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"The Impact of Various Exercise Durations on Postprandial Glucose Control in Adults with Prediabetes"

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Abstract

The global rise in the incidence of prediabetes is a major public health concern; it is primarily influenced by lifestyle factors such as diet and physical inactivity. Exercise plays a critical role in its managment by enhancing insulin sensitivity and controlling blood glucose levels. This study aims to assess the impact of an optimized exercise in term of intensity and postprandial timing (data not published) of different durations on glycemic markers in prediabetic individuals. This crossover study took place at Khyber Medical University involving 25 prediabetic adults diagnosed on American Diabetes Association criteria. Participants underwent four exercise sessions (already optimized in terms of intensity and post prandial timings) of different durations (15, 30, 45, and 60 minutes) after a standard breakfast of 250-calories. Glycemic markers, including glucose, insulin, and C-peptide levels were measured at multiple points: fasting, pre-exercise, 30 and 60 minutes' post-exercise. The data were analyzed using repeated measures ANOVA and paired sample t-test at a significant level of $p < 0.001$. Our results indicated a significant reduction in blood glucose levels post-exercise with longer durations showing more pronounced effects. Specifically, the 45 minutes' exercise session resulted in the most substantial decrease 1 hour post-exercise bringing the parameters close to baseline improving the insulin sensitivity. The study demonstrated that increasing the duration of postprandial exercise significantly enhances glycemic control in prediabetic individuals, with longer session of 45 minutes being more effective.

Key words: Aerobic exercise, Duration, Glucose regulation, Prediabetes

1. Introduction

Diabetes is a major global health issue in the 21st century, impacting 537 million adults as of 2021. This figure is expected to rise to 643 million by 2030 and 783 million by 2045 [1]. According to the International Diabetes Federation (IDF), it is anticipated that diabetes to cause 6.7 million deaths and medical expenses of over $966 billion by 2021, creating a significant socio-economic challenge. Typically, individuals go through a pre-diabetic stage before the onset of diabetes. The hallmark symptoms of this stage are impaired fasting glucose (IFG) and impaired glucose tolerance (IGT) [1, 2].

Physically inactive individuals with prediabetes are at a greater risk of developing diabetes compared to others [3]. If pre-diabetics do not receive early intervention, their likelihood of developing diabetes escalates to 74% [4]. Prediabetes not only leads to diabetes but may have other consequences, including nephropathy, retinopathy, neuropathy, myocardial infarction, stroke, and even mortality to name a few. Furthermore prediabetes significantly raises the risk of development of cardiovascular diseases resulting in more severe health outcomes [5]. Hence, it is crucial to identify and manage prediabetes in early stages.

Hostalek et al.,[6] highlight that pharmacological methods like metformin are options for managing and preventing diabetes. However, Davidson et al.,[7] have found that metformin may not be suitable for individuals with prediabetes. While various treatments for prediabetes exist, their effectiveness remains subject to debate. Research suggests that lifestyle modifications and maintaining a healthy diet are effective in reducing diabetes risk [8]. Additionally, Kirwan et al.,[9] have demonstrated that engaging in suitable physical activity, particularly aerobic exercise, can decrease the likelihood of progression of prediabetes to diabetes due to its ability to lower insulin resistance. Kargarfard et al.,[10] have shown that aerobic exercise positively affects individuals with prediabetes. The American Diabetes Association (ADA) advises that patients with type 2 diabetes or prediabetes to engage in at least 150 minutes of moderate-intensity exercise weekly, spreading over three sessions [11]. Conversely, Hrubeniuk et al.,[12] suggest that while physical activity can enhance glucose tolerance in those with prediabetes, the improvement is uncertain, possibly due to the brief nature of the interventions. This underscores the necessity for more research to determine the most effective exercise durations for prediabetic individuals.

However, no research has investigated the associated connection between physical activity, glucose, insulin and C-peptide levels with regard to duration of exercise in prediabetes. The objective of the current study is to investigate the effects of varied durations of aerobic exercise on the mentioned parameters in prediabetes. These results will help healthcare providers to create tailored programs for individuals with prediabetes to assist in their management and recovery.

