Research Article

The Effect Of Hyperbaric Oxygen Therapy on Lipid Profile, Blood Glucose, Hba1c Levels qnd Wound Healing in Diabetic Foot Ulcer Patients

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Abstract

Background: Diabetic foot ulcers are associated with impaired wound healing, poor glycemic control, dyslipidemia, and reduced functional capacity. Hyperbaric oxygen therapy is used as an adjunctive treatment; however, evidence regarding its dose–response effects on systemic metabolic and functional outcomes remains limited. **Objective:** This study aimed to evaluate the dose–response effects of hyperbaric oxygen therapy on glycemic control, lipid metabolism, and functional capacity in patients with diabetic foot ulcers. **Methods:** A quasi-experimental pretest–posttest study was conducted involving 48 patients with diabetic foot ulcers who underwent hyperbaric oxygen therapy. Participants were allocated into two groups: a 5-session group and a 10-session group. Glycemic parameters (fasting glucose and HbA1c), lipid profile (total cholesterol, triglycerides, HDL, and LDL), and functional capacity assessed using the Push Score were measured before and after therapy. Statistical analyses were performed using parametric or non-parametric tests based on data distribution, with between-group comparisons conducted to assess dose–response effects. **Results:** Both treatment groups showed significant improvements in all evaluated parameters ($p < 0.001$). However, the 10-session group demonstrated significantly greater reductions in fasting glucose and HbA1c, more favorable changes in lipid profile, and superior improvements in functional capacity compared with the 5-session group ($p < 0.001$ for all between-group comparisons), indicating a clear dose–response relationship. **Conclusion:** Hyperbaric oxygen therapy provides significant metabolic and functional benefits in patients with diabetic foot ulcers, with greater therapeutic effects observed following longer treatment duration. These findings support the use of extended hyperbaric oxygen therapy protocols to optimize systemic and functional outcomes in diabetic foot ulcer management.

Keywords: Hyperbaric Oxygen Therapy, Diabetic Foot Ulcers, Glycemic Control, Lipid Profile, Dose–Response, Functional Capacity.

1 Introduction

Diabetic foot ulcer (DFU) is one of the most serious chronic complications of diabetes mellitus (DM) and contributes substantially to morbidity, mortality, and the economic burden on the healthcare system. DFU is characterized by open wounds on the lower extremities that occur due to a combination of vascular disorders (macro- and microangiopathy), peripheral neuropathy, and repeated mechanical pressure on the foot. Loss of pain sensation and reduced tissue perfusion cause wounds to often go undetected early, become easily infected, and heal poorly [1].

The global prevalence of DFU is reported to reach 6 to 7% among the diabetic population, with a lifelong disability risk of 19 to 34% and an amputation rate of approximately 15% [1]. The incidence of DFU in Indonesia is around 15%, with an amputation rate reaching 30% and a mortality rate of 32% [2]. Regional data from East Java illustrate that approximately 9.08% of hospitalized type 2 diabetes cases were related to diabetic foot ulcers, with the majority of patients presenting with moderate-to-severe wound grades (Wagner grade 4–5) accompanied by infectious complications such as sepsis [3]. The high incidence and complication rates of DFU indicate that this condition represents an urgent public health problem requiring a more effective and efficient therapeutic approach.

The DFU wound healing process is a complex mechanism influenced by various pathophysiological factors, particularly tissue hypoxia, chronic inflammation, peripheral neuropathy, and vascular disorders. Chronic hyperglycemia in DM causes endothelial dysfunction, increased oxidative stress, and microcirculatory disturbances that ultimately reduce oxygen and nutrient supply to peripheral tissue [4], [5], [6]. This condition is worsened by chronic inflammation that inhibits immune cell migration, fibroblast activity, and angiogenesis, thereby slowing the regeneration of wound tissue [7].

Dyslipidemia is an important factor that frequently accompanies DM [8] and plays a major role in worsening DFU conditions. Increased levels of total cholesterol, triglycerides, and low-density lipoprotein (LDL), along with decreased high-density lipoprotein (HDL), contribute to accelerated atherosclerosis and impaired perfusion of lower

extremity tissue [9]. Impaired blood flow due to atherosclerosis causes more severe tissue hypoxia, increases infection risk, and directly impacts the delay in DFU wound healing [10], [11]. Lipid profile therefore plays an important role not only in cardiovascular risk among DM patients, but also in determining DFU wound healing outcomes.

Conventional management of DFU includes wound debridement, infection control with antibiotics, and management of metabolic factors. Although this approach can improve wound condition, it is still followed by a high incidence of new DFU cases and a slow healing process, with approximately 50,000 new cases occurring annually worldwide [12]. This condition drives the need for adjuvant therapies capable of improving tissue perfusion, suppressing inflammation, and accelerating the wound healing process.

Hyperbaric Oxygen Therapy (HBOT) has developed as a potential adjuvant modality for DFU patients. HBOT is administered by delivering high-concentration oxygen (approximately 98–100%) at a pressure of 2.0–2.4 atmospheres absolute (ATA) in a hyperbaric chamber, thereby increasing the dissolved oxygen in the blood and creating a pressure gradient that enhances oxygen diffusion into hypoxic tissue [13], [14]. This increase in dissolved oxygen levels is able to improve oxygen diffusion to ischemic tissue, stimulate angiogenesis, increase fibroblast activity, and strengthen the bactericidal capacity of leukocytes [15], [16].

The effects of HBOT are not limited to the wound area but also include systemic impacts on cellular metabolism. A number of studies show that HBOT can modulate glucose and lipid metabolism through activation of AMP-activated protein kinase (AMPK), increased antioxidant enzyme activity, and reduced systemic oxidative stress and inflammation [17]. This mechanism has the potential to lower triglyceride and total cholesterol levels and improve lipid balance, thereby supporting improved tissue perfusion and DFU wound healing [18].

Results of a recent meta-analysis show that HBOT significantly increases wound healing rates and reduces amputation rates in DFU patients [19]. Scientific evidence regarding the effect of HBOT on lipid profile changes and its relationship to DFU wound healing remains limited, particularly in developing countries including Indonesia. Studies that directly compare the effectiveness of different numbers of HBOT sessions, specifically between 5 sessions and 10 sessions, on changes in metabolic markers and wound healing outcomes have also not been widely reported.

Variation in HBOT practice, including the number of therapy sessions, is still frequently found in healthcare facilities without a strong quantitative evidence base. The relatively high-cost consideration makes determining the minimum effective number of sessions very important to optimize clinical benefit while reducing the economic burden on patients. This need underscores the necessity for research that systematically evaluates the effect of HBOT on lipid profile and wound healing in DFU patients while taking into account other metabolic parameters as supporting variables.

Based on this background, this study was conducted to analyze the effect of administering HBOT with different numbers of sessions on changes in lipid profile and wound healing in DFU patients, while continuing to take into account other metabolic parameters as supporting variables. The results of this study are expected to provide a scientific basis for more effective, efficient, and standardized use of HBOT in DFU management in Indonesia.

2 Methods

2.1 Type and Design of the Study

This study is a quasi-experimental study with a two group pre-test and post-test design.

