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Effects of a High-Protein Ketogenic Diet on Strength Training Performance and Body Composition in Recreational Weight Lifters

Running Tittle: High-Protein Keto Diet for Muscle Building

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ABSTRACT

Background :Weight Lifters often manipulate dietary protein to build muscles, and one dietary approach is a High-Protein Ketogenic Diet (HPKD). However, very little research has been conducted on the effects of a high-protein ketogenic diet on strength training performance and muscle building outcome goals. Therefore, the purpose of the present study is to investigate whether a high-protein ketogenic diet (HPKD) is an effective strategy to decrease fat mass (FM), and maintain lean body mass (LBM) without compromising strength training performance in recreational, weight lifters.

Method :In a parallel-arm, longitudinal, diet- and exercise-controlled design, 43 participants (mean ± SD age = 24.58 ± 9.26 years) exercised for 6 weeks while consuming either a high-protein ketogenic diet (HPKD) or a Normal Diet (ND). The HPKD intervention group (males, n = 13; females, n = 11) was instructed to consume a diet with 60% fat, 35% protein and 5% carbohydrates. Those in ND group (males, n = 10; females, n = 9) maintained a normal diet with 25% fat, 15% protein and 60% carbohydrates. Pre- and post-testing were conducted during the weeks prior to and following the intervention. The amount and composition of body fat mass (FM) and fat-free mass (FFM) was calculated using bioelectrical impedance analysis (BIA) method. Tests of strength training performance included One Repetition Maximum (1RM) in the back squat, deadlift and bench press.

Results : The HPKD group significantly decreased body weight (mean ± SD, Weight: -1.55 ± 2.38 kg, $p<0.05$), body fat percent (mean ± SD, %BF: -3.58 ± 0.85 kg, $p<0.05$), and fat mass (mean ± SD, FM: -2.80 ± 0.87 kg, $p<0.05$) compared to pre intervention measurements while significantly increased lean mass (mean ± SD, LM: 1.25 ± 2.02 kg, $p<0.05$) and basal metabolic rate (mean ± SD, BMR: 76.76 ± 2.02 kcal/d, BMR: +4.44%, $p<0.000001$) in 6 weeks. However, there were no significant differences ($p > 0.05$) found in any variables of the HPKD group compared to ND group (Weight: $p = 0.52$, Body Fat Percentage: $p = 0.62$, Fat Mass: $p = 0.58$, Lean Mass: $p = 0.63$, BMR: $p = 0.47$).

Additionally, the HPKD group experienced a significant increase in strength (1RM) for all three lifts (bench press: 8.13 ± 4.85 kg, $p < 0.05$; back squat: 5.0 ± 2.95 kg, $p < 0.05$; deadlift: 8.13 ± 7.04 kg, $p < 0.05$) between pre and post intervention. However, no significant effects were observed ($p > 0.05$) on strength for any variables of the HPKD group compared to ND group (back squat: $p = 0.29$; deadlift: $p = 0.15$; bench press: $p = 0.18$).

Conclusion

Our data show that adhering to a HPKD combined with Strength Training for 6 weeks can lead to significant decreases in %BF, FM, and body weight, while significantly improving LM, BMR and overall strength performance in all three main lifts. This indicates a high-protein ketogenic diet can be an effective strategy to reduce body weight and fat mass without negatively affecting lean body mass, strength, or power performance.

KEY MESSAGES

What is already known on this topic?

Only the standard ketogenic diet (SKD) has been studied extensively. There is less evidence related to outcomes of high-protein ketogenic diets (HPKD) in weight lifters. This is truly a novel finding, highlighting the potential for high protein ketogenic diets in weight lifting

populations. To our knowledge, the present study is the first that has assessed the use of a HPKD combined with Strength Training to evaluate body composition and performance outcomes.

What this study adds?

The high-protein ketogenic diet can be used as an effective tool to reduce body weight and fat mass, particularly in the period of 3–12 weeks, in recreational weight lifters without affecting lean body mass, strength or power performance.

How this study might affect research, practice or policy?

The results of this study will inform policy makers and program designers to promote high-protein ketogenic diet among recreational weight lifters as well as weight category athletes, such as boxers, MMA fighters, wrestlers, powerlifters or CrossFitters.

INTRODUCTION

The Ketogenic Diet (KD) have been found to be effective in managing several chronic conditions, such as epilepsy, metabolic syndrome, diabetes, cancers, and Alzheimer's disease [1-6]. Recently, it has gained resurgence in popularity due to its purported reputation for fighting obesity, not only within the scientific community, but also among the general public. Ketogenic Diet has emerged as a celebrated dietary plan for the treatment of obesity [6].

When examining the physiological and metabolic effects and the various health outcomes of ketogenic diets many studies found the favorable side effect of weight loss, fat loss, and changes in body composition. Therefore, the ketogenic diet has also been evaluated as a tool for weight loss in the overweight and obese populations.

In addition to the increasing popularity of ketogenic diets for weight-loss among the weight conscious people, they have recently become a popular trend among competitive athletes as a means of rapid weight loss for performance benefits [7]. Low-carbohydrate ketogenic diets are widely used among sports that are divided into weight class divisions, such as wrestling, boxing, and weight lifting [8,9]. Rapid body weight reduction prior to competition in athletes who compete in specific weight categories can be an appropriate and vital tool for performance success.

Ketogenic Diet

Ketogenic diet (KD) is a nutritional approach based on a reduced intake of carbohydrates (less than 20/30 g per day or 5% of total energy) [10–12], a high fat content and an adequate level of proteins, the latter generally close to or slightly higher than the ICMR's recommendation for Indians which is 0.9g / kg per day of body weight [13].

The KD is a high-fat, moderate-protein, and low-carbohydrate diet that typically supplies approximately 80% of calories from fat, 15% calories from protein, and 5% calories from carbohydrates [14,15]. This type of diet is vastly different than the typical western diet, of which carbohydrates generally make up the majority of calories consumed (50-60%), and followed by fat (25-35%) and protein (10-20%).

The guiding principle behind a ketogenic diet is the fuel shift from carbohydrates (CHO) to fat stores. It severely restricts CHO to induce ketosis, by limiting glucose availability to tissues. The intake of carbohydrates increases blood glucose, which in turn triggers an insulin response. Glucose is the main energy source for all metabolic processes and is particularly important in providing energy during exercise. When glucose and insulin are high, fat metabolism and fat oxidation are inhibited, and the body goes into a fat storing mode rather than a fat burning mode. On the other hand, when carbohydrate intake is low, or when carbohydrate stores (in the form of glycogen) are exhausted such as during a prolonged bout of endurance exercise, fatty acids can be broken down for energy. Additionally, when carbohydrate intake is minimal, ketones (a metabolic byproduct of fat metabolism) are produced, which are further used by the body for energy.

Furthermore, high fat, low carbohydrate diets have been found to enhance performance among endurance athletes and improve overall body composition [7-9]. Theoretically, limited glycogen stores lead to limited exercise capacity, while unlimited fat stores will lead to longer exercise capacity. Research has supported this notion that reliance on fats, not carbohydrates, can lead to enhanced endurance performance [18]. For these reasons, research into the benefits of a ketogenic diet among the exercising population has increased over the years.

High-Protein Ketogenic Diet

There are several versions of the ketogenic diet, including:

Standard ketogenic diet (SKD): This is a very low carb, moderate protein and high fat diet. It typically contains 80% fat, 15% protein, and only 5% carbs [9,10].

Cyclical ketogenic diet (CKD): This diet involves periods of higher-carbohydrates in between the ketogenic diet cycles, for example, five ketogenic days followed by two high-carbohydrate days as a cycle [19].

