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Research Article

The Effects of a Ketogenic Diet on Body Composition in Resistance Training Females

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Keywords

- Ketogenic diet; Body composition; Female athletes; Resistance training athletes

Abstract

Ketogenic diets are very high-fat, moderate-protein, carbohydrate-restricted diets. Studies have shown that ketogenic diets induce favorable metabolic and physiological changes, including weight loss and improved body composition.

Purpose: The purpose of this study was to examine if the ketogenic diet would produce a favorable impact on body composition by producing fat loss while maintaining lean body mass in resistance training women.

Methods: A sample of 20 women were assigned to either the ketogenic group (N=10) who followed a ketogenic diet of 70% fat, 20% protein, and 10% CHO or a control group (standard diet group) (N=10) who followed their usual standard diet. Both groups participated in resistance training of at least 3 times a week for a duration of 4 weeks. All measurements were taken at week 0 and end of week 4.

Results: Both the ketogenic group and control group participants lost overall body mass (2.35 lbs. + 3.67) and fat mass (1.06 lbs. + 2.97). Ketogenic group participants lost more overall body mass (4.36 lbs. + 3.59) than the control participants (0.34 lbs. + 2.57) (p=0.005). Fat mass decreased to a greater extent in the ketogenic group (2.15 lbs.+ 2.46) compared to the control group which gained fat mass (+0.17 lbs. + 3.08) (p=0.03). Those in the ketogenic group did not lose more lean muscle mass than the control group.

Conclusion: Results indicate that a ketogenic diet has a favorable impact on body composition of lean muscle mass and fat mass in female resistance training athletes.

ABBREVIATIONS

KD: Ketogenic Diet; FFM: Fat Free Mass; FM: Fat Mass; LBM: Lean Body Mass; VLCKD: Very Low Carbohydrate Ketogenic Diet; WD: Western Diet

INTRODUCTION

A ketogenic diet is a high-fat (70-75%), low-carbohydrate (5-10%) and moderate-protein (15-20%) diet. 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%). Ketogenic diets have been found to be effective in managing several chronic conditions, such as epilepsy, metabolic syndrome, diabetes, cancers, and Alzheimer's disease [1-5]. Furthermore, high fat, low carbohydrate diets have been found to enhance performance among endurance athletes and improve overall body composition [6-8]. For these reasons, research into the benefits of a ketogenic diet among the exercising population has increased over the years.

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. 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 [3,6,9].

When examining the physiological and metabolic effects and the various health outcomes of ketogenic diets many studies also 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 normal, overweight, and obese populations. Samaha and colleagues [10] found that severely obese subjects with a high prevalence of diabetes or the metabolic syndrome lost more weight during six months on a carbohydrate-restricted diet than on a calorie and fat-restricted diet, with a relative improvement in insulin sensitivity and triglyceride levels. Further, in a study by Yancy and colleagues [11], 120 community-dwelling hyperlipidemic persons were randomly assigned to either a low-carbohydrate, ketogenic diet or a low-fat, low-cholesterol, reduced-calorie diet for 24 weeks. They found that when compared to the low-fat group, patients in the low-carbohydrate group lost more weight, had a greater decrease in triglyceride levels, and had higher high-density lipoprotein cholesterol levels. Urbain and colleagues [12] assessed the impact of a 6-week non-energy-restricted ketogenic diet (KD) in healthy adults with an average BMI of 23.9 ± 3.1 kg/m^2. They found that even among normal healthy weight individuals, the KD led to a weight loss of -2.0 ± 1.9 kg ($P < 0.001$) with equal losses of fat-free and fat mass. Many studies demonstrate that while there is overall loss in body mass, fat free mass (lean body mass) also decreases following a ketogenic diet [13]. Therefore, concomitant methods of preserving lean body mass would be of interest for those who are looking to improve body composition.

