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Exploring the Interplay Between Exercise Duration and Effects on Lipid Profiles in Prediabetic Patients

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Abstract

Background: *Prediabetes is a critical health condition characterized by elevated plasma glucose levels, this condition often coexists with lipid abnormalities, which can exacerbate cardiovascular risks. This study aims to explore the effects of varying exercise durations on lipid profiles and cardiorespiratory fitness in prediabetic individuals to identify optimal exercise durations that might improve health outcomes and prevent the progression to T2DM.* ***Methods:*** *A crossover trial was conducted with 25 middle-aged participants. They engaged in four different durations of exercise sessions (15, 30, 45, and 60 minutes) at Sports Research Unit, with lipid profile assessments at multiple time points (fasting, pre-exercise, 30 minutes post-exercise, and 60 minutes post-exercise). The primary outcomes measured were changes in cholesterol, triglycerides (TG), high-density lipoprotein (HDL), and low-density lipoprotein (LDL) and cardiorespiratory parameters.* ***Results:*** *The study found that longer exercise durations led to significant reductions in both fasting and pre-exercise triglyceride levels and a notable decrease in LDL levels in a dose-response manner with respect to duration of exercise. There was also a significant increase in HDL levels post-exercise with longer workouts. Notably, there was no significant change in cardiorespiratory parameters.* ***Conclusion****: These findings suggest that extended durations of aerobic exercise may be beneficial for improving lipid profiles in prediabetic individuals, potentially slowing down the progression towards type 2 diabetes mellitus and reducing cardiovascular risk. The study highlights the importance of tailored exercise recommendations in managing prediabetes and associated metabolic risks.*

Keywords: Prediabetes, Exercise Duration, Lipid Profiles, Type 2 Diabetes Mellitus Prevention, Cardiovascular Health

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Introduction

Prediabetes (PD) is a stage in which the subject's plasma glucose levels are greater than normal but not high to be diagnosed as diabetics.[1] In recent years, the prevalence of PD has risen, particularly in poorer nations where it is more common than Type 2 Diabetes mellitus (T2DM).[2, 3] It is estimated that 5-10% of people with PD may develop T2DM, which is a widespread chronic condition with serious complications and a high death rate.[4] The World Health Organization (WHO) estimates that the world's diabetic population will reach 522 million by 2030.[5]

Numerous comorbidities, such as obesity and lipid abnormalities, have been linked to an increased risk of developing diabetes.[6] Previous research suggests that lipid abnormalities are common in individuals with PD.[7] A community-based cross-sectional survey found a robust link between blood lipid profiles and PD.[8] Prediabetics are frequently characterized by high levels of total cholesterol (CHOL), low-density lipoprotein cholesterol (LDL), and triglycerides (TG), as well as low levels of high-density lipoprotein cholesterol (HDL).[9] The relationship between lipid abnormalities and T2DM has been studied in a variety of populations, but few studies have been undertaken to assess this link between prediabetic individuals.[10] Diabetes development is more likely in the 5-10 years following the onset of PD, highlighting the need for effective preventative interventions.[9]

Exercise reduces fasting and postprandial plasma TG concentrations in individuals who are obese, or diabetic.[11] In healthy and metabolically normal obese individuals, acute resistance exercise (30 minutes after exercise) enhances total postprandial fatty acids oxidation and VLDL-TG plasma clearance.[12]

This article aims to explore how different lengths of exercise effects lipid profile and cardiorespiratory fitness parameters in prediabetic individuals. The goal is to find out the best exercise duration that can help improve these factors, which is important for the health and diabetes prevention in these individuals. This study will help in understanding better exercise plans for people with prediabetes.

Methodology

Study Design and Ethical Approval

This study employed a crossover experimental design to determine the acute effects of varying exercise durations on lipid metabolism and cardiorespiratory fitness in individuals with prediabetes. The crossover design was selected to ensure that each participant served as their own control, thereby reducing inter-individual variability and enhancing statistical power. Ethical approval for the study was obtained from the Institute of Basic Medical Sciences (IBMS)

Review Board under the reference number *KMU/IBMS/IRBE/meeting/2022/8075*. All participants provided informed consent prior to enrolment.