Targeted ketogenic diet (TKD): This diet permits adding additional carbohydrates around the periods of the intensive physical workout [19].

High-protein ketogenic diet (HPKD): This diet includes more protein and the ratio around 60% fat, 35% protein and 5% carbohydrates [16].

A high-protein ketogenic diet is more advanced method and primarily used by athletes, bodybuilders and weight lifters.

Importance of This Study

Only the standard ketogenic diet (SKD) has been studied extensively. There is less evidence related to outcomes of high-protein ketogenic diets (HPKD) in weight lifters.

Plus, a common assumption with weight lifters on a SKD is that with significant weight loss, there is a loss of lean body mass (LBM); which would have an adverse effect on performance by decreasing power [12]. That's because SKD is very low in carbohydrates (usually to <50 g/day) and moderate in protein (15% protein).

Authors of current literature have examined the combination of SKD and weight lifters; however, there is a large gap in research on the combination of HPKD and weight lifters. Hence, it is required to evaluate the effect of HPKD on resistance training performance and body composition in weight lifters.

In this study, we have analyzed the effect of a HPKD specifically on the people who perform weight lifting exercises for recreational purposes. That's because a very little research has been done in the area of HPKD-adaptation among people who lift weights for enjoyment, relaxation and self-improvement. Research testing specifically the influence of HPKD on recreational weight lifters remains poorly investigated overall.

Therefore, we aimed to evaluate the effect of a high-protein version of ketogenic diet (HPKD) on resistance training performance and body composition in recreational weight lifters following a six-week resistance training (RT) program.

Hypothesis

A HPKD will lead to significant reductions in body fat mass and body fat percentage in recreationally-trained, healthy, men and women, aged 18 – 45, following 6 weeks of a supervised, standardized, resistance training (RT) program. Strength, power, muscle size, and

muscle hypertrophy will not be different between the high-protein ketogenic diet (HPKD) and normal diet (ND).

Objectives

The present study was designed with following objectives:

1. To investigate the effects of a high-protein ketogenic diet (HPKD) compared to a normal diet (ND) on changes in body composition, as body fat mass (FM), body fat percentage (BF%), and lean body mass (LBM) with bioelectrical impedance analysis (BIA) method following a standardized, 6-week weight lifting exercise program.

2. To investigate the effects of a high-protein ketogenic diet (HPKD) compared to a normal diet (ND) on changes in strength and power, measured by 1RM in the barbell back squat, deadlift and barbell bench press exercises.

METHODS

The materials and methods selected for the study have been discussed under the following headings:

1. Experimental Design
2. Participants
3. Testing Preparation
4. Diet Intervention
5. Training Protocol
6. Measurements
7. Statistical Analyses

Experimental Design: This study used an experimental research design comparing High-Protein Ketogenic Diet (HPKD) versus Normal Diet (ND). Forty-three men and women enrolled in the present diet-and-exercise controlled, parallel-arm and longitudinal study.

Participants were screened and informed of study requirements prior to enrollment. They completed dietary preference questionnaires and interviews with the investigators prior to beginning to determine groups and enhance compliance.

During the interview, participants were given an overview of each diet and self-selected into the HPKD or ND group (Control Group). Participants strongly in favor of or in opposition to the

HPKD (males, n = 13; females, n = 11) or ND (males, n = 10; females, n = 9) were grouped according to their corresponding preference.

The intervention consisted of the 6-week diet and strength training program. The testing was conducted immediately pre-intervention at the beginning of the week 1 and post-intervention at the end of the week 6. Participants in both groups completed 6-weeks of a strength training program and followed the diet component of the study simultaneously.

Participants

This research was conducted using both male and female participants because male and female bodies tend to respond in distinctly different ways to dietary, exercise and lifestyle interventions.

All participants were recruited from and trained at the fitness center in Ahmedabad. Approval for research with human subjects was obtained from the Selinus University, Italy, and all participants provided written informed consent prior to participation.

Eligible participants were aged 18 – 48 years, consistently exercising at least 4 days per week for the past 2 years, participating in both cardiovascular and resistance exercise at least twice per week for the past 2 years, reported themselves as healthy, and were willing and able to comply with study protocols.

Participants were excluded for tobacco use of any form, a history of medical events or currently having any serious medical condition, reporting any supplement or medication use that might affect study outcomes, regularly consuming > 12 alcoholic beverages per week, appearing unfit to handle the training program, inability to complete baseline testing, having a BMI > 30, or becoming < 85% compliant with training or dietary interventions.

Initially, 59 participants were recruited. However, 16 out of 59 participants withdrew due to various reasons. Before beginning the experiment, 4 individuals removed themselves from the experiment citing scheduling conflicts and/or excessive time commitment, 9 were removed during testing for inadequate performance in the 1RM strength test, 2 withdrew for

family/personal reasons, and 1 was injured outside of the study and could not continue pre-intervention tests. Therefore, total 43 participants (males, n = 23; females, n = 20) were enrolled for the experiment and all the enrolled participants successfully completed the experiment.

There were no significant differences ($p>0.05$) between HPKD and ND groups for any variables including age, height, weight, and body mass index at baseline. The average age, height, weight, and BMI of participants was 24.56 years (mean ± SD, Age = 24.56 ± 7.60 years), 167.53

centimeters (mean ± SD, Age = 167.53 ± 5.62 cm), 70.67 kg (mean ± SD, Weight = 70.67 ± 8.22 years), 25.11 kg/m^2 (mean ± SD, BMI = 25.11 ± 1.85 kg/m^2) respectively.

It is important to note that a BMI of 25 kg/m^2 internationally is considered the cut-off for a healthy body weight can no longer be applied to Indians. According to the American Diabetes Association (ADA), a BMI of 25 kg/m^2 is now considered a new BMI cut-off for overweight category for Indians. Participants Baseline Characteristics are presented in table 1.

Table 1: Participants Baseline Characteristics

Particulars	Total (n = 43)	HPKD (n = 24)	ND (n = 19)	P Value
Age (Years)	24.56 ± 7.60	24.63 ± 7.06	24.47 ± 8.44	0.9503
Height (cm)	167.53 ± 5.62	166.04 ± 5.20	169.42 ± 5.70	0.0521
Wight (kg)	70.67 ± 8.22	70.31 ± 8.60	71.13 ± 7.92	0.7457
Sex (M/F)	23/20	13/11	10/9	—
BMI (kg/m^2)	25.11 ± 1.85	25.41 ± 1.93	24.72 ± 1.73	0.2225

Data are presented as Mean ± SD. No significant difference between groups ($p > 0.05$).
HPKD, High-Protein Ketogenic Diet group; ND, Normal Diet Group.

Testing Preparation

Participants were asked to refrain from physical exercise, supplement, and alcohol 24-hours prior to their performance testing dates and follow a typical sleeping pattern. The ND group (Normal Diet / Control Group) participants were asked to consume a typical normal diet prior to testing. The HPKD group consumed a high-protein ketogenic diet prior to midpoint and post-intervention test dates. Participants were asked to consume adequate water intake prior to testing and encouraged to drink an 8-ounce glass of water prior to bed and upon waking. Participants otherwise arrived at least 8-hours fasted to complete the testing battery. All performance testing was completed in the participant's same pair of athletic sneakers.

Dietary Intervention

Each participant was prescribed a diet suited to personal energy requirements as determined by the ICMR formula for Indians [20].

Participants that self-selected into the HPKD diet intervention group were provided nutritional education on the types of foods, risks, and expected outcomes prior to the nutrition intervention.