2.2 Population and Sample

The study population consisted of all diabetic foot ulcer (DFU) patients undergoing hyperbaric oxygen therapy (HBOT) at Lakesla Drs. Med. R. Rijadi S., Phys during the study period. The study was conducted at Lakesla Drs. Med. R. Rijadi S., Phys from December 2025 to March 2026. The population totaled 30 patients. Based on the Slovin formula with a 10% margin of error, a sample size of 23.076 was obtained, rounded up to 24 subjects per group. Thus, the total study sample was 48 subjects, divided into the HBOT 5-session group and the 10-session group.

The sample consisted of DFU patients who met the inclusion criteria. These criteria included diabetes mellitus patients with moderate to severe DFU based on the PUSH score, who underwent lipid profile, HbA1c, and blood glucose examinations before and after HBOT, had at least one lipid profile parameter above normal or borderline, completed 5 or 10 HBOT sessions, had stable metabolic therapy, and had normal chest X-ray and ENT examination results. Exclusion criteria included changes in lipid-lowering therapy, major changes in antidiabetic drug or insulin dosage, incomplete therapy, claustrophobia, contraindications to HBOT such as pneumothorax, and pregnancy.

Sampling was conducted using consecutive sampling, whereby all subjects meeting the inclusion criteria were enrolled sequentially until the required sample size was reached.

2.3 Research Variables and Operational Definitions

The independent variable was the number of HBOT sessions at 2.4 ATA, namely 5 and 10 sessions. The dependent variables included lipid profile (total cholesterol, triglycerides, HDL, LDL), blood glucose, HbA1c, and ulcer severity based on the PUSH score. Controlled variables included ulcer grade, age, gender, physical activity, time of blood sampling, and use of antidiabetic medication. HBOT was administered using the US Navy Table 9 protocol at a pressure of 2.4 ATA and grouped into 5 or 10 sessions. Lipid profile, blood glucose, and HbA1c parameters were measured using laboratory examination, while wound healing was assessed using the PUSH score.

2.4 Research Materials

Research equipment included a hyperbaric oxygen chamber, flowmeter, pulse oximeter, scale, sphygmomanometer, blood collection and storage equipment, and laboratory devices. Laboratory examinations used a clinical chemistry analyzer and an HbA1c testing device. Data processing was performed using SPSS, R, and Microsoft Excel. Research materials consisted of pure medical oxygen, venous blood samples, EDTA and SST tubes, antiseptic materials, reagents for glucose, lipid profile, and HbA1c testing, and supporting materials for sample storage and transportation.

2.5 Research Instrument

The main research instrument was hyperbaric oxygen therapy, used to assess changes in lipid profile, blood glucose, HbA1c, and wound healing in DFU patients.

2.6 Data Collection Procedure

The study observed the principles of confidentiality, informed consent, and anonymity. Subjects were given an explanation of the study and had the right to refuse without coercion. The study began with a preparation phase that included proposal preparation, obtaining research permits and ethical clearance, patient recruitment and selection, obtaining informed consent, grouping patients based on administration of HBOT for 5 or 10 sessions, and preparing research tools and materials. Next, baseline (pretest) data were obtained before the first HBOT session through examination of lipid profile, blood glucose, HbA1c, and PUSH score. Patients then underwent HBOT up to the 5th or 10th session according to their study group. After all therapy sessions were completed, a repeat measurement (posttest) of all study parameters was performed.

Blood sample collection and HBOT administration were carried out by competent medical personnel. Blood collection was performed twice, before HBOT and after all therapy sessions were completed. Venipuncture was performed on the cubital vein using an aseptic technique. Blood samples were placed in EDTA tubes for HbA1c examination and plain tubes for lipid profile and blood glucose examination. Lipid profile examination included total cholesterol and triglycerides using the enzymatic colorimetric CHOD–PAP and GPO–PAP methods, while HDL and LDL were examined using the Direct HDL and Direct LDL methods. Results were determined based on absorbance readings and standard curves.

Blood glucose was examined using the Glucose Oxidase Peroxidase (GOD–PAP) method, while HbA1c was examined using the ELISA method. The examination results were used to determine changes in glycemic control before and after HBOT. DFU improvement was assessed clinically based on wound area, exudate amount, and wound tissue type using the PUSH score parameter. All laboratory examination results and wound assessments were systematically recorded for subsequent analysis to determine changes in patient condition before and after HBOT administration.

2.7 Data Management

Data management included collection of examination results, editing, coding, data entry, and cleaning. These stages were carried out to ensure the data were complete, structured, and free of errors before analysis.

2.8 Data Analysis

Analysis was performed quantitatively using SPSS. Data were first analyzed descriptively and tested for normality using the Shapiro–Wilk test. Comparisons before and after HBOT within each group used the paired t-test or Wilcoxon signed-rank test, while comparisons of changes between the 5-session and 10-session groups used the independent t-test or Mann–Whitney U test, according to data distribution.

3 Results

3.1 Descriptive Analysis of Pre and Post Variables

Descriptive analysis was conducted to provide a general overview of the data characteristics in each group prior to hypothesis testing. Minimum, maximum, mean, and standard deviation values were calculated for each variable under pretest and posttest conditions in each group.

Table 1: Descriptive Statistics of Study Variables Before and After HBOT

Variable	Mean level difference	Group	Pre (Mean ± SD)	Post (Mean ± SD)
Lipid Profile Levels	Cholesterol total (mg/dL)	1 (5 session)	232.42 ± 17.46	221.54 ± 15.48
		2 (10 session)	236.21 ± 19.14	213.21 ± 17.56
	Trigliserida (mg/dL)	1 (5 session)	183.42 ± 51.04	168.92 ± 47.67
		2 (10 session)	206.50 ± 74.24	169.25 ± 65.13
	HDL (mg/dL)	1 (5 session)	40.62 ± 2.94	42.21 ± 2.70
		2 (10 session)	39.80 ± 3.33	44.78 ± 3.33
	LDL (mg/dL)	1 (5 session)	156.12±15.62	149.29±14.91
		2 (10 session)	162.00±18.83	143.88±18.26
Blood Glucose and HbA1c Levels	GDP (mg/dL)	1 (5 session)	192.54 ± 14.60	179.29 ± 12.11
		2 (10 session)	197.17 ± 15.94	165.79 ± 11.29
	HbA1c (%)	1 (5 session)	8.52 ± 0.56	8.24 ± 0.49
		2 (10 session)	8.56 ± 0.53	7.84 ± 0.43
Wound Improvement (Push Score)	PUSH Score	1 (5 session)	12.00 ± 1.93	10.38 ± 1.61
		2 (10 session)	11.92 ± 1.77	7.33 ± 1.17

Source: Primary Data 2026, processed

Based on Table 1, after HBOT administration there was a decrease in mean total cholesterol, triglycerides, FBG, HbA1c, and PUSH Score in both groups, while HDL levels increased. Descriptively, the HBOT 10-session group showed greater mean changes than the 5-session group in most study variables. For PUSH Score, the decrease from 11.92 to 7.33 in the 10-session group indicates greater wound improvement compared with the 5-session group, which decreased from 12.00 to 10.38. However, the LDL value in the table needs to be re-verified since the figures listed are still identical to total cholesterol.

3.2 Group 1 Effect Test

3.2.1. Changes in Lipid Profile of Group 1. The test of lipid profile changes in Group 1 was conducted by comparing values before and after treatment. For total cholesterol and triglycerides, analysis was performed using the Wilcoxon test. Results showed that total cholesterol and triglycerides had a significance value of <0.001, indicating a significant effect of HBOT on total cholesterol and triglyceride levels in Group 1. For HDL and LDL, analysis was performed using the paired t-test. Results showed that HDL and LDL had a significance value of <0.001, indicating a significant effect of HBOT on HDL and LDL levels in Group 1. The table below shows the results of the HBOT effect test on lipid profile levels in Group 1.