Sample Size Determination and Participant Recruitment

Sample size was estimated using G*Power version 3.1.9.2, adopting an alpha level of 0.05 and a statistical power of 0.80. The calculated minimum sample size was 12; however, to enhance the study's robustness and compensate for potential dropouts, the sample was increased to 25 participants. A purposive sampling technique was used to recruit individuals who met the American Diabetes Association (ADA)[13] criteria for prediabetes, defined as having fasting plasma glucose levels between 100–125 mg/dL and HbA1c levels between 5.7–6.4%. Eligibility screening included the International Physical Activity Questionnaire (IPAQ)[14] to confirm physical inactivity and the Physical Activity Readiness Questionnaire (PAR-Q)[15] to ensure safe participation in exercise testing.

Setting and Preparatory Procedures

All experimental sessions were conducted at the Sports Research Unit (SRU), Khyber Medical University, under controlled environmental conditions. Participants arrived at the laboratory after a 10–12-hour overnight fast, and each exercise trial began at approximately 8:00 AM to minimize circadian variation in metabolic markers. A standardized 250-calorie breakfast was provided before each session to unify pre-exercise nutritional status across visits.

Experimental Protocol

Each participant completed four separate laboratory visits, each separated by a minimum washout period of seven days to eliminate residual metabolic effects of previous exercise sessions. During each visit, participants performed treadmill exercise at a predetermined moderate-to-vigorous intensity equivalent to 70% of predicted maximum heart rate (PMHR), with session durations of 15, 30, 45, and 60 minutes, respectively. Exercise intensity was maintained using continuous heart rate monitoring via a Garmin heart rate monitor. Respiratory and metabolic parameters including VO_2, VCO_2, METS, substrate utilization, and respiratory quotient—were assessed using a breath-by-breath metabolic analyzer (COSMED, Italy).

The 60-minute session posed greater physical demands, and some participants were unable to complete the full duration. Such responses were documented to evaluate tolerance and feasibility of extended-duration exercise among prediabetic individuals.

Blood Sampling and Biochemical Analyses

Venous blood samples were collected during each visit at four time points:

Fasting (baseline), Pre-exercise (post-breakfast), 30 minutes post-exercise, 60 minutes post-exercise. Samples were analyzed for total cholesterol, triglycerides (TG), high-density lipoprotein (HDL), and low-density lipoprotein (LDL) using standardized clinical chemistry protocols. All biochemical analyses were performed in the same laboratory using identical equipment and reagents to minimize procedural variability.

Outcome Measures

Primary outcomes included the acute changes in lipid parameters (CHO, TG, HDL, LDL) in response to varying exercise durations. Secondary outcomes included cardiorespiratory variables such as VO_2, VCO_2, METS, energy expenditure, heart rate, and substrate oxidation patterns (fat vs. carbohydrate utilization). Anthropometric data including height, weight, BMI, waist circumference, and hip circumference were collected at baseline to characterize the study population.

Statistical Analysis

Data were analyzed using the General Linear Model (GLM) for repeated measures, enabling comparison of lipid and metabolic responses across the four exercise durations and time points. Where the GLM indicated statistical significance, Bonferroni-adjusted post hoc tests were applied to examine pairwise differences. Continuous variables were summarized as mean ± standard deviation. A p-value <0.05 was considered statistically significant. All analyses ensured adherence to the assumptions of normality and sphericity, with corrections applied where necessary.

Results

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.

Table 1: ***Demographic and Anthropometric Profile of Participants in the Study***

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/m²)	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	106.41±9.93	102.42±17.10	0.467
Waist to hip ratio (WHR)	0.97±0.04	0.92±0.05	1.01±0.02	0.659

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) and Body Mass Index (BMI).