2. Results

Anthropometric details and body composition of the participants

The results of the study indicate that the average age of the participants was approximately 34.88 years, with a significant age difference between both the genders; females averaged 32.25 years and males 36.11 years (p=0.025) indicating that females were slightly younger than males. The overall average height was 170 cm, with females with males being taller than females (p=0.002). Waist circumference also presented a statistically significant gender difference, with females at 98.75 cm and males at 103.76 cm (p=0.035). In contrast, differences in hip circumference and weight between genders did not reach statistical significance, (p=0.467) and weight (p=0.545). The Body Mass Index (BMI) averaged 30.34 kg/m^2 across all participants, with females on the higher BMI average of 31.48 kg/m^2 compared to males at

29.81 kg/m^2, though this difference was not statistically significant (p=0.372) as described in Table 1.

Notably, as presented in Table 1. there were significant gender differences in body composition measured at baseline: females had a higher fat mass (30.57 kg) and percentage (34.73%), compared to males (21.99 kg and 23.72%, respectively), with p-values of (0.004 and <0.001). Lean mass measurements also displayed significant differences; females had a lower lean mass compared to males, (p <0.001). The Lean Mass Index followed a similar pattern, being significantly higher in males than in females (p <0.001). The Basal Metabolic Rate (BMR) also differed significantly between genders, with males exhibiting a higher BMR compared to females (p<0.001). These results highlight significant differences in body composition and demographic between genders among the study participants at baseline.

Participant Characteristics	Total	Female (n=8)	Male (n=17)	p-value
Age	34.88±4.11	32.25±4.23	36.11±3.53	0.025
Height (cm)	170±6.70	164.25±2.91	172.70±6.28	0.002
Weight (kg)	87.85±14.56	85.21±13.77	89.1±13.77	0.545
BMI (kg/m^2)	30.34±4.27	31.48±4.30	29.81±4.28	0.372
Waist Circumference (cm)	102.16±12.22	98.75±17.10	103.76±10.73	0.035
Hip Circumference (cm)	105.13±12.43	102.42±17.10	106.41±9.93	0.467
Waist to hip ratio (WHR)	0.97±0.04	0.96±0.05	0.97±0.02	0.659
Fat mass (kg)	24.74±7.43	30.57±3.78	21.99±7.18	0.004
Fat mass (%)	27.25±6.92	34.73±6.50	23.72±3.51	<0.001
Lean mass (kg)	60.66±12.21	47.62±3.73	66.79±9.63	<0.001
Lean mass index	20.92±3.02	17.92±1.00	22.33±2.58	<0.001
BMR (kcal)	1815.32±227.82	1592.87±94.23	1920±193.88	<0.001
HbA1c	5.86±0.14	5.88±0.16	5.84±0.13	0.516

Table 1. *Demographic and Anthropometric Profile of participants in the study*

All the values in the table are presented as means ± standard deviation (SD) values for the demographic and anthropometric parameters of the study participant's, categorized overall and by gender, age (years), height (centimeters), waist and hip circumference (centimeters), weight (kilogram), Body Mass Index (BMI) and Basal Metabolic Rate (BMR) are presented.

Effects of Different Durations of Exercise on Glucose Regulation

Markers	Visits	Fasting Mean±S.D	0 min Mean±S.D	30 min Mean±S.D	60 min Mean±S.D	P-Values
Glucose (mg/dL)	15 minutes exercise	105.72±4.24	170.76±13.26	158.6±12.68	151.92±13.48	<0.001
	30 minutes exercise	103.76±3.43	169.32±13.53	147.84±9.07	140.52±8.21	<0.001
	45 minutes exercise	100.6±3.03	168.6±13.82	164.92±17.11	116.51±7.11	0.048

	60 minutes exercise	99.24±2.70	166.88±13.63	138.96±10.02	128.48±7.69	<0.001
Insulin (μU/mL)	15 minutes exercise	21.64±16.31	55.42±35.04	39.13±28.76	29.42±21.60	0.651
	30 minutes exercise	19.35±12.29	66.77±41.21	38.01±27.60	37.68±36.78	0.231
	45 minutes exercise	16.83±15.88	46.92±25.17	26.38±22.32	11.19±8.53	0.002
	60 minutes exercise	11.11±10.18	40.22±24.57	22.37±21.33	20.23±27.55	0.610
C-peptide (ng/mL)	15 minutes exercise	2.14±0.22	3.06±0.29	2.72±0.32	2.28±0.19	0.650
	30 minutes exercise	2.02±0.26	2.83±0.36	1.81±0.32	1.74±0.30	<0.001
	45 minutes exercise	1.87±0.28	2.65±0.32	1.74±0.27	1.32±0.27	<0.001
	60 minutes exercise	1.78±0.24	2.44±0.37	1.68±0.25	1.51±0.29	<0.001