Athletes have taken an interest in how ketogenic diets can help fuel their exercise training and performance. Some studies have demonstrated that high fat, low carbohydrate diets can improve endurance performance via increased capacity for and efficiency of fat oxidation [6,9,14,15]. More recently, strength and power athletes have turned to the ketogenic diet in the interest of losing body fat and improving lean body mass. Wilson and colleagues investigated the impact of an isocaloric and isonitrogenous ketogenic diet versus a traditional western diet on changes in body composition, performance, blood lipids, and hormonal profiles in male resistance-trained athletes [16]. Participants followed either a ketogenic diet (KD) or a traditional western diet (WD) for 11 weeks while participating in a resistance training program. Body composition, strength, power, blood lipid profiles and testosterone levels were all assessed. Researchers found that lean body mass (LBM) increased (KD 2.4% and WD 4.4%, $p < 0.01$) and fat mass decreased in both groups (KD -2.2 + 1.2 kg, WD -1.5 + 1.6 kg). Strength and power also increased to the same extent in the KD and WD conditions from weeks 1 to 11. Other notable changes were that testosterone increased significantly in the KD group but not the WD group. The researchers concluded that the KD can be used in combination with resistance training to cause favorable changes in body composition, performance, and hormonal profiles in resistance-trained men.

Following a Very Low Carbohydrate Ketogenic Diet (VLCKD) for a relatively short period of time (i.e. 30 days) can decrease body weight and body fat without negative effects on strength performance in high level athletes [17]. In a study examining the effects of a low carbohydrate diet on power, Paoli and colleagues found that a ketogenic diet did not affect strength performance in elite artistic gymnasts. In this crossover design study, eight elite artistic gymnasts consumed a VLCKD for 30 days. During the VLCKD the athletes performed their normal training program. Before and after the diet, body composition and various performance aspects (hanging straight leg raise, ground push up, parallel bar dips, pull up, squat jump, countermovement jump, 30sec continuous jumps) were assessed. After three months the same protocol and tests were performed before and after 30 days of the athletes' usual diet (a typically western diet, WD). No significant differences were detected between VLCKD and WD in all strength tests. Significant differences were found in body weight and body composition: after VLCKD there was a decrease in body weight (from 69.6 ± 7.3 kg to 68.0 ± 7.5 kg) and fat mass (from 5.3 ± 1.3 kg to 3.4 ± 0.8 kg, $p<0.001$) with a non-significant increase in muscle mass. These authors concluded that the effects of a short-term (i.e. 30 days) VLCKD on fat loss without the concomitant negative effects on performance may be a useful strategy for those athletes who compete in sports that involve weight categories [17].

The ketogenic diet remains controversial regarding overall benefits to athletes, but there appears to be enough evidence that supports its effectiveness on weight loss and fat loss and when combined with resistance training exercise, may preserve lean body mass. Rauch et al. determined that the combination of the ketogenic diet with a periodized resistance training program three times per week led to an increase in lean muscle mass for the ketogenic group (4.3 ± 1.7 kg) compared to the western diet group (2.2 ± 1.7 kg) [18]. According to Jabekk et al [19] including 60-100 minutes of resistance training twice per week for 10 weeks along with a ketogenic diet resulted in body fat loss without significantly affecting lean body mass. Due to the paucity of data regarding the effects of the ketogenic diet on resistance training female athletes, we hoped to determine if a low carbohydrate, ketogenic diet would have positive benefits for overall body composition among this population. More specifically, our target population was female fitness competitors who were interested in losing fat mass while maintaining lean body mass. We hypothesized that participants who were performing weekly resistance training while following a low carbohydrate ketogenic diet would lose overall body weight and fat mass. Furthermore, due to the anticipated breakdown of fatty acids for energy, we projected that lean body mass would be unaffected or sparingly so.