Table 2: ***Inter Visit Analyzing the Effects of Various Durations of Exercise on Lipid Profile***

Lipid parameters		**Fasting**	**Pre-exercise**	**30 minutes post-exercise**	**60 minutes post-exercise**	***p*-value**
		Mean±S.D	**Mean±S.D**	**Mean±S.D**	**Mean±S.D**	
Cholesterol (mg/dL)	**15 minutes exercise**	190.84±20.56	196.56±24.44	176.72±16.76	172.52±14.38	<0.001
	30 minutes exercise	191.32±20.32	196.8±21.11	178.64±15.15	173.12±13.93	<0.001
	45 minutes exercise	188.8±18.71	193.28±20.07	177.56±13.41	173.2±11.18	<0.001
	60 minutes exercise	188.68±22.66	192.4±22.51	174.68±14.07	170±12.36	<0.001
	***p*-value**	0.51	0.299	0.528	0.495	----------
Triglycerides (mg/dL)	**15 minutes exercise**	174.76±20.92	187.44±20.78	172.24±21.26	165.28±19.86	<0.001
	30 minutes exercise	172.84±19.52	185.24±17.65	172.4±16.91	166.16±17.88	0.001
	45 minutes exercise	169.52±19.7	175.52±26.11	168.52±16.13	163.56±18.58	0.016
	60 minutes exercise	168.96±20.67	179.76±17.15	167.44±2016	161.8±19.89	0.001
	***p*-value**	0.002	0.001	0.067	0.11	----------
HDL	**15 minutes**	41.52±2.24	40.12±1.88	41.72±3.35	42.84±3.25	0.01

	exercise					
	30 minutes exercise	41.68±1.57	40.12±1.99	41.56±3.82	42.52±3.70	0.074
	45 minutes exercise	41.4±2.38	40.8±1.63	42.16±3.20	42.84±3.67	0.002
	60 minutes exercise	41.76±2.54	41.6±2.00	42±3.56	43.16±3.47	0.013
	***p*-value**	0.785	0.005	0.445	0.243	----------
LDL	**15 minutes exercise**	84.88±10.54	89.52±10.91	84.64±10.56	80.84±10.23	<0.001
	30 minutes exercise	83.96±10.68	90.68±12.00	83.4±10.67	79.48±11.62	<0.001
	45 minutes exercise	82.96±11.52	88.28±10.63	82.12±10.55	77.76±10.80	<0.001
	60 minutes exercise	82.40±11.40	86.52±10.51	80.32±10.51	77.16±10.74	<0.001
	***p*-value**	0.024	<0.001	<0.001	<0.001	---------

The table presents the mean levels of cholesterol, triglycerides (TG), high-density lipoprotein (HDL), and low-density lipoprotein (LDL) in fasting states, pre-exercise, and at 30 and 60 minutes after exercise and across four different durations of exercise (15, 30, 45, and 60 minutes), along with their respective standard deviations (Std. D) and p-values. All measured differences between time points and across exercise durations were considered statistically significant at p-values less than 0.001.

According to Table 2 cholesterol levels showed significant reductions post-exercise across all durations. At 15 minutes of exercise, mean cholesterol levels decreased from 190.84 mg/dL (±20.56) at fasting to 172.52 mg/dL (±14.38) at 60 minutes post-exercise ($p < 0.001$). Similar trends were observed for 30, 45, and 60 minutes of exercise. Triglycerides levels also showed significant reductions post-exercise. For 15 minutes of exercise, triglycerides decreased from a pre-exercise level of 187.44 mg/dL (±20.78) to 165.28 mg/dL (±19.86) at 60 minutes post-exercise ($p < 0.001$). At 30, 45, and 60 minutes of exercise, significant decreases were observed (p = 0.001, 0.016, and 0.001, respectively). HDL levels increased across all exercise durations. At 15 minutes of exercise, HDL levels increased from 40.12 mg/dL (±1.88) pre-exercise to 42.84 mg/dL (±3.25) at 60 minutes post-exercise ($p = 0.01$). For 30, 45, and 60 minutes of exercise, the levels increased incrementally (p = 0.074, 0.002, and 0.013, respectively). LDL levels decreased significantly post-exercise across all durations. At 15 minutes of exercise, LDL levels decreased from 89.52 mg/dL (±10.91) pre-exercise to 80.84 mg/dL (±10.23) at 60 minutes post-exercise ($p < 0.001$). Similar reductions were observed at 30, 45, and 60 minutes of exercise, with LDL levels dropping ($p < 0.001$ for all).

