Natural Resources for Human Health
eISSN: 2583-1194

Original Research

Received 18 July 2026
Revised 17 Aug 2026
Accepted 01 Sep 2026

Natural Resources for Human Health 2026, Vol. 6 (21s): 01–10

KEYWORDS:
Diabetes mellitus; fasting blood glucose; cinnamon; Cinnamomum; swimming exercise; streptozotocin.

Effect of Cinnamon Bark Extract and Moderate-Intensity Swimming Exercises on Fasting Blood Glucose Levels in Streptozotocin-Induced Diabetes Model Rats: A Comparative Experimental Study

Arie Vonikartika[1], Tan Suyono[2], Maya Sari Mutia[3], Ali Napiah Nasution[4], ALyna Magdalyna Naulinta Hutapea[5*]

[1]Doctoral Program in Medicine, Faculty of Medicine and Dentistry, Universitas Prima Indonesia, Medan
[2]Center of Excellence for Phytodegenerative and Lifestyle Medicine, Faculty of Medicine, Dentistry and Health Science, Universitas Prima Indonesia, Medan
[3]Center of Excellence for Phytodegenerative and Lifestyle Medicine, Faculty of Medicine, Dentistry and Health Science, Universitas Prima Indonesia, Medan
[4]Center of Excellence for Phytodegenerative and Lifestyle Medicine, Faculty of Medicine, Dentistry and Health Science, Universitas Prima Indonesia, Medan
[5]Faculty of Nursing Science, Universitas Advent Indonesia, Indonesia
[*]Corresponding author
lynhutapea@unai.edu, ORCID: https://orcid.org/0000-0001-6805-3887

ABSTRACT: Diabetes mellitus (DM) is a chronic metabolic disease characterized by hyperglycemia due to impaired insulin secretion, insulin action, or both. Its prevalence continues to increase and can lead to various complications, making it a major global public health problem. Blood glucose control can be achieved through pharmacological and non-pharmacological approaches, including herbal ingredients and physical activity. This study aimed to analyze the effect of cinnamon bark extract and moderate-intensity swimming exercise on fasting blood glucose levels in type 2 diabetic model rats. This experimental study with a comparative design involved 15 diabetic model rats, divided into three groups of five each: an untreated control group, a group receiving cinnamon bark extract orally at 120 mg/kg body weight/day, and a group undergoing moderate-intensity swimming exercise for 19 days. Fasting blood glucose levels were measured periodically and analyzed using one-way ANOVA followed by the Bonferroni post hoc test. Significant differences in fasting blood glucose were found between groups. The swimming group differed significantly from the untreated group ($p = 0.007$), with mean fasting blood glucose decreasing from 305.20 ± 159.37 mg/dL on day 4 to 118.00 ± 48.77 mg/dL on day 19. The cinnamon bark extract group showed no significant difference compared with the untreated group ($p = 0.065$) or the swimming group ($p = 0.736$). In conclusion, moderate-intensity swimming exercise significantly reduced fasting blood glucose levels, whereas cinnamon bark extract at 120 mg/kg body weight/day for 19 days did not have a significant effect.

1. INTRODUCTION

Diabetes is a chronic disease that occurs when the pancreas does not produce enough insulin or when the body cannot use the insulin it produces effectively. Insulin is a hormone that regulates blood glucose levels. Hyperglycemia, also called increased

blood glucose or increased blood sugar, is a common effect of uncontrolled diabetes and, over time, causes serious damage to many body systems, especially nerves and blood vessels (WHO, 2024)

Diabetes mellitus can be classified into two types, namely type 1 DM and type 2 DM. Type I DM is a chronic hyperglycemia condition due to insulin insufficiency, so people with this disease are dependent on insulin. The causative factors include genetic, immune, and environmental factors; beta-cell decline; population; pregnancy; and other factors not directly related to the pancreas's ability to produce insulin (Aklia Suslia, 2016). The relative failure of pancreatic beta cells and insulin resistance contribute to the development of type 2 diabetes mellitus. Risk factors include age, obesity, family history, and lifestyle. A study conducted in Samarinda also identified age, family history, and poor dietary habits as important factors associated with diabetes mellitus (Brunner & Suddarth, 2002; Nuari, 2017; Bernadetha et al., 2024).

The prevalence of diabetes mellitus (DM) globally continues to increase. In 2021, the International Diabetes Federation (IDF) reported that around 10.5% (537 million) adults aged 20–79 years worldwide had DM. This figure represents 10.5% of the world's population in this group. This figure is projected to increase to 643 million (11.3%) by 2030 and reach 783 million (12.2%) sufferers by 2045. China is the country with the largest number of adult diabetics in the world. A total of 140.87 million Chinese people were living with diabetes in 2021(IDF Diabetes Atlas, 2021). In 2021, diabetes and kidney disease due to diabetes caused more than 2 million deaths. In addition, about 11% of deaths from cardiovascular disease were due to high blood glucose levels (WHO, 2024)

The situation in Indonesia is no less worrying; IDF 2024 data places Indonesia in the top five of the 10 most populous countries in the world with 19.5 million adult diabetics (20-79 years old) in 2021 and is predicted to remain ranked 5th out of 10 countries in the world, with the number of adult diabetics (20-79 years old) of 28.6 million in 2045. Data from the 2023 Indonesian Health Survey (SKI) show that the prevalence of DM, based on blood sugar levels, in the population aged ≥15 years is 11.7% (Persatuan Endokrinologi Indonesia, 2024).