MATERIALS AND METHODS

Subjects

Twenty female participants were recruited from the La Crosse, WI area (Mean age = 20.27 + 1.60) Prior to the study, written consent was obtained by all the participants. All procedures were approved by the UW-La Crosse Institutional Review Board for the Protection of Human Subjects. The sample consisted of women with no prior history of consuming a ketogenic or low carbohydrate diet. Participants were regularly active with cardiovascular and resistance training prior to the study. Participants were instructed to follow their individualized resistance-training program. Load, sets, and repetitions of the resistance training programs were dependent upon each participants' current level of fitness and experience. The participants were randomly assigned to either the ketogenic diet group (N=10) who followed a low carbohydrate ketogenic diet of 70% fat, 20% protein, and 10% CHO or a control group (nonketogenic diet group) (N=10) who followed their usual standard diet. Both groups followed their diet plan and participated in resistance training of at least 3 times per week for a duration of 4 weeks. All measurements were taken at week 0 and end of week 4.

Procedure

All participants completed pre- and post-study Bod Pod analyses to assess body composition changes. Measurements from the Bod Pod analysis included body mass, fat mass, fat free mass, and body composition totals and percentages. The ketogenic diet group received education materials, tip sheets, and instruction on how to follow a ketogenic diet. Those in the ketogenic diet group were not given a calorie target; instead, they were asked to meet their macronutrient goals daily. The control group received educational materials about the current dietary guidelines and the USDA's Myplate [20,21]. The control group was not given a calorie target but were instructed to follow their "normal standard diet." During the 4-week trial, the ketogenic diet group participants recorded a daily food log using the MyFitnessPal app [22]. Only the ketogenic diet group was required to log their food intake to ensure compliance with a ketogenic diet. Both groups logged their resistance training workouts. Participants were instructed to engage in minimal cardio to focus on the growth of lean muscle mass. Ketone and glucose values were assessed using McKesson 120 Urinary Analysis Strips. All measurements were taken at week 0 and end of week 4.

Statistical methods: Welch t-tests were used to compare metrics between the experimental and control groups. Simple linear regression was used to explore and test the relationship between body composition changes and measured ketone values for participants in the experimental group. All data exploration and related statistical analyses were performed in R 3.6.2 [23].

RESULTS AND DISCUSSION

Body mass loss

Overall body mass loss was calculated for both groups (pre minus post). On average, those in the ketogenic group lost 4.36 pounds (SD=3.59) compared to the control group which lost 0.34 on average (SD=2.58) (Table 1). Figure 1 shows overall body mass losses, separated by treatment. The ketogenic group lost more overall mass, on average (t(df=16.32) = -2.88, p=0.005).

Fat mass loss

Fat mass loss was calculated for both groups (pre minus post). On average, those in the ketogenic group lost 2.28 pounds (SD=2.42) compared to the control group which lost -0.17 on average (SD=3.08). Figure 2 shows fat mass losses, separated by treatment. The ketogenic group lost more fat mass, on average (t(df=17.05) = -1.97, p=0.032).

Fat free mass loss

Fat free mass loss was calculated for both groups (pre-post). On average, those in the ketogenic group lost 2.15 pounds (SD=3.72) compared to the control group which lost 0.51 on average (SD=3.13). The figure below is a boxplot of these fat free mass losses, separated by treatment. Figure 3 shows the ketogenic group did **not** lose more fat free mass, on average (t(df=17.49) = -1.07, p=0.15).

Data and dietary analysis were verified by a ketogenic food record, positive testing of urinary ketones and glucose, and a record of resistance training over the course of the study. Ketone and glucose values were verified by the McKesson 120 using 10SG Urine Reagent Strips. A value from 0 to +5 indicated the level of ketones or glucose present in the urinary sample. Ideally, we would expect a positive value for ketones and a value of "0" for glucose dependent upon the precision of the ketogenic diet.

Body mass loss vs. ketone value

Body mass loss was defined as pre-study body mass minus post-study body mass as above. Simple linear regression was used to investigate the relationship between body mass loss and ketone value. In summary, there is a significant relationship between body mass loss and ketone value (t(8)=3.4, p-value=0.009). The relationship is summarized by the equation: *Body Mass Loss* = 1.605 + 2.508*Ketone*. This means that as ketone value increases by 1-unit, average mass loss increases by 2.51 pounds (Figure 4).