Table 2. *Changes in glucose metabolism and insulin production*

Table 2. presents the levels of Glucose, Insulin, and C-peptide measured at different time points relative to exercise duration of the participants. The measurements were taken at fasting, pre-exercise, 30 and 60 minutes after exercise.

During the 15 minutes' of exercise session, starting from a fasting level of 105.72 mg/dL, glucose peaks just before exercise at 170.76 mg/dL, then decreased to 151.92 mg/dL after 60 minutes. There was a significant decrease in glucose levels at each interval ($p < 0.001$). Following the second visit of 30 minutes' exercise session glucose levels decreased more substantially after 60 minutes (140.52 mg/dL) compared to the 15-minute exercise session from a similar pre-exercise level, showing a significant change ($p < 0.001$). The third visit (45 minutes' exercise) shows the lowest fasting glucose levels (100.6 mg/dL) and lowest post-exercise level of 116.51 mg/dL. The fourth visit (60 minutes' exercise) showed improvement in glucose control, after 60 minutes and significant reductions at each interval ($p < 0.001$).

Insulin levels rose post meal and gradually decreased over the hour but not significantly ($p = 0.651$) in 15 minutes of exercise session. Similar trends were observed 30 minutes' exercise group with no significant change ($p = 0.231$). In the 45 minutes' exercise session insulin levels decreased near to baseline ($p = 0.02$). In the 60 minutes' exercise session starting at the lowest fasting level, insulin peaked lower than other groups before exercise and decreased, also without significant change ($p = 0.610$).

Levels increased before exercise and then decreased, post exercise in all sessions significantly, apart from the 15 minutes' exercise session where the change was not significant ($p < 0.650$).

Parameters	Time points	15 minutes exercise		30 minutes exercise				45 minutes exercise			60 m
		Mean Difference	Std. Error	P-Values	Mean Difference	Std. Error	P-Values	Mean Difference	Std. Error	P-Values	Mea Diffe e
Blood glucose	PE mins vs 30 min	12.160*	0.914	<0.001	21.480*	1.23	<0.001	38.200*	1.866	<0.001	27.92

levels (mg/dL)	PE mins vs 60 mins	18.840*	0.899	<0.001	28.800*	1.56	<0.001	52.080*	2.243	<0.001	38.40
	30 mins vs 60 min	6.680*	0.502	<0.001	7.320*	0.655	<0.001	13.880*	1.556	<0.001	10.48
Insulin (µU/mL)	PE mins vs 30 min	16.288*	5.242	0.029	28.764*	8.015	0.009	20.534*	4.736	0.001	17.85
	PE mins vs 60 mins	25.995*	5.571	0.001	29.097*	6.294	0.001	35.721*	4.859	<0.001	19.99
	30 mins vs 60 min	9.706	3.494	0.063	0.333	5.733	1	15.187*	3.272	0.001	2.14
C-Peptide (ng/mL)	PE mins vs 30 min	0.344*	0.023	<0.001	1.020*	0.09	<0.001	0.904*	0.076	<0.001	0.756
	PE mins vs 60 mins	0.788*	0.062	<0.001	1.084*	0.088	<0.001	1.332*	0.082	<0.001	0.932
	30 mins vs 60 min	0.444*	0.066	<0.001	0.064*	0.011	<0.001	0.428*	0.050	<0.001	0.176

Table 3. *Effects of Exercise Duration on Glycemic Markers in Prediabetic Patients*
microunits per milliliter (µU/mL), milligrams per deciliter (mg/dL), nanograms per milliliter (ng/mL)