Chronic complications of DM can include macrovascular and microvascular disorders. Macrovascular complications generally affect the heart, brain, and blood vessels, while microvascular disorders can occur in the eyes, peripheral nerves (neuropathy), and kidneys. Neuropathy complaints are also commonly experienced by people with DM, both motor, sensory, or autonomic neuropathy (Persatuan Endokrinologi Indonesia, 2024). Because diabetes is a long-lasting chronic metabolic disease that causes a variety of other complications, such as cardiovascular disease, the cost of its treatment has significantly burdened economies and health systems around the world. Therefore, developing economical, efficient, and simple strategies to prevent and treat diabetes is a major challenge (Lu et al., 2012). Trust in traditional medicine practices is one factor that can influence people's behavior when using health services. Traditional medicine, including the use of food and medicinal plants, is still used by the community as part of efforts to maintain health and basic health services (Kasole et al., 2019)

One medicinal plant that is easy for the public to find and use to control blood sugar levels is cinnamon. Cinnamon is a species of the genus Cinnamomum, a plant widely found in Indonesia that contains active substances such as polyphenols. Polyphenols can increase insulin receptors in patients with type 2 diabetes mellitus. Increased sensitivity of these receptors can enhance glucose absorption, ultimately lowering blood glucose levels toward normal values (Arini & Ardiaria, 2016). In addition to herbal remedies, moderate exercise can help control blood glucose levels in patients with DMT2. According to the WHO, the recommended dose for moderate-intensity exercise is 30 minutes daily or 3-5 times a week.

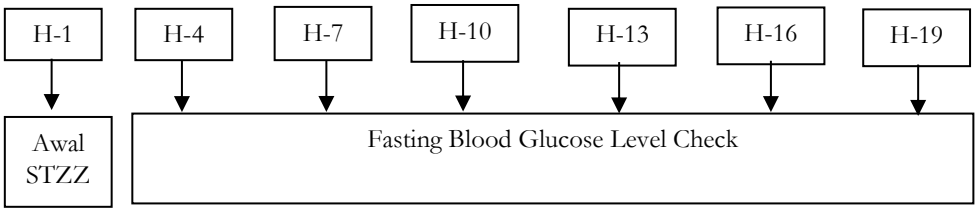
Physical exercise facilitates the transfer of glucose into cells and increases insulin sensitivity (Price & Wilson, 2005). For both types of diabetes, physical exercise has been shown to increase cellular glucose utilization, thereby lowering blood glucose levels (Corwin, 2009). In type 2 diabetes mellitus, physical exercise can improve overall glucose control. This is evidenced by a decrease in HbA1c concentration, which can serve as a guideline for reducing the risk of diabetes complications. Meanwhile, in type 1 diabetes mellitus, physical exercise can complicate metabolic regulation, so blood sugar control is not the goal of exercise (Sudoyo et al., 2015).

2. MATERIALS AND METHODS

This study employed a laboratory experimental design with a pretest-posttest control group design. The subjects of the study were 15 mice that were induced to develop a model of type 2 diabetes mellitus and were divided into three groups, namely the untreated control group (5 rats), the cinnamon extract treatment group (5 rats), and the group. In this study, experimental

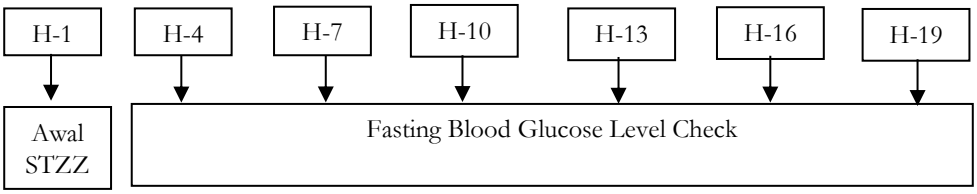
animals were treated for 19 days. Before the treatment, the experimental animals underwent a one-week adaptation period at the experimental animal breeding center of Universitas Prima Indonesia.