The HPKD group performed a daily fasted, morning finger-prick to observe blood ketone and glucose levels. The level of carbohydrate, protein, and fat were adjusted to maintain blood ketone levels at an appropriate range. The main goal of the ketogenic diet was to enter a state of nutritional ketosis (blood ketones >.05). Body composition was not a primary concern, and participants were encouraged to eat to satiety.

The high-protein ketogenic diet consisted of 40g or less of carbohydrate per day and an estimated macronutrient breakdown of roughly 60% fat, 35% protein, and 5% carbohydrate. Protein intake was estimated at a moderate 2.0 gram per kg of body weight. Participants in the HPKD group were encouraged to meet their protein requirements through eating chicken, eggs, meat, fish and whey protein.

Major intake of carbohydrate was instructed to come from non-starchy (low-carbohydrate) vegetables, nuts, seeds, and berries. To encourage sufficient vegetable consumption as part of a more ideal HPKD composition, the HPKD group counted only “net” carbohydrates as a part of the 5% quantity in grams; fiber and erythritol were subtracted from total grams of carbohydrate that participants were permitted to consume. Consumption of other sugar alcohols (such as maltitol) was discouraged due to greater amounts being absorbed and metabolized compared to erythritol, but stevia and artificial sweeteners were permitted.

For fat intake, the HPKD group was asked to consume meats with greater fat content (e.g., chicken thigh), whole eggs, desiccated coconut, olive oil, coconut cream, peanut butter, almond butter, and full-fat, unsweetened dairy except for milk.

Participants in the ND group were prescribed to follow a normal diet that consists of 60% carbohydrates, 25% fat and 15% protein. The ND group equally emphasized consumption of vegetables and also emphasized fruits, whole grains, and other starches. Participants in ND were asked to choose leaner meats, low-fat dairy and salad dressing, use more egg whites than whole eggs, use only a necessary minimum amount of a vegetable oil for cooking, refrain from potato chips and similar snack foods, and to be conscious of the amount of nuts/seeds consumed. Please refer to table 2 for Macronutrient Ratio in Diets.

Table 2: Macronutrient Ratio in Diets

Macronutrients	HPKD (n=24)	ND (n=19)
CHO	5% *	60%
Protein	35% *	15%

Fat	60% *	25%

Data are presented as Percentage. * Significantly different from ND group ($p < 0.05$). HPKD, High-Protein Ketogenic Diet group; ND, Normal Diet Group.

The macronutrient composition of HPKD diet was significantly different ($p<0.05$) compared to the ND diet. The HPKD group consumed high-protein (35%), very low carbohydrate (5%) and high fat (60%) diet while the ND group consumed high carbohydrate (60%), moderate fat (25%) and moderate protein (15%). The graphical representation of macronutrient ratio is presented in figure 1 and figure 2.

All participants were asked to avoid alcohol during the study and to keep the quantity below 2 servings per day if consumption was considered unavoidable. Those in the HPKD group were asked to only consume wine or liquor under such circumstances. The commercially available web- and app-based software MyFitnessPal was used to track dietary intakes.

All participants were also asked to track dietary information 7 days per week due to the greater degree of restriction. Diet logs were turned in to investigators weekly for dietary coaching to maintain consistency, reach nutritional targets, and review for accuracy. Diet logs were also used to calculate energy and macronutrient intake values. Both groups had the ability to meet with a Registered Dietitian whenever they felt necessary.

Training Protocol

All participants in both the HPKD and ND groups were instructed to perform the same; standardized, 6-week strength training program at the fitness center in Ahmedabad.

The training protocol consisted of 6 days of strength training sessions per week. Each subject participated in 2 deadlift days, 2 squat days and 2 bench press days per week. The program lasted for 6 weeks. So each subject participated in total 36 strength training sessions in 6 weeks, meaning 12 deadlift days, 12 squat days and 12 bench press days in 6 weeks. The training volume was recorded during each exercise session by the participants and reviewed weekly by the research staff.

All training sessions included exercises mainly aimed at increasing strength and muscle mass. The standardized workout session of the deadlift day, squat day and bench press day are reported in table 3, table 4, and table 5.

Table 3: Deadlift Day Protocol

Deadlift Day			
Exercise	**Set (no)**	**Volume (kg)**	**Rest (min)**
Deadlift	Set 1	10 Reps @ 50% of 1RM	1 – 2
	Set 2	8 Reps @ 60% of 1RM	1 – 2
	Set 3	6 Reps @ 70% of 1RM	2 – 3
	Set 4	4 Reps @ 80% of 1RM	2 – 3
	Set 5	2 Reps @ 90% of 1RM	3 – 5
	Set 6	1 Rep @ 100% of 1RM	3 – 5
Barbell Row	Set 1	8 Reps @ 60% of 1RM	1 – 2
	Set 2	8 Reps @ 60% of 1RM	1 – 2
	Set 3	6 Reps @ 70% of 1RM	2 – 3
	Set 4	6 Reps @ 70% of 1RM	2 – 3
	Set 5	4 Reps @ 80% of 1RM	3 – 5
	Set 6	4 Reps @ 80% of 1RM	3 – 5
Wide Grip Pull-ups	Set 1	AMRAP	3 – 5
	Set 2	AMRAP	3 – 5
	Set 3	AMRAP	3 – 5
	Set 4	AMRAP	3 – 5
	Set 5	AMRAP	3 – 5
	Set 6	AMRAP	3 – 5
Biceps Curls	Set 1	10 Reps @ 50% of 1RM	1 – 2
	Set 2	10 Reps @ 50% of 1RM	1 – 2
	Set 3	8 Reps @ 60% of 1RM	1 – 2
	Set 4	8 Reps @ 60% of 1RM	1 – 2
	Set 5	6 Reps @ 70% of 1RM	1 – 2
	Set 6	6 Reps @ 70% of 1RM	1 – 2

AMRAP, As Many Reps As Possible; 1RM, One-Repetition Maximum.

Table 4: Squat Day Protocol

Exercise	Set (no)	Volume (kg)	Rest (min)
Back Squats	Set 1	10 Reps @ 50% of 1RM	1 – 2
	Set 2	8 Reps @ 60% of 1RM	1 – 2
	Set 3	6 Reps @ 70% of 1RM	2 – 3
	Set 4	4 Reps @ 80% of 1RM	2 – 3
	Set 5	2 Reps @ 90% of 1RM	3 – 5
	Set 6	1 Rep @ 100% of 1RM	3 – 5
Overhead Squats	Set 1	8 Reps @ 60% of 1RM	1 – 2
	Set 2	8 Reps @ 60% of 1RM	1 – 2
	Set 3	6 Reps @ 70% of 1RM	2 – 3
	Set 4	6 Reps @ 70% of 1RM	2 – 3
	Set 5	4 Reps @ 80% of 1RM	3 – 5
	Set 6	4 Reps @ 80% of 1RM	3 – 5
Jump Squats	Set 1	AMRAP	3 – 5
	Set 2	AMRAP	3 – 5
	Set 3	AMRAP	3 – 5
	Set 4	AMRAP	3 – 5
	Set 5	AMRAP	3 – 5
	Set 6	AMRAP	3 – 5
Calf Raises	Set 1	10 Reps @ 50% of 1RM	1 – 2
	Set 2	10 Reps @ 50% of 1RM	1 – 2
	Set 3	8 Reps @ 60% of 1RM	1 – 2
	Set 4	8 Reps @ 60% of 1RM	1 – 2
	Set 5	6 Reps @ 70% of 1RM	1 – 2
	Set 6	6 Reps @ 70% of 1RM	1 – 2

AMRAP, As Many Reps As Possible; 1RM, One-Repetition Maximum.