Our findings show significant reductions in blood glucose levels post-exercise across all durations of exercise. Specifically, a 15-minute exercise session resulted in a mean decrease of 12.16 mg/dL both 30 minutes post-exercise 60 minutes, (p= 0.001). The greatest reduction observed at 45 minutes post-exercise (38.20 mg/dL), indicating a dose-response relationship between the duration of exercise and the extent of glucose decrement. Similarly, insulin levels demonstrated a significant decrease from pre-exercise values at preceding time points for all exercise durations. After 45 minutes of exercise, the mean difference in insulin levels was 20.53 µU/mL at 30 minutes (p=0.001) and 35.72 µU/mL at 60 minutes (p<0.001), with continued significance noted at 45 and 60 minutes of exercise. C-peptide levels also showed significant reductions across all exercise durations. Following 15 minutes of activity, the mean decrease in C-peptide was 0.344 ng/mL at 30 minutes and 0.788 ng/mL at 60 minutes post-exercise (p<0.001 for both). These changes indicate a consistent and significant enhancement in insulin sensitivity and beta-cell function with exercise.

The inter-time-point comparisons further emphasized the progressive nature of metabolic improvements. The change in blood glucose levels from 30 to 60 minutes post-exercise remained significant across all exercise durations, confirming the sustained effects of exercise. Notably, while the insulin response showed a peak at the 45-minute mark, the C-peptide levels continued to decrease steadily, reflecting a sustained effect on beta-cell function. The application of the general linear model with stringent Bonferroni correction assures the robustness of these findings despite multiple comparisons, emphasizing the reliability of exercise as an intervention for improving glycemic control.

Parameters for Insulin sensitivity	**15 minutes workout**		**30 minutes workout**		**45 minutes workout**		**60 minutes workout**		**p-values**
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	
HOMA-IR	5.67	4.26	4.97	3.15	4.19	3.94	2.73	2.51	<0.001
HOMA- β	70.10	55.99	63.59	42.86	56.68	56.98	36.82	36.78	0.004
FCPGR	0.02	0.00	0.02	0.00	0.02	0.00	0.02	0.00	<0.001

Table 4. Effects of various duration of exercise on Insulin resistance and Beta cell function
Effects of varying durations of aerobic exercise on markers of insulin resistance and beta-cell function, measured by HOMA-IR (Homeostatic Model Assessment of Insulin Resistance), HOMA- β (Homeostatic Model Assessment of Beta-Cell Function), and FCPGR (Fasting C-Peptide to Glucose Ratio). Data is shown as mean values with standard deviations (SD) for different exercise durations

Table 4 shows a decreasing trend in insulin resistance over the visits with increasing duration of exercise. The mean HOMA-IR values drop significantly from 5.67 for the 15-minute workouts to 2.73 for the 60-minute workouts, with a highly significant p-value (<0.001), indicating a strong effect of longer exercise duration on reducing insulin resistance. Similarly, Beta-cell function, measured by HOMA- β, showed an improvement with longer durations of aerobic exercise. The values decrease from a mean of 70.10 for 15 minutes to 36.82 for 60 minutes, with the decrease being statistically significant (p=0.004). Suggesting the importance of durations of aerobic exercise which could be beneficial in improving beta-cell function. The Fasting C-Peptide to Glucose Ratio remains relatively stable across all durations.