Fat mass loss vs. ketone value

Fat mass loss was defined as pre-study fat mass minus post-study fat mass as above. Simple linear regression was used to investigate the relationship between fat mass loss and ketone value In summary, there is a significant relationship

Table 1: Overall differences between the ketogenic diet group and the standard diet group in body mass, fat mass, and fat free mass.

Diet Group	Body Mass (lbs.) Pre-test (Mean ± SD)	Body Mass (lbs.) Post-test (Mean ± SD)	Difference in BM Pre-Post (lbs.) (Mean ± SD)	Fat Mass (lbs.) Pre-test (Mean ± SD)	Fat Mass (lbs.) Post-test (Mean ± SD)	Difference in FM Pre-Post (lbs.) (Mean ± SD)	FFM (lbs.) Pre-test (Mean ± SD)	FFM (lbs.) Post-test (Mean ± SD)	Difference in FFM Pre-Post (lbs.) (Mean ± SD)
Ketogenic diet (N=10)	163.69 ± 20.93	159.33 ± 20.43	4.36 ± 3.59*	49.55 ± 10.69	47.28 ± 11.88	2.28 ± 2.42**	114.21 ± 12.48	112.05 ± 10.33	2.15 ± 3.72
Standard diet (Control) (N=10)	139.85 ± 18.74	139.50 ± 20.30	0.34 ± 2.57	33.56 ± 12.90	33.73 ± 11.86	-0.17 ± 3.08	106.28 ± 9.43	105.78 ± 10.86	0.51 ± 3.13

Abbreviations: BM = Body Mass, FM = Fat Mass, FFM = Fat Free Mass, BF = Body Fat
*Significant difference between diet groups p = 0.005
** Significant difference between diet groups p = 0.03

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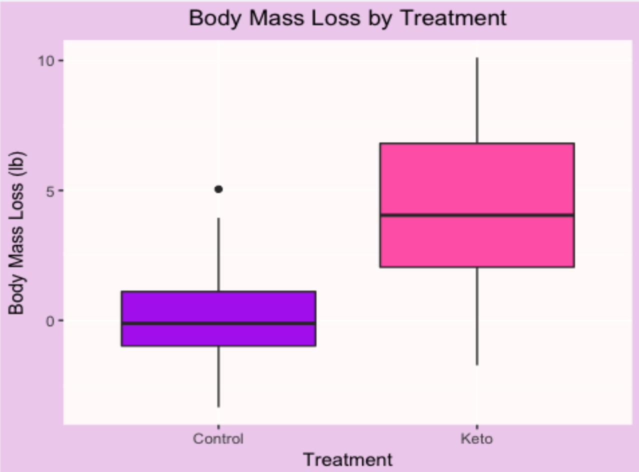

Figure 1 The ketogenic group lost more overall mass, on average (t(df=16.32) = -2.88, p=0.005).

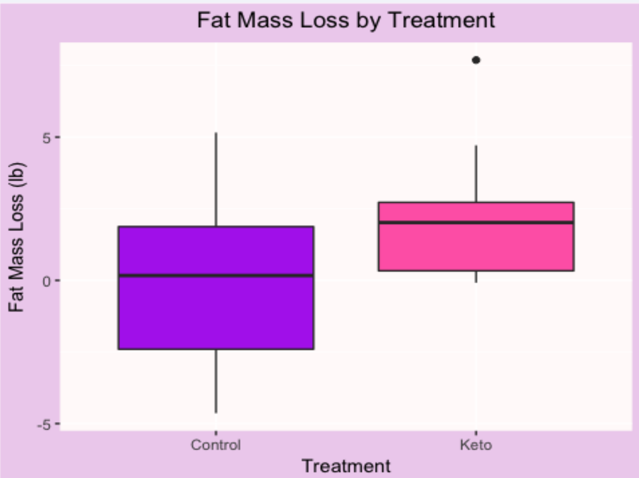

Figure 2 The ketogenic group lost more fat mass, on average (t(df=17.05) = -1.97, p=0.032).