Table 5: Bench Press Day

Exercise	Set (no)	Volume (kg)	Rest (min)
Barbell Bench Press	Set 1	10 Reps @ 50% of 1RM	1 – 2
	Set 2	8 Reps @ 60% of 1RM	1 – 2
	Set 3	6 Reps @ 70% of 1RM	2 – 3

	Set 4	4 Reps @ 80% of 1RM	2 – 3
	Set 5	2 Reps @ 90% of 1RM	3 – 5
	Set 6	1 Rep @ 100% of 1RM	3 – 5
Military Press	Set 1	8 Reps @ 60% of 1RM	1 – 2
	Set 2	8 Reps @ 60% of 1RM	1 – 2
	Set 3	6 Reps @ 70% of 1RM	2 – 3
	Set 4	6 Reps @ 70% of 1RM	2 – 3
	Set 5	4 Reps @ 80% of 1RM	3 – 5
	Set 6	4 Reps @ 80% of 1RM	3 – 5
Bar Dips	Set 1	AMRAP	3 – 5
	Set 2	AMRAP	3 – 5
	Set 3	AMRAP	3 – 5
	Set 4	AMRAP	3 – 5
	Set 5	AMRAP	3 – 5
	Set 6	AMRAP	3 – 5
Chest Fly	Set 1	10 Reps @ 50% of 1RM	1 – 2
	Set 2	10 Reps @ 50% of 1RM	1 – 2
	Set 3	8 Reps @ 60% of 1RM	1 – 2
	Set 4	8 Reps @ 60% of 1RM	1 – 2
	Set 5	6 Reps @ 70% of 1RM	1 – 2
	Set 6	6 Reps @ 70% of 1RM	1 – 2

AMRAP, As Many Reps As Possible; 1RM, One-Repetition Maximum.

Every strength training session consisted of the three types of exercise sets that are presented in Table 6.

Table 6: Types of Exercise Sets

Type of Set	Purpose	Instructions to Participants
Low-volume, High-intensity	For increasing strength	Perform 1 Rep @ 100% of 1RM and 2 Reps @ 90% of 1RM with longer-rest of 3 – 5 minutes.

Medium-volume, Moderate-intensity	For hypertrophy	Perform 4 Reps @ 80% of 1RM and 6 Reps @ 70% of 1RM with medium-rest of 2 – 3 minutes.
High-volume, Low-intensity	For increasing muscle endurance	Perform 8 Reps @ 60% of 1RM and 10 Reps @ 50% of 1RM with short-rest of 1 – 2 minutes.

If participants reached muscular failure prior to completing the required number of repetitions, a training partner or a trainer assisted until the target number of repetitions were achieved up to a maximum of 2 forced repetitions.

Weight was increased from set-to-set until a load inducing muscular failure was found. Moreover, all participants were instructed to mentally focus on the target muscles of each exercise.

All participants were instructed to perform a dynamic warmup lasting 5 – 10 minutes prior to all training sessions. They were trained to successfully move the weight through the required range of motion as the goal. For all other resistance training exercises, the goal of the movement was to fully contract the primary muscles through a complete range of motion with minimal incorporation of secondary, assistance muscles, all-the-while trying to maintain constant tension in the target muscles to a point of muscular failure.

Completed weight and repetitions were reported by the participants each week to ensure compliance with training. Supervised training sessions were offered to subjects throughout the week with a Certified Strength and Conditioning Specialist. Subjects were instructed to attend at least one supervised session every week.

Compliance was monitored via the supervised training sessions and by weekly collection of the subjects' workout logs. The research staff reviewed logs each week and recommended training loads for the first set of each exercise for the subsequent week.

Measurements

All measurements were performed at the fitness center in Ahmedabad. Height was measured without shoes to the nearest 0.5 cm with a stadiometer. Weight was obtained in the morning on an empty stomach using a calibrated balance scale and estimated to the nearest 100g. Participants

were instructed to wear light weight clothes while measuring weight. Height and weight were used to calculate body mass index (BMI) (kg/m2). The amount and composition of body fat mass (FM) and fat-free mass (FFM) was calculated using bioelectrical impedance analysis (BIA) method with InBody 770 Body Composition Analyser.

Tests of strength training performance included One Repetition Maximum (1RM) method. The 1RM tests were conducted with the assistance of a Certified Strength and Conditioning Specialist and recorded by the researchers. Maximal strength 1 RM strength was determined for the squat, deadlift and bench press using a free weight barbell.

For the squat, each participant descended to the parallel position by flexing the knees and hips until the greater trochanter of the femur reached the same horizontal plane as the superior border of the patella and then completed the movement by ascending to the upright and standing position. Proper form throughout the lift was evaluated to verify a proper lift.

For the bench press, each participant eccentrically lowered the bar until it contacted the chest and then upon touching (no bouncing) the chest the bar was then returned to the starting position with fully extended elbows. Any trials failing to meet standardized technique criteria were not counted as a good lift.

For deadlift, each participant ensured the head and neck are in a neutral position with eyes facing forward (avoid rounding of the spine) and knees in line with the toes. To perform the deadlift, participants pulled the bar straight up by extending the knees and hips in a slow, smooth and continuous movement, until the legs were straight and the body upright.

The procedure for the 1 RM testing consisted of a warm up of 5–10 repetitions with approximately 40–60% of perceived maximum, a second set consisting of three to five repetitions with approximately 60–80% of perceived maximum followed by one repetition attempts with progressively heavier weight until the 1 RM was achieved. This was determined within 3-5 maximal attempts and 3-5 minutes of rest was allowed between efforts.

All participants in the HPKD group were instructed to conduct a urine test to assess baseline β-hydroxybutyrate (β-OHB) levels. These levels assessed the levels of ketones in the urine. The HPKD group was instructed to fill 50ml urine sample in the sample cup with urine. The urine tests were done at baseline and weeks one, three, and six of the intervention.

Statistical Analyses

All data are presented as mean ± SD. Means and standard deviations were calculated for each variable. Significance was set a priori with an alpha of 0.05.

The independent variables were the 6-week high-protein ketogenic diet and normal diet. The dependent variables were measures of body composition (body fat %, weight, lean body mass, and fat mass) and measures of 1RM strength (deadlift, back squat and bench press).

An independent *t-test* was conducted to determine the presence of any significant differences at baseline between groups (HPKD vs ND). A paired samples *t-test* was used to determine the significant differences within groups (pre intervention vs post intervention). To examine statistical differences within groups, change scores were computed for each dependent variable (post minus pre-intervention value).

RESULTS

The purpose of this experiment was to investigate whether a high-protein ketogenic diet (HPKD) is an effective strategy to decrease fat mass (FM), and maintain lean body mass (LBM) without compromising strength training performance in recreational, weight lifters. The experiment started on Monday, 14th February, 2022 and ended on Sunday, 27th March, 2022. It lasted for 6 weeks.

The core findings of this study have been presented under the following headings:

1. Dietary and Training Compliance
2. Dietary Intake Comparison
3. Caloric Deficit Comparison
4. Training Volume Results
5. Pre and Post Intervention Changes in Strength in HPKD group
6. Pre and Post Intervention Changes in Strength in ND group
7. Strength Comparison between HPKD and ND group
8. Pre and Post Intervention Body Composition Changes in HPKD group
9. Pre and Post Intervention Body Composition Changes in ND group
10. Body Composition Comparison between HPKD and ND groups
11. Pre and Post Intervention BMR Changes in HPKD group
12. Pre and Post Intervention BMR Changes in ND group
13. BMR Comparison between HPKD and ND groups

1. Dietary and Training Compliance

No significant differences ($p>0.05$) were found in dietary and training compliance between HPKD and ND groups (Table 7).