Table 2: Results of the Lipid Profile Change Test, Group 1

Variable	Statistical Test	Z/t Value	Sig. (2-tailed)
Total cholesterol	Wilcoxon	-4.299	<0.001
Trigliserida	Wilcoxon	-4.300	<0.001
HDL	Paired t-test	-17.364	<0.001
LDL	Paired t-test	11.922	<0.001

3.2.2. Changes in Blood Glucose and HbA1c of Group 1. The test of changes in blood glucose and HbA1c levels in Group 1 was conducted by comparing values before and after treatment. For the blood glucose variable, analysis was performed using the Wilcoxon test because the data were not normally distributed. In Group 1, results showed that the blood glucose variable had a significance value of <0.001, indicating a significant effect of HBOT on blood glucose levels in treatment Group 1. For HbA1c, analysis was performed using the paired t-test. The t value was 16.740 with a significance value of <0.001, indicating a significant effect of HBOT on HbA1c levels.

Table 3: Results of the Blood Glucose and HbA1c Change Test, Group 1

Variable	Measurement	Statistical Test	Z/t Value	Sig. (2-tailed)
GDP	Pre vs Post	Wilcoxon	-4.295	<0.001
HbA1c	Pre vs Post	Paired t-test	16.740	<0.001
	Mean Difference	0.279 ± 0.082		

3.2.3. Changes in Push Score of Group 1. The test of Push score changes to assess wound improvement in Group 1 was conducted by comparing Push score values before and after treatment. Analysis was performed using the Wilcoxon test. Results showed that the wound improvement variable had a significance value of <0.001, indicating a significant effect of HBOT on wound improvement in treatment Group 1.

Table 4: Results of the Push Score Change Test, Group 1

Variable	Measurement	Statistical Test	Z/t Value	Sig. (2- tailed)
Push Score	Pre vs Post	Wilcoxon	-4.443	<0.001
	Negative Ranks	24 (Mean Rank: 12,50)		

3.3 Group 2 Effect Test

3.3.1. Changes in Lipid Profile of Group 2. The test of lipid profile changes in Group 2 was conducted by comparing values before and after treatment. For total cholesterol and triglycerides, analysis was performed using the Wilcoxon test. Results showed that total cholesterol and triglycerides had a significance value of 0.001, indicating a significant effect of HBOT on total cholesterol and triglyceride levels in treatment Group 1. For HDL and LDL, analysis was performed using the paired t-test. Results showed that HDL and LDL had a significance value of <0.001, indicating a significant effect of HBOT on HDL and LDL levels in Group 2.

Table 5: Results of the Lipid Profile Change Test, Group 2

Variable	Measurement	Statistical Test	Z/t Value	Sig. (2- tailed)
Total Cholesterol	Pre vs Post	Wilcoxon	-4.305	<0.001
	Negative Ranks	24 (Mean Rank: 12.50)		
Trigliserida	Pre vs Post	Wilcoxon	-4.289	<0.001
	Negative Ranks	24 (Mean Rank: 12.50)		
HDL	Pre vs Post	Paired t-test	-43.851	<0.001
	Mean Difference	-4.975 ± 0.556		
LDL	Pre vs Post	Paired t-test	72.369	<0.001
	Mean Difference	3.125 1.227		

3.3.2. Changes in Blood Glucose and HbA1c of Group 2. The test of changes in blood glucose and HbA1c levels in treatment Group 1 was conducted by comparing values before and after treatment. For blood glucose and HbA1c, analysis was performed using the paired t-test because the data were normally distributed. In Group 2, results showed that blood glucose and HbA1c had a significance value of <0.001, indicating a significant effect of HBOT on blood glucose and HbA1c levels in treatment Group 2, as shown in Table 6 below.

Table 6: Results of the Blood Glucose and HbA1c Change Test, Group 2

Variable	Measurement	Statistical Test	t Value	Sig. (2- tailed)
GDP	Pre vs Post	Paired t-test	31.329	<0.001
	Mean Difference	31.375 ± 4.906		
HbA1c	Pre vs Post	Paired t-test	32.801	<0.001
	Mean Difference	3.721 0.108		

3.3.3. Changes in Push Score of Group 2. The test of Push score changes to assess wound improvement in Group 2 was conducted by comparing Push score values before and after treatment. Analysis was performed using the Wilcoxon test. Results showed that the wound improvement variable had a significance value of <0.001, indicating a significant effect of HBOT on wound improvement in treatment Group 2.

Table 7: Results of the Push Score Change Test, Group 2

Variable	Measurement	Statistical Test	Z Value	Sig. (2- tailed)
Push Score	Pre vs Post	Wilcoxon	-4.369	<0.001
	Negative Ranks	Mean Rank: 12.50)		

3.4. Between-Group Effect Test

3.4.1. Comparison of Lipid Profile Between Groups. The test of between-group comparison of lipid profile changes was conducted by comparing the differences in change of total cholesterol, triglycerides, HDL, and LDL between Group 1 and Group 2. Analysis of changes in total cholesterol and triglycerides used the Mann–Whitney U test. Analysis of changes in HDL and LDL used the independent t-test.

Table 8: Results of the Between-Group Comparison of Lipid Profile Changes

Variable	Group	N	Mean Rank / Mean Diff	Statistical Test	Z/t Value	Sig. (2-tailed)
ΔChol	Group 1	24	36.50	Mann- Whitney U	-5.963	<0.001
	Group 2	24	12.50			
ΔTG	Group 1	24	36.46	Mann- Whitney U	-5.931	<0.001
	Group 2	24	12.54			
ΔHDL	Group 1	24	Mean Diff: - 3.383	Independent t-test	- 23.196	<0.001
	Group 2	24	95% CI: -3.677 - -3.089			
ΔLDL	Group 1	24	Mean Diff: 11.292	Independent t-test	18.053	<0.001
	Group 2	24	95% CI: 10.033 - 12.551			

3.4.2. Comparison of Glycemic Variables Between Groups. The test of between-group comparison of changes in glycemic variables, namely blood glucose and HbA1c, was conducted by comparing the differences in change in FBG and HbA1c values between Group 1 and Group 2. Analysis of changes in FBG used the Mann–Whitney U test. Analysis of changes in HbA1c using the independent t-test showed a t value of 16.034 with a significance of <0.001.

Table 9: Results of the Between-Group Comparison of Glycemic

Variable	Group	N	Mean Rank / Mean Diff	Statistical Test	Z/t Value	Sig. (2-tailed)
ΔGDP	Group 1	24	36.50	Mann -Whitney U	-5.952	<0.001
	Group 2	24	12.50			
ΔHbA1c	Group 1	24	Mean Diff: 0.442	Independent t-test	16.034	<0.001
	Group 2	24				

3.4.3. Comparison of Wound Improvement (Push Score) Between Groups. The test of between-group comparison of wound improvement as reflected in Push Score changes was conducted by comparing the differences in change in Push Score values between Group 1 and Group 2. Analysis using the Mann–Whitney U test showed a Z value of -6.116 with a significance of <0.001. The mean rank value was 36.50 in Group 1 and 12.50 in Group 2.