Overall, the results indicate that varying the duration of exercise significantly impacts lipid profiles, with notable improvements in cholesterol, triglycerides, HDL, and LDL levels following anaerobic exercise sessions. Cholesterol and triglycerides generally decrease post-exercise, while HDL increases, suggesting a beneficial effect of exercise on lipid profiles. LDL decreases after an initial increase, highlighting the complex dynamics of lipid metabolism in response to physical activity. These findings suggest that structured exercise regimens can effectively improve lipid parameters in prediabetic individuals, potentially reducing the risk of progression to Type 2 Diabetes Mellitus.

Table 3: ***Acute Responses of Lipid Metabolism to Exercise: Analysis Across Four Exercise Durations***

		15 minutes exercise			30 minutes exercise			45 minutes exercise			60 minutes exercise		
Parameters	**Time points**	**Mean Difference**	**Std. Error**	***p*-Values**	**Mean Difference**	**Std. Error**	***p*-Values**	**Mean Difference**	**Std. Error**	***p* - Values**	**Mean Difference**	**Std. Error**	***p*-Values**
Cholesterol (mg/dL)	**PE mins vs 30 min**	19.84	2.44	0	18.16	2.37	0	15.72	2.28	0	17.72	2.43	0
	PE mins vs 60 mins	24.04	3.16	0	23.68	3.23	0	20.08	2.84	0	22.4	3.14	0
	30 mins vs 60 min	4.2	1.41	0.04	5.52	1.8	0.03	4.36	1.36	0.02	4.68	1.42	0.019
Triglycerides (mg/dL)	**PE mins vs 30 min**	15.2	2.18	0	12.84	1.98	0	7	4.54	0.82	12.32	1.84	0
	PE mins vs 60 mins	22.16	2.36	0	19.08	2.59	0	11.96	5.09	0.16	17.96	2.55	0
	30 mins vs 60 min	6.96	1.79	0	6.24	1.79	0.01	4.96	1.51	0.02	5.64	1.48	0.005
HDL	**PE mins vs 30 min**	-1.6	0.5	0.02	-1.44	0.52	0.06	-1.36	0.51	0.08	-0.39	0.6	1
	PE mins vs 60 mins	-2.72	0.62	0	-2.4	0.62	0	-2.04	0.61	0.02	-1.56	0.51	0.031
	30 mins vs	-1.12	0.59	0.4	-0.96	0.35	0.07	-0.68	0.23	0.04	-1.16	0.37	0.026

	60 min			2									
	PE mins vs 30 min	4.88	0.78	0	7.28	0.64	0	6.16	0.62	0	6.2	0.76	0
LDL	**PE mins vs 60 mins**	8.68	1.11	0	11.2	1.02	0	10.52	1.05	0	9.36	1.22	0
	30 mins vs 60 min	3.8	0.8	0	3.92	0.88	0	4.36	0.94	0	3.16	0.75	0.002

The table 3 presents a post hoc analysis of the effects of various durations of exercise (15, 30, 45, and 60 minutes) on lipid profiles measured at pre-exercise, 30 minutes post-exercise, and 60 minutes post-exercise. This analysis was conducted following significant findings from a general linear model.

A significant increase in cholesterol levels was observed at both 30 and 60 minutes post-exercise across all exercise durations. The mean differences ranged from 15.72 mg/dL at 45 minutes to 24.04 mg/dL at 15 minutes, all showing statistically significant changes (p=0.000). The increases were more pronounced immediately after exercise and showed a smaller yet significant increase from the 30-minute mark to the 60-minute mark across all durations. Triglycerides also demonstrated a significant reduction post-exercise. The changes were most notable in the shorter durations (15 and 30 minutes), with mean differences of 22.16 mg/dL and 19.08 mg/dL from pre-exercise to 60 minutes post-exercise, respectively. The effect appeared to diminish slightly with longer exercise durations, but remained significant. HDL levels increased post-exercise, with the most significant increase observed from pre-exercise to 60 minutes. LDL levels showed an decrease from pre-exercise to post-exercise measurements, with significant changes noted at both 30 and 60 minutes across all exercise durations.

Overall, these results suggest that different exercise durations have a significant and immediate impact on lipid profiles, with cholesterol and HDL levels increasing, whereas triglycerides decrease and LDL generally decreases post-exercise. The observed patterns indicate robust responses in lipid metabolism to aerobic exercise, with potential implications for managing dyslipidemia and enhancing cardiovascular health.

