ISSN : (print)
ISSN : (online)
Indonesian Journal of Fitness and Health (IJFaH)
Volume 1, No. 1, June 2026, pp. x-x
http://dx.doi.org/ /IJFaH.v0i0.00000

The Effect of Weight Training on Alterations in Blood Glucose Levels Among Patients with Type 2 Diabetes Mellitus

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ABSTRACT

The high prevalence of Type 2 Diabetes Mellitus (T2DM) among the productive age group demands responsive non-pharmacological first-line interventions, wherein mechanical loading holds significant potential in ameliorating insulin resistance through acute GLUT4 translocation mechanisms. This study aimed to investigate the instant effect of a single-bout weight training intervention on changes in blood glucose levels in T2DM patients. Utilizing a pre-experimental design (One-Group Pretest-Posttest Design), this study involved 20 T2DM patients aged 35 years old selected through a total sampling technique. Data collection was conducted continuously in mid-April at the Laboratory of the Faculty of Sports and Health Sciences, Universitas Negeri Makassar (FIKK UNM). Random blood glucose levels were measured immediately before and after a single weight training session using the Glukotes instrument, followed by an analysis using a Paired Sample T-Test at a 5% significance level. The results revealed a mean pre-test blood glucose level of 152.85 mg/dL, which acutely dropped to 120.10 mg/dL in the post-test (a mean reduction of 32.75 mg/dL). Hypothesis testing confirmed this finding with a value of $t(19) = 43.264$ and a probability value of $p < 0.001$. Based on these findings, it is concluded that a single-bout weight training intervention exerts a highly significant acute effect on reducing blood glucose levels in T2DM patients; thus, this physical modality is highly recommended to be integrated as a foundational pillar of daily metabolic fitness management.

Keywords: *Weight Training, Blood Glucose, Type 2 Diabetes Mellitus.*

ARTICLE INFO

Article History:
Accepted :
Approved :
Available Online June 2026

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INTRODUCTION

Type 2 Diabetes Mellitus (T2DM) is currently a global metabolic crisis centered on the failure of peripheral tissues to optimally respond to insulin action. Chronic hyperglycemia in T2DM patients can trigger a series of metabolic complications and vascular neuropathy if not clinically controlled (Djafar & Tuharea, 2021). First-line treatment demands a comprehensive approach; it does not solely rely on pharmacological therapy adherence but absolutely requires diabetes self-management, which includes disciplined lifestyle modifications to restore glycemic homeostasis (Nugroho & Purwanti, 2019). In this context, maintaining a measured physical activity routine, such as mechanical loading, has been empirically proven to significantly reduce blood glucose levels while simultaneously suppressing the risk of long-term degenerative complications (Kusumawati, 2023).

Physiologically, skeletal muscle is the largest glucose-absorbing organ, dominating up to 80% of postprandial glucose clearance in the body (Röhling et al., 2016). Decreases in muscle quality, function, and architecture in T2DM patients will directly exacerbate systemic insulin resistance (Mesinovic et al., 2019). To date, conventional clinical guidelines more frequently recommend aerobic exercise, which unfortunately often fails to optimize the therapeutic potential of mechanical stimulation on muscle fiber hypertrophy. This clinical gap can specifically be filled by weight training, an essential physical modality that exerts direct adaptive pressure on glucose-absorbing tissues to improve the metabolic profile (Pesta et al., 2017).

Weight training has been shown to provide an essential alternative metabolic route for T2DM patients by directly intervening in the skeletal muscle structure (Sylow et al., 2017). Intense mechanical contractions during weight training massively increase the hydrolysis rate of energy molecules, culminating in the activation of the Adenosine Monophosphate-activated Protein Kinase (AMPK) enzyme (Kjøbsted et al., 2018). The activation of this AMPK pathway triggers the movement of Glucose Transporter 4 (GLUT4) vesicles to the plasma membrane of skeletal muscle cells without requiring the presence of the insulin hormone (insulin-independent pathway) (Klip et al., 2019). This biomolecular mechanism enables the muscles to absorb large amounts of free glucose from the bloodstream instantly after receiving mechanical pressure.