Table 10. Results of the Between-Group Comparison of Push Score Changes

Variable	Group	N	Mean Rank	Statistical Test	Z Value	Sig. (2-tailed)
Δpush Score	Group 1	24	36.50	Mann- Whitney U	-6.116	<0.001
	Group 2	24	12.50			

3.5. Bar Chart Visualization

3.5.1. Changes in Lipid Profile Levels Pre and Post in Groups 1 and 2

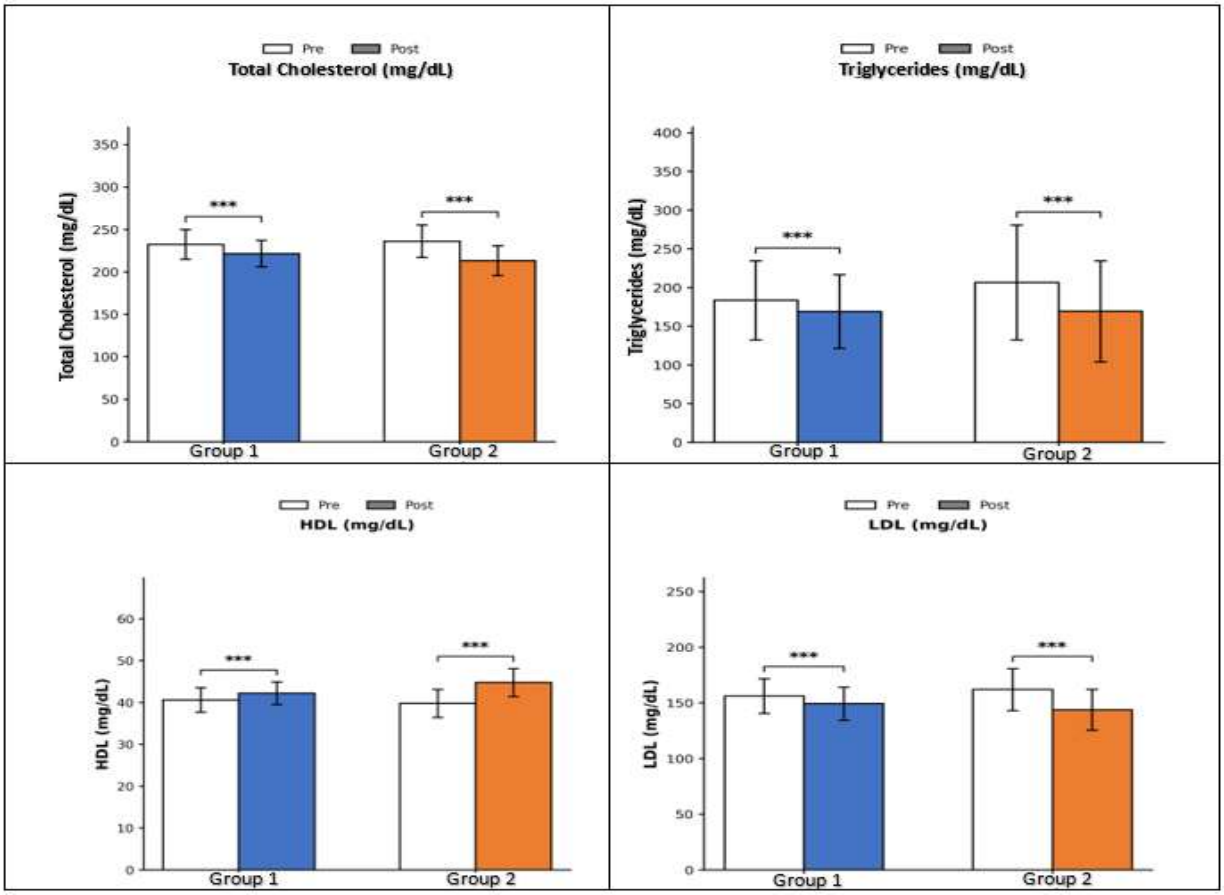

Figure 1: Chart of Changes in Total Chol, TG, HDL, LDL Levels Pre and Post in Group 1 and Group 2
Source: Primary Data 2026, processed

Figure 1 displays the changes in mean lipid profile in both groups. A decrease in mean cholesterol is visible in both groups, with a relatively comparable decrease between Group 1 and Group 2 when viewed visually, although the Mann-Whitney U test result on ΔChol shows that the between-group difference remains statistically significant. The error bar range under both conditions and both groups is relatively consistent, reflecting the uniformity of the total cholesterol decrease response across all study subjects. The consistently decreasing bar pattern in both groups is in line with the previous Wilcoxon test results showing that all subjects in each group experienced a decrease in total cholesterol.

Changes in mean triglycerides in both groups had a relatively wider error bar range compared to other variables, both under pre and post conditions, reflecting high individual variability in triglyceride levels among study subjects. Although individual variability was high, the direction of change remained consistently decreasing in both groups after treatment. The wide error bar range for this parameter is consistent with the earlier normality test results showing that triglyceride distribution was not normal in both groups, so hypothesis testing for this variable appropriately used the Wilcoxon Signed Ranks Test and the Mann-Whitney U test for between-group comparison.

An increase in mean HDL in both groups after treatment is shown by the post bar being higher than the pre bar in each group. This increase appears visually greater in Group 2 than in Group 1, consistent with the Independent Samples t-test result on ΔHDL showing a mean difference of 3.383 mg/dL between groups. The consistent direction of increase in both groups makes this the one lipid profile variable that changed in the direction of increase, unlike total cholesterol, triglycerides, and LDL, which all decreased.

The decrease in mean LDL in both groups after treatment appears greater in Group 2 than in Group 1, consistent with the Independent Samples t-test result on ΔLDL showing a mean difference of 11.292 mg/dL between groups, the largest difference among the lipid profile variables measured. The error bar range in the post condition of Group 2 appears relatively narrow, reflecting high precision in the estimate of LDL reduction in that group. This pattern is consistent with the relatively small standard deviation value in Table 1 for the LDL_Post parameter of Group 2.