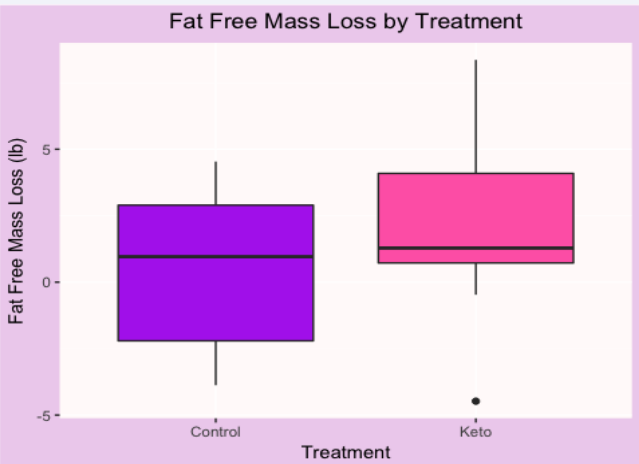

Figure 3 The ketogenic group did not lose more fat free mass, on average (t(df=17.49) = -1.07, p=0.15).

between fat loss and ketone value (t(8)=2.14, p-value=0.064). The relationship is summarized by the equation: *Fat Mass Loss* = 0.819 + 1.328*Ketone*. This means that as ketone value increases by 1-unit, average fat mass loss increases by 1.328 pounds (Figure 5).

Fat Free Mass Loss vs. Ketone Value

Fat-free mass loss was defined as pre-study fat-free mass minus post-study fat-free mass as above. Simple linear regression was used to investigate the relationship between fat-free mass loss and ketone value. In summary, there is **not** a significant relationship between fat-free mass loss and ketone value (t(8)=0.98, p-value=0.354) (Figure 6).

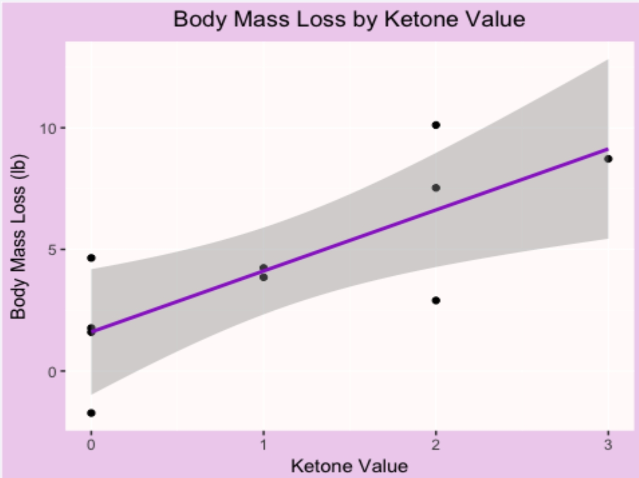

Figure 4 There is a significant relationship between body mass loss and ketone value (t(8)=3.4, p-value=0.009). The relationship is summarized by the equation: *Body Mass Loss* = 1.605 + 2.508*Ketone*. This means that as ketone value increases by 1-unit, average mass loss increases by 2.51 pounds.

Figure 5 There is a significant relationship between fat loss and ketone value (t(8)=2.14, p-value=0.064). The relationship is summarized by the equation: *Fat Mass Loss* = 0.819 + 1.328*Ketone*. This means that as ketone value increases by 1-unit, average fat mass loss increases by 1.328 pounds.