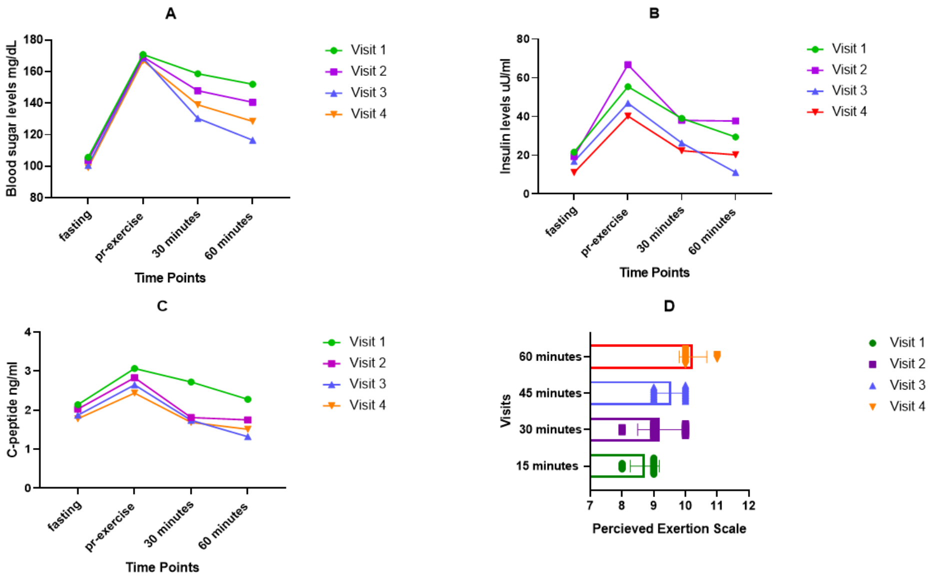


Figure 1. *Analysis of Physiological Responses and Perceived Exertion Across Various Durations of Exercise*

Figure 1 (A,B and C) shows the glycemic parameters on the Y-axis and the time points for blood taken for analysis of glycemic parameters on the X-axis. Fig. 1 (D)represents the "duration of exercise " on the Y-axis, which includes 15 minutes, 30 minutes, 45 minutes, and 60 minutes, and "Perceived Exertion Scale" on the X-axis, ranging from 7 to 12.

Fig.1(A) shows that the blood glucose levels increased pre-exercise post-meal and then decreased "30 mins" and "60 mins" time points post exercise. The pattern seems fairly consistent across all four visits with the most pronounced decrease in 45 minutes duration of exercise.

Similarly, Fig. 1(B) Graph B depicts Insulin response peaks pre-exercise in response to meal and drops at "30 mins" and "60 mins" with 45 minutes of exercise bringing insulin levels more close to baseline after 60 minutes of exercise.

Fig. 1(C) shows a slight increase pre-exercise and gradual decrease post exercise. This decrease could indicate that the body's insulin sensitivity has increased due to exercise, which is a common response, leading to lower insulin levels as glucose is taken up by the muscles during recovery. The levels are relatively consistent across all visits.

Fig. 1(D) represents the average workout time at a certain level of perceived exertion during each of the four visits. The perceived exertion correlates with workout duration, with longer workouts generally associated with higher perceived exertion levels.

3. Discussion

The positive effects of regular exercise, such as enhanced insulin sensitivity and better blood sugar control, are often linked to long-term changes brought about by consistent physical activity. Our research stands out as the first study to investigate the changes in blood glucose, insulin, and C-peptide levels following exercise sessions of 15, 30, 45, and 60 minutes, our study delivers valuable insights into the duration-based changing aspects of post-meal glycemic regulation. Earlier studies have consistently found that engaging in physical activity after eating can lead to lower blood sugar levels compared to remaining inactive but the optimal duration for glucose regulation still remains uncertain [13-15].

Our findings support the recommendations from various scientific organizations [16] who suggest that 30 minutes of moderate-intensity physical activity (exceeding 10 METs hours per week) on most, if not on all, days is beneficial for glucose regulation [16].

The current study underscores that moderate aerobic exercise for 45 minutes has shown significant improvements in improving glucose regulation in adults with prediabetes, reinforcing conclusions from previous studies, such as the one conducted by Choi et al., [17] which observed similar benefits from an 8-week exercise program for obese students. Engaging in moderate aerobic exercise, such as 45 minutes at 70% of PMHR, effectively reduced insulin levels and improved glucose uptake efficiency. This reduction in insulin could be due to enhanced insulin sensitivity during exercise. These findings align with earlier research, including studies by Sigal et al. and Hansen et al., [18, 19] which also reported improved glycemic control and metabolic health in response to structured exercise programs.

Furthermore, another study reported that a 40 minutes session of 70% high-intensity interval training (HIIT), was found to be more beneficial in reducing HbA1C levels and fasting blood glucose, thus slowing the progression to type 2 diabetes in young adults with prediabetes [20]. This suggests that not only the presence of exercise but also its intensity and volume play critical roles in managing blood sugar levels. In a controlled study by Kargarfard et al., [10] including obese men with prediabetes only were assigned to either an aerobic training group or a control group. The aerobic group engaged in 60-minute sessions of moderate exercise three times a week for 12 weeks, leading to significant improvements in several health markers such as body mass, BMI, VO2max, and insulin resistance [10].

