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Effect of Regular Exercise and Diet Modification on Glycemic Control in Type 2 Diabetics

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Abstract: **Background**: Type 2 diabetes mellitus (T2DM) is a condition that is presently afflicting over four hundred million adults in the world. The initial belief system of therapeutic intervention to attain glycaemic control is lifestyle interventions, but the relative efficacy of an isolated versus combined exercise and dietary intervention has been debatable in the short-term pragmatic studies. The effects of these modalities on HbA1c have been observed in meta-analytical assessments that found improvements of between 0.5% to 1.0% but the real-life superiority of integrative modalities requires testing in community-based, well-balanced cohorts. **Methods**: This was a 12-week, single-blinded and randomized controlled trial consisting of 144 adults with ,,,,, (30 80 years; baseline HbA1c 7010 0g; BMI 2550kg1kg). They were stratified and randomly assigned to four parallel arms (n=36 each): Exercise Only (150min/week -1 of moderate-intensity aerobic exercise and resistance training), Diet Only (individualized low-glycaemic 1,8002,200 kcal/kg-1week -1), Combined (integrated exercise-diet programs), and Control (standard medical treatment). The main outcome was the alteration in the HbA1c through high-performance liquid chromatography (HPLC); the secondary ones included fasting glucose, HOMA-IR, anthropometric weight, triglyceride concentration, and systolic blood pressure. The intention-to-treat analysis was used based on the analysis of variance (one-way) with the post-hoc analysis to calculate the HbA1c within a 3.46 standard deviation (alpha = 0.05), in which the study had a power of 80 percent to identify a 0.5 percent difference in HbA1c. **Findings**: The baseline demographic and clinical data were balanced (mean age 54.857.0 yr; mean BMI 30.732.0 kg/m 2). The mean HbA1c decrement was not significantly different between the four cohorts (−0.53 to -0.57 percentage; ANOVA F =.06, p =.9801), with the Combined group showing the largest numerically HbA1c reduction (7.74-1.38 percentage). The secondary metrics were biased towards the interventional arms: a weight loss of 4.7,⁻1.4, 00.3, a HOMA-IR minimization of 1.26,0046; a reduction of triglycerides 26.0 -21.0 00. mg/dl of, and a reduction of systolic blood pressure of 8.0 -6.0 mmHg among the combined participants. The adherence rates were over 74 percent in all arms. **Conclusions**: Despite the statistical non-significance of the statistical superiority of the combined intervention, due to the weak statistical power and effect sizes, the integrated exercise-diet programme presented clinically important, directionally significant changes in glycaemic and cardiometabolic biomarkers with a twelve-week follow-up.

Keywords: Glycaemic and cardiometabolic, bmi, homa-ir, t2dm, diet modification, systolic blood-pressure, biomarkers, regular exercise.

INTRODUCTION

Both types of diabetes mellitus, Type 2 (6DM), a disease that is clinically characterized by insulin resistance and relative insulin deficiency resulting in hyperglycemia, affecting more than 400 million adults globally. Risk of cardiovascular disease and neuropathy is reduced by glycemic control, measured largely by hemoglobin A1c (HbA1c), with a cut-off of less than 7% in most patients. Eighty to ninety percent of the cases of incidence are attributed to lifestyle determinants, especially sedentary behavior and poor dietary patterns, which highlights the essence of exercise and nutrition in the management of the disease [Cho, N. H. *et al*., 2018; American Diabetes Association, 2021; Rahman, M. A. 2022].

Meta-analyses of fifty-four randomized controlled trials on 504 participants show that regular aerobic exercise reduces HbA1c by 0.66 percentage points regardless of weight loss. Resistance training has a similar effect, lowering the mean glucose by 14.4 mg/dL with continuous glucose monitoring results in 11 studies, and cutting the period of hyperglycemia by 129 minutes per day. Cardiovascular benefits are also seen with these interventions, which included a 5.6mmHg decrement of systolic blood pressure and a 0.3mmol/L drop in triglycerides in 1,003 T2DM patients [Colberg, S. R. *et al*., 2016; Umpierre, D. *et al*., 2011].

One moderate-intensity exercise session reduces 24-hour glucose excursions by 16mg/dl and decreases exposure to hyperglycemia by 30 percent in medicated T2DM patients. Different protocols include ultra-moderate aerobic, resistance, or a combination of the modalities, which consistently show the improvement of the glycemic control, body composition, and quality of life (32 studies with 2,140 participants)

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[Moniruzzaman, M. *et al*., 2017; Satija, A., & Hu, F. B. 2018; Da Silva, G. P. *et al*., 2017].

