respondents' blood glucose levels were measured using a Random Blood Sugar (GDS) test, which was recorded in the laboratory results of Diabetes Mellitus patients at the Kampung Masjid Community Health Center in North Labuhan Batu. The results of the respondents' blood glucose measurements are presented in Table 4.4 below.

Table 4. Statistical Description of Respondents' Blood Glucose Levels

Blood Glucose Levels	
Min	204
Max	547
Mean	307.53

Participants' blood glucose levels ranged from 204 to 547 mg/dL, with an average of 307.53 mg/dL, as shown in the table above. Consequently, most patients continued to experience hyperglycemia, and blood glucose control for most respondents did not improve.

Bivariate Analysis

The Masjid Village Health Center in North Labuan Batu conducted a bivariate study to determine the relationship between physical activity (GPA) and blood glucose levels (FBS) in individuals with diabetes mellitus. A normality test was performed to confirm the type of statistical test before conducting the correlation test.

Normality Testing

Using a significance level of 0.05, the Kolmogorov-Smirnov test was used to test for normality. Any data with a p-value greater than 0.05 is considered normally distributed, while any data with a p-value less than 0.05 is considered non-normally distributed. See Table 4.5 for the results of the normality test.

Table 3. Data Normality (Kolmogorov Smirnov)

Variables	KS	Sig. (P-Value)	Conclusion
KGD	0.133	0.016	Not normally distributed
GPAQ	0.200	0.000	Not normally distributed

The following table displays the results of the Kolmogorov-Smirnov test: a pvalue of 0.000 for physical activity and a p-value of 0.016 for blood glucose levels. Since neither value is greater than 0.05, we can conclude that the data for both variables do not follow a normal distribution. I used the non-parametric Spearman's rho test to analyze the relationship between physical activity and blood glucose levels.

Correlation Testing

Diabetes mellitus patients were examined for the relationship between physical activity and blood glucose management using the Spearman rho correlation test. This test determines the direction and strength of the relationship. Table 6 shows the results of the correlation analysis.

Table 6. Correlation Test Results

	Kontrol Gula Darah		Kesimpulan
Aktifitas Fisik	Koefisien Kontingensi	-0.615	Hubungan Kuat Positif-Signifikan
	Asymp. Sig. (2-tailed)	0.000	
	N	55	

The Spearman rho test in the table above yields a correlation coefficient (r) of 0.615 and a p-value of 0.000 (<0.05). This indicates that in people with diabetes mellitus, the correlation between physical activity and blood glucose levels is strong and statistically significant. The negative direction of the relationship indicates that participants' blood glucose levels decreased as their physical activity increased.

Discussions Interpretation of Patient Characteristics and Gender Distribution

The research demonstrated that among diabetes mellitus patients receiving care at Kampung Masjid Primary Health Center in North Labuhan Batu, 67.3% were female while 32.7% were male, representing a pronounced gender disparity in disease prevalence. This elevated prevalence in women aligns with epidemiological patterns documented in multiple large-scale studies. According to Sabila et al. (2023) and Siregar et al. (2024), women possess several biological characteristics predisposing them toward increased diabetes risk. These include greater proportional distribution of subcutaneous adipose tissue, cyclical fluctuations in estrogen and progesterone levels, and hormonal changes during perimenopause that substantially reduce estrogen concentrations. The postmenopausal decrease in estrogen represents a particularly significant risk factor, as this hormone normally enhances insulin sensitivity through multiple mechanisms including increased glucose transporter expression, improved mitochondrial function, and reduced inflammatory responses in peripheral tissues.

Without estrogen's protective effects, women experience accelerated development of insulin resistance, resulting in elevated fasting blood glucose and impaired glucose tolerance despite comparable physical activity levels to their male counterparts. Beyond biological mechanisms, the gender disparity reflects substantial differences in physical activity patterns and lifestyle factors between sexes. Research by Maugeri et al. (2020) indicates that women in many societies experience regularly lower levels of habitual physical activity compared to men, primarily due to culturally determined patterns of work distribution, domestic responsibilities, and social constraints on recreational time. The documented preponderance of women with diabetes at this primary health facility reflects these interconnected biological and sociocultural factors, suggesting that interventions targeting women specifically may require both enhanced medical management and structured support for increased physical activity implementation within their daily schedules and social contexts.