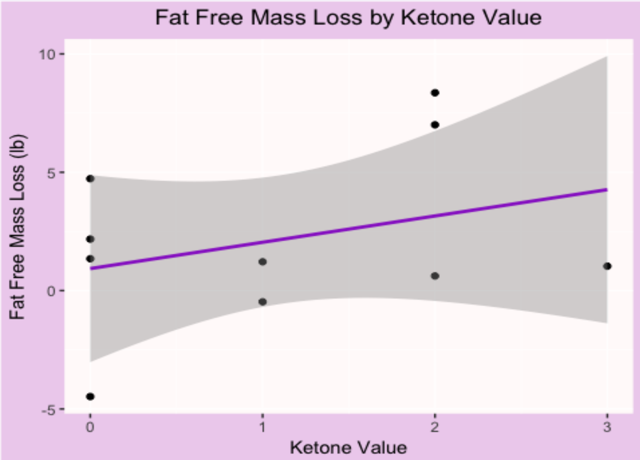

Figure 6 There is not a significant relationship between fat-free mass loss and ketone value (t(8)=0.98, p-value=0.354).

DISCUSSION

The primary purpose of this study was to evaluate the effects of a ketogenic diet on body composition among resistance training female athletes. The present study found that participants following a ketogenic diet lost more overall body mass, fat mass, and maintained lean body mass to a greater extent than control subjects. Our results are consistent with the literature demonstrating that following a ketogenic diet does result in overall weight loss [18,19,24]. Consistent with Jabekk, we observed a weight loss of 4.36 + 3.59 lbs. in the ketogenic diet group over the course of four weeks [19]. Jabekk found a mean weight loss of 5.6 + 2.6 kg (12.3 + 5.7 lbs.) over the course of 10 weeks [19]. Johnston et al. reported their ketogenic diet group lost 6.3 + 0.6 kg (13.9 + 1.32 lbs.) over the course of a 6-week trial [24]. Overall, these studies demonstrate a trend of weight loss of about 1 to 2 lbs. per week following a ketogenic diet. This aligns with the recommended safe rate of weight loss.

Weight loss can have positive health benefits and can have performance benefits for certain athletic populations. This is especially true if the weight lost comes from fat mass rather than lean body mass (muscle). Jabekk et al [19] was specifically interested in how resistance training would impact weight loss among overweight women who followed a ketogenic diet compared to those who consumed a regular diet [19]. Results from their study showed that the ketogenic group lost 5.6 + 2.9 kg (12.3 + 6.4 lbs.) (p = 0.001) of fat mass with no significant change in lean body mass while the control group (regular diet group) had no significant change in fat mass, but gained 1.6 + 1.8 kg (3.52 + 3.96 lbs.) of lean body mass [19]. Rauch et al [18] conducted an 11-week study designed to specifically measure the effects of ketogenic dieting on skeletal muscle and fat mass of college-aged men. Twenty-six participants were divided into a very low carbohydrate ketogenic diet (VLCKD) group and a traditional diet group. Similar to our study, subjects participated in a resistance training program three times per week. Rauch et al found that the VLCKD group lost 2.2 + 1.2 kg (4.85 + 2.65 lbs.) of fat mass compared to the traditional diet group (1.5 + 1.6 kg, 3.30 + 3.52 lbs.). More importantly, they found that lean body mass increased to a greater extent in the VLCKD group (4.3 + 1.7 kg, 9.48 ± 3.78 lbs.) as compared to the traditional diet group (2.2 + 1.7 kg, 4.85. ± 3.78 lbs.) [18]. Regarding fat mass, their findings align with our data in that our ketogenic diet group lost 2.28 + 2.46 lbs. of fat mass compared to our control group, which actually gained fat mass (0.17 lbs. + 3.08). Contrary to Rauch et al, in our study, lean muscle mass decreased in both groups. Our ketogenic group lost 2.15 ± 3.72 lbs. of lean body mass compared to the control group which lost 0.51 ± 3.13 lbs. One explanation for this loss of lean body mass may be explained by the level of ketones achieved by our ketogenic diet group. Ketone bodies can spare protein catabolism, which may explain the preservation of lean tissue observed across some studies [3]. While we saw an overall increase in ketones from week 1 to week 4, it may not have been to the degree needed to preserve lean body mass. Despite this, we still conclude that lean muscle mass was not lost significantly more in one group over the other. The pattern among several studies is that more body mass and fat mass is lost among participants following a ketogenic diet compared to those following a standard American diet. Adding resistance training can be a beneficial adjunct in preserving lean body mass [13]. We conclude that the ketogenic diet may be a safe and effective means for favorable body composition changes for the resistance training female.