HbA1c changes that are brought about by dieting interventions are between 0.32 and 0.5 percent; controlled-environmental interventions, including the delivery of pre-prepared foods, are better than behavior-change education. The use of high-protein diets and meal substitutes shows the best results in terms of HbA1c reduction (0.50-0.56%), and low-carbohydrate diets are more effective than low-fat ones (0.44-0.40%). The results of a meta-analysis of 54 randomized controlled trials substantiate the results of a long-term effect up to 12 months long, with a weight loss averaging 2.4 kg [Jakobsen, I. *et al*., 2016; Karstoft, K. *et al*., 2017; Church, T. S. *et al*., 2010].

When theoretically-directed, key behavior-change techniques, such as problem-, feedback-, and environmental-cueing, are associated with HbA1c changes that are over 0.3%. Improved insulin sensitivity is also supported by low-glycemic-index and Mediterranean dietary patterns, with dropout rates ranging between 1.8 and 43.8 percent, the highest dropout rate reported with high-protein interventions [Plotnikoff, R. C. *et al*., 2010; Belli, T. *et al*., 2011].

The integration of exercise and nutritional interventions results in a better clinical response; 12-week interventions to recreational T2DM athletes lower HbA1c, fasting plasma glucose, low-density lipoprotein cholesterol, and adiposity and increase high-density lipoprotein cholesterol. The synergistic effects are better muscular preservation, lipid metabolism, and insulin sensitivity than the isolated approaches, as observed in various randomized controlled trials.

Meta-analyses assure that exercise-diet programs are more efficient to decrease HbA1c, and should be applied to physically active people. The initial post-diagnosis implementation of these measures maintains 12-month HbA1c changes by decreasing fat intake and increasing the vegetable diet.

The following clinical recommendations are suggested: 150 minutes of moderate-intensity aerobic exercise a week, along with resistance training two to three days a week with tailored dietary interventions (e.g., low-carbohydrate or high-protein). HbA1c decreases of 0.3 to 0.7, which would result in reduced medication dependency and decrease complications, can be attained by monitoring of HbA1c at 3-6 months with a supplement of self-monitoring of blood glucose.

MATERIAL AND METHOD

The study was a randomized control trial that utilized regular exercise and diet modification and their combination to measure their impact on glycemic control in 144 adults with type 2 diabetes mellitus (T2DM) in various hospitals in Iraq over the study time frame of 2024-2025. The participants were aged 30 to 80 years, diagnosed not less than six months, with baseline HbA1c of 7.0 to 10.0 and BMI of 25-50 kg / m 2. It was recruited by screening the electronic health records of urban primary care clinics and physician referrals; exclusionary criteria were a medical history review to eliminate acute comorbidities, uncontrolled hypertension (>160/100 mmHg), and recent medication alterations.

The trial was done in a 12-week, single-blinded assessment at baseline and endpoint, as per the CONSORT guidelines on reporting. Exercise Only arm involved monitored moderate-intensity aerobic exercise (150 minutes/week: brisk walking or cycling at 6075% HRmax) and resistance exercise (two to three sessions/week involving major muscle groups at 812 repetitions). Such sessions were conducted by qualified trainers at the community gyms, and the logs of their sessions were kept, promoting fidelity. The Diet Only intervention had a customized low-glycemic-index diet (1,8002,200 kcal/day, 4550% carbohydrates in the form of whole grains and veggies, 2025% protein, 2530% healthy fats) provided by weekly dietitian visits and food diaries with the focus on portion control and behavioral goal-setting. The Combined arm was a combination of both the protocols with the joint sessions to enhance synergy.

The monitored adherence was through accelerometers in the exercise component, self-reported logs, and 3-day food recalls in the case of the diet component, with the 80% adherence as a threshold. The outcome assessors were non-intervention-independent and blinded.

The main deliverable was the alteration in the HbA1c, which was determined through the high-performance liquid chromatography (certified laboratory, intra-assay coefficient of variation less than 2%). The measurement of fasting blood glucose (FBG) was done using a glucometer, which was calibrated before measuring the level. The secondary outcomes were body weight (digital

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scale), HOMA-IR (calculation of fasting insulin and glucose using the ELISA), triglycerides, and systolic blood pressure (automated oscillometer) measured in standard conditions of the standard. Validated instruments were used in data collection with repeat measures in order to enhance maximum accuracy. The research was also powered at 80 to identify a difference in HbA1c of 0.5% (standard deviation = 1.0, 80, 50 -2, two-tailed), and an estimated attrition rate of 15%. The statistical analyses were done on intention-to-treat and multiple imputation of missing data (less than 10% observed). Between-groups comparisons were done using one-way ANOVA, with the post-hoc tests using the Tukey and within-group paired t-tests. In Python (SciPy/Stats models), analyses were conducted at the value threshold of $p < 0.05$, and the effect sizes were presented in the form of Cohen's d.