Age Stratification and Metabolic Changes

The age distribution of participants revealed that 49.1% were aged 46-55 years, 36.4% were older than 55 years, and only 14.5% were younger than 45 years, demonstrating a strong concentration of diabetes cases in the middle-aged and older adult populations. According to the American Diabetes Association (2023), this agerelated pattern reflects multiple physiological changes inherent to the aging process. These include progressive decline in pancreatic beta cell function and insulin secretion capacity, age-related development of abdominal adiposity and visceral fat accumulation, and impaired sensitivity of peripheral tissues to insulin signaling. Additionally, aging involves accumulation of cellular senescence, increased oxidative stress, and declining mitochondrial function, all of which compromise the cellular mechanisms underlying glucose homeostasis and glucose uptake.

Complementing these cellular-level changes, older adults commonly experience reduced muscle mass, altered dietary patterns favoring processed foods with high simple carbohydrate content, and decreased occupational and recreational physical activity. Research by Piggin (2020) emphasizes that the combined effect of age-related physiological decline and behavioral factors such as sedentary occupations and limited exercise participation creates a particularly challenging context for glycemic control in this age group. The concentration of diabetes in individuals over 45 years observed in this study supports targeted interventions specifically designed for the behavioral and metabolic characteristics of middle-aged and older populations, including gentle resistance training to preserve muscle mass and promote glucose utilization, consistent with recommendations from the American Diabetes Association (2023).

Physical Activity Patterns and Physiological Implications

The study documented that 45.5% of diabetes mellitus patients engaged in lowlevel physical activity (less than 600 MET-minutes per week), 34.5% performed moderate-level activity (600-3000 MET-minutes per week), and only 20% achieved high-level activity (greater than 3000 MET-minutes per week), with a mean physical activity score of 1471.93 MET-minutes per week. This relatively low overall physical activity level carries substantial physiological consequences related to glucose metabolism and insulin sensitivity. When skeletal muscles contract during physical activity, multiple molecular mechanisms activate that promote glucose uptake independent of insulin signaling. specifically, as documented by Stocks et al. (2022), muscle contraction activates adenosine monophosphate-activated protein kinase (AMPK), which phosphorylates proteins involved in glucose transporter trafficking. This activation causes GLUT4 glucose transporters stored within intracellular vesicles to translocate to the muscle cell surface, enabling glucose entry into myocytes without requiring insulin stimulation. This insulin-independent glucose uptake mechanism proves particularly valuable in individuals with type 2 diabetes mellitus who demonstrate impaired insulin signaling due to tissue-level insulin resistance.The translocation process involves coordinated movement of GLUT4-containing storage vesicles toward the sarcolemma, where specialized SNARE protein complexes mediate fusion with the cell membrane.

According to Whytock et al. (2025), during contraction, the permeability of muscle membranes to blood glucose increases approximately 17-fold compared to resting conditions, and in tissues demonstrating enhanced insulin sensitivity, increases of up to 35-fold have been documented. Importantly, this exercise-induced glucose uptake mechanism remains functional in individuals with type 2 diabetes despite impaired insulin-mediated uptake, making regular physical activity a particularly valuable intervention for this population. The prolonged insulin-sensitizing effects of exercise can persist for 24-72 hours after exercise cessation, providing continued metabolic benefits even during rest periods between activity sessions.In contrast, the low physical activity demonstrated by 45.5% of study participants implies that these individuals are not activating these glucose-promoting mechanisms with sufficient frequency or intensity to produce meaningful glycemic improvement. Prolonged sedentary behavior contributes to progressive development of insulin resistance through multiple mechanisms. According to Salari et al. (2024), sedentary time leads to increased fat accumulation in adipose tissue and ectopic fat deposition in liver and muscle, which impairs insulin signaling cascades. Additionally, sedentary behavior is associated with chronic low-grade inflammation characterized by elevated circulating cytokines such as tumor necrosis factor-alpha (TNF-α), interleukin-6 (IL-6), and C-reactive protein (CRP), all of which suppress insulin receptor signaling in skeletal muscle and adipose tissue.The relationship between reduced physical activity and impaired glucose control became evident in the bivariate analysis showing that increased activity levels were associated with substantially lower blood glucose measurements. Furthermore, the findings of Kusuma et al. (2022) and Piggin (2020) demonstrated that active lifestyle constitutes one of the most influential modifiable risk factors for poor glycemic control in type 2 diabetes. These observations suggest that interventions specifically targeting the low-activity population at this primary health facility could yield substantial improvements in metabolic parameters through systematic implementation of supervised exercise programs adapted to patient capabilities and preferences.

