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

A Thesis Presented By

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To

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DECLARATION

I hereby declare that this thesis represents my own work which has been done after registration for the degree of PhD at Selinus University, and has not been previously included in a thesis or dissertation submitted to this or any other institution for a degree, diploma or other qualifications.

I have read the University's current research ethics guidelines, and accept responsibility to meet the University's professional, institutional and federal standards for conducting research with human participants.

I have attempted to identify all the risks related to this research that may arise in conducting this research, obtained the relevant ethical and/or safety approval (where applicable), and acknowledged my obligations and the rights of the participants.

____

Shivang Patel
Student

Date:

CERTIFICATE

This is to certify that this thesis entitled **"Effects of a High-Protein Ketogenic Diet on Strength Training Performance and Body Composition in Recreational Weight Lifters"** submitted to Selinus University for the degree of **Doctor of Philosophy,** in the subject of Food Science, has been carried out by **Shivang Patel** under my supervision and guidance.

No part of this thesis has been submitted elsewhere for award of any degree, diploma, fellowship or any other similar title prior to this date.

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APPROVAL

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

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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 CON (control) 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 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.

CHAPTER 1
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 Indian recommended daily intake (ICMRs recommendation) of 0.9 g per kg 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.

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

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.

Justification

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, I 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, I 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.

CHAPTER 2
BIBLIOGRAPHY

Here is a list of all the sources I used to generate my ideas about the topic including those cited in my thesis as well as those I did not cite.

In finer terms, it is the complete list of PhD thesis, research papers, books, journals, websites and other important works that I have studied in the creation of the work.

The sources are listed in alphabetical order by name of the author.

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CHAPTER 3
REVIEW OF LITERATURE

The literature relevant to the study has been reviewed and presented under the following headings:

1. Metabolic Energy Pathways
2. Energy Balance and Requirements
3. Carbohydrate Requirements
4. Protein Requirements
5. Fat Requirements
6. Standard Ketogenic Diet
7. High-Protein Ketogenic Diet

Metabolic Energy Pathways

An understanding of the three major energy systems is critical for understanding the relative importance of the macronutrients in the diet of a physically active person.

The human body needs energy to function, but where does this energy come from? Ultimately, the energy that keeps us moving comes from the food we eat. However, we cannot use energy directly from food—it must first be converted into adenosine triphosphate (ATP), the immediate useable form of chemical energy utilized for all cellular function. The body does store a minimal amount of ATP within the muscles, but the majority is synthesized from the foods we eat. Food is made up of carbohydrates, fats and proteins, and these nutrients are broken down into their simplest forms (glucose, fatty acids and amino acids) during digestion. Once these nutrients are broken down, they are transported through the blood to either be used in a metabolic pathway or stored for later use.

Because we do not store a significant amount of ATP and need a continuous supply, it must be constantly resynthesized. This occurs in several ways using one of three energy systems:

1. Phosphagen (ATP-PC) System
2. Glycolytic (Anaerobic) System
3. Oxidative (Aerobic) System

Each of these is a primary contributor of energy at different exercise intensities and durations. Ultimately, maximal exercise intensities are dictated by available high energy phosphate molecules and their rate of regeneration.

Phosphagen (ATP-PC) System:

During short-term, intense activities, a large amount of power needs to be produced by the muscles, creating a high demand for ATP. The phosphagen system (also called the ATP-CP system) is the quickest way to resynthesize ATP (Robergs & Roberts 1997).

Creatine phosphate (CP), which is stored in skeletal muscles, donates a phosphate to ADP to produce ATP: ADP + CP = ATP + C. No carbohydrate or fat is used in this process; the regeneration of ATP comes solely from stored CP. Since this process does not need oxygen to resynthesize ATP, it is anaerobic, or oxygen-independent. As the fastest way to resynthesize ATP, the phosphagen system is the predominant metabolic energy system used for all-out exercise lasting up to about 10 seconds. However, since there is a limited amount of stored CP and ATP in skeletal muscles, fatigue occurs rapidly.

The pathway is associated with high-intensity (> 90% maximum), short-duration (6 – 10 seconds) exercise (Baechle & Earle, 2008). ATP pools are relatively insufficient for any amount of exercise, and exercise cannot deplete ATP pools by more than 60% (Constantin-Teodosiu, Greenhaff, McIntyre, Round, & Jones, 1997). Therefore, ATP is mostly regenerated by creatine phosphate and adenosine diphosphate (ADP) via creatine kinase, as the creatine phosphate pool is about 5-fold greater than the ATP pool (McArdle, Katch, & Katch, 2010).

ATP may also be replenished by the enzyme, adenylate kinase, which transfers a phosphate from one ADP to another ADP to produce ATP and adenosine monophosphate (Baechle & Earle, 2008).

An effective workout for this system is short, very fast sprints on the treadmill or bike lasting 5–15 seconds with 3–5 minutes of rest between each. The long rest periods allow for complete replenishment of creatine phosphate in the muscles so it can be reused for the next interval.

Examples of physical activity that primarily source energy from the phosphagen system include a 1RM test and short-duration or short-distance sprints with 3-5 minutes of passive rest between sets.

Glycolytic (Anaerobic) System:

Glycolysis is the predominant energy system used for all-out exercise lasting from 30 seconds to about 2 minutes and is the second-fastest way to resynthesize ATP. During glycolysis, carbohydrate—in the form of either blood glucose (sugar) or muscle glycogen (the stored form of glucose)—is broken down through a series of chemical reactions to form pyruvate.

For every molecule of glucose broken down to pyruvate through glycolysis, two molecules of usable ATP are produced (Brooks et al. 2000). Thus, very little energy is produced through this pathway, but the trade-off is that you get the energy quickly.

Once pyruvate is formed, it has two fates: conversion to lactate or conversion to a metabolic intermediary molecule called acetyl coenzyme A (acetyl-CoA), which enters the mitochondria for oxidation and the production of more ATP (Robergs & Roberts 1997).

Relative to the phosphagen system, glycolysis replenishes ATP at a slower rate, but it contains a greater capacity for ATP generation due to larger amounts of glucose storage as muscle or liver glycogen and blood glucose (Baechle & Earle, 2008; Creer, Ricard, Conlee, Hoyt, & Parcell, 2004).

Glycolysis generates 2 – 3 ATP and 2 pyruvate, molecule-1 of glucose, so although it has greater potential than the phosphagen system, the anaerobic system relative to the oxidative pathway, total ATP generation potential is still considered small.

Pyruvate is the end-product of glycolysis, which can either enter the mitochondria and tricarboxylic acid cycle or be converted to lactate. The fate of pyruvate depends on the exercise conditions, oxygen supply, and coinciding energy demands. If exercise intensity is and remains high (approximately 70% of max for 15 seconds or more), pyruvate is converted to lactate, yet if exercise intensity is low to moderate (up to 65% of max), pyruvate enters the oxidative pathway and the tricarboxylic acid cycle for greater ATP generation (Baechle & Earle, 2008).

Maximum effort is distinct from maximum intensity; maximum effort means that the individual is attempting to perform their best despite a probable decline in maximum intensity (workload). When maximal effort is exerted by an individual for a period of time ranging from 10 to 60 seconds, glycolysis is the primary energy system. However because

ATP is gradually being depleted, maximal effort no longer equals maximal workload, and maximal effort physical activity then correlates to an intensity of 75 – 90% max when glycolysis is the primary energy system (Baechle & Earle, 2008).

After 60 seconds and up to 3 minutes of sustained maximal effort, glycolysis continues to contribute as much as 50% of the ATP required to fuel activity. However with increasing durations, the aerobic, oxidative pathway becomes the primary energy system. The aerobic pathway can utilize all macronutrients as precursors, but each macronutrient enters the tricarboxylic acid cycle at a different stage. Glucose becomes the alpha keto-acid pyruvic acid, which can be converted to acetyl-CoA and enter the tricarboxylic acid cycle. Fatty acids undergo beta oxidation with the end product of acetyl-CoA.

However, amino acids can enter as acetyl-CoA via pyruvic acid, alpha-ketoglutarate, succinyl-CoA, fumarate, or oxaloacetate depending on which specific amino acid is being metabolized, which also affects the net ATP yield. However, proteins and amino acids are typically utilized for ATP generation only during starvation or long-duration (> 90 minutes), fasted exercise (Baechle & Earle, 2008; Dohm, Williams, Kasperek, & van Rij, 1982; Graham, Rush, & MacLean, 1995; Lemon & Mullin, 1980). The net ATP yield from one acetyl-CoA is about 15 ATP depending on numerical rounding (Baechle & Earle, 2008; Brooks, Fahey, & White, 1996).

An effective workout for this system can last for 30 seconds to 2 minutes with an active-recovery period twice as long as the work period (1:2 work-to-rest ratio).

Examples of activity primarily reliant upon glycolysis are weightlifting exercises performed to volitional failure at 65 – 80% 1RM (8 – 10 reps), moderate distance (e.g., 400m) sprints, or intermittent high intensity efforts, such repeated maximal effort sprints with an active-recovery period twice as long as the work period.

Oxidative (Aerobic) System:

Since humans evolved for aerobic activities (Hochachka, Gunga & Kirsch 1998; Hochachka & Monge 2000), it's not surprising that the aerobic system, which is dependent on oxygen, is the most complex of the three metabolic energy systems. This pathway requires oxygen to produce ATP, because carbohydrates and fats are only burned in the presence of oxygen. This pathway occurs in the mitochondria of the cell and is used for activities requiring sustained energy production. Aerobic glycolysis has a slow rate of ATP production and is predominantly utilized during longer-duration, lower-intensity activities after the phosphagen and anaerobic systems have fatigued.

When using carbohydrate, glucose and glycogen are first metabolized through glycolysis, with the resulting pyruvate used to form acetyl-CoA, which enters the Krebs cycle. The electrons produced in the Krebs cycle are then transported through the electron transport chain, where ATP and water are produced (a process called oxidative phosphorylation) (Robergs & Roberts 1997).