Table 7: Dietary and Training Compliance

Compliance	Total (n = 43)	HPKD (n = 24)	ND (n = 19)	P Value
Dietary Compliance (%)	93.33 ± 3.60	93.19 ± 3.87	93.50 ± 3.32	0.77754362
Training Compliance (%)	94.16 ± 3.82	94.32 ± 3.68	93.95 ± 4.09	0.75663418

Data are presented as Mean ± SD. No significant difference between groups ($p > 0.05$).
HPKD, High-Protein Ketogenic Diet group; ND, Normal Diet Group.

However, training compliance in the HPKD group was 0.37% better than the ND group and dietary compliance in the ND group was 0.31% better than the HPKD group (Figure 3).

2. Dietary Intake Comparison

Diets were well-tolerated, and excellent compliance was observed for both diets.

The HPKD (males, n = 13; females, n = 11) followed a diet with 60% fat, 35% protein and 5% carbohydrates. Those in ND group (males, n = 10; females, n = 9) maintained a normal diet with 25% fat, 15% protein and 60% carbohydrates (Table 8).

Table 8: Dietary Intake Comparison

Particulars	Sex	Total (n = 43) (M = 23) (F = 20)	HPKD (n = 24) (M = 13) (F = 11)	ND (n = 19) (M = 10) (F = 9)
Energy Needs (kcal/d)	**M + F**	2433.49 ± 261.22	2427.82 ± 283.20	2440.65 ± 238.00
	Male	2636.17 ± 153.24	2659.10 ± 135.73	2606.37 ± 176.33
	Female	2200.40 ± 129.36	2154.50 ± 103.19	2256.51 ± 141.39
Diet Calories (kcal/d)	**M + F**	2311.81 ± 248.16	2306.43 ± 269.04	2318.61 ± 226.10
	Male	2504.36 ± 145.58	2526.14 ± 128.95	2476.05 ± 167.51
	Female	2090.38 ± 122.89	2046.77 ± 98.03	2143.69 ± 134.32
CHO (grams/d)	**M + F**	169.77 ± 161.82	28.83 ± 3.36 *	347.79 ± 33.91
	Male	179.33 ± 173.00	31.58 ± 1.61 *	371.41 ± 25.13

	Female	158.77 ± 151.63	25.58 ± 1.23 *	321.55 ± 20.15
CHO (%)	**M + F**	-	5 % ± 0	60 % ± 0
	Male	-	5 % ± 0	60 % ± 0
	Female	-	5 % ± 0	60 % ± 0
Protein (grams/d)	**M + F**	151.06 ± 60.54	201.81 ± 23.54 *	86.95 ± 8.48
	Male	165.30 ± 65.63	221.04 ± 11.28 *	92.85 ± 6.28
	Female	134.68 ± 50.87	179.09 ± 8.58 *	80.39 ± 5.04
Protein (%)	**M + F**	-	35 % ± 0	15 % ± 0
	Male	-	35 % ± 0	15 % ± 0
	Female	-	35 % ± 0	15 % ± 0
Fat (grams/d)	**M + F**	114.28 ± 47.00	153.76 ± 17.94 *	64.41 ± 6.28
	Male	125.09 ± 50.98	168.41 ± 8.60 *	68.78 ± 4.65
	Female	101.84 ± 39.61	136.45 ± 6.54 *	59.55 ± 3.73
Fat (%)	**M + F**	-	60 % ± 0	25 % ± 0
	Male	-	60 % ± 0	25 % ± 0
	Female	-	60 % ± 0	25 % ± 0

Data are presented as Mean ± SD. * significantly different from ND group ($p < 0.05$). HPKD, High-Protein Ketogenic Diet group; ND, Normal Diet Group.

The intake of fat, protein, and carbohydrates (macronutrient composition) in HPKD diet was significantly different ($p<0.05$) compared to the ND diet.

The HPKD group consumed high-protein, very low carbohydrate and high fat diet. On the other hand, the ND group consumed high carbohydrate, moderate fat and low protein diet (Figure 4).

3. Caloric Deficit Comparison

All participants in both groups were prescribed a diet with 5% caloric deficit so there was no significant difference ($p>0.05$) in the mean of calorie deficit between groups (Figure 5).

The average caloric deficit of HPKD was 121.39 kcal per day (mean ± SD, Caloric Deficit = 121.39 ± 14.16 kcal/d) and ND was 122.03 kcal per day (mean ± SD, Caloric Deficit = 122.03 ± 11.90 kcal/d) (Table 9).

Table 9: Caloric Deficit Data

Particulars	Sex	Total (n = 43) (M = 23) (F = 20)	HPKD (n = 24) (M = 13) (F = 11)	ND (n = 19) (M = 10) (F = 9)
Caloric Deficit (kcal/d)	**M + F**	-121.67 ± 13.06	-121.39 ± 14.16	-122.03 ± 11.90
	Male	-131.81 ± 7.66	-132.95 ± 6.79	-130.32 ± 8.82
	Female	-110.02 ± 6.47	-107.72 ± 5.16	-112.83 ± 7.07
Caloric Deficit (%)	**M + F**	-	5 % ± 0	5 % ± 0
	Male	-	5 % ± 0	5 % ± 0
	Female	-	5 % ± 0	5 % ± 0

Data are presented as Mean ± SD. No significant difference between groups ($p > 0.05$).
HPKD, High-Protein Ketogenic Diet group; ND, Normal Diet Group.

4. Training Volume Comparison

We found no significant difference ($p>0.05$) in the means of back squat, deadlift and bench press volume between HPKD and ND groups (Table 10).

Table 10: Six Week Training Volume Data

Exercise	Sex	Total (n = 43) (M = 23) (F = 20)	HPKD (n = 24) (M = 13) (F = 11)	ND (n = 19) (M = 10) (F = 9)
Back Squat (kg/6w)	**M + F**	15516.28 ± 4752.59	15800.00 ± 5012.68	15157.89 ± 4511.51
	Male	19565.22 ± 2243.09	20030.77 ± 2100.55	18960.00 ± 2386.63
	Female	10860.00 ± 1198.42	10800.00 ± 1314.53	10933.33 ± 1113.55

Deadlift (kg/6w)	**M + F**	19227.91 ± 8851.11	19950.00 ± 9075.77	18315.79 ± 8716.35
	Male	27130.43 ± 2676.91	27969.23 ± 1724.04	26040.00 ± 3349.03
	Female	10140.00 ± 1531.56	10472.73 ± 1866.06	9733.33 ± 938.08
Bench Press (kg/6w)	**M + F**	14986.05 ± 5180.44	15350.00 ± 5515.91	14526.32 ± 4831.48
	Male	19408.70 ± 2471.27	20030.77 ± 2317.82	18600.00 ± 2545.58
	Female	9900.00 ± 1159.85	9818.18 ± 1177.98	10000.00 ± 1200.00

Data are presented as Mean ± SD. * Significantly different from ND group ($p < 0.05$).
HPKD, High-Protein Ketogenic Diet group; ND, Normal Diet Group.

However, the average back squat, deadlift and bench press volume of HPKD group was relatively better compared to ND group (Figure 6).

5. Pre and Post Intervention Changes in Strength in HPKD group

There was a significant effect of HPKD ($p<0.05$) on strength for all the variables (back squat, deadlift and bench press) between PRE and POST intervention (Figure 7).

The HPKD group experienced a significant increase in 1RM for all three lifts (bench press: 8.13 ± 4.85 kg, $p < 0.05$; back squat: 5.0 ± 2.95 kg, $p < 0.05$; deadlift: 8.13 ± 7.04 kg, $p < 0.05$) (Table 11).