3.5.2. Changes in Blood Glucose, HbA1c, and Push Score Pre and Post in Groups 1 and 2

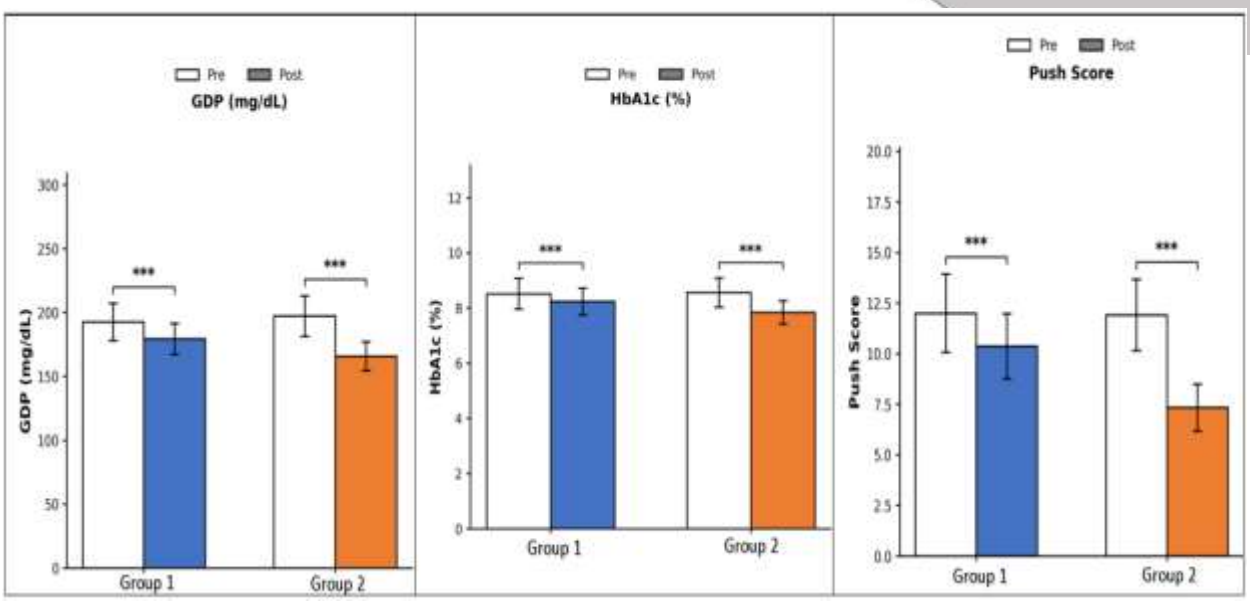

Figure 2: Chart of Changes in Blood Glucose, HbA1c, and Push Score Levels Pre and Post in Group 1 and Group 2
Source: Primary Data 2026, processed

Figure 2 shows that mean FBG decreased in both groups after treatment. The decrease in Group 2 appears greater than in Group 1, consistent with the Mann-Whitney U test result comparing ΔFBG between groups, which showed a highly significant difference. The height of the post bar in Group 2 is far lower than in Group 1, while the error bar range under both conditions remains relatively narrow, indicating consistency of response among subjects within each group. The consistent decreasing pattern across all subjects, as previously reported in the Wilcoxon test results showing that all 24 subjects in each group experienced a decrease in FBG, is clearly visualized through the narrow error bar range on both post bars.

The decrease in mean HbA1c is clearly visible in both groups, with a decrease that is visually greater in Group 2 than in Group 1. This is consistent with the Independent Samples t-test result comparing ΔHbA1c between groups, which showed a mean difference of 0.442 percent with very high significance. The error bar range under the post condition in Group 2 is slightly narrower than under the pre-condition, indicating that variability among subjects actually decreased after the ten-session duration treatment. This pattern differs from Group 1, where the error bar range under the pre and post conditions was relatively similar, indicating that the longer treatment duration contributed to homogenization of subjects' response in long-term glycemic control.

Changes in mean Push Score in both groups reflect the change in wound improvement among study subjects. The decrease in score in both groups reflects wound improvement, since a lower score indicates a better condition. The decrease in Group 2 appears far greater than in Group 1, consistent with the Mann-Whitney U test result on ΔPush Score, which showed the highest Z value among all parameters compared between groups. The error bar range under the post condition in Group 2 appears narrower than in Group 1, indicating a more homogeneous response to wound improvement in the group with the longer treatment duration.

4 Discussion

4.1 Effect of HBOT on Total Cholesterol Levels

Total cholesterol is one of the variables widely used to assess lipid metabolism status and cardiovascular disease risk. The total cholesterol value represents the accumulation of various lipoprotein fractions in circulation, including low-density lipoprotein (LDL), high-density lipoprotein (HDL), and very low-density lipoprotein (VLDL). Increased total cholesterol levels are frequently associated with lipid metabolism disorders that affect the development of atherosclerosis, coronary heart disease, and other cardiovascular complications [20].

Results showed that total cholesterol levels decreased in both groups after HBOT. Mean total cholesterol in Group 1 decreased from 232.42 ± 17.46 mg/dL to 221.54 ± 15.48 mg/dL, while in Group 2 it decreased from 236.21 ± 19.14

mg/dL to 213.21 ± 17.56 mg/dL. The greater decrease in Group 2 indicates that HBOT with a higher number of sessions produces a more optimal improvement in lipid profile compared with HBOT with a lower number of sessions.

The decrease in total cholesterol that occurred is related to improved insulin sensitivity following HBOT. Insulin resistance contributes to various lipid metabolism disorders through increased synthesis of atherogenic lipoproteins and disrupted fatty acid metabolism. Improved insulin sensitivity can reduce hepatic triglyceride lipoprotein production and increase the efficiency of lipid metabolism, thereby lowering total cholesterol levels. The relationship between insulin resistance and dyslipidemia has been widely reported as one of the main components of metabolic syndrome [21].

Improved lipid metabolism can also occur through increased activity of enzymes involved in lipoprotein catabolism. Better lipoprotein lipase activity increases the breakdown of triglycerides in lipoprotein particles, thereby accelerating the clearance of lipids from circulation. This indirectly affects the reduction in total cholesterol levels. Metabolic adaptation that continues over time can increase the use of lipids as an energy source and improve lipid profile [22].

The magnitude of the decrease in total cholesterol in Group 2 shows that a longer HBOT duration produces more optimal physiological adaptation. Changes in lipid metabolism require a gradual adaptation process through changes in enzymatic activity, gene expression regulation, and improved metabolic function across various tissues. Longer HBOT exposure allows these processes to proceed more effectively, resulting in a greater decrease in total cholesterol [23].

Improvement in total cholesterol levels is important because high cholesterol levels are one of the main risk factors for cardiovascular disease. Cholesterol accumulation in blood vessel walls contributes to the formation of atherosclerotic plaque, which can cause narrowing or obstruction of blood vessels. The progressive process of atherosclerosis underlies various cardiovascular diseases such as coronary heart disease, myocardial infarction, and stroke [24].

The relationship between total cholesterol levels and cardiovascular risk is influenced not only by the amount of cholesterol circulating but also by the quality and distribution of the lipoprotein fractions that compose it. The decrease in total cholesterol accompanied by a decrease in LDL and an increase in HDL, as found in this study, indicates a comprehensive improvement in lipid profile [20].

The findings of this study are in line with various studies reporting that interventions that improve energy metabolism and insulin sensitivity can significantly lower total cholesterol levels. A systematic review conducted by Kraus et al. (2019) [22] showed that regular, sustained interventions are associated with improved lipid profile marked by a decrease in total cholesterol and reduced atherogenic risk. These results support the findings of this study, which show that the group with a greater number of intervention sessions obtained a greater improvement in lipid profile compared with the group with fewer sessions.

4.2 Effect of HBOT on Triglyceride Levels

Results showed that triglyceride levels decreased in both groups after HBOT was administered. Mean triglycerides in Group 1 decreased from 183.42 ± 51.04 mg/dL to 168.92 ± 47.67 mg/dL, while in Group 2 it decreased from 206.50 ± 74.24 mg/dL to 169.25 ± 65.13 mg/dL. The greater decrease in Group 2 indicates that HBOT with a higher number of sessions has a greater effect on the improvement of triglyceride metabolism. This finding shows that the duration of intervention exposure plays a role in determining the magnitude of the resulting metabolic response.

A notable characteristic of the triglyceride variable in this study is the large standard deviation compared with other lipid variables. This high variability indicates fairly substantial differences in response among individuals. Triglyceride levels are a highly dynamic variable influenced by various factors including dietary intake patterns, energy balance, body fat distribution, physical activity, hormonal factors, and genetic factors. High biological variation causes triglyceride levels to tend to have a wider data spread compared with total cholesterol or HDL [25].

