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RESEARCH ARTICLE

Impact of Ketogenic Diet on Body Composition during Resistance Training among Untrained Individuals

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Abstract:

Background:

Resistance training (RT) has been established as the most efficient approach for lean body mass maintenance required for preserving a sufficiently high metabolism during weight loss.

Objective:

This study aimed to evaluate the impacts of the ketogenic diet (KD) and regular diet (RE) in combination with 8-week resistance exercise (RT), on body weight, body fat mass (BFM), and lean body mass (LBM) of untrained individuals.

Methods:

Twenty untrained participants were randomly assigned to the RE+RT and KD+RT as control and experimental groups, respectively. Sixty to ninety minutes of diversified resistance exercise were performed by both groups, three sessions weekly, and diet was self-administered with a recommended daily energy and protein intakes. Body composition was measured using a Bioelectrical Impedance Analyzer. One-way Analysis of Covariance (ANCOVA) was applied to analyze the data.

Results:

The results showed a greater post-intervention adjusted mean for body weight and LBM in the normal dietary group in comparison with the experimental group. After controlling for baseline measurements, there was a statistically significant difference in body weight ($p < .0005$) and BFM ($p = .001$) between groups.

Conclusion:

Resistance training along with a ketogenic diet may decrease BFM without notable changes in LBM, whilst RT on a normal diet might increase LBM without remarkably influencing BFM.

Keywords: Resistance training, Lean body mass, Ketogenic diet, Weight loss, Body fat mass, Dietary carbohydrate.

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1. INTRODUCTION

The global prevalence of obesity has increased at an alarming rate, signalling an urgent need for safe, effective and sustainable weight-loss strategies. In the early 1920s, the ketogenic diet (KD), which is a high-fat (70%), very-low-carbohydrate (5%), moderate-protein diet (25%) [1], was formulated as a treatment for intractable epilepsy in children. However, when antiepileptic agents became available, the diet fell out of favor. Despite this, since 2018, the KD has gained so much traction that the term "keto" is now seven to ten times more popular than the terms "Paleo" and "Atkins" [2, 3]. This is perhaps due to the efficacy of the KD as a potential weight loss strategy because of the low-carb diet trend. The fundamental principle of this diet is that drastic restriction of dietary carbohydrate, with its resulting ketosis, promotes fat

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oxidation, increased energy expansion and satiety promotes negative calorie balance and eventual weight loss [4].

A variety of studies have deduced that a lower carbohydrate diet with no energy limitation seems to be as efficient as low-fat energy straitened diets in triggering weight reduction to a certain extent during a time of up to 1 year [5 - 7]. A systematic review concluded that high-protein or low-carb diets are more efficient within a period of six months and as efficient as low-fat diets in reducing the possibility of cardiovascular disease and losing weight till one year [6, 8].

A major concern connected with the efficiency of any regime for losing weight is its effect on body composition, hence making it difficult to compare the effectiveness of various diets based on the reduction of body weight alone. Numerous slimming diets that reduce body fat occurs with an implicit lean body mass (LBM) reduction, which in many instances, it has been suggested as a justification for the long run fail of several weight-loss programs [9]. This is because maintaining or increasing LBM is important for preserving a sufficiently high metabolism to minimize the tendency of weight return, which is the main problem regarding the so-called "yo-yo" effect [10] apart from keeping adequate body function with aging [11].

The most efficient approach for retaining or increasing LBM is through resistance exercises [12]. Resistance training has been established to restrict the LBM loss during weight reduction [13, 14]. Moreover, resistance exercise is capable of ameliorating metabolic disorders that come along with poor glycemic control and overweight, to cut down both the requirement and diabetes medication, systolic blood pressure and abdominal adiposity [15].

Nutritional interventions that could result in exceptional LBM retention during weight loss would be beneficial to athletes in the weight-class restricted sports or those looking to improve body composition by preserving LBM while reducing fat mass for competitions. However, it has been reported that very-low-carbohydrate diets bring about substantial losses of LBM [16], but other authors disagree [17 - 19].

To date, the efficacy of KD in athletes seeking to improve body composition as well as those looking to improve strength and power performance, has gained minimal attention. The majority of exercise studies that have examined high-fat diets thus far and have also contained a number of carbohydrates sufficient to limit or prevent ketosis, have been underpowered, and/or were too short to allow for adaptation to the diet [20]. The results also revealed that an experimental diet was unable to achieve the full spectrum of benefits expected from a sustained ketogenic diet [20].