Table 11: Pre and Post Intervention Changes in Strength in HPKD group

Parameter	**Data**	**HPKD (n=24) (M = 13) (F = 11)**		
		M + F	**Male**	**Female**
Back Squat 1RM (kg)	**Pre**	60.83 ± 20.09	78.08 ± 6.63	40.45 ± 5.68
	Post	65.83 ± 20.89 *	83.46 ± 8.75 *	45.00 ± 5.48 *
	Changes	5.00 ± 2.95	5.38 ± 3.80	4.55 ± 1.51
	P Value	0.00000002	0.00025661	0.00000159

Deadlift 1RM (kg)	**Pre**	75.00 ± 31.83	103.08 ± 6.63	41.82 ± 6.43
	Post	83.13 ± 37.82 *	116.54 ± 7.18 *	43.64 ± 7.78 *
	Changes	8.13 ± 7.04	13.46 ± 4.27	1.82 ± 3.37
	P Value	0.00000939	0.00000009	0.10392052
Bench Press 1RM (kg)	**Pre**	55.83 ± 20.09	73.08 ± 6.63	35.45 ± 5.68
	Post	63.96 ± 22.98 *	83.46 ± 9.66 *	40.91 ± 4.91 *
	Changes	8.13 ± 4.85	10.38 ± 5.19	5.45 ± 2.70
	P Value	0.00000003	0.00001063	0.00005310

Data are presented as Mean ± SD. * Indicates a significant difference ($p < 0.05$) in the post intervention data. HPKD, High-Protein Ketogenic Diet group; ND, Normal Diet Group, 1RM, One-Repetition Maximum.

6. Pre and Post Intervention Changes in Strength in ND group

It is important to note that both groups experienced increases in all three lifts tested. The ND group also showed a statistically significant effect ($p<0.05$) on strength between PRE and POST intervention (Figure 8).

There was a significant increase in 1RM for all the variables (bench press: 6.58 ± 2.39 kg, $p < 0.05$; back squat: 4.21 ± 1.87 kg, $p < 0.05$; deadlift: 5.26 ± 5.89 kg, $p < 0.05$) (Table 12).

Table 12: Pre and Post Intervention Changes in Strength in ND group

Parameter	**Data**	**ND (n = 19) (M = 10) (F = 9)**		
		M + F	**Male**	**Female**
Back Squat 1RM (kg)	**Pre**	58.95 ± 19.26	75.50 ± 8.96	40.56 ± 4.64
	Post	63.16 ± 18.80 *	79.00 ± 9.94 *	45.56 ± 4.64 *
	Changes	4.21 ± 1.87	3.50 ± 2.42	5.00 ± 0.00
	P Value	0.00000001	0.00132295	0.00000244
Deadlift	**Pre**	71.05 ± 32.56	100.50 ± 8.96	38.33 ± 2.50

1RM (kg)	**Post**	76.32 ± 36.32 *	108.50 ± 13.95 *	40.56 ± 3.91 *
	Changes	5.26 ± 5.89	8.00 ± 6.75	2.22 ± 2.64
	P Value	0.00105547	0.00456755	0.03526520
Bench Press 1RM (kg)	**Pre**	53.95 ± 19.26	70.50 ± 8.96	35.56 ± 4.64
	Post	60.53 ± 20.13 *	77.50 ± 10.61 *	41.67 ± 5.00 *
	Changes	6.58 ± 2.39	7.00 ± 2.58	6.11 ± 2.20
	P Value	0.00000001	0.00001268	0.00003303

Data are presented as Mean ± SD. * Indicates a significant difference ($p < 0.05$) in the post intervention data. HPKD, High-Protein Ketogenic Diet group; ND, Normal Diet Group, 1RM, One-Repetition Maximum.

7. Strength Comparison between HPKD and ND groups

No significant effects were observed ($p > 0.05$) on strength for any variables compared (back squat: $p = 0.29$; deadlift: $p = 0.15$; bench press: $p = 0.18$) between HPKD and ND groups (Table 13).

Table 13: Strength Comparison between HPKD and ND groups

Parameter	**HPKD (n=24)**			**ND (n=19)**			**P-Value**
	Pre	**Post**	**Change**	**Pre**	**Post**	**Change**	
Back Squat 1RM (kg)	60.83 ± 20.09	65.83 ± 20.89	5.00 ± 2.95	58.95 ± 19.26	63.16 ± 18.80	4.21 ± 1.87	0.29
Deadlift 1RM (kg)	75.00 ± 31.83	83.13 ± 37.82	8.13 ± 7.04	71.05 ± 32.56	76.32 ± 36.32	5.26 ± 5.89	0.15
Bench Press 1RM (kg)	55.83 ± 20.09	63.96 ± 22.98	8.13 ± 4.85	53.95 ± 19.26	60.53 ± 20.13	6.58 ± 2.39	0.18

Data are presented as Mean ± SD. No significant difference between groups ($p > 0.05$). HPKD, High-Protein Ketogenic Diet group; ND, Normal Diet Group, 1RM, One-Repetition Maximum.

However, the HPKD group experienced better increments in strength for all three lifts (back squat: +5kg/6w, deadlift: +8.13kg/6w, bench press: +8.13kg/6w) than the ND group (back squat: +4.21kg/6w, deadlift: +5.26kg/6w, bench press: +6.58kg/6w) (Figure 9).

8. Pre and Post Intervention Changes in Body Composition in HPKD group

There was a significant effect of HPKD ($p<0.05$) on body weight (kg), body fat (%), fat mass (kg), and lean mass (kg) between PRE and POST intervention (Figure 10, Figure 11, Figure 12, and Figure 13).

The HPKD group lost 1.55kg weight (mean ± SD, Weight: -1.55 ± 2.38 kg, $p<0.05$), dropped 3.58% body fat ((mean ± SD, Body Fat: -3.58 ± 0.85 kg, $p<0.05$), reduced 2.80kg fat mass (mean ± SD, Fat Mass: -2.80 ± 0.87 kg, $p<0.05$), and increased 1.25kg lean mass (mean ± SD, Lean Mass:1.25 ± 2.02 kg, $p<0.05$) in 6 weeks (Table 14).

Table 14: Pre and Post Intervention Changes in Body Composition in HPKD group

Variable	Data	HPKD (n=24) (M = 13) (F = 11)		
		M + F	Male	Female
Weight (kg)	Pre	70.31 ± 8.60	76.12 ± 6.42	63.44 ± 4.98
	Post	68.76 ± 7.72 *	74.26 ± 5.22 *	62.25 ± 4.29 *
	Change	-1.55 ± 2.38	-1.86 ± 2.09	-1.19 ± 2.75
	P Value	0.004130	0.007711	0.181941
Body Fat (%)	Pre	18.35 ± 4.71	21.33 ± 3.66	14.83 ± 3.13
	Post	14.77 ± 4.55 *	17.74 ± 3.59 *	11.27 ± 2.68 *
	Change	-3.58 ± 0.85	-3.59 ± 0.91	-3.56 ± 0.82
	P Value	0.000001	0.000001	0.000001
Fat Mass (kg)	Pre	13.27 ± 4.95	16.44 ± 4.08	9.52 ± 2.81
	Post	10.47 ± 4.35 *	13.33 ± 3.58 *	7.09 ± 2.23 *
	Change	-2.80 ± 0.87	-3.11 ± 0.79	-2.43 ± 0.85
	P Value	0.000001	0.000001	0.000003

Lean Mass (kg)	**Pre**	57.04 ± 3.96	59.68 ± 2.59	53.92 ± 2.88
	Post	58.29 ± 3.75 *	60.93 ± 1.99 *	55.16 ± 2.80 *
	Change	1.25 ± 2.02	1.25 ± 1.87	1.24 ± 2.29
	P Value	0.006147	0.033036	0.101526

Data are presented as Mean ± SD. * Indicates a significant difference ($p < 0.05$) in the post intervention data. HPKD, High-Protein Ketogenic Diet group; ND, Normal Diet Group.