Results of the variance homogeneity test showed that the triglyceride variable had non-homogeneous variance between groups. This finding indicates that the degree of variability in triglyceride change differs between Group 1 and Group 2. This condition can be explained by the complexity of triglyceride metabolism regulation, which involves various physiological pathways. Response to intervention does not always occur to the same degree in every individual because it is influenced by baseline metabolic condition, insulin sensitivity, body composition, and varying genetic factors [24].

The magnitude of the decrease in triglycerides in Group 2 shows that intervention conducted over a longer duration allows for more optimal metabolic adaptation. This adaptation includes increased fatty acid oxidation capacity, improved mitochondrial function, and increased efficiency in using lipids as an energy source. This process will

reduce the accumulation of triglycerides in circulation and improve overall lipid metabolism balance. Metabolic adaptation that occurs repeatedly is known to produce a greater effect on lipid metabolism compared with a shorter intervention exposure [23].

The decrease in triglyceride levels has important clinical implications because hypertriglyceridemia is one of the main components of atherogenic dyslipidemia. High triglyceride levels are often accompanied by an increase in small dense LDL particles and a decrease in HDL, which together increase atherosclerosis risk. Improvement in triglyceride levels therefore reflects not only improved lipid metabolism but also a decrease in overall cardiovascular risk [26].

The findings of this study are in line with various studies reporting that interventions that improve insulin sensitivity and increase energy metabolism are associated with a decrease in triglyceride levels. A systematic review conducted by Ross et al. (2016) [23] showed that interventions conducted continuously can produce improved lipid profile marked by a decrease in triglycerides and reduced atherogenic dyslipidemia risk. These results support the findings of this study, which show that the group with a greater number of intervention sessions obtained a greater decrease in triglycerides compared with the group with fewer sessions.

4.3 Effect of HBOT on High-Density Lipoprotein (HDL) Levels

Results showed that HDL levels increased in both groups after the intervention was administered. Mean HDL in Group 1 increased from 40.62 ± 2.94 mg/dL to 42.21 ± 2.70 mg/dL, while in Group 2 it increased from 39.80 ± 3.33 mg/dL to 44.78 ± 3.33 mg/dL. The greater increase in Group 2 shows that intervention with a higher number of sessions has a more optimal impact on improving lipid profile. This finding shows that increased intervention duration is associated with an increased ability of the body to maintain cholesterol metabolism balance.

The increase in HDL levels found in this study is related to improved insulin sensitivity and overall lipid metabolism. Insulin resistance is known to be associated with decreased HDL levels through increased production of triglyceride-rich lipoproteins and disrupted HDL particle maturation. Improved insulin sensitivity will increase the efficiency of lipid metabolism so that the formation and function of HDL can proceed more optimally. The relationship between insulin sensitivity and increased HDL levels has been reported as one of the indicators of metabolic improvement in individuals with impaired glucose and lipid metabolism [21].

The increase in HDL can also be explained through improved activity of enzymes involved in lipoprotein metabolism, such as lecithin-cholesterol acyltransferase (LCAT) and cholesteryl ester transfer protein (CETP). Better regulation of the activity of these enzymes will increase the HDL maturation process and improve the ability of HDL to transport cholesterol from peripheral tissue to the liver. This mechanism contributes to increased HDL concentration in circulation and increased effectiveness of the reverse cholesterol transport process [27].

The change in HDL found in this study has a different biological meaning compared with other lipid variables. Total cholesterol, triglycerides, and LDL show changes in the direction of decrease, while HDL increased. This pattern reflects a comprehensive improvement in lipid profile. The increase in HDL shows that the intervention given not only reduces atherogenic lipid components but also increases the lipoprotein fraction that plays a protective role in cardiovascular health [20].

The standard deviation values for HDL in both groups were relatively small both before and after the intervention. This condition shows that the variation in HDL levels among individuals is relatively low, so the response to the intervention occurred relatively uniformly. Results of the variance homogeneity test also showed that the change in HDL had a homogeneous distribution between groups. This characteristic indicates that the benefit of the intervention for increasing HDL can be felt consistently by most study subjects.

The magnitude of the increase in HDL in Group 2 shows that a longer intervention duration allows for more optimal metabolic adaptation. This adaptation includes increased lipid oxidation capacity, improved lipoprotein metabolism enzyme function, and increased efficiency of cholesterol transport. Adaptation that occurs repeatedly will strengthen the physiological mechanisms that support increased HDL levels, so the resulting effect is greater compared with the group with a lower number of sessions [23].

The findings of this study are in line with various studies reporting that interventions that improve energy metabolism and insulin sensitivity can significantly increase HDL levels. A systematic review conducted by Ross et al. (2016) [23] showed that interventions conducted continuously are associated with increased HDL levels and improvement in various cardiovascular risk indicators. These results support the findings of this study, which show that the group with a greater number of intervention sessions obtained a greater increase in HDL compared with the group with fewer sessions.

4.4 Effect of HBOT on Low-Density Lipoprotein (LDL) Levels

Results showed that LDL levels decreased in both groups after the intervention was administered. Mean LDL in Group 1 decreased from 156.12 ± 15.62 mg/dL to 149.29 ± 14.91 mg/dL, while in Group 2 it decreased from 162.00 ± 18.83

mg/dL to 143.88 ± 18.26 mg/dL. The greater decrease in Group 2 shows that intervention with a higher number of sessions has a more optimal impact on improving atherogenic lipid profile. This finding indicates that increased intervention duration is associated with more effective cholesterol metabolism improvement.

The decrease in LDL levels that occurred in this study is related to improved insulin sensitivity and lipid metabolism regulation following the intervention. Insulin resistance can increase the production of atherogenic lipoproteins in the liver and disrupt the LDL clearance process from circulation. Improved insulin sensitivity will increase the efficiency of lipid metabolism, thereby reducing LDL levels in the blood. The relationship between insulin resistance and increased LDL has been widely reported as part of the metabolic disorder that underlies the development of cardiovascular disease in individuals with type 2 diabetes mellitus and metabolic syndrome [21].

The magnitude of the decrease in LDL in Group 2 shows that longer intervention exposure allows for more optimal metabolic adaptation. This adaptation includes increased lipid metabolism capacity, improved hepatic function in managing cholesterol, and increased efficiency in using lipids as an energy source. The greater response in the group with a higher number of sessions indicates a cumulative effect from the intervention given, resulting in a more apparent improvement in lipid profile [23].

The standard deviation values for LDL in both groups were relatively stable before and after the intervention. Nevertheless, results of the variance homogeneity test showed that the change in LDL had a non-homogeneous data spread characteristic between groups. This condition indicates that the degree of individual variation in response to the intervention differs between Group 1 and Group 2. This difference can be influenced by various factors, including genetic variation, baseline metabolic condition, insulin sensitivity, body composition, and differences in individual ability to respond to changes in lipid metabolism [24].

The decrease in LDL levels has very important clinical implications because LDL is a major causal factor in the development of atherosclerosis. Strong scientific evidence shows that the lower the LDL level, the lower the risk of cardiovascular events such as myocardial infarction, coronary heart disease, and ischemic stroke. This relationship is linear, so every decrease in LDL levels will be followed by a proportional decrease in cardiovascular risk. The "lower is better" concept for LDL is currently a main principle in various dyslipidemia management and cardiovascular disease prevention guidelines [24].