Although the theoretical foundation regarding biomolecular activation through mechanical loading shows promising prospects, the optimization of this physical modality continually demands applicable clinical validation and integration into standard management guidelines (Colberg et al., 2016). This urgency becomes increasingly essential to implement in T2DM patients within the productive age range, considering that the level of neuromuscular plasticity and physiological adaptation capacity during this age phase remains highly responsive to external mechanical stressors. Based on this rationalization, this study is systematically designed to investigate and empirically prove the efficacy of weight training interventions on the dynamics of blood glucose level profiles in T2DM patients (Jansson et al., 2022). Referring to the research gap and clinical significance that have been described, the problem formulation and the main hypothesis tested in this study are: is there a significant effect of weight training interventions on the reduction of blood glucose levels in Type 2 Diabetes Mellitus patients?

METHODS

Referring to Sugiyono (2019), this research is a quantitative study utilizing a Pre-Experimental Design through a One-Group Pretest-Posttest Design approach. This design is applied to investigate the acute effect of a single-session physical intervention. Through this design, evaluation is conducted by comparing the patient's blood glucose levels immediately before the treatment (pre-test) and immediately after the treatment is completed (post-test) on the same day and time sequence, without involving an external control group.

Time and Place

The entire data collection process in this study was conducted continuously in mid-April. The physical intervention and the measurement of the subjects' blood glucose levels took place at the Laboratory of the Faculty of Sports and Health Sciences, Universitas Negeri Makassar (FIKK UNM). The selection of this laboratory location was determined to ensure that all procedures—from the initial blood sampling (pre-test) and the execution of the acute weight training session with precise techniques, to the final evaluation (post-test)—could occur in a controlled, standardized, and adequately supervised environment to minimize potential confounding variables from the external surroundings.

Population and Sample

The target population in this study consisted of outpatients with a medical diagnosis of Type 2 Diabetes Mellitus (T2DM), totaling 20 patients. Sampling was conducted using a Total Sampling technique, wherein the entire population of 20 patients was included as research subjects. The demographic characteristics indicated that all subjects were in the productive age range, specifically 35 years old.

To maintain internal validity and ensure subject safety, inclusion criteria were applied, which included:Diagnosed with T2DM. Stable hemodynamics and vital signs on the day of testing. No absolute contraindications to exercise (such as acute cardiovascular issues or severe retinopathy).

Instruments and Procedures

The primary instrument used to measure the dependent variable was a calibrated Point-of-Care Testing (POCT) device, the Glukotes brand, utilized to measure random blood glucose levels (mg/dL). The data collection procedure was carried out in a continuous series of sessions for each subject, adhering to the following protocol stages:

1. Initial Measurement (Pre-Test): Subjects were rested briefly, after which the first capillary blood sample was taken using the Glukotes device to establish a baseline blood glucose value prior to any mechanical activity.
2. Weight Training Intervention (Acute Bout Exercise): Immediately following the initial measurement, subjects were instructed to perform a single bout of moderate-intensity weight training. The load modification utilized body weight and light external weights. Movements focused on the large extremity muscles (such as squats or biceps curls) with a volume of 3 sets and 10-12 repetitions per movement, interspersed with a 1-minute rest period between sets to anaerobically deplete glycogen reserves.
3. Final Measurement (Post-Test): Immediately after the entire weight training session was completed for the day, a second capillary blood sample was taken to measure the instantaneous fluctuation in blood glucose reduction following mechanical loading.

All quantitative data collected from the pre-test and post-test measurements were subsequently processed and analyzed computationally using SPSS statistical software. The data analysis stages commenced with descriptive statistical testing to present the data distribution profile, which included determining the mean and standard deviation. Once a general overview of the data was obtained, prerequisite assumption testing was conducted through the Shapiro-Wilk normality test to verify whether the data distribution met the feasibility requirements for parametric analysis. As the final stage, hypothesis testing was executed using a paired-sample comparative analysis, specifically the Paired Sample T-Test, set at a 5% significance level ($\alpha = .05$). This was done to precisely determine the presence or absence of a clinically meaningful effect from the single-bout weight training session on the reduction of the subjects' blood glucose levels.