Moreover, our research contributes to the understanding of glucose regulation post-meal. We found that shorter exercise durations, like 15 minutes, can significantly decrease blood glucose levels immediately after meals, although the changes in insulin levels were not statistically significant. These short bouts of exercise can be particularly effective right after meals when glucose from food is being absorbed. This aligns with findings from Dipietro et al.,[21] who highlighted the benefits of short walks post-meal for enhancing 24-hour glycemic control [21].

Additionally, the overall impact of regular physical activity extends beyond immediate post-exercise effects, suggesting long-term benefits for insulin sensitivity and better overall blood sugar management [12]. These benefits are crucial for individuals with prediabetes, as regular exercise can help mitigate the progression to more severe conditions [22, 23]. Notably, even walking alone has been shown to result in considerable improvements in glycemic control, demonstrating that consistent, moderate activity can be a valuable part of managing prediabetes [24, 25].

In summary, our study alongside existing literature suggests the duration of exercise are key factors in enhancing glucose regulation in individuals with prediabetes. Engaging in a moderate physical activity, for a longer duration after meals, is advisable for those with prediabetes, as it leads to greater reductions in blood glucose levels and boosts insulin sensitivity. These insights not only support existing guidelines recommending regular moderate-intensity exercise but also highlight the tailored benefits that specific types of exercise can offer in the management of prediabetes.

4. Materials and Methods

Experimental design

Before the beginning of baseline testing, all participants were carefully briefed on the complete details of the study and their involvement in it. Written informed consent was duly acquired from every participant, confirming their agreement to partake in the study. The procedures and methodologies employed in this research were carried out after the approval from human ethics committee of the KMU (Institutional Research Ethical Board of IBMS) under the ethical number (NO: KMU/IBMS/IRBE/meeting/2022/8075) in accordance with Helsinki declaration 1964. Sample size was calculated using G Power 3.1.9.2 software, the sample size was calculated to be 25 taking a, 'significance level (α) of 0.05 and a high power (β) of 0.95'. In this experiment, non-probability purposive sampling was used.

The study aimed to investigate the effects of various duration of aerobic exercise on glycemic parameters and insulin sensitivity, in adults with prediabetes postprandially. The authors tend to determine the best duration of exercise for prediabetics.

Participants

A cohort of 25 individuals both males and females, between age range of 25 to 45 years, with prediabetes completed the study. Originally, 30 candidates were recruited from local health facilities, out of which 25 met the inclusion criteria based on their fasting plasma glucose levels ranging from 100 to 126 mg/dL and HbA1c percentages spanning 5.7% to 6.4% [26]. Individuals with a history of cardiovascular conditions, those on lipid lowering drugs with any disability, lactating and pregnant woman, enrolled in some other exercise program were excluded from the study. The participants who lead sedentary lifestyles, which were defined as exercising for less than 30 minutes a day specified via IPAQ questionnaire [27].

Forty-eight hours prior to initiating the study protocol, all participants completed a two-day baseline assessment, which included anthropometric measurements, followed by blood testing. On the first day, measurements of weight, height, Body Mass Index (BMI), and body plethysmography were conducted. The following day, participants had their fasting blood glucose (FBS) and HbA1c levels measured. Following the initial assessments, participants were asked to visit the Sports Research Unit (SRU) at the Department of physiology KMU for four visits seven days apart. They engaged in a monitored exercise routine for different durations, while maintaining their usual physical activity and dietary habits. Throughout the duration of the study, no dietary modifications were suggested to any of the participants.

Anthropometric parameters and body composition

The body composition of the participants was measured using an “professional electronic body composition equipment” by “Wunder” model: MOD.WBA 300, Sr. NO: DK 019.336 REV 01 from Italy. The meter was synced with the "wMed PRO Ink" software to calculate weight (in kilograms), body mass index (BMI, in kilograms per square meter), body fat percentage, and fat mass (in kilograms). Waist-to-hip ratio (WHR) was determined to the closest centimeter using a soft measuring tape, by measuring the waist at the midpoint between the lower rib and the top of the hip bone, ensuring the tape was snug but not compressing the skin, and then dividing this measurement by the circumference of the hips at the widest part of the buttocks [28].