The increase in HDL that occurred simultaneously with the decrease in LDL in this study shows a comprehensive improvement in lipid profile. The ratio between atherogenic lipoprotein and protective lipoprotein becomes better after the intervention is given. This condition is more beneficial compared with a change in a single lipid parameter alone because it reflects an overall improvement in cholesterol metabolism balance. Improvement in lipid profile occurring simultaneously is known to provide greater benefit to cardiovascular health compared with a change in a single lipid component alone [20].

The findings of this study are in line with various studies reporting that interventions that improve insulin sensitivity and energy metabolism are associated with a decrease in LDL levels. A scientific review conducted by Ference et al. (2024) showed that improved lipid metabolism accompanied by a decrease in LDL contributes directly to a decreased risk of atherosclerosis and cardiovascular events [24]. These results support the findings of this study, which show that the group with a greater number of intervention sessions obtained a greater decrease in LDL compared with the group with fewer sessions.

4.5 Effect of HBOT on Blood Glucose

Results showed that FBG levels decreased in both groups after the intervention was administered. Mean FBG in Group 1 decreased from 192.54 ± 14.60 mg/dL to 179.29 ± 12.11 mg/dL, while in Group 2 it decreased from 197.17 ± 15.94 mg/dL to 165.79 ± 11.29 mg/dL. The greater decrease in Group 2 shows that a longer intervention duration has a greater impact on the improvement of glycemic control. This finding indicates a relationship between increased number of intervention sessions and the magnitude of the resulting metabolic response.

The decrease in FBG levels found in this study is related to increased insulin sensitivity following the intervention. Better insulin sensitivity will increase the ability of muscle tissue and adipose tissue to take up glucose from circulation, thereby lowering plasma glucose levels. Improved insulin sensitivity also affects the suppression of hepatic glucose production through inhibition of the gluconeogenesis and glycogenolysis processes. Increased insulin sensitivity is known to be one of the main mechanisms involved in improved glycemic control in various forms of metabolic intervention [28].

The greater decrease in FBG in Group 2 shows that a longer intervention duration allows for more optimal metabolic adaptation. This adaptation can take the form of greater increases in insulin sensitivity, increased tissue oxidative capacity, and improved efficiency in using glucose as an energy source. Physiological response to an intervention is

generally cumulative, so increased frequency or duration of exposure will produce a more apparent metabolic change compared with shorter exposure [29].

The difference in FBG decrease between the two groups can also be related to the cellular adaptation process, which proceeds gradually. This adaptation includes increased activity of enzymes involved in glucose metabolism, improved mitochondrial function, and increased ability of peripheral tissue to utilize glucose. Adaptation that proceeds over a longer period allows for more stable physiological changes, so the effect on blood glucose reduction is greater in the group undergoing intervention with a higher number of sessions [30].

The standard deviation values under the post HBOT condition appeared lower compared with the initial condition in both groups. This condition shows that the variation in blood glucose levels among individuals became smaller after the intervention was administered. This decrease in variation indicates that the effect of the intervention not only produces an improvement in mean FBG but also creates a more uniform response in most study subjects. This characteristic is consistent with the error bar visualization showing a relatively narrow range of data variation after treatment.

Improvement in FBG levels has important clinical implications because chronic hyperglycemia is a major factor contributing to the development of diabetes complications. Long-term exposure to high glucose can trigger the formation of advanced glycation end products (AGEs), increase oxidative stress, cause endothelial dysfunction, and activate various inflammatory pathways involved in tissue damage. Better blood glucose control is known to be associated with a decreased risk of microvascular and macrovascular complications, making it a main target in the management of metabolic disorders [31].

The findings of this study are in line with various studies reporting that interventions capable of increasing insulin sensitivity and improving glucose metabolism contribute to a decrease in FBG levels. A review by Bird and Hawley (2017) showed that increased duration and intensity of intervention is associated with greater improvement in glycemic control compared with shorter exposure [30]. These results support the findings of this study, which show that the group with a greater number of intervention sessions obtained a greater decrease in FBG compared with the group with fewer sessions.

4.6 Effect of HBOT on Glycated Hemoglobin (HbA1c)

Results showed that HbA1c levels decreased in both groups after the intervention was administered. Mean HbA1c in Group 1 decreased from 8.52 ± 0.56% to 8.24 ± 0.49%, while in Group 2 it decreased from 8.56 ± 0.53% to 7.84 ± 0.43%. The greater decrease in Group 2 shows that intervention with a higher number of sessions produces better long-term glycemic control improvement compared with intervention with a lower number of sessions. This finding shows that the metabolic changes occurring during the intervention period affected not only daily blood glucose levels but also chronic glucose exposure as reflected in the HbA1c value.

The decrease in HbA1c that occurred in this study is one of the improvements in glucose control occurring continuously over the intervention period. HbA1c levels are strongly influenced by long-term blood glucose exposure, so every consistent decrease in blood glucose will contribute to a decrease in HbA1c. The close relationship between fasting blood glucose and HbA1c shows that the improvement in glucose metabolism occurring in this study proceeded continuously and was not merely temporary. Consistent glucose control is known to be a main factor determining the success of HbA1c reduction in individuals with chronic hyperglycemia [28].

The magnitude of the decrease in HbA1c in Group 2 indicates that increased intervention duration provides additional benefit to long-term glycemic control. Physiological adaptation that proceeds over a longer period allows for more stable improvement in glucose metabolism, so the effect on HbA1c is greater. This response is consistent with the concept that HbA1c reflects cumulative glucose exposure over a certain period. Intervention conducted repeatedly and continuously will produce a stronger metabolic effect compared with intervention of shorter duration [32].

The standard deviation values for HbA1c in both groups also showed a decreasing tendency after the intervention. This condition indicates that the variation in glycemic control among individuals became smaller after treatment was administered. This decrease in variation shows that the benefit of the intervention was not only experienced by a small subset of subjects but was felt relatively evenly by most study participants. The homogeneity of response shown in the HbA1c parameter is also supported by the results of the variance test, which showed a relatively uniform distribution of HbA1c change between the two groups.

The findings of this study are in line with various studies reporting that interventions that improve insulin sensitivity and glucose regulation contribute to a decrease in HbA1c. A resesarch by Umpierre et al. (2011) showed that increased frequency and duration of intervention is associated with a greater decrease in HbA1c compared with programs with lower exposure. These results support the findings of this study, which show that the group with a

greater number of intervention sessions obtained a greater decrease in HbA1c compared with the group with fewer sessions.

4.7 Effect of HBOT on Wound Improvement Based on Push Score

Results showed that mean Push Score decreased in both groups after the intervention was administered. Mean Push Score in Group 1 decreased from 12.00 ± 1.93 to 10.38 ± 1.61, while in Group 2 it decreased from 11.92 ± 1.77 to 7.33 ± 1.17. The greater decrease in Group 2 shows that intervention with a higher number of sessions produces greater wound improvement compared with the group undergoing intervention with a lower number of sessions. This finding shows a relationship between intervention duration and the level of wound improvement achieved.

The wound improvement that occurred in this study is related to increased efficiency of energy metabolism, as shown by the improvement in glycemic and lipid profile parameters. Better blood glucose control will increase the availability of energy at the cellular level, so body tissue is able to perform physiological functions more optimally. This condition affects increased activity tolerance, reduced fatigue, and an increased ability to perform various daily physical activities. The relationship between improved metabolic status and increased functional capacity has been widely reported in various clinical studies [33].