Blood Glucose Control Status and Metabolic Dysfunction Indicators

The study revealed that blood glucose measurements among diabetes patients ranged from 204 to 547 mg/dL, with a mean value of 307.53 mg/dL. Using the diagnostic criteria established by the Indonesian Endocrinology Association (PERKENI, 2021), which defines controlled glucose levels as ≤ 200 mg/dL and uncontrolled levels as > 200 mg/dL, the overwhelming majority of study participants demonstrated adequately controlled blood glucose. This mean glucose concentration of 307.53 mg/dL represents a substantial elevation above the target range and indicates widespread failure of current management strategies to achieve therapeutic goals at the primary healthcare level. The elevated mean value reflects a composite of multiple interrelated factors including insufficient physical activity, inadequate pharmacological management, dietary patterns high in refined carbohydrates and low in fiber, chronic stress, and potentially suboptimal medication adherence.

According to PERKENI (2021), sustained elevation of blood glucose at these levels establishes conditions conducive to the development of chronic diabetic complications including microvascular damage (neuropathy, nephropathy, retinopathy) and macrovascular disease (myocardial infarction, cerebrovascular accident, peripheral arterial disease). The pathophysiological mechanisms underlying these complications involve glucose-mediated protein glycation, reactive oxygen species generation, and inflammatory pathway activation that collectively damage endothelial structures and neural tissues. Al-Khawaldeh et al. (2022) documented that patients with diabetes mellitus who maintained regular physical activity demonstrated substantially lower blood glucose levels compared to sedentary patients, with mean differences often exceeding 60-80 mg/dL. This observation directly supports the hypothesis that increased physical activity represents an evidence-based intervention capable of producing clinically meaningful improvements in glycemic control.

Molecular Mechanisms Linking Physical Activity to Improved Glycemic Control

The bivariate analysis revealed a significant negative correlation ($r = -0.615$, $p = 0.000$) between physical activity levels and blood glucose concentration, indicating that increased physical activity was associated with improved glycemic control. This relationship likely reflects multiple convergent physiological mechanisms operating at cellular and systemic levels. According to recent comprehensive reviews by Stocks et al. (2022) and Zhang et al. (2025), acute exercise triggers insulin-independent glucose uptake through the GLUT4 translocation mechanism described previously. Additionally, regular exercise training produces chronic adaptations that enhance whole-body insulin sensitivity through several mechanisms.

First, exercise training increases capillary density within skeletal muscle through angiogenic signaling, improving nutrient delivery to muscle tissue and facilitating glucose entry via enhanced blood flow. Second, regular exercise elevates the expression of glucose utilization enzymes including hexokinase II and glycogen synthase, enabling enhanced conversion of transported glucose to glucose-6-phosphate for glycolytic metabolism or glycogen storage. Third, chronic exercise training increases the absolute number and surface area of GLUT4 transporters expressed in muscle membranes, amplifying capacity for glucose uptake. These adaptations collectively increase the quantity of glucose that skeletal muscle can extract from blood during both rest and activity periods.

Furthermore, research by Yuan et al. (2023) using Mendelian randomization methodology identified obesity, lean muscle mass, and chronic low-grade inflammation as significant mediators through which physical activity reduces type 2 diabetes risk. The study documented that physical activity reduces systemic inflammation markers including tumor necrosis factor-alpha, interleukin-6, and C-reactive protein, which normally suppress insulin receptor signaling in muscle and adipose tissue. By reducing circulating inflammatory mediators, physical activity improves cellular insulin receptor responsiveness and downstream signaling cascade activation, thereby enhancing both insulin-stimulated and insulin-independent glucose uptake pathways.

The findings of Ayubi et al. (2024) further illuminated the molecular basis for exercise-mediated glucose improvements by demonstrating that physical activity increases GLUT4 translocation from 17-fold above baseline permeability to glucose during acute exercise. Chronic exercise training produces sustained increases in baseline GLUT4 abundance and improved capacity for phosphorylation of signaling proteins including AMP-activated protein kinase (AMPK), protein kinase C (PKC), and protein kinase B (AKT), which regulate glucose transporter trafficking. These molecular adaptations persist for extended periods between exercise sessions, providing sustained improvements in glucose uptake capacity.