Table 4: ***Changes in Respiratory and Metabolic Parameters During Different Workout Durations***

Respiratory parameters	15 minutes workout	30 minutes	45 minutes workout	60 minutes workout	*p*-values
	Mean±S.D	Mean±S.D	Mean±S.D	Mean±S.D	
Steps	2091±272.55	2760±213.73	4020±462.73	4096±435.85	<0.001
Duration (min)	15±0.33	29.6±0.91	44.28±0.89	46.24±3.32	<0.001
BSA (m^2)	1.97±0.16	1.97±0.16	1.97±0.16	1.97±0.16	0.327
VO2 (mL/min)	1118.38±362.48	1114.19±452.25	1117.18±394.74	1119.26±470.85	0.947
VCO2 (mL/min)	474.03±296.32	567.19±386.57	545.53±353.38	534.75±439.98	0.591
METS	4.57±1.18	4.55±1.41	4.59±1.34	4.58±1.6	0.903
HR (bpm)	123±8.58	122±10.56	121±9.2	124±5.67	0.837
Eeh (kcal/h)	155±107.47	194±131.17	167±118.78	170±138.34	0.866
FAT (kcal/day)	1801±1991.05	2412±234.56	1321±177.63	1358±1686.6	0.144
CHO (kcal/day)	1976±1765.02	2264±2310.17	2793±205.09	2753±2765.16	0.222
RQ	0.94±0.19	0.9±0.17	1±0.18	0.93±0.13	0.584

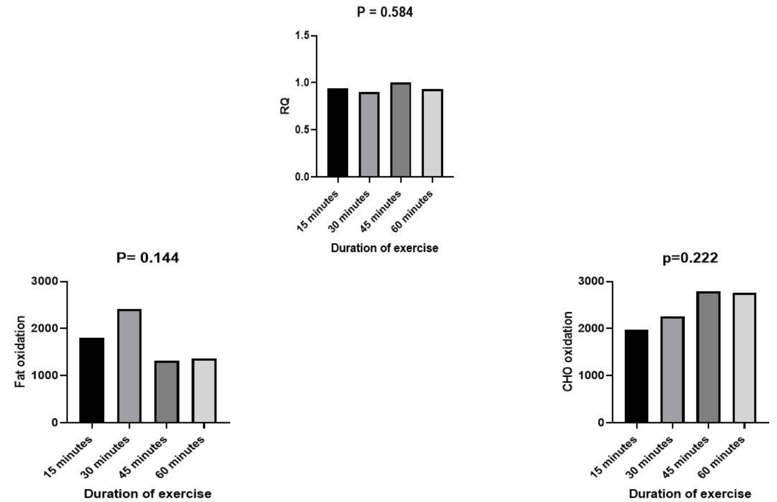

Figure 1: Effects of Exercise Duration on Respiratory Quotient, Fat Oxidation, and Carbohydrate Oxidation

The Table 4 presents the data in form of mean and standard deviation for various respiratory parameters measured while figure presents the visual representation of the data during workouts of increasing duration (15, 30, 45, and 60 minutes). Notable results include:

There was a significant increase in the number of steps taken and the duration of the workout as exercise lengthens. From 2091.44 steps in a 15-minute workout to 4096.72 steps in a 60-minute session, the data clearly shows that participants are more active for longer periods ($p < 0.001$ for both steps and duration). Both BSA remained constant across all exercise durations, with no statistical differences observed (*p*-values of 0.327). This consistency suggests that the physical characteristics of the participants did not influence the primary outcomes of the study. VO2 and VCO2 both increased with the duration of exercise, indicating higher metabolic rates. However, these increases were not statistically significant (*p*-values of 0.947 and 0.591, respectively), suggesting a wide variability in individual metabolic responses to exercise. METS slightly increased as exercise durations extended, though not significantly ($p = 0.903$). A significant decrease in HR was observed in the 60-minute workout compared to shorter durations ($p < 0.001$), which could indicate improved cardiovascular efficiency or fatigue. There was an initial increase in the amount of FAT and CHO used during the exercise, particularly noted from 15 to 30 minutes. However, as the exercise duration continued to 45 and 60 minutes, there was a decrease in FAT usage while CHO usage remained high but did not reach statistical significance (*p*-values of 0.144 and 0.22, respectively). RQ values varied across the durations, starting at 0.94 for 15 minutes and peaking at 1.00 for 45 minutes, before slightly reducing to 0.93 in the 60-minute session (p = 0.584). These changes suggest a shift in substrate utilization from predominantly fats to a mix and then primarily carbohydrates.