The aerobic energy system provides nearly all ATP at rest (30% intensity), and during long-duration exercise it remains the primary energy system. Glycolysis will continue to contribute to energy demands – the proportion of which depending upon the fitness level of the individual and the intensity of the exercise (Baechle & Earle, 2008). Complete oxidation of glucose via glycolysis, the Krebs cycle and the electron transport chain produces 36 molecules of ATP for every molecule of glucose broken down (Robergs & Roberts 1997). Thus, the aerobic system produces 18 times more ATP than does anaerobic glycolysis from each glucose molecule.

Fat, which is stored as triglyceride in adipose tissue underneath the skin and within skeletal muscles (called intramuscular triglyceride), is the other major fuel for the aerobic system, and is the largest store of energy in the body. When using fat, triglycerides are first broken down into free fatty acids and glycerol (a process called lipolysis). The free fatty acids, which are composed of a long chain of carbon atoms, are transported to the muscle mitochondria, where the carbon atoms are used to produce acetyl-CoA (a process called beta-oxidation).

Following acetyl-CoA formation, fat metabolism is identical to carbohydrate metabolism, with acetyl-CoA entering the Krebs cycle and the electrons being transported to the electron transport chain to form ATP and water. The oxidation of free fatty acids yields many more ATP molecules than the oxidation of glucose or glycogen. For example, the oxidation of the fatty acid palmitate produces 129 molecules of ATP (Brooks et al. 2000).

Well-trained individuals may be able to sustain exercise for extended durations at or above 75% maximal oxygen consumption. However, untrained individuals will be at 50 – 60% maximal oxygen consumption while at their lactate threshold (McArdle et al., 2010).

The mechanisms permitting well-trained individuals to sustain greater workloads include enhanced lactate clearance and reliance upon fatty acid metabolism via the oxidative system (Baechle & Earle, 2008; Brooks & Mercier, 1994). Examples of primarily aerobic events include a 5km run or a triathlon.

While the phosphagen system and glycolysis are best trained with intervals, because those metabolic systems are emphasized only during high-intensity activities, the aerobic system can be trained with both continuous exercise and intervals.

Examples of activity primarily reliant upon oxidative system are 60 minutes aerobic activity at 70%–75% maximum heart rate, 15 to 20 minute tempo workout at 80%–85% maximum heart rate and multiple 3 minute sprints at 95%–100% maximum heart rate with 3 minute active recovery.

Energy Balance and Requirements

Energy is a fuel provided by the macronutrients consumed in the diet: carbohydrate, fat and protein. Our body needs energy for maintaining body temperature and metabolic activity for supporting physical activity and growth. Energy requirements of individuals are proportional to their energy expenditure, which depends on their age, sex, body composition, diet, levels of occupational activity (sedentary/moderate/heavy activity), levels of non-occupational activity (physical exercise), and sleep pattern, typically for eight hours in a day (Nutrient Requirements And Recommended Dietary Allowances For Indians: A Report Of The Expert Group Of The ICMR, 2020).

Energy expenditure may be estimated or measured. Measurement of energy expenditure is considered the most valid method for determining an individual's energy requirements, yet measurement of total energy expenditure (TEE) is considered impractical in most situations (Thomas, Erdman, & Burke, 2016).

In case of energy requirements for Indians, the comparison of BMR derived from FAO/WHO/UNU equations and BMR observed among Indians suggest that the equation can over estimate BMR by 10-12%. BMR of Indians is 10% (12.6% in rural subjects) and 9% lower for males and females respectively than the international values derived from FAO/WHO/UNU equations (Shetty PS, Soares MJ, Validity of Schofield's predictive equations for basal metabolic rates of Indians, Ind J Med Res, 1988).

Table 1: Equation for Prediction of BMR (kcal/24h)

Sex	Age (years)	Prediction equation proposed by FAO/WHO/UNU Consultation (2004)
Males	18-30	15.1xB.W.(kg)+692.2
	30-60	11.5xB.W.(kg)+873
	>60	11.7xB.W.(kg)+587.7
Females	18-30	14.8xB.W.(kg)+486.6
	30-60	8.1xB.W.(kg)+845.6
	>60	9.1xB.W.(kg)+658.5

(FAO/WHO/UNU Consultation, 2004)

BMR is highly dependent on body composition and people with low body fat will have higher BMR compared to high fat population (Nutrient Requirements And Recommended Dietary Allowances For Indians: A Report Of The Expert Group Of The ICMR, 2020).

There are three important terms while defining energy expenditure using physical activity estimation. These are – Physical Activity Ratio (PAR), Physical Activity Level (PAL) and Total Energy Expenditure (TEE).

The Physical Activity Ratio (PAR) is expressed as the ratio of the energy cost of an individual activity per minute to the cost of the basal metabolic rate (BMR) per minute (Nutrient Requirements And Recommended Dietary Allowances For Indians: A Report Of The Expert Group Of The ICMR, 2020).

TEE includes an individual's basal metabolic rate, the thermic effect of food, and the thermic effect of physical activity (Thomas et al., 2016). TEE is calculated as a multiplication of basal metabolic rate (BMR) and physical activity level (PAL). A change in either BMR or PAL could lead to a change in the TEE value (Nutrient Requirements And Recommended Dietary Allowances For Indians: A Report Of The Expert Group Of The ICMR, 2020).

PAL Values proposed by ICMR Expert Group in comparison with recommended values of the FAO/WHO/UNU Consultation, 2004 are mentioned in table 2.

Table 2: PAL Values proposed by ICMR

Level of activity	ICMR 1989[12]	ICMR 2010[13]	ICMR 2020	FAO/WHO/UNU 2004[11]
Sedentary Work	1.60	1.53	1.40	1.40-1.69
Moderate Work	1.90	1.80	1.80	1.70 – 1.99
Heavy Work	2.50	2.30	2.30	2.00 – 2.40*

(Nutrient Requirements And Recommended Dietary Allowances For Indians: A Report Of The Expert Group Of The ICMR, 2020).

An alternative and more feasible measurement is resting energy expenditure (REE), which may then be adjusted according to established factors to account for the thermic effect of physical activity and food (Van Baak, 1999).

Estimations of REE can be made using pre-established equations. The Cunningham equation is considered more accurate for athletes due to incorporation of a measurement of fat-free mass (FFM), which is typically greater in athletes than sedentary individuals, thereby making a greater relative contribution to TEE (Cunningham, 1991; Thomas et al., 2016).

Any approximation of TEE must, by definition, include the thermic effect of physical activity. As REE estimation equations only predict REE, it must be adjusted for diet and activity level by a factor of 1.2, for little to no exercise, to 2.5 or more, for strenuous daily exercise (Thomas et al., 2016; van Baak, 1999).

If FFM is unknown, an athlete can estimate their body fat percentage, use an alternative equation, such as the Mifflin – St. Jeor equation or the dietary reference intakes (DRIs) (Mifflin et al., 1990; U.S. Department of Health and Human Services [HHS], 2015; Thomas et al., 2016).

The TEE increases proportional to the volume and intensity of exercise. Therefore, athletes and recreationally-active persons have greater energy requirements to maintain body mass. This concept is known as energy balance (King, Tremblay, & Blundell, 1997).

A eucaloric diet matches total energy intake to TEE with body weight remaining relatively constant. However, nearly all individuals will, at some time, desire weight change, and body weight changes can be achieved by a positive energy balance (greater intake than expenditure) or a negative energy balance (greater expenditure than intake) for body weight gain or loss, respectively. Once target weight is achieved, a eucaloric diet is most appropriate, and in more advanced scenarios, diet may be periodized on a daily basis according to energy expenditure. The macronutrient composition of energy requirements can affect athletic performance and body composition adaptations to exercise. (Jeukendrup, 2017; Thomas et al., 2016).

Carbohydrate Requirements

Carbohydrates (CHO) are the major source of available energy in human diets comprising more than 60% - 78% of total energy intake, particularly in India (Radhika G, Ganesan A, Sathya RM, Sudha V, Mohan V, Dietary carbohydrates, glycemic load and serum high-density lipoprotein cholesterol concentration among South Indian adults, European journal of clinical nutrition, 2009).

The glucose breaks down to pyruvate by the glycolysis pathway. Pyruvate may be converted to lactate anaerobically or to acetyl CoA aerobically. Once it is converted to acetyl CoA, glucose is not retrievable. Glucose is metabolized and is stored as glycogen, which is the main source of energy. Making glucose from protein is called gluconeogenesis. When there is inadequate supply of CHO, ketone bodies are formed from fat fragments and in contrary when CHO is abundant, the body uses the glucose to make fat (Nutrient Requirements And Recommended Dietary Allowances For Indians: A Report Of The Expert Group Of The ICMR, 2020).

The major dietary sources of CHO in Indians are sugars, cereals and millets, roots and tubers, pulses and legumes to a limited extent from vegetables, fruits and dairy. Indian dietaries are predominantly high in starch from cereals, millets and root vegetables. Examples are rice, wheat, sorgham, maize and potatoes. Sugars from fruits and vegetables are limited as consumption is very low. Sources of free/ added sugars in diets are sugar sweetened carbonated beverages, fruit juices and concentrates, sweets and desserts, cakes, biscuits, chocolates and candies and beverages such as tea and coffee (Nutrient Requirements And Recommended Dietary Allowances For Indians: A Report Of The Expert Group Of The ICMR, 2020).

CHO serve as the main source of energy for majority of the Indian population. The median intake of CHO by the Indian men and women are 320 g per day each providing 72% energy in the rural areas and 300 and 261 g per day respectively, providing about 60% energy in the urban areas (Nutrient Requirements And Recommended Dietary Allowances For Indians: A Report Of The Expert Group Of The ICMR, 2020).