Synergistic Effects of Combined Interventions and Clinical Implications

Recent high-quality evidence indicates that combining structured physical activity with dietary modifications produces superior glycemic control compared to either intervention alone. According to research by Hadi et al. (2025) conducted in Bangladesh, structured physical activity programs lasting 12 weeks combined with dietary modifications significantly reduced fasting plasma glucose from 10.0 to 6.3 mmol/L (180 to 113 mg/dL), representing a clinically meaningful improvement of approximately 37%. These findings affirm that comprehensive lifestyle modification approaches produce substantially greater glycemic improvements than isolated interventions. The combination of aerobic and resistance exercise proved particularly effective, with aerobic components enhancing insulin sensitivity and cardiovascular fitness while resistance training increased skeletal muscle mass, providing larger glucose storage capacity and enhancing insulin-mediated glucose disposal.The research by Zhang et al. (2025) examining mechanisms of exercise effects on glucose metabolism identified that regular exercise enhances phosphatidylinositol 3kinase (PI3K) activity within skeletal muscle, which participates in both insulindependent and insulin-independent glucose uptake pathways. Exercise-induced activation of PI3K receives signaling from insulin receptor substrates (IRS-1 and IRS2) that are phosphorylated both through canonical insulin signaling and through alternative pathways activated by muscle contraction.

These observations suggest that exercise efficacy for glycemic control operates through multiple partially redundant signaling pathways, ensuring that glucose-lowering effects persist even when specific pathway dysfunction becomes apparent in individuals with severe insulin resistance. From a primary healthcare perspective, the implications are substantial. The current findings demonstrate that low physical activity levels represent a modifiable risk factor directly contributing to poor glycemic control at Kampung Masjid Primary Health Center. The Prolanis (Chronic Disease Management Program) initiative should be expanded beyond its current emphasis on medication management and glucose monitoring to include structured, supervised exercise prescriptions. Such programs might include twice-weekly supervised diabetes gymnastics (diabetes-specific gymnastics), organized community walking groups, and resistance training instruction adapted to patient age and functional capacity. Research by Liu et al. (2025) demonstrated that community-based peer support programs for diabetes management delivered through primary healthcare centers achieve clinically significant improvements in HbA1c and sustained improvements in psychosocial outcomes including diabetes distress and quality of life when physical activity components are regularly integrated.

Barriers to Physical Activity Implementation and Solutions

Despite knowledge of physical activity benefits, the study documented that 45.5% of patients remained in the low-activity category, suggesting substantial barriers to exercise implementation in this primary healthcare setting. Potential barriers include occupational demands of agricultural or informal sector work limiting leisure time, inadequate recreational facilities in rural areas, limited transportation to exercise locations, limited patient knowledge regarding appropriate exercise prescriptions for diabetes, and insufficient healthcare provider time to regularly counsel and monitor physical activity adherence. According to Hadi et al. (2025), addressing these barriers requires health system-level modifications including development of accessible exercise facilities within or near primary healthcare centers, training of healthcare workers in exercise prescription methodology, and integration of community health workers into activity promotion efforts. The research by Cisdi (2024) on the intersectional approach to diabetes management in primary care emphasizes the critical role of Puskesmas as community health centers positioned to address social determinants of health including physical activity access. Within the Indonesian healthcare system, Puskesmas can serve as coordinating centers for community-based physical activity programs, partnering with local community organizations, schools, and workplace settings to promote activity opportunities accessible to diverse patient populations. This systems-level approach recognizes that individual motivation alone proves insufficient without concurrent modification of environmental and social structures that either facilitate or impede activity participation.

Long-Term Health Outcomes and Prevention of Complications

The present findings demonstrating improved glycemic control with increased physical activity carry substantial implications for prevention of diabetes-related complications. Chronic hyperglycemia at the documented mean levels of 307.53 mg/dL substantially accelerates development of both microvascular and macrovascular complications. PERKENI (2021) documented that each 1% reduction in glycosylated hemoglobin (HbA1c) below 7% reduces microvascular complications by approximately 37% and macrovascular complications by approximately 21%, with even greater reductions observed with more substantial glycemic improvements. The negative correlation identified in this study suggests that patients transitioning from the lowactivity category (mean activity under 600 MET-minutes per week) to moderate or high activity levels could achieve meaningful improvements in long-term glycemic control sufficient to substantially reduce complication risk.

Beyond direct glucose-lowering effects, physical activity produces multiple additional health benefits protective against diabetes complications. Regular exercise improves blood pressure control, reduces triglyceride levels, raises high-density lipoprotein cholesterol, and reduces overall cardiovascular disease risk through improvements in endothelial function and reduced arterial inflammation. Skeletal muscle strengthening through resistance components preserves functional capacity in aging diabetic populations, reducing fall risk and associated morbidity. Psychologically, regular physical activity reduces depression and anxiety symptoms frequently comorbid with diabetes, thus improving treatment adherence and quality of life.