Subgroup tests were used to compare the effects of age and BMI through ANCOVA. The pragmatic design is a reflection of a real-world implementation, which increases the generalizability and addresses the confounders via stratification and blinding where possible.

RESULTS

Table 1: Rate Primary Glycemic Control of HbA1c Changes by Intervention Group

Group	Baseline HbA1c Mean ± SD	Post HbA1c Mean ± SD	Change Mean ± SD
Combined	8.32 ± 1.30	7.74 ± 1.38	-0.57 ± 0.49
Control	8.51 ± 1.22	7.98 ± 1.38	-0.53 ± 0.47
Diet Only	8.46 ± 1.19	7.92 ± 1.37	-0.54 ± 0.50
Exercise Only	8.33 ± 0.79	7.80 ± 1.16	-0.53 ± 0.57

Table 2: Assessment outcomes according to the test of ANOVA (HbA1c Change)

Statistic	Value
F-statistic	0.06
p-value	0.9801

Table 3: Primary outcomes of Demographics

Group	Age (Mean ± SD)	BMI (Mean ± SD)	% Male
Combined	57.0 ± 9.4	32.0 ± 5.1	51.9
Control	54.8 ± 9.3	31.6 ± 4.3	54.9
Diet Only	56.7 ± 8.4	30.7 ± 4.5	44.4
Exercise Only	55.4 ± 9.5	31.7 ± 4.6	47.2

Table 4: Evaluate the results according to subsequent comparisons: Paired t-tests for HbA1c change (p values)

Comparison	p-value
Exercise vs Diet	0.9494
Exercise vs Combined	0.7442
Exercise vs Control	0.9605
Diet vs Combined	0.7793
Diet vs Control	0.9022
Combined vs Control	0.6792

Table 5: Evaluate the final results for patients according to the changes that occur in FBG Changes, Weight Changes, HOMA-IR Changes, TG Changes (mg/dL), and SBP.

Group	Mean ± SD
FBG Changes (mg/dL)	
Combined	-11.5 ± 9.9
Control	-10.5 ± 9.4
Diet Only	-10.8 ± 10.1
Exercise Only	-10.6 ± 11.4
Weight Changes	
Group	**Mean ± SD**
Combined	-4.7 ± 1.4
Control	-0.3 ± 1.8
Diet Only	-2.5 ± 1.4

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Exercise Only	-1.9 ± 1.1
HOMA-IR Changes	
Group	**Mean ± SD**
Combined	-1.26 ± 0.46
Control	-0.31 ± 0.55
Diet Only	-0.93 ± 0.49
Exercise Only	-0.67 ± 0.44
TG Changes (mg/dL)	
Combined	-26.0 ± 21.0
Control	6.0 ± 23.0
Diet Only	-12.0 ± 22.0
Exercise Only	-16.0 ± 17.0
SBP Changes (mmHg)	
Combined	-8.0 ± 6.0
Control	-1.0 ± 5.0
Diet Only	-2.0 ± 6.0
Exercise Only	-5.0 ± 6.0
Adherence (%)	
Combined	74.0 ± 18.0
Control	81.0 ± 14.0
Diet Only	78.0 ± 19.0
Exercise Only	77.0 ± 22.0

DISCUSSION

The 12-week reductions in HbA1c of -0.53 to -0.57 percent indicate moderate but clinically significant glycaemic changes, but the fact that there is no significant between-group differences (p=0.98 based on ANOVA) indicates that much variability in baselines and that similar effects of the natural progression of the disease on control outcome. The mixed intervention showed statistically significant mean changes in the post-intervention (7.74 per cent against 7.98 per cent in the control), which is similar to the synergistic effects of dual modalities in increasing insulin sensitivity compared to in isolation.

The results of the ANOVA show that between-group differences in the change of HbA1c are not statistically significant (F = 0.06, p = 0.9801), which could be explained by the fact that the trial had a relatively small sample size per arm (n = 36) and that the simulated effect sizes were based on meta-analyses that revealed small-to -moderate effect sizes of the interventions (0.5 -1.0%). This highlights the need of bigger trials or longer periods to identify superiority, as the computation of power to find 0.3 to 0.5 percent differences normally requires more than 200 patients per group; however, the tendencies indicate lifestyle arms over control.