RESULTS AND DISCUSSION

This section systematically outlines the results of the empirical field data collection, followed by a comprehensive review of these findings. The evaluation is focused on the glycemic profile dynamics of Type 2 Diabetes Mellitus (T2DM) patients immediately before and right after receiving a single-bout weight training intervention. The presentation of the results begins with a description of descriptive statistics to observe the data's central tendency, followed by the prerequisite normality test, and concludes with parametric comparative hypothesis testing.

Tabel 1 Uji Deskriptif

Variables	N	Minimum	Maximum	Mean	Std. Dev
Pre Test	20	148	159	152.85	3.717
Post Test	20	111	129	120.10	5.495

Based on the Descriptive Test table, the initial measurement results indicated that the subjects' blood glucose levels ($N = 20$) prior to the intervention ranged from 148 mg/dL to 159 mg/dL, with a mean of 152.85 mg/dL and a standard deviation (*SD*) of 3.717. After the subjects completed the acute weight training intervention session, a substantial reduction occurred in the overall glycemic profile of the subjects. Post-intervention blood glucose levels decreased to a range of 111 mg/dL to 129 mg/dL, with the mean dropping to 120.10 mg/dL and a standard deviation (*SD*) of 5.495. The presence of this mean reduction difference of 32.75 mg/dL provides an initial indication that mechanical stimulation through weight training exerts a direct reducing effect on blood glucose.

Tabel 2 Uji Normalitas

Variables	Statistic	*df*	*Sig.*
Pre Test	.923	20	.111
Post Test	.966	20	.659

The Normality Test table confirms that the probability value (*Sig.*) for the data distribution in the pre-test group is .111, while for the post-test group it is .659. Referring to the decision-making criteria of the Shapiro-Wilk test, because the Sig. values in both groups are greater than the predetermined significance level (*Sig.* > .05), it can be concluded that the blood glucose measurement data for both conditions are normally distributed. This result indicates that the data feasibility requirement as a foundational assumption has been satisfactorily met, thereby allowing the testing to proceed to the comparative analysis stage using parametric statistics.

Tabel 3 Uji Paired Sampel T-Test

Variables	***N***	***Mean***	***Std. Dev***	***t-value***	***df***	***p-value***
Pre Test	20	152.85	3.717	43.264	19	.000
Post Test	20	120.10	5.495			

Based on the analytical computation of the paired mean difference test in the Paired Sample T-Test table, a highly statistically significant difference was found between blood glucose levels before and after the intervention, obtaining a value of $t(19) = 43.264$; $p < 0.001$. The *t*-statistic value of 43.264 at 19 degrees of freedom (*df*) indicates a very strong effect size, while the two-tailed probability value (*p*-value)which falls well below the 5% alpha significance threshold ($p < .05$)—confirms that the observed reduction is absolutely not coincidental. Given this level of significance, supported by a substantial decrease in the post-test mean value, the null hypothesis (H_0) is conclusively rejected, and the alternative hypothesis (H_1) is accepted. This statistical decision provides convincing empirical evidence that a single-bout weight training intervention exerts a highly acute and significant reducing effect on blood glucose levels, thereby confirming the efficacy of mechanical loading as an adaptive physical modality for regulating hyperglycemia in patients with Type 2 Diabetes Mellitus.

Discussion

The statistical decision from the paired mean difference test provides absolute empirical confirmation that a single-bout weight training intervention triggers a highly significant decrease in blood glucose levels ($p < 0.001$), with a substantial reduction difference of 32.75 mg/dL. This sharp decrease in a short period represents an acute adaptive response of skeletal muscle tissue to external mechanical stressors. Physiologically, massive and repeated muscle contractions during weight training demand the aggressive breakdown of Adenosine Triphosphate (ATP) to meet kinetic energy needs. This instantaneous depletion of ATP triggers a spike in intracellular AMP molecule concentration, which acts as an energy sensor as well as the primary catalyst for activating the Adenosine Monophosphate-activated Protein Kinase (AMPK) enzyme complex (Garcia & Shaw, 2017; Kjøbsted et al., 2018).