Untreated Group (KTP): Tkus DMT2 With High Fat Diet (HFD) before and during intervention



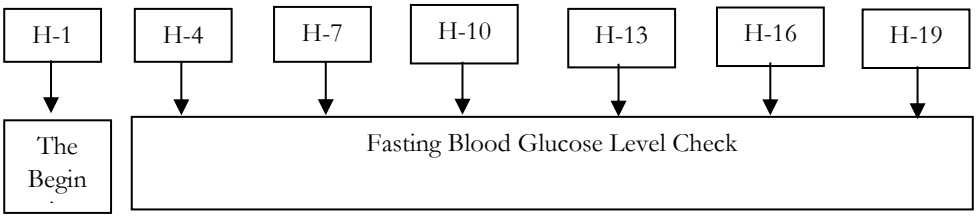
Treatment Group: DMT2 Rats + Cinnamon Extract

By giving a high-fat diet (HFD) before and during the intervention



Treatment Group: DMT2 mice + moderate-intensity exercise

By giving a high-fat diet (HFD) before and during the intervention



2.1 Inclusion and Exclusion Criteria

The inclusion criteria were T2DM rats, namely adult male Wistar rats (Rattus norvegicus) with a body weight of 150-200 g and blood glucose above 250 mg/dL after STZ injection. The exclusion criteria were rats that died before treatment, rats with a body weight below 150 g, and STZ-induced male Wistar rats with blood glucose below 200 mg/dL. The experimental treatment was carried out for three weeks following a one-week acclimatization period. This research received approval from the Research Ethics Committee of Universitas Prima Indonesia, number 014/KEPK/UNPRI/XII/2023.

2.2 Extraction

Cinnamon bark extraction was performed by maceration using 90% ethanol as the solvent. Powdered cinnamon bark simplicia was weighed and placed into a maceration vessel. The powder was then soaked in 90% ethanol at a 1:10 (w/v) ratio until the entire material was fully submerged. The vessel was tightly sealed and wrapped in aluminum foil, and maceration was carried out for 3 × 24 hours at room temperature with daily stirring.

After maceration, the mixture was filtered to separate the filtrate from the residue, yielding the first filtrate. The residue was extracted twice more with 90% ethanol using the same procedure, yielding a second and a third filtrate. All filtrates were collected and concentrated using a rotary evaporator at 37 °C until a viscous extract was obtained. The extract was weighed to determine its weight and calculate the extract yield. The viscous extract was then stored in a closed container under appropriate conditions until used in the next stage of the research.

2.3 Ingredients

This study used 10 male Wistar rats weighing 150-200 g. The main materials included cinnamon bark extract, streptozotocin (STZ) at 45 mg/kg BW, a high-fat diet (HFD), and glucometer test strips. The rats were kept under controlled conditions with ad libitum access to feed and water.

2.4 Research Procedure

(i) Test Animal Preparation

The test animals weighed 150-200 g and were in good health with normal function. The animals were acclimatized to the animal house for 14 days, adapting to the new habitat, with feeding and drinking standardized across all animals. During the acclimatization period, the rats were fed commercial pellet feed and given water ad libitum. The animals were housed in stainless-steel cages with adequate ventilation in a room maintained at 20-26 °C, with a relative humidity of 40-70%, and a 12-hour light and 12-hour dark cycle. The purpose of the acclimatization process was to prevent stress and to ensure that all animals were in relatively the same condition before treatment.

(ii) STZ Induction in Rats

After the acclimatization period, on day 15, the rats were induced with STZ at 45 mg/kg BW intraperitoneally (Halim S., 2023). A syringe was filled with ketamine (HCl 100 mg/1 mL) at a dose of 20-40 mg/kg BW to anesthetize the male white rats. The injection was administered intraperitoneally (IP), punctured at two-thirds of the posterior abdomen, and the injection site was disinfected with 70% alcohol beforehand.

(iii) Post-Induction Care and Diet

After STZ induction, the rats were left for 48 hours while being fed HFD plus 2 mL of egg once daily via oral gavage, and given a drink containing sucrose solution at 6.8 g/kg BW in 100 mL of water, with 40 mL administered to each rat twice daily. Blood glucose levels were measured 3 days after STZ induction, and an increase in blood glucose was used as an indicator of experimental diabetes mellitus. The rats were given high-fat feed before and during treatment. The diabetogenic HFD was prepared to induce T2DM by mixing 200 g of goat fat, 100 g of boiled egg yolk, 100 g of sucrose, and 1,000 g of corn rice. The goat fat was first heated until melted, while the egg yolks were obtained from boiled eggs. The goat fat and egg yolks were then mixed into 1,000 g of corn rice (Gani et al., 2013).

(iv) Treatment of Experimental Animals

a. Untreated group: One group of DM rats (5 rats) received no treatment.

b. Cinnamon extract group: One group of DM rats (5 rats) received cinnamon bark extract at a dose of 120 mg/kg BW orally using a gavage tube. The extract was administered once daily for 19 days.

c. Exercise group: One group of DM rats (5 rats) was made to swim for 25 minutes. Swimming was performed intermittently, with 2 minutes of swimming followed by 1 minute of rest, for a total of 25 minutes. The session was conducted once every 3 days for 19 days.