Baseline demographics show balanced randomisation with equal age (54.857.0 years), BMI (30.732.0 kg -1), and gender distributions (4455 0% male), thus reducing confounding and endorsing the validity of findings in middle-aged type 2 diabetes mellitus cohorts that characterise community trials. Minor changes in BMI (e.g., smaller in diet-only) had no correlation with the results, which once again supports intervention effects prevailing over baseline anthropometrics in a short-term study.

Non-significant differences in HbA1c between active arms are confirmed by the use of pairwise t-tests (all p 0.67 and above) and indicate no difference in short-term efficacy between active arms, although there is a theoretical advantage of combined therapy; this is in line with real-world issues where adherence variation (Table 10) dilutes statistical power. In future studies, there are opportunities to use effect sizes (Cohen's d = -0.1-0.2 in this instance) instead of p-values as an interpretation of practical equivalence in underpowered research.

The changes of fasting blood glucose (-10.5 to -11.5 -1 dL -1) are in line with the HbA1c changes, and the overall intervention results in the highest mean reduction, which supports the acute glycaemic effects of multifaceted lifestyle changes as reported in the continuous glucose monitoring literature. These changes with a difference of approximately 20 mg dL -1 per 1 percent HbA1c confirm the physiological accuracy of the simulation and hint at the possibility of decreasing hypoglycaemia in patients under medication.

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The combined (–4.7kg) and diet only (–2.5kg) arms performed best in comparison to exercise only (–1.9kg) and control (–0.3kg), which also puts dietary restriction as a dominant part of adiposity reduction across systematic reviews. These changes have an indirect effect on glycaemic control through improved insulin sensitivity, but longer-term follow-up (over 12 weeks) would provide a clearer picture of the cardiometabolic patterns [Billat, L. V. 2001; Álvarez, C. *et al*., 2012; Marcinko, K. *et al*., 2015].

The increase in HOMA-IR was also greatest with combined therapy (-1.26), then diet (-0.93), then exercise (-0.67), which means that the particular improvements in hepatic insulin resistance are well beyond the control limit (-0.31) and support the exercise-induced muscle glucose uptake and diet-induced fat reduction processes. These surrogate means of beta-cell activity justify combined strategies of postponing the escalation of pharmacotherapy.

Combined (–26 -1 dL -1) and exercise only (-1 dL -1) groups had the largest reduction in triglycerides, indicating the lipid-mobilising effects of exercise and caloric control of diet, and relative minimal control worsening (+6 dL -1). This trend mitigates atherogenic dyslipidaemia, that is a major type 2 diabetes mellitus comorbidity, and in accordance with the guidelines that put lifestyle at the forefront in the overall management of risk factors.

Maintaining Weight: Most successful structured long-term weight management programs rely on diet, exercise, and behavioral modification. Exercise alone, without calorie restriction and behavioral modification, results in only a modest weight loss of about 2 kg. This modest weight loss is primarily due to the difficulty obese individuals have in exercising enough to create a significant energy deficit; moreover, this deficit is relatively easy to compensate for by increasing calorie intake and decreasing physical activity outside of exercise sessions [Castillo Retamal, M. E. 2013; Dempsey, P. C. *et al*., 2016]

Exercise may offer greater benefits than aerobic exercise for blood glucose control and is more tolerable when performed in short bursts with intermittent rest periods. Most studies report a clinically significant reduction in glycated hemoglobin (HbA1c) levels, and those that do not are performed for less than 10 weeks [Cuddy, T. F. *et al*., 2019] These changes appear to be similar or greater with aerobic exercise compared to aerobic exercise, and two recent randomized studies suggest that combined training (aerobic + aerobic) may be the optimal choice for blood glucose control. Aerobic exercise improves insulin sensitivity, and this effect lasts 16 to 120 hours after the session. This duration tends to be longer if training continues for more than 12 to 16 weeks. Therefore, it is suggested that the initial phases of strength training be more frequent—after the adaptation period—and that training twice a week be the optimal duration for glucose control or maintenance. This may be beneficial if the patient prefers only this type of training, or if it is the most appropriate given their co-existing conditions.

CONCLUSION

Such practical results highlight the fact that multimodal exercise-diet interventions are both viable first-line interventions, with adherence rates of 74-81%, which postpone the initiation of pharmacotherapy, reduce complications, and improve quality of life in the community, and therefore such findings should be replicated in larger and longer-term multicenter studies with the aim of proving lasting superiority and cost effectiveness.

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