The minimal amount of CHO required is determined by the brain's requirement for glucose. The average minimum amount of glucose utilized by the brain is approximately 100 g per day (Nutrient Requirements And Recommended Dietary Allowances For Indians: A Report Of The Expert Group Of The ICMR, 2020).

The diets primarily consist of CHO, proteins and fats as the sources of energy; therefore, non-availability of glucose to the brain does not arise. However, as an alternate source of energy, when the CHO consumption is very low and availability of glucose is less, the energy needs are partially met by utilizing keto acids obtained from break down of fats or utilizing energy from endogenous protein catabolism. This means that the brain can adapt to a CHO-free diet that is sufficient in energy (Nutrient Requirements And Recommended Dietary Allowances For Indians: A Report Of The Expert Group Of The ICMR, 2020).

Dietary carbohydrates are recommended to compose 45 to 65% of an individual's energy needs, regardless of physical activity (HHS, 2015).

Carbohydrates are of paramount nutritional consideration for athletes due to their nearly exclusive role as energy substrate (Fink, 2005).

Weight Lifters are recommended to consume carbohydrates, not as a proportion of total energy, but as a proportion of bodyweight relative to exercise volume with the amount usually falling within the range of 50 to 70% of daily energy intake, depending on total intake. Athletes competing in extreme endurance events may consume up to 80% of their daily Calories as carbohydrate (Fink, 2005).

Typical recommendations range from 3 – 12 grams of carbohydrate per kg of body weight per day for activity levels ranging from rest (3g per kg of body weight per day) to 5+ hours per day of moderate to high intensity (12g per kg of body weight per day) exercise. Most active individuals fall within a 5 – 10 grams per kg of body weight per day range to support exercise volumes averaging 1 – 3 hours per day. (Burke, 2001; Burke et al., 2004; Jeukendrup, 2017; Jeukendrup & Jentjens, 2000; Thomas et al., 2016).

Special attention is afforded to carbohydrates before, during, after, and between (if occurring on the same day) bouts of exercise. In the 1 to 4 hours leading up to a bout of exercise, it is recommended to consume 1 to 4 g per kg of body weight to ensure the body has adequate fuel supply for the bout (Thomas et al., 2016).

For long durations of activity (> 90 minutes), a carbohydrate loading strategy may be used to increase stored muscle glycogen above normal resting values. Carbohydrate loading strategies involve increasing daily carbohydrate consumption by 2 to 4 g per kg of body weight per day for

1 to 3 days prior to the event (Bussau, Fairchild, Rao, Steele, & Fournier, 2002; Hawley, Schabort, Noakes, & Dennis, 1997; Thomas et al., 2016).

During exercise, carbohydrate refueling strategies vary from 0 to 90 grams of carbohydrate consumed per hour. Exercise bouts lasting no more than 60 minutes do not appear to benefit from carbohydrate consumption during exercise, as pre-event nutrition is sufficient (Thomas et al., 2016).

When performance is a primary consideration and exercise bouts will be separated by only short periods of time (e.g., < 8 hours), carbohydrate ingestion in the "post-exercise window of opportunity" is emphasized. Specifically, recommendations are to consume 1.0 to 1.2 g per kg of body weight per hour for up to 4 hours following the first bout of exercise (Burke et al., 2004; Jeukendrup, 2004; Jeukendrup, 2011, 2017; Thomas et al., 2016).

Numerous studies have examined the relationship of carbohydrates and performance to determine the aforementioned guidelines, and the attention has been rightfully earned. In general, carbohydrate intake for performance is of benefit when carbohydrates are consumed and a detriment when they are not consumed or reduced in quantity. However, only 16 grams per hour are required to improve performance, and no additional benefit is observed with greater quantities (Jeukendrup, 2004).

One important concept surrounding carbohydrate-based nutrition and performance is the crossover point. The crossover point concept illustrates the bioenergetic necessity of carbohydrate use at higher exercise intensities. Brooks and Mercier define the crossover point as the intensity at which metabolic demands shift from a primary reliance upon lipid to primarily carbohydrate, 70% maximal aerobic power (Brooks & Mercier, 1994).

The significance of the crossover point becomes evident with the understanding that most endurance training occurs above 70% maximal aerobic power (Baechle & Earle, 2008; Burke et al., 2004).

Carbohydrate content of the diet also predicts time to exhaustion. Noncompetitive athletes pre-exhausted their stored muscle glycogen 48 hours prior to testing. The glycogen depleting exercise consisted of 90 minutes exercise at the median intensity between their individual onset of blood lactate and lactate threshold followed by a series of 1 minute bouts at 125% maximal oxygen consumption until the intensity could no longer be maintained. For the two days following glycogen depletion prior to testing, participants consumed either a low-carbohydrate (10% carb, 35% protein, 55% fat) or high-carbohydrate (65% carb, 20% protein, 15% fat) diet. Participants then completed a time-to-exhaustion test at an intensity equal to 125% the intensity of their lactate threshold. Individuals who consumed the high-carbohydrate diet were able to maintain exercise at the required intensity for 23.2 minutes compared to only 18.3 minutes for individuals who consumed the low-carbohydrate diet (Lima-Silva, De-Oliveira, Nakamura, & Gevaerd, 2009).

Dietary carbohydrate intake also has putative roles in muscle recovery apart from carbohydrate replenishment. Carbohydrate ingestion versus fasting after exercise improves recovery and net protein balance by attenuating muscle protein breakdown in active individuals (Børsheim et al., 2004).

Additionally, the insulin response to carbohydrate feeding may assist with improving muscle protein synthesis when consumed with protein (Ivy, 2004; Ivy, Ding, Hwang, Cialdella-Kam, & Morrison, 2008).

However, exactly how carbohydrate-induced changes to protein balance may translate into body composition augmentation, if at all, is presently unclear (Aragon et al., 2017), though it is generally believed that carbohydrate restriction will impair the acquisition of muscle tissue (Tinsley & Willoughby, 2016). Therefore, due to several metabolic and central functions, carbohydrates are presently the primary consideration in the field of sports nutrition.

Protein Requirements

Protein is regarded as a macronutrient perhaps equally as important as carbohydrate for sports performance. Whereas carbohydrate can have an immediate effect on performance, dietary protein is critical for long-term success due to its roles in stimulating muscle protein synthesis and the functions of protein in the structure of contractile muscle proteins, enzymes, peptide hormones, and antibodies.

Dietary proteins provide amino acids for the synthesis of body proteins, which are structural and biologically active proteins (i.e. enzymes, hormones), and for other biologically important nitrogenous compounds. Adequate dietary protein is essential during growth when new tissue proteins are being synthesized. Dietary protein is essential for synthesis of new proteins to replace those that are being broken down (Nutrient Requirements And Recommended Dietary Allowances For Indians: A Report Of The Expert Group Of The ICMR, 2020).

Dietary proteins should supply the nine nutritionally essential amino acids (EAA), of the total twenty, in proper proportions and in adequate quantities to synthesize tissue proteins in the body. The other eleven amino acids, though required for protein synthesis, are not considered nutritionally essential since the body can synthesize them from other sources (Nutrient Requirements And Recommended Dietary Allowances For Indians: A Report Of The Expert Group Of The ICMR, 2020).

The RDA for protein is 0.8 grams of protein per kg of body weight per day or 10 – 35% of daily energy intake (HHS, 2015).

However, it has become universally accepted that individuals participating in exercise have greater protein needs (Phillips & Van

Loon, 2011; Thomas et al., 2016), and novel techniques in protein quantification suggest that even non-exercising individuals would benefit from protein as high as 2.2 grams of protein per kg per day (Pencharz, Elango, & Wolfe, 2016).

Similar to carbohydrate, protein is recommended to be dosed according to body mass to better suit the unique needs of the individual. Active persons require 1.2 to 2.0 grams of protein per kg of body weight per day. Traditionally, the exact number has been decided by the type of sport and the body composition goals of the individual (Fink, 2005).

More recently, protein recommendations have become more sophisticated and specific and take into account alteration of intensity on training days or cycle of training. One of the major reconsiderations has been that total daily protein intake should increase during periods of calorie restriction and more intense or more novel training stimuli regardless of the classification of activity (e.g., endurance or strength). A review on the quantity of protein during calorie restriction in resistance-trained, lean athletes suggested that greater protein intakes in the range of 2.3 – 3.1 grams of protein per kg of body weight per day would be most effective for preserving, or even increasing muscle mass (Helms, Zinn, Rowlands, & Brown, 2014).

When individuals engage in greater volumes of exercise or exercise with which they are unfamiliar, they incur greater exercise-induced muscle damage (Phillips, 2012).

A study by Witard, Jackman, Kies, Jeukendrup, and Tipton compared diets containing 1.5 and 3.0 grams of protein per kg of body weight per day during one week each of normal, recovery (reduced-volume), or intensified (higher-volume, higher-intensity) training in trained cyclists. The results indicated that the higher protein intake attenuated a decline in time trial performance following intense training and effectively prevented an increase in the psychological stress of greater exercise volume and intensity. In a separate report from the same investigators, 3.0 grams of protein per kg of body weight per day reduced the incidence of upper respiratory tract infections likely by attenuating a training-induced decrease in leukocyte function (Witard, Jackman, Kies, Jeukendrup, and Tipton, 2011).

Therefore, increasing protein intake above the normal 1.2 – 2.0 grams of protein per kg of body weight per day range is apparently necessary under certain conditions, supporting the concept of periodized nutrition for protein.

Increased dietary protein intake is often associated with acquisition of muscle tissue. A recent study compared diets containing 4.4 and 1.8 grams of protein per kg body weight per day while maintaining constant carbohydrate and fat intake in noncompetitive, resistance-trained athletes for 8 weeks. The larger protein intake group significantly increased their total daily energy intake. However, no significant differences were observed between the high and normal protein groups for body weight, Fat Free Mass (FFM), or Fat Mass (FM), making the investigation the first to report no increase in FM during a period of overfeeding (Antonio, Peacock, Ellerbroek, Fromhoff, & Silver, 2014).