Strengths and Limitations of Current Analysis

This investigation contributed valuable local evidence characterizing the relationship between physical activity and glycemic control in a specific Indonesian primary healthcare setting. The use of the validated Global Physical Activity Questionnaire and objective blood glucose measurements from medical records provided relatively robust measurements of the primary variables examined. The correlational strength ($r = -0.615$) represents a clinically meaningful association, and the statistical significance level of $p = 0.000$ demonstrated that findings did not result from random sampling variation.

However, several limitations merit acknowledgment. The cross-sectional study design precluded determination of temporal relationships or causal mechanisms; future prospective or experimental designs could strengthen causal inference. The study examined physical activity at a single point in time without characterizing longitudinal activity patterns or seasonal variation in activity levels. The sample was restricted to patients accessing a single primary healthcare facility in one geographic location, potentially limiting generalizability to other Indonesian regions or healthcare systems. Unmeasured confounding variables such as dietary composition, medication adherence, stress levels, sleep quality, and metabolic factors beyond glucose measurement (such as HbA1c or insulin resistance markers) could have influenced observed relationships. Despite these limitations, the findings provide actionable local evidence supporting the prioritization of physical activity promotion in diabetes management protocols at the primary healthcare level.

Implications for Clinical Practice and Public Health Policy

The research demonstrates that substantial opportunity exists for improving glycemic control through structured physical activity interventions at Indonesian primary healthcare facilities. Clinical practitioners at Community Health Centers should systematically assess physical activity levels using validated instruments such as the Global Physical Activity Questionnaire, provide evidence-based counseling regarding activity targets consistent with WHO recommendations (minimum 150 minutes per week of moderate-intensity aerobic activity or equivalent vigorous activity, plus resistance training two times weekly), and monitor activity adherence during routine patient encounters. Recognition of individual barriers to activity implementation within each patient's specific life circumstances enables development of personalized activity prescriptions more likely to achieve sustainable behavior change. From a public health policy perspective, findings support investment in infrastructure facilitating physical activity within communities served by primary healthcare facilities. This might include construction of community exercise facilities, training of health workers and community leaders in exercise prescription and supervision, integration of activity promotion into national chronic disease management programs such as Prolanis, and development of policies supporting occupational wellness initiatives that increase activity opportunities during working hours. International evidence from Cisdi (2024) and Liu et al. (2025) demonstrates that such systematic approaches substantially increase physical activity participation rates and achieve sustained improvements in glycemic control, quality of life, and reductions in healthcare utilization.

IV. CONCLUSION

This study demonstrated a significant negative correlation (r = -0.615, p = 0.000) between daily physical activity and blood glucose levels in diabetes mellitus patients at Kampung Masjid Primary Health Center, confirming that increased physical activity substantially improves glycemic control. The research revealed that 45.5% of patients engaged in low physical activity, while the mean blood glucose concentration of 307.53 mg/dL far exceeded therapeutic targets of 200 mg/dL or less. Gender and age distribution showed predominance of women (67.3%) and middle-aged to older adults (85.5% over 45 years), suggesting that specific population groups require targeted interventions. The significant correlation supports evidence-based physical activity promotion as a critical modifiable factor for improving metabolic outcomes in primary healthcare settings. These findings provide locally applicable evidence for Indonesian healthcare systems to prioritize integrated diabetes management approaches combining pharmacological intervention with structured exercise supervision and behavioral support.

However, several limitations constrain generalizability and causal inference. The cross-sectional design prevented determination of temporal relationships or establishment of causality, and examination of a single healthcare facility in North Labuhan Batu limits applicability to other geographic regions. Unmeasured confounding variables including dietary patterns, medication adherence, stress levels, and comprehensive metabolic markers beyond glucose measurement may have observed influencing associations. Future research should employ prospective longitudinal designs incorporating multiple primary healthcare facilities across diverse geographic regions, measure HbA1c alongside random glucose for comprehensive glycemic assessment, and examine mediating mechanisms through inflammatory biomarkers and anthropometric factors. Additionally, intervention trials implementing structured physical activity programs with systematic adherence monitoring would strengthen causal evidence. Future studies should also investigate culturally adapted exercise interventions addressing gender-specific barriers and age-appropriate activity prescriptions to enhance sustainability and effectiveness in Indonesian primary care contexts.

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