(v) Blood Glucose Measurement

Fasting blood glucose (FBG) was measured after STZ injection, 3 days after STZ administration, and again on day 4. FBG measurements continued on days 7, 10, 13, 16, and 19. Blood was collected from the caudal vein by cutting a small portion of the tail tip. Once blood flowed out, it was placed on a glucose test strip and measured with a glucometer (Accu-Chek).

2.5 Data Analysis

Data were reported using descriptive statistics, including mean and standard deviation (SD). The Shapiro-Wilk test was used to examine the normality of the data distribution. One-way analysis of variance (ANOVA) and the post hoc Tukey test were used to compare the study groups. All statistical analyses were performed using SPSS, and $P < 0.05$ was considered statistically significant.

Natural Resources for Human Health
eISSN: 2583-1194

3. RESULTS AND DISCUSSION

Fasting blood glucose levels were measured in all experimental groups beginning on day 1 after streptozotocin (STZ) induction and subsequently on days 4, 7, 10, 13, 16, and 19. The experimental rats were considered diabetic on day 4. The mean blood glucose levels in each group are presented in the following table and figure.

3.1 Univariate Analysis

Univariate analysis was performed to describe fasting blood glucose levels in the experimental rats throughout the study period. The data were summarized using means and standard deviations on days 4, 7, 10, 13, 16, and 19.

Table 1. Mean Blood Glucose Levels in All Experimental Groups

No	Groups	H-4		H-7		H-10		H-13		H-16		H-19	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	No Treatment	256,80	81,52	423,60	132,35	384,2	109,42	305	157,15	331	160,21	369,6	118,54
3	Cinnamon Extract	275,80	78,90	246,60	163,88	267,80	113,45	197,60	124,16	200,40	185,51	197,60	124,16
4	Swimming	305,20	159,37	179,20	82,03	247,20	106,86	141,00	90,37	158,20	60,47	118	48,77

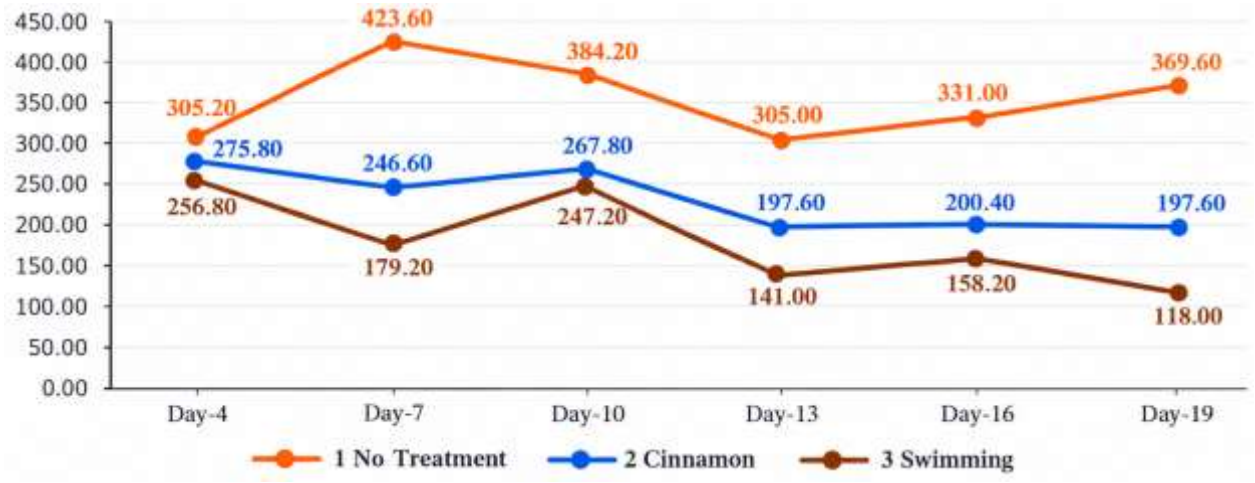


Figure 1. Average Fasting Blood Sugar Levels in all groups

Fasting blood glucose (GDP) levels were measured on days 1, 4, 7, 10, 13, 16, and 19 post-induction with streptozotocin (STZ). Rats confirmed to have diabetes mellitus (DM) on day 4 after induction. Mean and standard deviations of GDP levels for the control group (without treatment), the cinnamon treatment, and the swimming intervention were recorded periodically throughout the observation period.

In the untreated control group, the initial GDP level (day 4) was 256.80 ± 81.52 mg/dL and reached a peak on day 7 (423.60 ± 132.35 mg/dL). Although it had decreased on day 13 (305 ± 157.15 mg/dL), GDP levels increased again to reach 369.6 ± 118.54 mg/dL on day 19. These fluctuations reflect unstable blood glucose dynamics without intervention.

In contrast, the cinnamon and swim treatment groups showed a consistent downward trend in GDP levels throughout the observations: Cinnamon Group: Starting from 275.80 ± 78.90 mg/dL on day 4, GDP levels gradually decreased to 197.60 ± 124.16 mg/dL on day 19 (although there was a minor increase on days 10 and 16).