9. Pre and Post Intervention Changes in Body Composition in ND group

Results from ND group also showed a statistically significant difference ($p<0.05$) on body weight (kg), body fat (%), fat mass (kg), and lean mass (kg) between PRE and POST intervention (Figure 14).

The ND group lost 1.97kg weight, dropped 3.70% body fat, reduced 2.96kg fat mass and increased 0.99kg lean mass on average in 6 weeks (Table 15).

Table 15: Pre and Post Intervention Changes in Body Composition in ND group

Variable	**Data**	**ND (n = 19) (M = 10) (F = 9)**		
		M + F	**Male**	**Female**
Weight (kg)	**Pre**	71.13 ± 7.92	73.62 ± 8.34	68.36 ± 6.82
	Post	69.16 ± 7.18 *	72.14 ± 6.93 *	65.85 ± 6.21 *
	Change	-1.97 ± 1.90	-1.48 ± 2.44	-2.51 ± 0.88
	P Value	0.000266	0.087437	0.000027
Body Fat (%)	**Pre**	17.48 ± 4.06	18.94 ± 4.31	15.86 ± 3.26
	Post	13.77 ± 3.84 *	15.43 ± 3.85 *	11.94 ± 3.05 *
	Change	-3.70 ± 0.81	-3.51 ± 0.90	-3.92 ± 0.67

	P Value	0.000001	0.000001	0.000001
Fat Mass (kg)	**Pre**	12.73 ± 4.43	14.25 ± 4.87	11.03 ± 3.35
	Post	9.77 ± 3.70 *	11.34 ± 3.83 *	8.02 ± 2.79 *
	Change	-2.96 ± 1.01	-2.91 ± 1.26	-3.02 ± 0.71
	P Value	0.000001	0.000047	0.000001
Lean Mass (kg)	**Pre**	58.40 ± 3.66	59.37 ± 3.61	57.33 ± 3.61
	Post	59.39 ± 3.79 *	60.80 ± 3.51 *	57.84 ± 3.64 *
	Change	0.99 ± 1.41	1.43 ± 1.72	0.50 ± 0.80
	P Value	0.006797	0.027923	0.094883

Data are presented as Mean ± SD. * Indicates a significant difference ($p < 0.05$) in the post intervention data. HPKD, High-Protein Ketogenic Diet group; ND, Normal Diet Group.

10. Body Composition Comparison between HPKD and ND groups

Body composition analysis showed that both groups decreased body weight by approximately 2% (HPKD: from 70.31 to 68.76 kg, ND: from 71.13 to 69.16 kg) in 6 weeks. Although these differences were not statistically significant ($p > 0.05$), they induced a relative change in body composition. There were notable changes in body fat percentage, fat mass, and lean mass in both groups. The HPKD group dropped 3.58% body fat, reduced 2.80kg fat mass and increased 1.25kg lean mass. On the other hand, the ND group also dropped 3.70% body fat, reduced 2.96kg fat mass and increased 0.97kg lean mass in 6 weeks (Table 16).

Table 16: Body Composition between HPKD and ND groups

Parameter	**HPKD (n=24)**			**ND (n=19)**			**P-Value**
	Pre	**Post**	**Change**	**Pre**	**Post**	**Change**	
Body Weight (kg)	70.31 ± 8.60	68.76 ± 7.72	-1.55 ± 2.38	71.13 ± 7.92	69.16 ± 7.18	-1.97 ± 1.90	0.524471
Body Fat (%)	18.35 ± 4.71	14.77 ± 4.55	-3.58 ± 0.85	17.48 ± 4.06	13.77 ± 3.84	-3.70 ± 0.81	0.623079

Fat Mass (kg)	13.27 ± 4.95	10.47 ± 4.35	-2.80 ± 0.87	12.73 ± 4.43	9.77 ± 3.70	-2.96 ± 1.01	0.583520
Lean Mass (kg)	57.04 ± 3.96	58.29 ± 3.75	1.25 ± 2.02	58.40 ± 3.66	59.39 ± 3.79	0.99 ± 1.41	0.625995

Data are presented as Mean ± SD. No significant difference between groups ($p > 0.05$). HPKD, High-Protein Ketogenic Diet group; ND, Normal Diet Group.

However, no significant differences were observed ($p > 0.05$) in any variables between HPKD and ND groups (Weight: $p = 0.52$, Body Fat Percentage: $p = 0.62$, Fat Mass: $p = 0.58$, Lean Mass: $p = 0.63$) (Figure 15).

11. Pre and Post Intervention Changes in BMR in HPKD group

The HPKD group demonstrated a significant improvement ($p<0.05$) in basal metabolic rate (BMR: +4.44%) between pre and post intervention (Figure 16).

Within HPKD group, the average increment of BMR in females was +5.40%, which was 1.61% higher than the average increment of BMR in males (Male BMR: +3.79%) (Table 17).

Table 17: Pre and Post Intervention Changes in BMR in HPKD group

Parameter	Data	M + F (n = 24)	Male (n = 13)	Female (n = 11)
BMR (kcal/d)	**Pre**	1734.16 ± 202.29	1899.35 ± 96.95	1538.93 ± 73.71
	Post	1810.92 ± 191.64 *	1971.33 ± 78.79 *	1621.34 ± 63.56 *
	Changes	76.76 ± 35.62	71.97 ± 31.63	82.41 ± 40.66
	% Change	4.44	3.79	5.40
	P-Value	0.000001	0.000003	0.000052

Data are presented as Mean ± SD. * Indicates a significant difference ($p < 0.05$) in the post intervention data. HPKD, High-Protein Ketogenic Diet group; ND, Normal Diet Group.

12. Pre and Post Intervention Changes in BMR in ND group

ND group also showed a statistically significant increment ($p<0.05$) in basal metabolic rate (BMR: +4.07%) between pre and post intervention (Figure 17).

Within ND group, the average increment of BMR in females was +3.91%, which was 0.23% lower than the average increment of BMR in males (Male BMR: +4.14%) (Table 18).

Table 18: Pre and Post Intervention Changes in BMR in ND group

Parameter	Data	M + F (n = 19)	Male (n = 10)	Female (n = 9)
BMR (kcal/d)	Pre	1743.32 ± 170.00	1861.69 ± 125.95	1611.79 ± 101.00
	Post	1813.94 ± 166.32 *	1939.31 ± 104.60 *	1674.63 ± 91.90 *
	Changes	70.62 ± 28.53	77.62 ± 36.91	62.84 ± 13.03
	% Change	4.07	4.14	3.91
	P-Value	0.000000	0.000094	0.000001

Data are presented as Mean ± SD. * Indicates a significant difference ($p < 0.05$) in the post intervention data. HPKD, High-Protein Ketogenic Diet group; ND, Normal Diet Group.

13. BMR Comparison between HPKD and ND groups

The BMR of participants was calculated pre and post intervention using the InBody770 Body Composition Analyzer. The InBody770 uses the Cunningham equation to determine the BMR using a known regression equation based on the amount of Lean Mass a participant has. Therefore, when the participants gained the Lean Mass (HPKD: 1.25kg; ND: 0.99kg) during the intervention, their BMR (HPKD: +4.44%; ND: +4.07%) also increased (Table 19).