The magnitude of the decrease in Push Score in Group 2 shows that a longer intervention duration provides an opportunity for more optimal physiological adaptation. Wound improvement generally requires more time compared with biochemical changes because it involves tissue remodeling processes, increased neuromuscular system efficiency, and changes in the work capacity of organs involved in physical activity. Longer intervention exposure allows this adaptation process to proceed more maximally, resulting in a greater increase in functional capacity [34].

The standard deviation values for Push Score under the post-intervention condition showed a decreasing tendency compared with the baseline condition, particularly in Group 2. This condition indicates that the variation in wound improvement among individuals became smaller after the intervention was administered. Results of the variance homogeneity test also showed that the change in Push Score had a homogeneous distribution between groups. This characteristic shows that the benefit of the intervention for functional capacity occurred relatively consistently in most study subjects.

Wound improvement has important clinical significance because it is directly related to quality of life. Good wound improvement allows an individual to carry out daily activities independently, maintain productivity, and reduce dependence on assistance from others. A decline in functional ability is often associated with increased risk of morbidity, decreased quality of life, and increased hospitalization rates in individuals with chronic disease. Increased functional capacity is therefore one of the clinical outcomes highly relevant in evaluating the success of an intervention [33].

Wound improvement occurring together with improvement in glycemic and lipid profile parameters shows that the benefit of the intervention is not limited to changes in laboratory biomarkers but also produces an impact that can be felt directly in daily life. This condition is important because the success of an intervention is measured not only by changes in biochemical parameters but also by its ability to improve individual function and quality of life in a real way [34].

The findings of this study are in line with various studies reporting that continuously conducted interventions can increase functional capacity through improvement of metabolic, musculoskeletal, and cardiovascular function. The greater increase in functional capacity in the group with a higher number of intervention sessions shows that continuity and duration of intervention implementation play an important role in producing optimal physiological adaptation. These results support the concept that improvement in body function requires a process that proceeds progressively and continuously so that the benefits obtained can reach a maximal level.

4.8 Effect of HBOT Sessions on Lipid Profile, Blood Glucose, HbA1c, and Wound Improvement

HBOT sessions are one of the important factors determining the magnitude of the resulting physiological response. Biological adaptation in metabolic and functional systems does not occur instantly but develops progressively through repeated exposure to a stimulus over a certain period. The longer an individual receives appropriate intervention exposure, the greater the opportunity for changes at the cellular, tissue, and organ system levels that contribute to improved health condition. This concept is known as a dose-response relationship, namely the relationship between the magnitude of intervention exposure and the magnitude of the resulting biological response [23].

Results showed that all observed variables changed in a favorable direction in both groups. Decreases in total cholesterol, triglycerides, LDL, blood glucose, HbA1c, and Push Score, accompanied by an increase in HDL, were found in the groups undergoing five and ten sessions of HBOT. The magnitude of change in nearly all variables tended

to be higher in Group 2, which underwent ten sessions of intervention, compared with Group 1, which underwent only five sessions. This pattern shows that an increased number of sessions provides additional benefit to the improvement of metabolic status and functional capacity.

The difference in response between the two groups can be explained through a cumulative metabolic adaptation mechanism. Improvement in glucose metabolism requires a series of biological changes involving increased insulin sensitivity, increased glucose transporter expression, optimization of mitochondrial function, and increased efficiency of energy utilization by peripheral tissue. This adaptation develops gradually over time, so longer intervention exposure will produce a greater change compared with shorter exposure [29].

The greater improvement in lipid profile in Group 2 also supports the presence of a cumulative effect from HBOT. Lipid metabolism involves complex regulation in adipose tissue, liver, skeletal muscle, and the hormonal system. A longer HBOT duration allows for increased activity of lipid metabolism enzymes, improved fatty acid oxidation, increased clearance of atherogenic lipoprotein, and optimization of the reverse cholesterol transport process. This adaptation contributes to a greater decrease in total cholesterol, triglycerides, and LDL, as well as a greater increase in HDL, in the group with a longer intervention duration [20].

The greater decrease in fasting blood glucose and HbA1c in Group 2 indicates that intervention duration plays an important role in improving glycemic control. HbA1c reflects mean blood glucose levels over approximately the past two to three months, so changes in this parameter reflect the sustainability of the metabolic effect occurring during the intervention period. The better response in the group with a higher number of sessions shows that the effect of the intervention is not only acute but is also able to produce a more stable and sustained metabolic adaptation [35].

The most notable response in this study was seen in the wound improvement variable assessed with the Push Score. The greater decrease in Push Score in Group 2 shows that wound improvement requires repeated and sustained stimulus to achieve optimal results. Increased functional capacity is related to various physiological changes, including increased neuromuscular efficiency, increased oxidative capacity of muscle, improved movement coordination, and increased ability of the cardiovascular system to meet energy demand during physical activity. These changes generally develop progressively, so the group with a higher number of sessions obtains greater benefit [34].

The magnitude of improvement found in Group 2 shows that the physiological response to intervention follows the principle of biological adaptation. The body will respond to a given stimulus through a series of compensatory processes to maintain homeostasis. If the stimulus is given repeatedly and for an adequate duration, the body's adaptive capacity will increase, producing a greater physiological change. Conversely, a stimulus given over a shorter period tends to produce a more limited response because the adaptation process has not yet developed optimally [23].

The pattern of change found in this study also shows a relationship between metabolic improvement and wound improvement. Better blood glucose control will increase the availability of energy for body tissue, while improved lipid profile will increase the efficiency of energy metabolism and lower the risk of vascular disorders [33]. The findings of this study are in line with various studies showing that increased frequency or duration of intervention is associated with increased clinical benefit. A systematic analysis conducted by Bull et al. (2020) showed that metabolic and cardiovascular benefit increases gradually with greater exposure to a regularly conducted intervention program [36]. This relationship shows that the success of a program is determined not only by the type of intervention given but also by the consistency and duration of its implementation.

5 Conclusion

Based on the results of the study on the effect of Hyperbaric Oxygen Therapy (HBOT) on lipid profile, blood glucose, HbA1c levels, and wound improvement in diabetic foot ulcer (DFU) patients, it can be concluded that HBOT has an effect on the improvement of lipid profile levels in DFU patients after therapy. In addition, HBOT also has an effect on the decrease in blood glucose levels and hemoglobin A1c (HbA1c) levels in DFU patients. Administration of HBOT also has an effect on the improvement of wound condition in DFU patients as assessed using the Pressure Ulcer Scale for Healing (PUSH).

Based on the results of the study and the conclusions obtained, HBOT can be considered as an adjuvant therapy in diabetic foot ulcer patients because it has the potential to help wound improvement and support metabolic control in diabetes mellitus patients. Future research is recommended to conduct long-term follow-up to assess the sustainability of the effect of HBOT on metabolic control and wound improvement, given that the number of therapy sessions plays a role in producing more optimal metabolic and clinical improvement. In addition, future research is recommended to use a design with a stricter control group, a larger sample size, and a longer follow-up period to

evaluate the sustainability of the effect of HBOT on metabolic parameters and wound healing. Selection of research variables can also be expanded to include inflammatory markers, oxidative stress, and vascular parameters to obtain a more comprehensive understanding of the physiological mechanism of HBOT in DFU patients. In its implementation, multidisciplinary collaboration among medical personnel, wound care nurses, and rehabilitation personnel needs to be strengthened to optimize HBOT implementation and ensure optimal therapy outcomes for patients.

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