In the swimming group, the period began with the highest average of 305.20 ± 159.37 mg/dL on day 4, then declined continuously to 118 ± 48.77 mg/dL on day 19.

3.2 Bivariate Analysis

The results of the normality test using the Shapiro-Wilk test and homogeneity as a condition for the one-way ANOVA statistical test can be seen in the table below:

Table 2. Mean Blood Glucose Levels in All Groups

Normality Test (p-value)*	No Treatment	Cinnamon	Swimming	Homogeneity Test
	0.208	0.542	0.267	0.081

The normality test using the Shapiro–Wilk test showed that fasting blood glucose levels in the no-treatment group had a p-value of 0.208, the cinnamon extract group had a p-value of 0.542, and the swimming group had a p-value of 0.267. All p-values were > 0.05, so the fasting blood glucose data in all three groups were normally distributed.

The results of the homogeneity of variance test using Levene's Test showed a Levene statistic of 3.115 with a significance value of 0.081 ($p > 0.05$). These results indicate that the variance of fasting blood glucose levels did not differ significantly among the three groups, so the assumption of homogeneity of variance was met, and the analysis could proceed using One-Way ANOVA.

The One-way ANOVA test yielded a p-value of 0.007 ($p < 0.05$), indicating a significant difference in fasting blood glucose levels among the groups. Subsequently, a Bonferroni Post Hoc test was performed to identify significant differences between groups (Dahlan, 2008). The differences between groups can be seen in the following table.

Table 3. Results of the Bonferroni Post Hoc Test

Comparison	Mean Difference	p-value	95% CI	Conclusion
No treatment vs. cinnamon extract	172.00	0.065	-9.12 – 353.12	Not significant
No treatment vs. swimming	251.60	0.007	70.48 – 432.72	Significant
Cinnamon extract vs. swimming	79.60	0.736	-101.52 – 260.72	Not significant

Based on the Bonferroni Post Hoc analysis, a significant reduction in fasting blood glucose levels was found only in the moderate-intensity swimming group compared with the no-treatment group ($p = 0.007$; mean difference = 251.60). Meanwhile, the cinnamon extract group showed no significant difference, either compared with the no-treatment group ($p = 0.065$) or the swimming group ($p = 0.736$). This indicates that the main difference found in the One-Way ANOVA results originated from the effectiveness of moderate-intensity swimming exercise.

3.4 Discussion

Based on the results of the study, administration of cinnamon extract led to a change in fasting blood glucose levels, starting at 275.80 ± 78.90 mg/dL on the 4th day and gradually decreasing to 197.60 ± 124.16 mg/dL on the 19th day. These results are in line with in vitro research, which shows that cinnamon can increase glucose absorption through insulin receptor activation (IR), insulin receptor autophosphorylation, glycogen synthesis, and related enzymes. In vivo, cinnamon extract may increase glucose utilization in mice (Plantamor, 2016). The group of diabetic animals that were fed cinnamon showed a significant decrease in average food consumption, suggesting that cinnamon also tended to increase satiety. In addition, at long-term use, the group of diabetic animals fed cinnamon showed lower fasting blood glucose (FBG) levels (on days 20 and 30) as well as lower blood glucose levels 2 hours post-meal (on day 30). (Ranasinghe et al., 2012)

Many studies have examined the mechanism of action of cinnamon as a hypoglycemic agent, as reviewed by Medagama (2015); this is possibly due to its effects at various stages of the insulin signaling pathway. Several studies indicate that the polyphenol content of cinnamon also exhibits antioxidant activity that can help repair cell damage caused by oxidative stress in

hyperglycemic conditions. This is evidenced by the increase in serum glutathione (GSH) levels in DM patients who received cinnamon extract therapy for 12 weeks (Sahib, 2016).

The administration of cinnamon bark extract in this study did not show a statistically significant difference in fasting blood glucose levels when compared to the control group ($p = 0.065$) or the moderate-intensity swimming exercise group ($p = 0.736$). Although the p-value in the cinnamon extract group was relatively close to the significance threshold ($\alpha = 0.05$) compared with the control group, no statistically significant differences were observed. Therefore, these findings indicate insufficient scientific evidence to confirm the hypoglycemic effects of cinnamon extract in the experimental model used. Another reason for the absence of significant differences is the variety of cinnamon species and their extract matrices. The genus Cinnamomum includes a wide range of species with non-homogeneous phyto-constituent compositions. Variations in species, plant organ parts, extraction methods, and the content of active substances such as cinnamaldehyde and polyphenols directly affect bioavailability and biological activity. As a result, the use of certain cinnamon extracts does not always produce outputs equivalent to the powder form or different species of Cinnamomum.