Considering that research must maintain internal validity and make multiple considerations, it is not currently advisable to prescribe protein intakes greater than 2.0 grams of protein per kg of body weight per day when protein must be controlled. Indeed, different protein intakes within a 0.8 – 1.8 grams of protein per kg of body weight per day range can differentially affect body composition and must be controlled in research examining body composition.

Addition of protein to carbohydrate compared to an isocaloric amount of carbohydrate alone consumed post-exercise enhances rates of muscle glycogen resynthesis (Berardi, Price, Noreen, & Lemon, 2006; Ivy et al., 2002).

Protein utilization and deposition are dependent on intake of adequate energy. Adequate non-protein energy from carbohydrate and fat is essential for dietary amino acid to be utilized for protein synthesis and for amino acid related functions in the body. If adequate dietary energy is not available, dietary protein is inefficiently utilized (Nutrient Requirements And Recommended Dietary Allowances For Indians: A Report Of The Expert Group Of The ICMR, 2020).

An important factor in establishing human protein requirement on habitual diets is the quality of the dietary proteins in terms of their nutritionally essential (indispensable) amino acid content. Efficiency of utilization of dietary protein depends upon its digestion and absorption of the released amino acids. Plant proteins, mainly in cereals, legumes and vegetables are of poorer quality than animal proteins, not only because of their lower digestibility but also because they are often limiting in one or more of the nutritionally essential amino acids of human requirement. Cereal proteins are generally deficient in lysine and pulses or legume proteins contain low amounts of methionine. However, when both cereals and pulses (legumes) are present in the diet in proper proportions, proteins from these two sources complement each other by providing lysine or methionine to a significant extent to meet the requirement of the deficiency of the nutrient (Nutrient Requirements And Recommended Dietary Allowances For Indians: A Report Of The Expert Group Of The ICMR, 2020).

Fat Requirements

Fats are regarded as essential in healthful quantities without a significantly prominent role in sports nutrition, and as a result, fewer studies exist examining the role of dietary lipid for athletes. The most recent recommendations for Americans have become less restrictive on total fat intake to prevent disruptions caused by insufficient intake of essential fats. However, reducing total fat below 20% of total calories is not recommended (HHS, 2015).

As protein is not typically utilized for ATP synthesis, fats are the only macronutrient considered an alternative fuel source to carbohydrates preferentially utilized at lower exercise intensities (below 70% maximal oxygen consumption). Oxidation of fat in place of carbohydrate may offer benefits to performance via glycogen sparing, and strategies improving fat oxidation capacities include fasting, pre-exercise fat intake, and chronic high-fat diets (Spriet, 2014; Burke, 2015; Burke & Kiens, 2006; Peters, St Amand, Howlett, Heigenhauser, & Spriet, 1998; Randle, Garland, Hales, & Newsholme, 1963; Stellingwerff et al., 2006; Thomas et al., 2016).

Fat oxidation during moderate intensity training increases with training experience, yet higher exercise intensities do not experience the same metabolic shift (Coggan, Kohrt, Spina, Bier, & Holloszy, 1990; Deuster et al., 1989; Gollnick, 1985; Jones et al., 1980; Purdom, Kravitz, Dokladny, & Mermier, 2018).

Similarly, moderate intensity exercise performance following fat-adaptation is equal or improved compared to diets containing high carbohydrate availability, while high-intensity exercise performance suffers (Fleming et al., 2003; Havemann et al., 2006; Lambert, Speechly, Dennis, & Noakes, 1994; Thomas et al., 2016).

Fats that are used as such at the table or during cooking (oils, ghee, butter and vanaspati) are termed as “visible” fats. Adults with sedentary lifestyle should consume about 25 g of visible fat, while individuals involved in hard physical work require 30 - 40g of visible fat (Dietary Guidelines for Indians, National Institute of Nutrition, Indian Council of Medical Research, 2011).

Fats that are present as an integral components of various foods are referred to as "invisible" fat . Most animal foods provide high amounts of "invisible" fat. The small amounts of "invisible" fat present in various foods add up to a substantial level in our daily diet which is about 15 g in rural population and 30g among urban population in India (Dietary Guidelines for Indians, National Institute of Nutrition, Indian Council of Medical Research, 2011).

The intakes of visible and invisible fat in Indian adult should range between 20-30% of total calories (Dietary Guidelines for Indians, National Institute of Nutrition, Indian Council of Medical Research, 2011).

Standard Ketogenic Diet

Typical definitions of a Ketogenic Diet (KD) are often limited to two guidelines. First, less than 50 g or 5% of total calories per day can come from total carbohydrates, and second, at least 70% of total calories per day should come from fat (Westman, 1999; Westman, Yancy, Edman, Tomlin, & Perkins, 2002; Yancy, Olsen, Guyton, Bakst, & Westman, 2004).

Evidence for low-carbohydrate diets extend back millions of years. Paleontological investigations suggests that early humans went through periods of fat- or protein-based metabolism likely due to low carbohydrate availability at least on a seasonal basis (Balter, Braga, Telouk, & Thackeray, 2012; Peters & Vogel, 2005).

However, the potential for low carbohydrate diets as a result of food availability likely disappeared with the advent of farming, and deliberate KDs were not implemented until the early 1900s for the treatment of epilepsy (Masino & Rho, 2012).

The typical macronutrient guidelines, as well as the majority of studies, associated with a KD are in sedentary individuals possessing one or more comorbidities (Ballard et al., 2013; Baranano & Hartman, 2008; D'Agostino et al., 2013; Paoli, Cenci, & Grimaldi, 2011; Paoli, Rubini, Volek, & Grimaldi, 2013; Perez-Guisado & Munoz-Serrano, 2011a, 2011b; Perez-Guisado, Munoz-Serrano, & Alonso-Moraga, 2008; Seyfried & Mukherjee, 2005; Volek, Fernandez, Feinman, & Phinney, 2008; Volek et al., 2009; Westman, 1999; Westman et al., 2007; Westman & Vernon, 2008; Westman et al., 2002; Westman, Yancy, Mavropoulos, Marquart, & McDuffie, 2008; Yancy, Foy, Chalecki, Vernon, & Westman, 2005; Yancy et al., 2004).

However, a recent study found that well-trained endurance athletes maintained a state of ketosis while consuming an average of 82 g (10.4%

energy from carbohydrates) and 226 g (69.5% from fat) per day (Volek et al., 2016).

Due to the known effects of exercise on glucose tolerance and the fact that high-intensity exercise primarily utilizes carbohydrate as a fuel substrate, it is logical that athletes may have more flexible guidelines for a KD than sedentary individuals (Brooks & Mercier, 1994).

This is practically relevant, as research concerning KDs in sedentary individuals typically aims to induce an energy deficit, which makes a “less than” guideline suitable. However, athletic performance does not benefit from an energy deficit, and “less than” guidelines should not be utilized in the description of a KD for an individual or population seeking improved or maintained athletic performance (Mountjoy et al., 2014; Thomas et al., 2016).

Dietary carbohydrate restriction causing ketosis does not negatively impact exercise performance while simultaneously improving overall body composition (Jordan M Joy, 2018).

A recent study found that the participants following a ketogenic diet and resistance training two days per week significantly improved leg strength and body composition without affecting upper body strength and power. There were no significant differences in any performance measures between Ketogenic diet and Normal diet, yet Ketogenic diet showed significant improvements in body composition. This indicates a ketogenic diet can be an effective weight management tool in tactical athletes without affecting performance (Emily Barnhart, 2018).

A Ketogenic diet can represent an adequate dietary approach for body building athletes. Despite the lack of hypertrophic response in the Ketogenic diet group, muscle mass was maintained, a phenomenon that often does not occur during low-calorie diets. Similarly, although the time of year was not the one that athletes usually dedicate to training for fat loss ("cutting"), Ketogenic diet proved to be a good strategy to reduce body fat (Antonio Paoli, Lorenzo Cenci, PierLuigi Pompei, Nese Sahin, Antonino Bianco, Marco Neri, Massimiliano Caprio, Tatiana Moro, 2021).

For endurance athletes, the literature supports LC/KDs as an e
ective strategy to reduce body weight and fat mass, particularly in the period of 3–12 weeks. Limited studies demonstrate a significant improvement in exercise performance at submaximal (~60%) intensities. However, exercise performance at higher intensities may actually be impaired (Kristin L. Harvey, Lola E. Holcomb, Stephen C. Kolwicz, 2019).

High-Protein Ketogenic Diet

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 High- Protein Ketogenic Diet and weight lifters. 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. A very few researchers have evaluated the effect of HPKD on strength training performance and body composition in weight lifters.

A High-Protein Keto Diet is meant for those who need protein to help protect muscle mass, like bodybuilders and older people who need to prevent muscle breakdown, It’s also a good option for those who show signs of a protein deficiency (Moira Lawler, 2020).

High protein, low carb diets have become increasingly popular as a means of encouraging weight loss while maintaining or increasing muscle mass (Darryn Willoughby, Susan Hewlings, Douglas Kalman, 2018).

High protein, low carb diets may promote weight loss, preserve muscle mass, improve blood sugar control, lower your risk of heart disease, and enhance bone health (Jillian Kubala, 2020).

The biggest drawback to HPKD is that excess protein in your body is converted to glucose and used as fuel. This glucose can hinder your ability to fully get into ketosis and stay there (which is the ultimate goal of the ketogenic diet in general). When you are in ketosis, your body is burning ketones as fuel (which are created by the liver from stored fat) rather than glucose (Karissa Long, Katie Austin, 2020).

It can take longer to reach ketosis if you follow a high-protein keto diet, typically 60% fat, 35% protein, 5% carbs. This is because protein can be converted to glucose. It might take one to two days longer for the body to reach ketosis, burning fat for fuel. However high-protein keto diets are beneficial for people who work out a lot or are aiming to reduce their body fat percentage, because protein helps muscles repair and is also satiating (Rachel Hosie, 2015).