Sample analysis

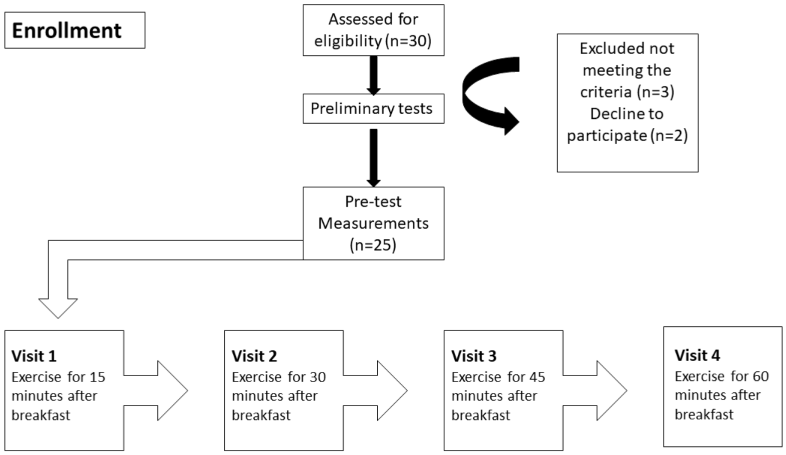
Blood samples, each 5 ml, were collected at fasting, pre-exercise, 30 and 60 minutes post exercise in each visit. These samples were drawn by a trained phlebotomist, scheduled between 8:00 to 12:00 a.m. Participants were advised to avoid intense physical activity and the consumption of any supplements for two days before each visit. Once collected, the blood was immediately placed into tubes containing anticoagulant. The samples were then centrifuged at 1200 rpm for 5 minutes to separate the plasma. This was stored at -80 degrees Celsius until it was time for subsequent analysis.

Plasma glucose analysis was done using (Abbott, Freestyle, glucometer) available commercially. Serum Insulin levels, were analyzed using commercially available kits Elisa for human samples (Insulin-IN374S, C-peptide: CP179S-USA). The results were run in duplicate and were then analyzed.

Insulin sensitivity was gauged through the following formulas [29]: HOMA-IR = (Fasting insulin (uU/ml)* Fasting blood glucose (nmol/l))/22.5. and HOMA- β = (20 * fasting insulin (uU/ml))/(Fasting blood glucose (mmol/L)-3.5). For the estimate of β-cell function the ratio of fasting C-peptide (FCP) to fasting plasma glucose (FPG) was used [30].

Exercise training program

The participants were asked to visit the lab four times, seven days apart as a washout period between the visits. They were asked to attend the lab at fasting and were provided with a standardized breakfast of 250 calories to ensure uniform glucose levels prior to exercise. After breakfast, they engaged in aerobic exercise. Blood samples were drawn at fasting, pre-exercise, 30 and 60 minutes’ post exercise. Each visit had different exercise duration (Figure 2):



Visit 1: Participants engaged in exercise activity for 15 minutes.
Visit 2: The duration of exercise was extended to 30 minutes.
Visit 3: The participants completed a session of 45 minutes of aerobic exercise.
Visit 4: The final visit consisted of exercise session lasting 60 minutes. However, this demanded a greater fitness level from the participants. The participants not able to exercise for 60 minutes duration of exercise were asked to discontinue, if any signs of hypoglycemia such as nausea, trembling, hunger, or an accelerated heartbeat were exhibited by an individual. The aerobic activity consisted of walking on a (treadmill from Taiwan). The participants exercised at 70% of their 'Predicted Maximum Heart rate (PMHR) calculated using formula 220-age'[31]. Participants were equipped with heart rate monitors (HRM Garmin) for ensuring that the participants are working out in the specified exercise intensity. All sessions were conducted under the supervision of the research team.

Data analysis

Data was analyzed using SPSS version 23 and Prism Grpahpad version 8. The data normality was checked using Shapiro wilk-test. Demographic differences were analyzed via student t test for gender wise differences. To evaluate the differences in various exercise durations ANOVA was used. For relation among various time points and diabetic parameters repeated measure ANOVA using post hoc via a general linear model with Bonferroni correction was used.

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Author Contributions:

"I. Shah conceived the idea and designed the experiments."
"S. Shah. And S. Tauqir conducted the experiments."
"M. Malik conducted the statistical analysis of the study"
"All authors contributed equally to the writing of the manuscript."

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Conflicts of Interest

The author(s) declare(s) that there is no conflict of interest regarding the publication of this article.

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