The administration of cinnamon bark extract in this study did not show a statistically significant difference in fasting blood glucose levels when compared to the control group ($p = 0.065$) or the moderate-intensity swimming exercise group ($p = 0.736$). Although the p-value in the cinnamon extract group was relatively close to the significance threshold ($\alpha = 0.05$) compared with the control group, no statistically significant differences were observed. Therefore, these findings indicate insufficient scientific evidence to confirm the hypoglycemic effects of cinnamon extract in the experimental model used. Another reason for the absence of significant differences is the variety of cinnamon species and their extract matrices. The genus Cinnamomum includes a wide range of species with non-homogeneous phyto-constituent compositions. Variations in species, plant organ parts, extraction methods, and the content of active substances such as cinnamaldehyde and polyphenols directly affect bioavailability and biological activity. As a result, the use of certain cinnamon extracts does not always produce outputs equivalent to the powder form or different species of Cinnamomum (Baker et al., 2008)

The absence of uniform conclusions is also found in more recent studies. A 2024 meta-analysis of 24 randomized controlled trials (RCTs) showed that cinnamon supplementation was associated with reductions in fasting blood glucose, HOMA-IR (Homeostatic Model Assessment of Insulin Resistance), and HbA1c in people with type 2 diabetes. However, these findings were extrapolated from various human clinical trials with varying doses and intervention durations, so the results cannot be directly compared with experimental tests on streptozotocin (STZ)-induced animal models (Moridpour et al., 2024).

In addition, the absence of a significant difference between the cinnamon extract treatment and the swimming exercise group ($p = 0.736$) indicates that this study did not detect a statistically significant difference between the two interventions under the experimental conditions. However, this finding does not establish that the interventions are equivalent or share the same physiological mechanism. Physical activity and adequate nutritional intake are important components of health maintenance, although their specific effects depend on the intervention and population studied (Utamayasa, 2021). In the present study, the significant difference between the moderate-intensity swimming group and the untreated control group suggests that swimming produced a measurable change in fasting blood glucose under the experimental conditions.

Based on the Bonferroni Post Hoc test, a statistically significant decrease in fasting blood glucose (FBG) levels was observed only in the moderate-intensity swimming exercise group when compared to the untreated control group (p-value = 0.007; mean difference = 251.60 mg/dL). In contrast, the cinnamon bark extract treatment showed no significant difference, either compared to the untreated group (p-value = 0.065) or the swimming exercise group (p-value = 0.736). These results confirm that the between-group difference detected in the One-Way ANOVA test was primarily driven by the deviation in FBG levels between the moderate swimming group and the control group. This indicates that, under the current experimental conditions, the swimming exercise intervention produced a more pronounced and measurable glucose-lowering response than the other comparison groups.

These findings are consistent with the longitudinal profile of FBG dynamics observed in the swimming group. The test animals in this group began the observation period with a high mean glucose level (305.20 ± 159.37 mg/dL on day 4) and then gradually decreased to 118.00 ± 48.77 mg/dL on day 19. It should be noted that this apparent decrease represents an intrinsic temporal change (longitudinal within-group change), whereas the Post Hoc test confirms the significance of the between-group

difference. In general, this trend supports prior literature indicating that structured physical exercise can control hyperglycemia in diabetic animal models.

The mechanism of skeletal muscle contraction triggers Molecularly, the hypoglycemic effect of swimming exercise. During physical activity, mechanical stimulation of the muscles induces intracellular glucose uptake via a pathway largely independent of insulin (insulin-independent pathway). Muscle contraction activates specific protein kinases, such as AMP-activated protein kinase (AMPK), and triggers an increase in cytosolic calcium. These two signals are the main drivers of the translocation of glucose transporter type 4 (GLUT4) from intracellular vesicles to the plasma membrane of muscle cells. Because skeletal muscle is the body's main glucose-using tissue, the massive translocation of GLUT4 to the membrane increases its capacity to take up circulating glucose to meet energy needs, causing blood glucose levels to drop drastically. This mechanism is crucial in diabetic conditions where insulin signaling is impaired (Richter et al., 2025).

Beyond the acute effects during exercise, regular swimming provides long-term metabolic adaptations. Regular aerobic exercise has been shown to increase GLUT4 abundance and total GLUT4 expression, enhance mitochondrial oxidative capacity, optimize glycogen synthesis, and restore muscle insulin sensitivity. Thus, glucose regulation occurs not only during swimming but also continues through the refinement of muscle tissue's metabolic capacity after exercise (Richter & Hargreaves, 2013).

The results of this study reinforce various previous experimental studies in diabetic rat models. In type 2 diabetic rats induced by a high-fat diet and streptozotocin (STZ), an eight-week swimming program was reported to lower FBG, suppress fasting insulin levels, improve the Homeostatic Model Assessment of Insulin Resistance (HOMA-IR), and correct dyslipidemia. The study by Ghiasi et al. also confirmed that swimming significantly restored oral glucose tolerance (OGTT) and lowered HbA1c. Furthermore, Okon et al. and Chis et al. reported that moderate-intensity swimming treatment in STZ-induced diabetic rat models not only dampened hyperglycemia but also provided systemic protection of vascular function and inflammatory markers (Ghiasi et al., 2015).