Many people find HPKD easier to follow, because it allows you to eat more protein and less fat than the standard keto diet (Julie Upton, 2018).

In the short term, high-protein, low-carbohydrate ketogenic diets reduce hunger and lower food intake significantly more than do high-protein, medium-carbohydrate non ketogenic diets (Alexandra M Johnstone, Graham W Horgan, Sandra D Murison, David M Bremner, Gerald E Lobley, 2008).

CHAPTER 4
METHODS

The present investigation was carried out to evaluate the effects of a high-protein ketogenic diet on strength training performance and muscle building outcome goals in healthy males and females.

We aimed 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 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.

Table 3: 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 (ICMR Nutrients Requirements for Indians, A Report of the Expert Group 2020).

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 (Grembecka, 2015).

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.

Table 4: 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 below.

Figure 1: Carbohydrate, Protein and Fat Ratio in HPKD

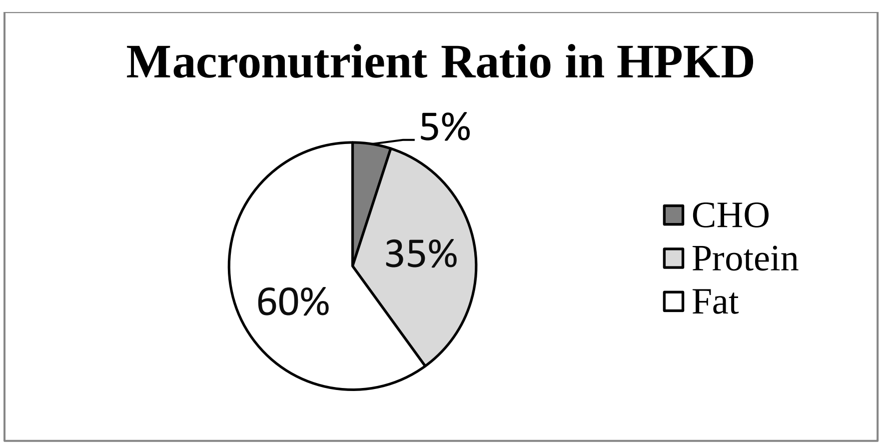
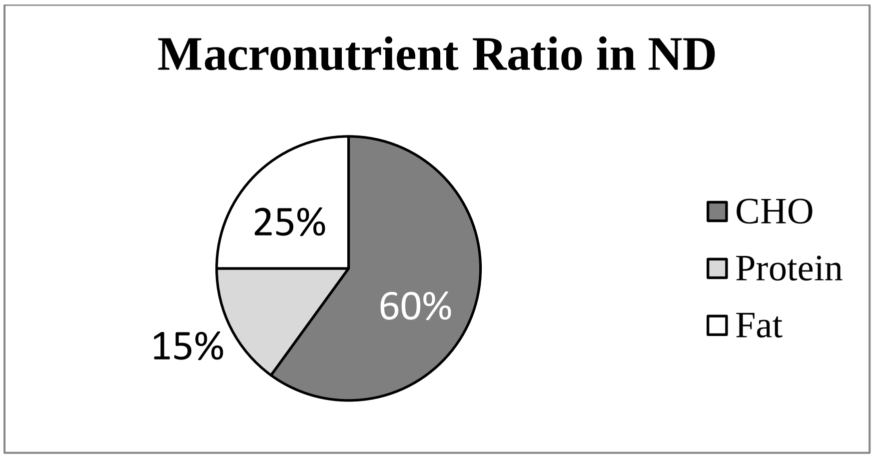


Figure 2: Carbohydrate, Protein and Fat Ratio in HPKD in ND



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 5, table 6, and table 7.

Table 5: 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 6: 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 7: 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 8.

Table 8: 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 statistical analysis was performed using SPSS software (version 25.0; SPSS, Inc., Armonk, NY, USA). 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).

CHAPTER 5
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

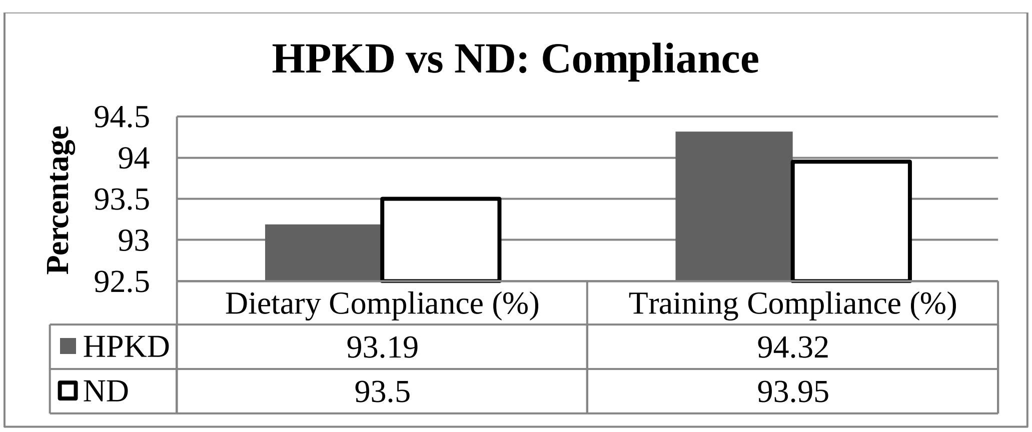
No significant differences (p>0.05) were found in dietary and training compliance between HPKD and ND groups. However, training compliance in the HPKD group was 0.37% better than the ND group and dietary compliance in the ND group was 0.31% better than the HPKD group.

Table 9: 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.

Figure 3: Compliance Comparison between HPKD and ND groups



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.

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.

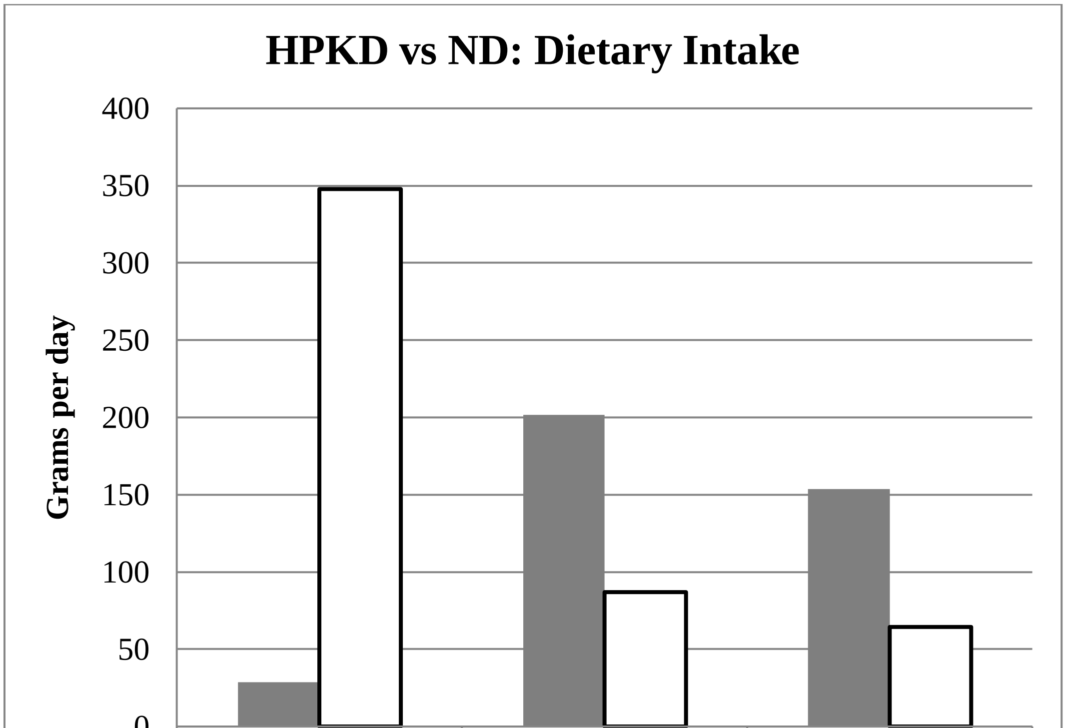
Table 10: Dietary Intake Comparison

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.

Figure 4: Dietary Intake Comparison between HPKD and ND groups



	CHO (g)	Protein (g)	Fat (g)
HPKD	28.83	201.81	153.76
ND	347.79	86.95	64.41

3. Caloric Deficit Comparison

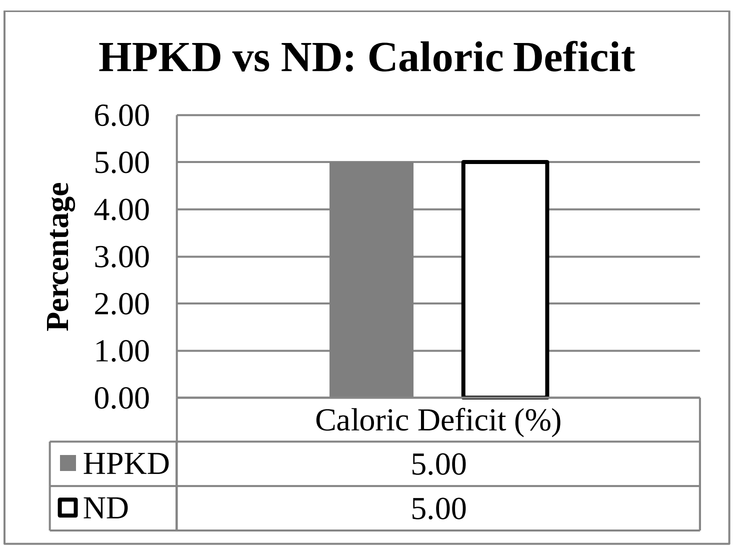
All participants in both groups were prescribed a diet with 5% caloric deficit so there was no significant difference ($p>0.05$) in the mean of calorie deficit between groups. The average caloric deficit of HPKD was 121.39 kcal per day (mean ± SD, Caloric Deficit = 121.39 ± 14.16 kcal/d) and ND was 122.03 kcal per day (mean ± SD, Caloric Deficit = 122.03 ± 11.90 kcal/d).