Table 19: Changes in BMR between HPKD and ND

Parameter	Data	HPKD (n=24) (M = 13) (F = 11)			ND (n = 19) (M = 10) (F = 9)			P-Value
		M + F	Male	Female	M + F	Male	Female	
BMR (kcal/d)	Change (kcal)	76.76 ± 35.62	71.97 ± 31.63	82.41 ± 40.66	70.62 ± 28.53	77.62 ± 36.91	62.84 ± 13.03	0.47
BMR (%change)	Change (%)	4.44	3.79	5.4	4.07	4.14	3.91	

Data are presented as Mean ± SD. No significant difference between groups ($p > 0.05$). HPKD, High-Protein Ketogenic Diet group;
ND, Normal Diet Group.

However, there was no significant change ($p > 0.05$) in BMR between HPKD and ND groups ($p = 0.47$). Both groups demonstrated nearly similar results in BMR (Figure 18).

DISCUSSION

The aim of the current study was to examine the effects of a High-Protein Ketogenic Diet (HPKD) on strength training performance and body composition in recreational weight lifters. The main findings of the current study were that consuming a HPKD and following a strength training protocol for six weeks can help reduce weight, drop %BF, decrease FM, increase LM, and gain 1RM strength in deadlift, back squat and bench press.

The present study revealed that adhering to a HPKD combined with Strength Training for 6 weeks resulted in significant decreases in weight, body fat percentage, and fat mass compared to the pre intervention measurements, while significantly improving lean body mass and basal

metabolic rate. Additionally, all subjects significantly increased total strength training performance and overall power.

This is truly a novel finding, highlighting the potential for high protein ketogenic diets in weight lifting populations. To our knowledge, the present study is the first that has assessed the use of a HPKD combined with Strength Training to evaluate body composition and performance outcomes.

The discussion has been presented under the following headings:

1. Body Composition
2. Strength Performance
3. Basal Metabolic Rate
4. Limitation of the Study
5. Strength of the Study

Body Composition

The use of a HPKD to improve body composition measures has been a topic of interest for many years. There have been numerous studies comparing the weight loss effects of following a high-fat ketogenic diet versus a low-fat diet, showing far superior results in the former.

Similarly, in the present study, the HPKD group lost an average of 1.55kg weight (mean ± SD, Weight: -1.55 ± 2.38 kg, $p<0.05$), dropped 3.58% body fat (mean ± SD, Body Fat: -3.58 ± 0.85 kg, $p<0.05$), reduced 2.80kg fat mass (mean ± SD, Fat Mass: -2.80 ± 0.87 kg, $p<0.05$), and increased 1.25kg lean mass (mean ± SD, Lean Mass:1.25 ± 2.02 kg, $p<0.05$) in 6 weeks compared to pre intervention measurements.

The post intervention results from a present study concluded that a HPKD diet was significantly more effective in reducing body weight (kg), body fat (%), and fat mass (kg), while increasing lean mass (kg) compared to the pre intervention measurements.

However, there were no significant differences ($p > 0.05$) found in any variables between HPKD and ND groups (Weight: $p = 0.52$, Body Fat Percentage: $p = 0.62$, Fat Mass: $p = 0.58$, Lean Mass: $p = 0.63$). Body composition analysis showed that both groups decreased body weight by approximately 2% (HPKD: from 70.31 to 68.76 kg, ND: from 71.13 to 69.16 kg) in 6 weeks.

Although these differences were not statistically significant ($p > 0.05$), they induced a relative change in body composition. There were notable changes in body fat percentage, fat mass, and lean mass in both groups. The HPKD group dropped 3.58% body fat, reduced 2.80kg fat mass

and increased 1.25kg lean mass. On the other hand, the ND group also dropped 3.70% body fat, reduced 2.96kg fat mass and increased 0.97kg lean mass in 6 weeks.

It is important to note that all participants in both groups were prescribed a diet with 5% caloric deficit so there was no significant difference ($p>0.05$) in the mean of calorie deficit between groups.

Strength Performance

There was a significant effect of HPKD ($p<0.05$) on strength for all the variables (back squat, deadlift and bench press) between pre and post intervention. The HPKD group experienced a significant increase in strength (1RM) for all three lifts (bench press: 8.13 ± 4.85 kg, $p < 0.05$; back squat: 5.0 ± 2.95 kg, $p < 0.05$; deadlift: 8.13 ± 7.04 kg, $p < 0.05$).

However, no significant effects were observed ($p > 0.05$) on strength for any variables compared (back squat: $p = 0.29$; deadlift: $p = 0.15$; bench press: $p = 0.18$) between HPKD and ND groups. It is important to note that the HPKD group experienced relatively better increments in strength for all three lifts (back squat: +5kg/6w, deadlift: +8.13kg/6w, bench press: +8.13kg/6w) than the ND group (back squat: +4.21kg/6w, deadlift: +5.26kg/6w, bench press: +6.58kg/6w).

Additionally, we found no significant difference ($p>0.05$) in the means of back squat, deadlift and bench press volume between HPKD and ND groups. The average back squat, deadlift and bench press volume of HPKD group was relatively better compared to ND group.

Basal Metabolic Rate

The HPKD group demonstrated a significant improvement ($p<0.05$) in basal metabolic rate (BMR: +4.44%) between pre and post intervention measurements. Within HPKD group, the average increment of BMR in females was +5.40%, which was 1.61% higher than the average increment of BMR in males (Male BMR: +3.79%). However, there was no significant change ($p > 0.05$) in BMR between HPKD and ND groups ($p = 0.47$). Both groups demonstrated nearly similar results in the increment of BMR.

Limitation of the Study

The present study is not without limitations. The number of participants and sex differences influenced variance and reduced observed power, making it difficult to detect changes. Caution should be used when interpreting the results of the present study, as the sample size restricts the generalizability. The relatively small sample size in the HPKD and ND groups greatly affects the statistical significance of the study. Another limitation of the current study is that compliance

and adherence was self-reported. Furthermore, the ketone result (negative or positive ketone production) was self-measured. Even though ketone production was monitored by the researchers; all HPKD participants were not producing ketones for the entire duration of the study.

Strength of the Study

Strengths of the present study include the effects of a monitored dietary intervention on body composition and strength. The present study has demonstrated that a supervised dietary intervention along with a validated strength training protocol can significantly improve overall body composition and strength performance. It is evident in the current study that with a proper dietary changes and a systematic strength training routine, all subjects were able to significantly improve their body composition and increase strength in for all three main lifts, despite which diet the subjects followed.

CONCLUSION

The field of sports nutrition is currently divided on the topic of carbohydrate restriction in weight lifters. While opinions and beliefs favor either the established importance of carbohydrates or the relatively novel strategy of fat-adaptation, the current dissertation offers insight on the debate.

The present observations indicate that dietary carbohydrate restriction causing ketosis does not negatively impact exercise performance while simultaneously improving overall body composition. Our data suggests that adhering to a HPKD can lead to weight loss and improved body composition outcomes without negatively affecting lean body mass, strength, or power performance.

This indicates a high-protein ketogenic diet can be an effective strategy to reduce body weight and fat mass, particularly in the period of 3–12 weeks, in recreational weight lifters without affecting performance.

Weight lifters looking to explore novel nutritional approaches such as the high-protein ketogenic diet may be able to improve performance while simultaneously improving body composition.

These results could also be useful for weight category athletes, such as Olympic weightlifters, powerlifters, boxers, MMA fighters, wrestlers, or CrossFitters seeking to lose a significant amount of body fat without compromising performance.

Future research should investigate long-term (> 6 weeks) adherence to HPKD and always verify that participants achieve ketosis during the intervention. Future research should also be directed

to the long term physiological adaptations which occur with a HPKD and strength training, as well as the hormonal and psychological changes that may also transpire.

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