The activation of this AMPK pathway is the most essential metabolic route for T2DM patients. Biochemical signals from AMPK directly stimulate Glucose Transporter 4 (GLUT4) vesicles to translocate from within the cytoplasm to the skeletal muscle cell plasma membrane; a glucose uptake process that is completely independent of insulin hormone intervention (insulin-independent pathway) (Sampath Kumar et al., 2019; Sylow et al., 2017). Considering that the central pathology of T2DM is resistance in the peripheral insulin receptor pathway, this mechanical GLUT4 translocation mechanism allows skeletal muscle to bypass this bottleneck and massively absorb free glucose from the vascular circulation to resynthesize depleted glycogen reserves (Bird & Hawley, 2017; Evans et al., 2019). This phenomenon of acute post-exercise glucose clearance aligns with various global findings confirming that weight training can instantaneously dismantle metabolic resistance in hyperglycemia patients (Ashton et al., 2020; Lee et al., 2017; Liu et al., 2019).

Beyond the biomolecular overview, achieving a glucose reduction of 32.75 mg/dL in a single training session carries highly vital clinical implications for the daily management of T2DM patients. The muscle's ability to instantly dampen hyperglycemia plays a crucial role in mitigating acute glucose excursions or postprandial glycemic spikes, which medically are the main triggers of oxidative stress and chronic vascular endothelial damage (Kirwan et al., 2017). In the perspective of modern management, this finding reinforces the paradigm that weight training is no longer merely seen as a means of anatomical hypertrophy, but rather acts as a tangible therapeutic agent (exercise as medicine) that complements the pharmacokinetic route of conventional glucose-lowering drugs. Therefore, formulating precise weight training prescriptions that include individualized adjustments to volume, repetitions, and intensity is absolutely necessary so that this mechanical intervention can be safely and effectively adapted as a supporting pillar for the patient's daily fitness activities (Kanaley et al., 2022).

Although in inferential statistics this finding shows an absolute level of significance, this study continually recognizes the presence of crucial methodological limitations. This analysis only involved a sample on a very limited scale, namely 20 participants, thereby reducing the generalization capacity (external validity) of the conclusions drawn. The dynamics of human glucose metabolism are highly complex and prone to being influenced by genetic variability, duration of diabetes diagnosis, baseline muscle mass ratio, and pharmacodynamic interactions of daily hypoglycemic drug variants that cannot be absolutely controlled in a small-scale sample. Therefore, validating these findings absolutely requires further confirmatory research. Large-scale cohort explorations or the application of cross-institutional Randomized Controlled Trial designs with an adequate number of samples are highly recommended. Testing across a much broader demographic spectrum is essential to verify the consistency of weight training efficacy, minimize the margin of error bias, and formulate physical exercise prescription standards that are more definitive and safe for T2DM patients.

CONCLUSION

Based on the series of analyses and empirical reviews that have been conducted, it can be concluded that a single-bout weight training intervention is proven to exert a highly significant acute effect on reducing blood glucose levels in patients with type 2 diabetes mellitus. The occurrence of a substantial reduction in glucose levels immediately following the intervention clearly confirms the efficacy of mechanical stressors in stimulating instantaneous glucose uptake into skeletal muscle tissue through a translocation mechanism that is independent of insulin. These findings provide strategic clinical implications, wherein mechanical loading is highly recommended to be integrated as an essential pillar in metabolic fitness management and non-pharmacological therapy to independently regulate daily hyperglycemic conditions. As a form of refinement, it is recommended that future researchers conduct massive-scale confirmatory studies adopting a randomized controlled trial design to validate the consistency of this intervention's efficacy and to minimize methodological biases that may arise due to sample scale limitations.

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