Table 11: 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.

Figure 5: Caloric Deficit Comparison between HPKD and ND groups



4. Training Volume Comparison

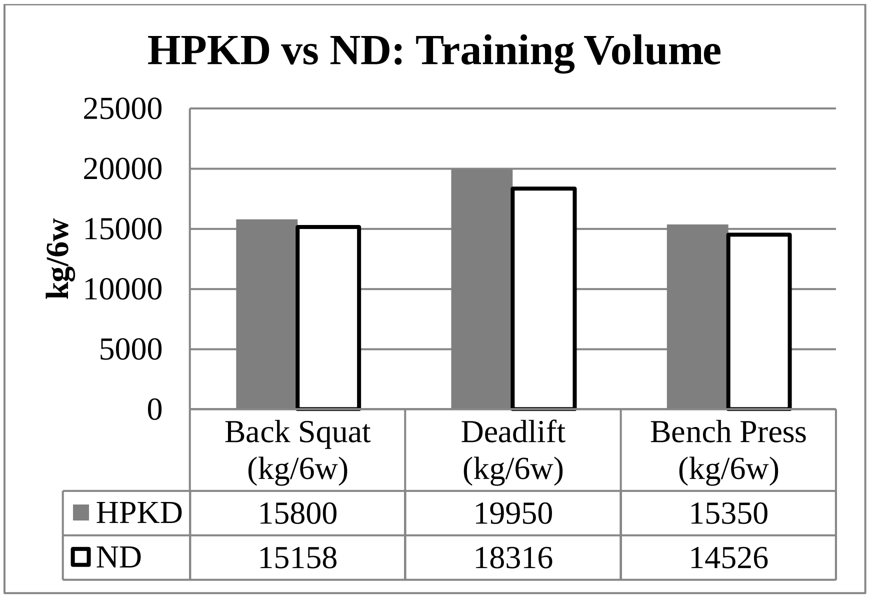
We found no significant difference ($p>0.05$) in the means of back squat, deadlift and bench press volume between HPKD and ND groups. However, the average back squat, deadlift and bench press volume of HPKD group was relatively better compared to ND group.

Table 12: 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.

Figure 6: Training Volume Comparison between HPKD and ND groups



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

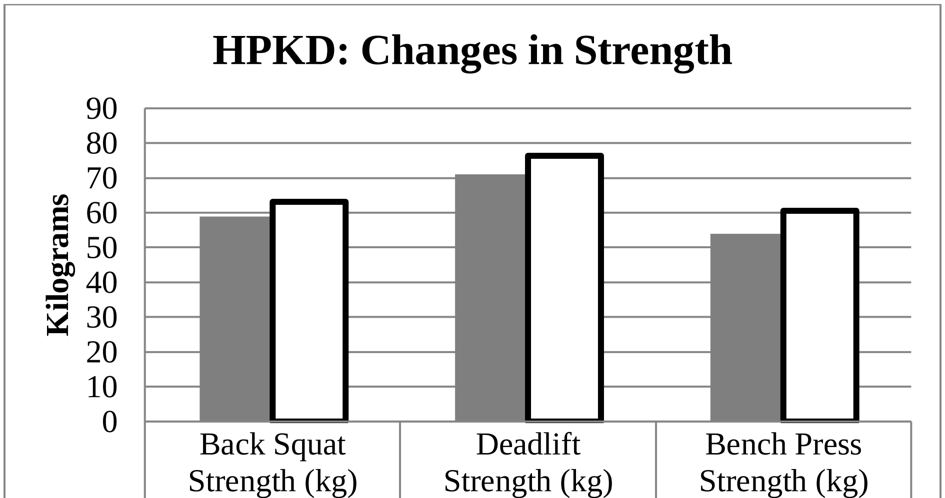
There was a significant effect of HPKD ($p<0.05$) on strength for all the variables (back squat, deadlift and bench press) between PRE and POST intervention. The HPKD group experienced a significant increase in 1RM for all three lifts (bench press: 8.13 ± 4.85 kg, $p < 0.05$; back squat: 5.0 ± 2.95 kg,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

Table 13: 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.

Figure 7: Changes in Strength within HPKD group



	Back Squat Strength (kg)	Deadlift Strength (kg)	Bench Press Strength (kg)
Pre	58.95	71.05	53.95
Post	63.16	76.32	60.53

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

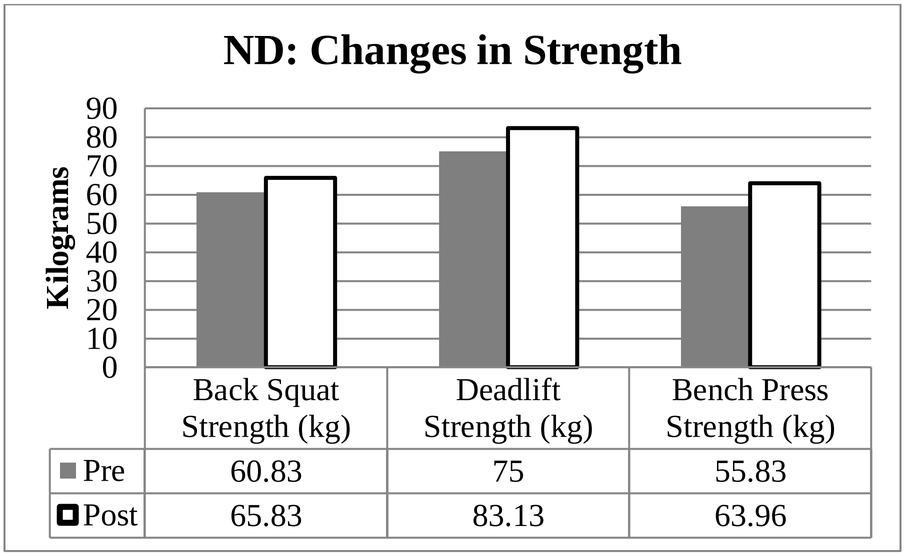
It is important to note that both groups experienced increases in all three lifts tested. The ND group also showed a statistically significant effect ($p<0.05$) on strength between PRE and POST intervention. There was a significant increase in 1RM for all the variables (bench press: 6.58 ± 2.39 kg, $p < 0.05$; back squat: 4.21 ± 1.87 kg, $p < 0.05$; deadlift: 5.26 ± 5.89 kg, $p < 0.05$).

Table 14: 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 1RM (kg)	**Pre**	71.05 ± 32.56	100.50 ± 8.96	38.33 ± 2.50
	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.

Figure 8: Changes in Strength within ND group



7. Strength Comparison between HPKD and ND groups

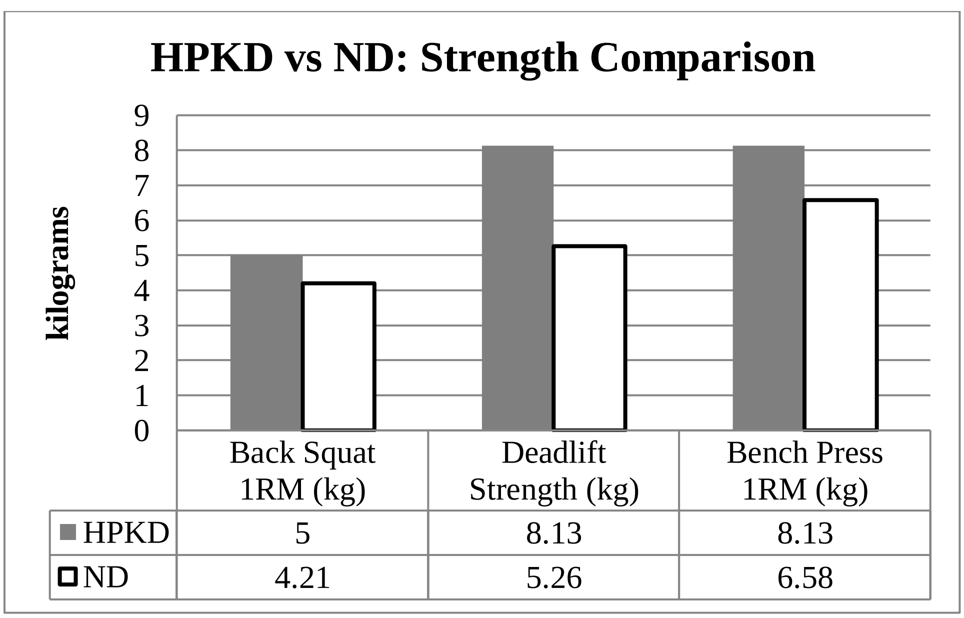
No significant effects were observed ($p > 0.05$) on strength for any variables compared (back squat: $p = 0.29$; deadlift: $p = 0.15$; bench press: $p = 0.18$) between HPKD and ND groups. However, the HPKD group experienced better increments in strength for all three lifts (back squat: +5kg/6w, deadlift: +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).

Table 15: 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.

Figure 9: Strength Comparison between HPKD and ND groups



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. 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 16: 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.