Discussion

The American College of Sports Medicine recommends individuals should engage in 150 minutes of moderate physical activity per week. Although the intervention in the study significantly enhanced aerobic metabolic capacity, it consisted of different durations of activates. It has been suggested that short-term high-intensity interval training might be an efficient way to promote health due to its time efficiency, and the findings from this study support the notion that such training can impact certain health parameters. However, the study also shows that to effectively treat hyperlipidemia a greater volume of training is necessary. Thus, the results support the American College of Sports Medicine's recommendations regarding the required training volume for health benefits.[16]

The duration of exercise significantly affects lipid profiles, with various studies highlighting different impacts based on the intensity, type, and duration of exercise. Walking exercise programs, even at longer durations, do not significantly alter lipid profiles, despite their positive effects on body composition.[17] Conversely, regular exercise, even below the recommended weekly duration, can positively affect HDL cholesterol levels, demonstrating a duration-response relationship with lipid profiles.[18] Similarly, high-intensity continuous exercise significantly affected total cholesterol and low-density lipoprotein levels, while interval training improved HDL.[19] High-intensity exercise over a short duration notably improved lipid profiles in young with hyperlipidemia without dietary restrictions.[20]

Our findings demonstrated that although there were noticeable shifts in the utilization of fats and carbohydrates as exercise duration increased, these changes were not statistically significant (*p*-values for FAT = 0.144 and CHO = 0.22; RQ = 0.584). This result points to a significant individual variability in how metabolism responds to extended physical activity. The RQ is a crucial indicator of metabolic substrate usage; an RQ close to 0.7 typically indicates fat utilization, around 1.0 suggests carbohydrate utilization, and values in between indicate a mix. In this study, the RQ values suggest that: At shorter durations (15 and 30 minutes), there was a mixed substrate utilization with a slight preference for fats. At 45 minutes, there was a noticeable shift towards carbohydrate utilization, likely due to depletion of readily available fat stores.

By 60 minutes, although the RQ slightly reduced, it indicated that carbohydrates continue to be a significant energy source, possibly due to the sustained intensity and duration of exercise leading to continued glycogen use. This trend may reflect a metabolic shift where, during longer exercise sessions, there is an increased reliance on carbohydrates following the depletion of readily available fat reserves. This observation supports the idea that extended durations of exercise alter substrate usage patterns, primarily showing increased carbohydrate metabolism as exercise lengthens. [21]

The duration of exercise significantly affects substrate metabolism in prediabetics, with specific training regimens enhancing metabolic flexibility. In prediabetic individuals, prolonged exercise training enhances the oxidation of fats and the metabolic response to exercise. For example, Gaitán et al.,[22] suggests that interval training over two weeks significantly increased fat oxidation during exercise in obese adults with prediabetes, highlighting the benefits of specific exercise modalities on metabolic health in this population.[22] Additionally, adaptations in fat and carbohydrate metabolism following extended endurance training for 2 hours show an increase in fat utilization and a reduction in glucose oxidation, suggesting a shift towards greater metabolic efficiency.[23] These findings are important as they indicate that tailored exercise regimens could potentially ameliorate the metabolic disturbances typically associated with prediabetes.

Conclusion

In conclusion, the results indicate that longer durations of exercise contribute to significant reductions in both fasting and pre-exercise triglyceride levels as well as LDL levels at all measured times. Furthermore, there was a significant increase in HDL levels pre-exercise with longer workouts. These findings underscore the potential benefits of extended exercise durations for improving various lipid parameters, which are indicators of cardiovascular health. Our study explains that prolonged exercise shifts fuel utilization from fats to carbohydrates, corroborating the body's metabolic flexibility to adapt to different energy demands during sustained physical activity. This adaptation is essential for designing training regimes that optimize fuel use, especially in endurance training or in managing conditions like diabetes where energy utilization is critical.

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