These physiological benefits have also been observed in human translational studies. Jones et al. (2009) showed that a 12-week moderate-intensity water activity intervention in subjects with impaired glucose tolerance successfully suppressed fasting insulin by up to 44% and postprandial glucose by 30.4%. In Indonesia, Pramono et al. (2020) reported that 30 minutes of sudden swimming activity (acute exercise) reduced mean blood glucose levels by 0.5 mmol/dL in young individuals. This body of evidence reinforces the idea that repeated involvement of many large muscle groups in water exercise is a strong stimulus for increasing peripheral glucose utilization.

Nevertheless, the glycemic response to physical exercise is not always uniform across the literature. (Liu et al., 2026) reported that 12 weeks of progressive swimming exercise in STZ-induced type 1 diabetic rats successfully improved muscle strength and bone structure, but did not produce a significant difference in blood glucose compared to the diabetic control group. This discrepancy in results underscores that the effectiveness of swimming interventions is strongly determined by the initial extent of pancreatic beta-cell damage induced by STZ, the degree of endogenous insulinemia, and variations in exercise duration and intensity.

On the other hand, the absence of a significant difference between the cinnamon extract group and the swimming group (p-value = 0.736) does not indicate that the two share the same biological mechanism of action. The statistical result is more appropriately interpreted to mean that, at the dose, duration, and extract specifications used in this study, the hypoglycemic effect of cinnamon extract was not yet strong enough to match or surpass the massive metabolic response produced by swimming exercise. The management of diabetes mellitus has 4 main pillars: meal planning, physical activity, administration of hypoglycemic agents, and education. (Sudoyo et al., 2014) stated that the first step in diabetes management is non-pharmacological management in the form of meal planning and physical exercise.

For future research, evaluation of the effects of cinnamon bark extract is advised, using graded variations in dose and intervention duration to confirm a dose-response relationship. Standardization of Cinnamomum species, extraction techniques, and quantification of key bioactive compounds, such as cinnamaldehyde and polyphenols, is necessary to achieve precise comparability between studies. In addition, subsequent studies need to integrate fasting blood glucose analysis with more comprehensive metabolic and molecular markers, including serum insulin, HOMA-IR, HbA1c, GLUT4 expression, AMPK activity, lipid profile, and indicators of oxidative stress and inflammatory cytokines. Mapping these molecular variables is crucial to determine whether the observed glycemic improvement is driven by restoration of insulin sensitivity, improved peripheral

glucose utilization, modulation of metabolic pathways, or other cellular mechanisms. For the swimming exercise modality, further studies should consider variations in exercise prescription, including intensity, frequency, session duration, program length, and environmental variables such as water temperature. The use of multi-parameter intensity research designs is strongly recommended to identify the exercise dosage most effective at controlling hyperglycemia in animal models.

4. CONCLUSION

Cinnamon bark extract did not produce statistically significant differences in fasting blood glucose levels compared with either the untreated control group or the moderate-intensity swimming group. In contrast, the swimming group showed a significant difference compared with the untreated control group. However, the comparison between the swimming and cinnamon extract groups was not statistically significant. These findings suggest that, under the conditions of this study, moderate-intensity swimming was associated with a more clearly detectable glycemic response than cinnamon bark extract. However, its superiority over the extract was not statistically established. Further studies should investigate different extract doses, intervention durations, extract standardization, and characteristics of diabetes models to clarify the potential antihyperglycemic effects of cinnamon bark extract.

REFERENCES

[1] Arini, P. J., & Ardiaria, M. (2016). Pengaruh Pemberian Seduhan Bubuk Kayu Manis (Cinnamomum zeylanicum) Terhadap Kadar Glukosa Darah Puasa dan 2 Jam Pascaprandial Pada Penderita Diabetes Melitus Tipe 2. Journal of Nutrition College, 5, 198–206.

[2] Baker, W., William, G., White, C., Kluger, J., & Coleman, C. (2008). Effect of Cinnamon on Glucose Control and Lipid Parameters. Diabetes Care, 31(1), 1–3. https://doi.org/10.2337/dc07-1711.Abbreviations

[3] Bernadetha, Y. Palin T., & Satriani. (2024). Factors related to the incidence of diabetes mellitus at the Trauma Health Center in Samarinda City. International Journal of Engineering, Science and Information Technology, 4(3), 72–75. https://doi.org/10.52088/ijesty.v4i3.528

[4] Brunner, & Suddarth. (2002). Buku Ajar Keperawatan Medikal Bedah. EGC.

[5] Corwin, E. J. (2009). Buku Saku Patofisiologi. EGC.

[6] Ghiasi, R., Soufi, F. G., Somi, M. H., Mohaddes, G., & Bavil, F. M. (2015). Swim Training Improves HOMA-IR in Type 2 Diabetes Induced by High-Fat Diet and Low Dose of Streptozotocin in Male Rats. Tabriz University of Medical Sciences, 5(3), 379–384. https://doi.org/10.15171/apb.2015.052

[7] IDF Diabetes Atlas. (2021). IDF Diabetes Atlas 10TH (10 TH Edit). International diabetes Federation.