Figure 10: Pre and Post Intervention Changes in Body Weight in HPKD group

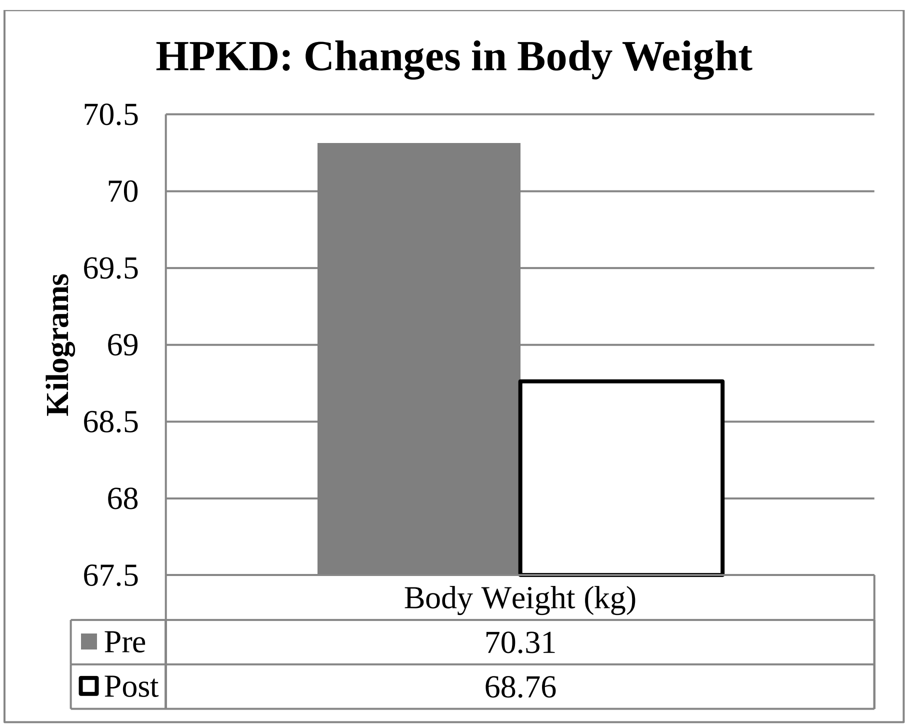


Figure 11: Pre and Post Intervention Changes in Fat Mass in HPKD group

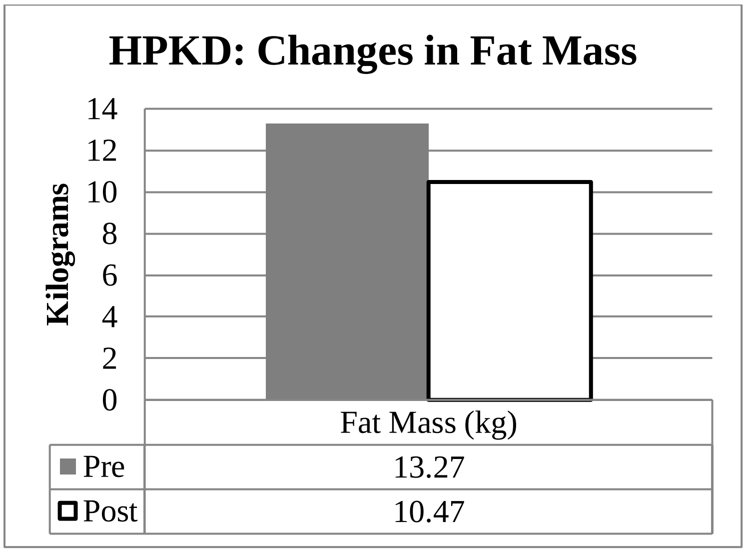


Figure 12: Pre and Post Intervention Changes in Body Fat Percentage in HPKD group

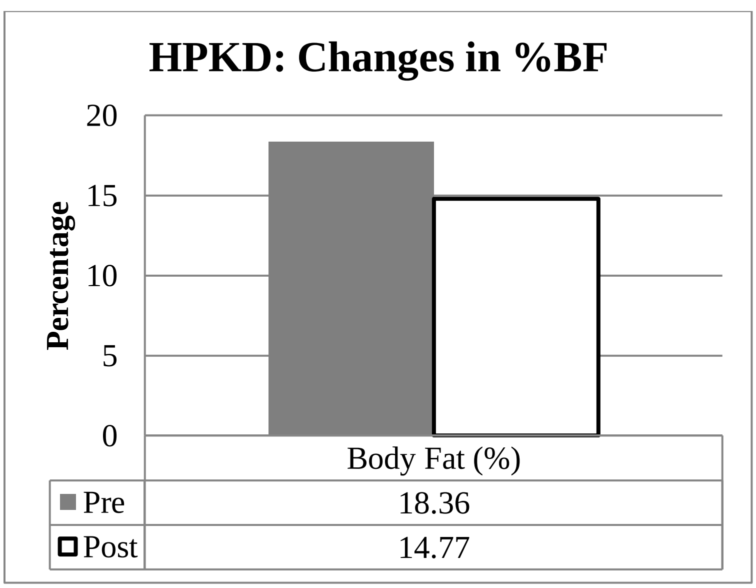
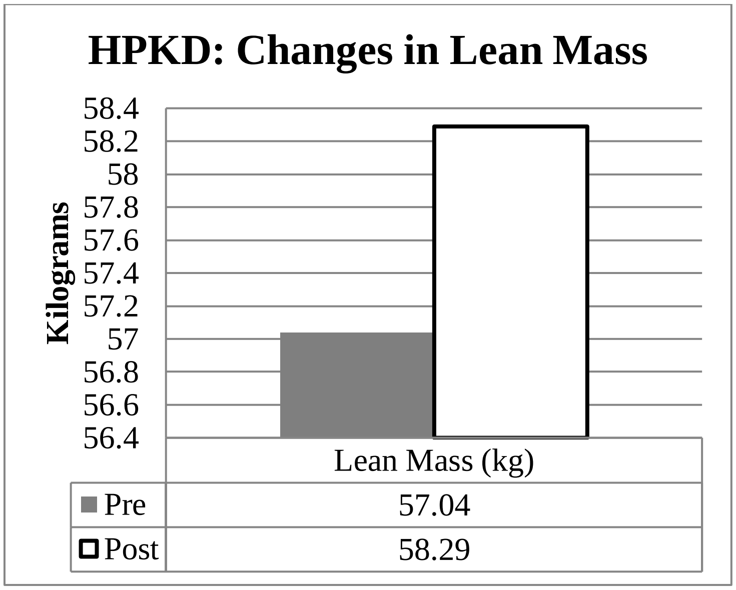


Figure 13: Pre and Post Intervention Changes in Lean Mass in HPKD group



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

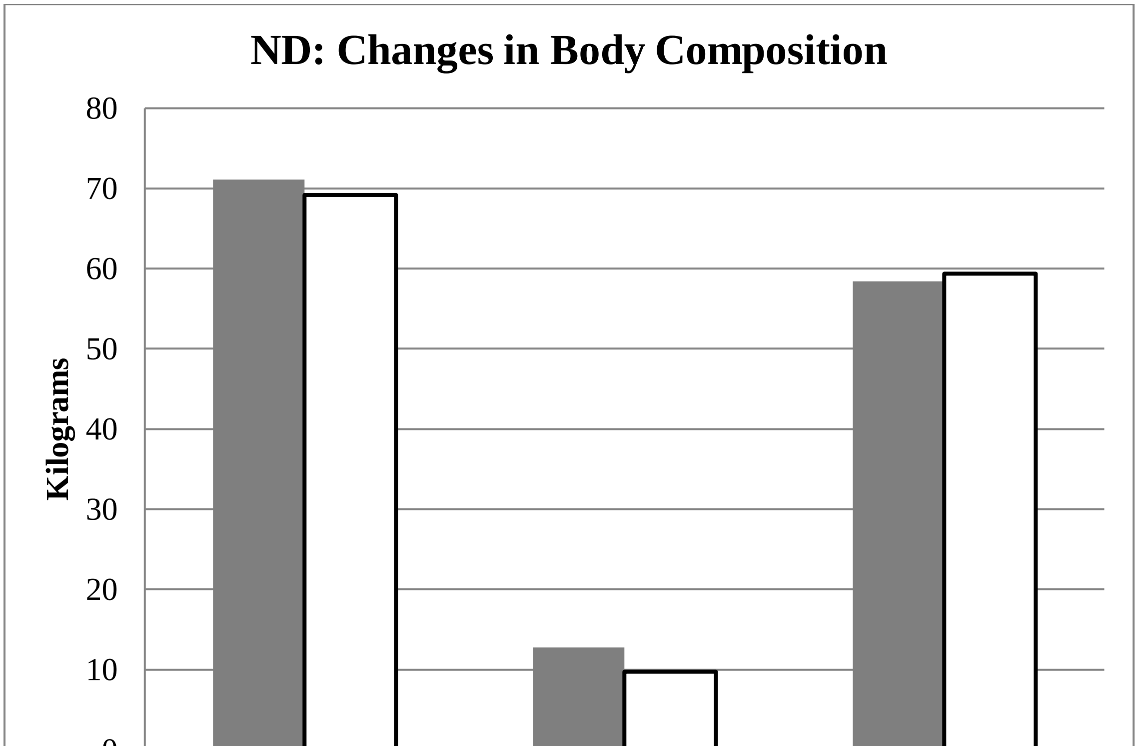
Results from ND group also showed a statistically significant difference ($p<0.05$) on body weight (kg), body fat (%), fat mass (kg), and lean mass (kg) between PRE and POST intervention. The ND group lost 1.97kg weight, dropped 3.70% body fat, reduced 2.96kg fat mass and increased 0.99kg lean mass on average in 6 weeks.

Table 17: 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.

Figure 14: Pre and Post Intervention Changes in Body Composition in ND group



	Body Weight (kg)	Fat Mass (kg)	Lean Mass (kg)
Pre	71.13	12.73	58.4
Post	69.16	9.77	59.39

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.