While there is still much controversy surrounding the value and safety of ketogenic diets, Volek and Westman [3] strongly recommend that research continue into the study of ketogenic diets for not only weight loss, but for physical performance benefits as well. They argue that "…studies have shown that very-low-carbohydrate diets may result in improved or maintained endurance exercise performance." (p. 861). Rhyu and Cho [25] determined that despite similar weight loss among their study groups (ketogenic diet group vs. nonketogenic diet group in Taekwondo athletes), their ketogenic diet group finished 2,000 m sprints in less time and felt less fatigue as measured by the Wingate test. In combining resistance training with the ketogenic diet, Wilson et al [16] determined that the ketogenic diet did not negatively impact strength and performance measurements, such as bench press, squat, and anaerobic power among male athletes. Urbain and colleagues [12], on the other hand, found "a mildly negative impact" on endurance capacity, peak power and time to exhaustion among their study participants, despite positive effects on weight loss. Therefore, these authors concluded that a ketogenic diet may be a matter of concern in competitive athletes. While we found favorable changes in body composition among those following a ketogenic diet combined with resistance training, we did not assess strength or athletic performance variables among this group of participants (limitation). In a small unpublished follow up study by our group, we found no significant differences in performance measures of back squat, bench press, vertical jump, flexed arm hand, and perception of muscle soreness between those in the ketogenic diet group and those in the standard diet group [26].

It is important to note that the literature clearly emphasizes that adaptation to a low carbohydrate, ketogenic diet takes time. There are reports of negative side effects during the first week or two when the body is shifting from the use of glucose as fuel toward the use of fatty acids and ketones as fuel. Reported adverse symptoms include loss of appetite, headaches, gastrointestinal discomfort, lightheadedness, weakness, and fatigue [12,24,27]. Among participants in our study, several of the ketogenic diet group reported feeling tired during everyday activities along with their exercise and hungrier during the first week of following the ketogenic diet. During the second to forth week, most participants reported feeling extremely energetic. Additionally, physical sensations of reduced hunger occurred, despite overall calorie consumption declining among the ketogenic group from week 1 to week 4 (mean calorie consumption week 1 = 1341 + 306; mean calorie consumption week 4 = 1227 + 428). This may be explained by the notion that higher consumption of fat in the diet along with decreased consumption of carbohydrates has been shown to decrease appetite via increasing overall satiety [28]. Thus, when examining any effects of the ketogenic diet, whether it is body composition changes or performance markers, studies must take this adaptation phase into consideration. Evidence supports that studies should last beyond three to four weeks to account for this early period of feelings of the "ketogenic flu" [27].

CONCLUSION

While the application of ketogenic diets has evolved of the years, little to no research has been done on female resistance training athletes. There is conflicting evidence in the literature regarding the safety and efficacy of the ketogenic diet and its application and impact appears to be specific to the outcome measured (metabolic health, body composition, seizure disorders, endurance, strength, or power.) The results of the present study suggest that this diet may have a favorable impact on achieving weight loss goals, but more importantly preserving lean body mass among resistance training female athletes and therefore, may be an effective adjunct to reaching desired training and body composition goals.

LIMITATIONS

While we found favorable changes in body composition among those following a ketogenic diet combined with resistance training, we did not assess strength or athletic performance variables among this group of participants. Some studies have indicated that ketogenic diets, combined with resistance training do not negatively impact strength and performance measurements, such as bench press, squat, and anaerobic power among male athletes [16]. We highly recommend that in future studies, strength and performance should be assessed among female resistance training athletes.

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