[8] Jones, L., Meredith-Jones, K., & Legge, M. (2009). The Effect of Water-Based Exercise on Glucose and Insulin Response in Overweight Women : A Pilot Study. 18(10).

[9] Kasole, R., Martin, H. D., & Kimiywe, J. (2019). Traditional Medicine and Its Role in the Management of Diabetes Mellitus : (Patients' and Herbalists' Perspectives). 2019. https://doi.org/10.1155/2019/2835691

[10] Liu, Y., Yang, Z., Deng, T., Bi, C., Li, H., Qu, P., Chen, Y., Liang, D., Xu, J., Li, N., Ding, G., & Wang, H. (2026). Food Environment and Childhood Overweight / Obesity : A Systematic Review. Advances in Nutrition, 17(1), 100564. https://doi.org/10.1016/j.advnut.2025.100564

[11] Lu, T., Sheng, H., Wu, J., Cheng, Y., Zhu, J., & Chen, Y. (2012). Cinnamon extract improves fasting blood glucose and glycosylated hemoglobin levels in Chinese patients with type 2 diabetes. Nutrition Research, 32(6), 408–412. https://doi.org/10.1016/j.nutres.2012.05.003

[12] Medagama, A. B. (2015). The glycaemic outcomes of Cinnamon: a review of the experimental evidence and clinical trials. 1–12. https://doi.org/10.1186/s12937-015-0098-9

[13] Moridpour, A. H., Kavyani, Z., Khosravi, S., Farmani, E., Daneshvar, M., Musazadeh, V., & Faghfouri, A. H. (2024). The effect of cinnamon supplementation on glycemic control in patients with type 2 diabetes mellitus: An updated systematic review and dose-response meta-analysis of randomized controlled trials. Phytotherapy Research, 38(1), 117–130. https://doi.org/10.1. Phytotherapy Research, 38(1), 1, 38, 117–130. https://doi.org/https://doi.org/10.1002/ptr.8026

[14] Nuari, N. A. (2017). Strategi Manajemen Edukasi Pasien Diabetes Mellitus. CV. Budi Utama.

[15] Persatuan Endokrinologi Indonesia. (2024). Pedoman pengelolaan dan pencegahan diabetes melitus tipe 2 di Indonesia 2024.

[16] Pramono, B. A., Mustar, Y. S., Marsudi, I., & Ashadi, K. (2020). Aktivitas air : rekomendasi penurunan kadar glukosa darah Water activity : recommendations for reducing blood glucose levels PENDAHULUAN Kelangsungan hidup dan kesehatan metabolisme tubuh sangat bergantung pada peran glukosa darah (Nort. Jurnal SPORTIF: Jurnal Penelitian Pembelajaran, 6(1), 173–183. https://doi.org/https://doi.org/10.29407/js_unpgri.v6i1.13979 Aktivitas

[17] Price, S. A., & Wilson, L. M. (2005). Patofisiologi: Konsep Klinis Proses-Proses Penyakit (Volume 1 dan 2). EGC.

[18] Ranasinghe, P., Perera, S., Gunatilake, M., Abeywardene, E., & Gunapala, N. (2012). Effects of Cinnamomum zeylanicum (Ceylon cinnamon) on blood glucose and lipids in a diabetic and healthy rat model. 73–79. https://doi.org/10.4103/0974-8490.94719

[19] Richter, E., Bilan, P. J., & Klip, A. (2025). A Comprehensive View Of Muscle Glucose Uptake : Regulation By Insulin, Contractile Activity, And Exercise Authors A Comprehensive View Of Muscle Glucose Uptake : Regulation By Insulin, Contractile Activity, And Exercise. American Physiological Society, 1867–1945. https://doi.org/10.1152/physrev.00033.2024

[20] Richter, E. A., & Hargreaves, M. (2013). Exercise, GLUT4, and Skeletal Muscle Glucose Uptake. American Physiological Society, Figure 2, 993–1017. https://doi.org/10.1152/physrev.00038.2012

[21] Sahib, A. S. (2016). Anti-diabetic and antioxidant effect of cinnamon in poorly controlled type-2 diabetic Iraqi patients : A randomized, placebo-controlled clinical trial. https://doi.org/10.5455/jice.20160217044511

[22] Sudoyo, A., Setiyohadi, B., Alwi, I., Simadibrata, M., & Setiati, S. (2014). Buku ajar ilmu penyakit dalam (6th ed.). Internal Publishing.

[23] Utamayasa, I. G. D. (2021). Effect of physical activity and nutrition during the Covid-19 pandemic. International Journal of Engineering, Science and Information Technology, 1(1), 52–54. https://doi.org/10.52088/ijesty.v1i2.58

[24] WHO. (2024). Diabetes. https://www.who.int/health-topics/diabetes#tab=tab_1