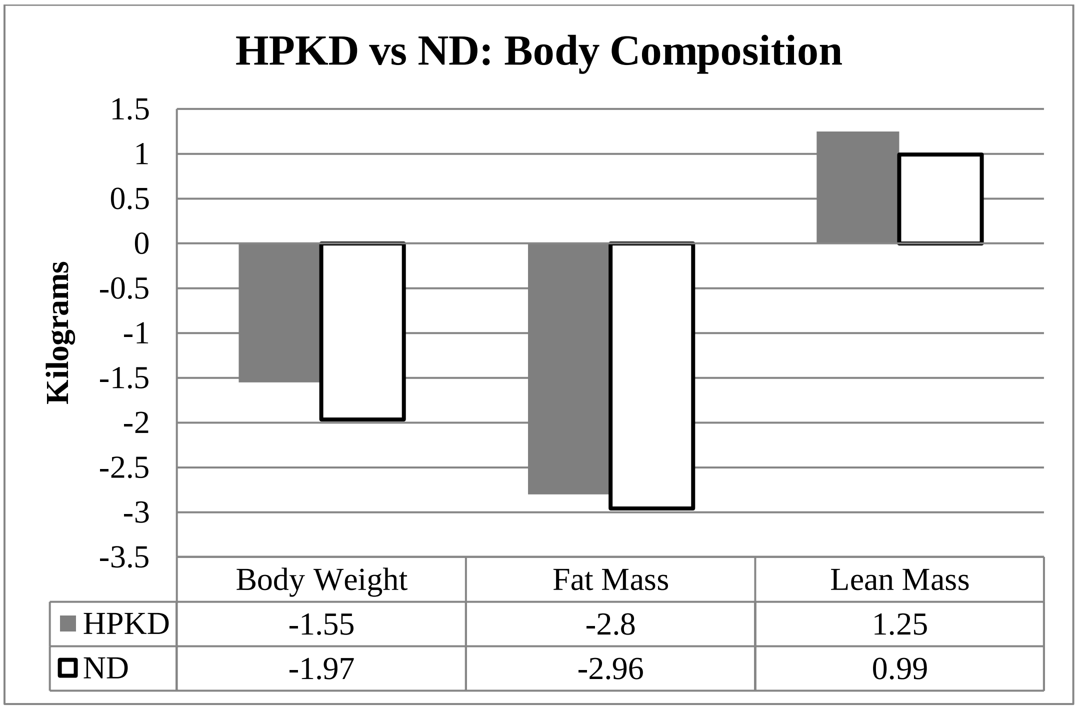
However, no significant differences were observed (p > 0.05) in any variables between HPKD and ND groups (Weight: p = 0.52, Body Fat Percentage: p = 0.62, Fat Mass: p = 0.58, Lean Mass: p = 0.63).

Table 18: 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.

Figure 15: Body Composition between HPKD and ND groups



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

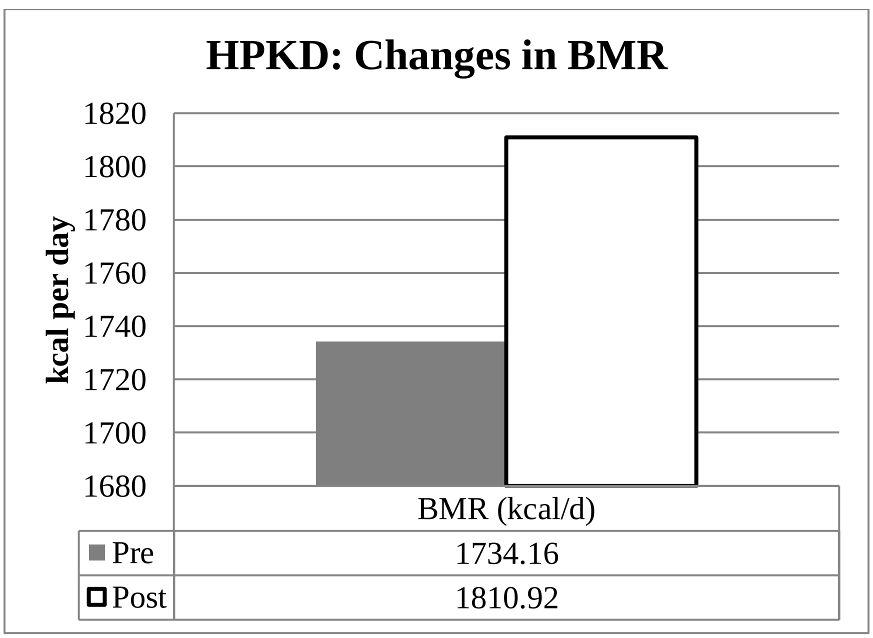
The HPKD group demonstrated a significant improvement ($p<0.05$) in basal metabolic rate (BMR: +4.44%) between pre and post intervention. Within HPKD group, the average increment of BMR in females was +5.40%, which was 1.61% higher than the average increment of BMR in males (Male BMR: +3.79%).

Table 19: 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.

Figure 16: Changes in BMR in HPKD group



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

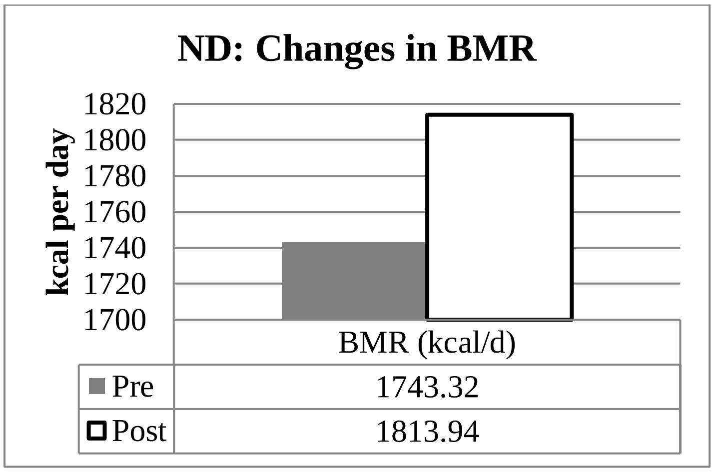
ND group also showed a statistically significant increment ($p<0.05$) in basal metabolic rate (BMR: +4.07%) between pre and post intervention. Within ND group, the average increment of BMR in females was +3.91%, which was 0.23% lower than the average increment of BMR in males (Male BMR: +4.14%).

Table 20: 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.

Figure 17: Pre and Post Intervention Changes in BMR in ND group



13. BMR Comparison between HPKD and ND groups

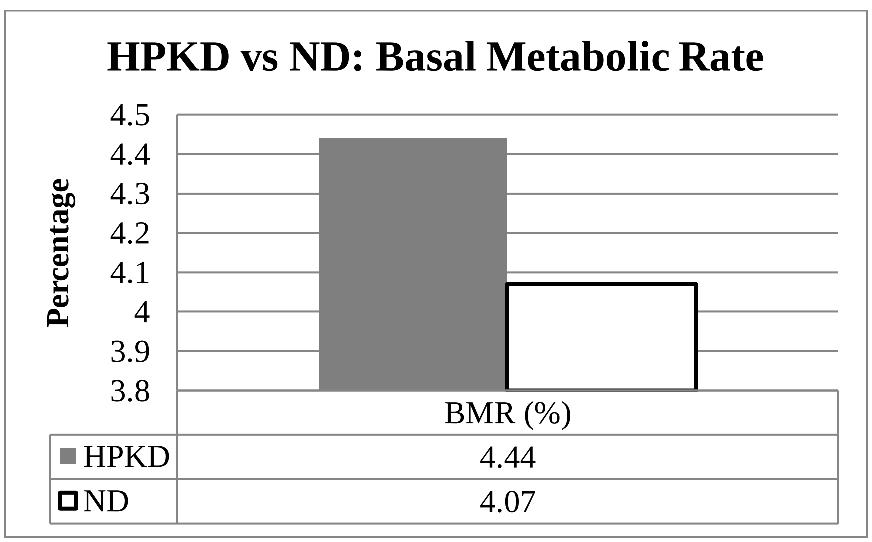
The BMR of participants was calculated pre and post intervention using the InBody770 Body Composition Analyzer. The InBody770 uses the Cunningham equation to determine the BMR using a known regression equation based on the amount of Lean Mass a participant has. Therefore, when the participants gained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

Table 21: 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.

Figure 18: Changes in BMR between HPKD and ND group



CHAPTER 6
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 [53-57].

Additionally, a recent meta-analysis showed that subjects had significantly greater long-term reductions in body weight following a high-fat ketogenic diet as opposed to a low-fat diet [58]. Specifically, Volek, et al. found that greater weight and fat loss was achieved with no significant loss of LBM when following a high-fat ketogenic diet versus a low-fat diet [56].

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.

CHAPTER 7
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, or wrestlers, 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.

ABBREVIATIONS

HPKD – High Protein Ketogenic Diet

ND – Normal Diet

KD – Ketogenic Diet

CD – Control Diet

CON – Control Group

%BF – Body Fat Percent

BW – Body Weight

FM – Fat Mass

FFM – Fat-Free Mass

LM – Lean Mass

BMR – Basal Metabolic Rate

1RM – One Repetition Maximum

CHO – Carbohydrate

ICMR – Indian Council of Medical Research

WHO – World Health Organization

ACSM – America College of Sports Medicine

ACE – American Council on Exercise

ADA – American Diabetes Association

ADP – Adenosine Diphosphate

ATP – Adenosine Triphosphate

BHB – Beta-hydroxybutyrate

BIA – Bioelectric Impedance Analysis

BIS – Bioelectric Impedance Spectroscopy

BMC – Bone Mineral Content

BMI – Body Mass Index

BPM – Beats Per Minute

CoA – Coenzyme A

DRI – Dietary Reference Intakes

DXA – Dual Energy X-Ray Absorptiometry

ECF – Extracellular Fluid

HR – Heart Rate

RDA – Recommended Dietary Allowance

REE – Resting Energy Expenditure

TEE – Total Energy Expenditure

SD – Standard Deviation

AMRAP – As Many Reps As Possible

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