As the fat loss may seem to be lesser on fat-limited diet compared to carbohydrate-limited one, and since resistance training (RT) looks to be the most successful approach for muscle mass increment, an amalgamation of both strategies may increase the chance of weight loss with a favorable change in body composition. As such, the aim of the current study is to evaluate the impacts of ketogenic and normal diets, in combination with resistance exercises on body composition, in particular body weight, lean body mass and body fat mass (BFM). We hypothesized that there would be a significant difference in selected variables from pre to post-intervention and between two groups.

2. METHODOLOGY

2.1. Participants

This study was carried out with 20 participants who were randomly assigned to the intervention group (n = 10) with the mean age 35.2 ± 10.1 years, height 1.66 ± 0.1 m, bodyweight 64.9 ± 16.1 kg, and BMI 23.59 ± 4.56; and control group (n = 10) with the mean age 33.2 ± 10.5 years, height 1.69 ± 0.1 m, bodyweight 68.8 ± 12.5 kg, and Body Mass Index (BMI) 24.12 ± 3.6. Control group received a regular diet and resistance exercise (RE+RT), and the intervention group was imposed on the keto diet and resistance exercise (KD+RT). They had not previously been taking low carbohydrate diets and had not attended resistance training for the past six months. Participants were omitted if they had been on androgenic-anabolic steroids within the last two years, had any physical disabilities or recent medical conditions that would interfere with resistance exercises. All participants were asked for a written informed consent after an explanation of the procedure and possible risk of the experiment prior to the start of the study. The research was reviewed and approved by the University Malaya advisory panel for research involving human participants on 05/09/2019.

2.2. Training Protocol

Following a two-week diet adaptation period for the KD+RT group, both groups participated in an 8-week resistance training. All exercises were performed at FitClub, a 24-hour Gym and all sessions supervised by at least one qualified instructor. The eight-week personal training program consists of three hypertrophy sessions per week, organized into a two-day upper limb and one-day lower limb, along with at least 24-hour rest between each session to encourage recovery [21].

Prior to data collection, a familiarization phase was expected to take place in order to accustom all participants to the exercises in the personal training program. Within this session, the 8-repetition maximum (8-RM) test for all exercises was assessed for all individuals. All sessions were conducted after a 10-min warmup with low intensity on a cardio machine. Stimulation of mechanical strain was done by utilizing the medium to high loads [22]. The volume did not decline as the rest between sets remained for three minutes [23]. To obtain better recovery, push and pull exercises were intermixed [24]. Groups were requested to enhance loads as long as they exceeded rates of repetition without having an error in technique. In the meantime, participants were requested to retain their level of physical activity and avoid participation in any other resistance exercises during the time of this study. Participants of both groups had consistent attendance in the exercise sessions.

2.3. Diet Intervention

Daily multivitamin and mineral supplements, LifePak

(Nuskin, USA), were given to the participants of both groups. Individuals in each group were counseled during a single group session by a registered dietitian. Participants in the KD+RT group were informed about the principles and usage of dietary intervention and were given an available eBook on the ketogenic diet ("The complete ketogenic diet for beginners") [25] in addition to handouts. An average energy surfeit was set up for participants of both groups upon determination of their weekly training load and energy expenditure.

The preparation of food was self-administered, while a daily caloric consumption of 39 kcal/kg/day was recommended for all participants to encourage a hyper-energetic condition. A protein consumption of 2 gr/kg/day was advised for both groups to ensure maximal anabolic response [26]. Macronutrient Distribution of macronutrient for regular diet participants was about 20% fat, 35% carbohydrate and 45% protein, while for the keto diet group, macronutrient distribution of macronutrient was about 70% fat, 5% carbohydrate and 25% protein. They were allowed *Ad libitum* meal timing and frequency during the day.

The presence and subsequent compliance with ketosis state for the KD+RT group were controlled through evaluating urinary ketones, concentration of acetoacetic acid and acetone, using reagent strips (*Ketone Reagent Strips for Urinalysis, DIRUI Industrial Co., Ltd., Jilin, China*) twice weekly, starting from the second week until the completion of the study. Keto diet group was asked to start up the dietary intervention with a maximum 20 gr/day of carbohydrate and to steadily enhance carbohydrate consumption, but not exceeding 5% of their caloric consumption, at their choice, until they retained a change in color on the urine test strips.

2.4. Body Composition

Measurements of body composition were conducted at baseline (week 2) and following the resistance training intervention (week 10), using an InBody 570 Multi-frequency Bioelectrical Impedance Analyzer (*Biospace Co., Ltd, CA, USA*). The InBody 570 body composition analyzer splits body mass into three components: fat, muscle, and bone mineral [27]. A wall-mounted stadiometer was used to measure participant's height without shoes.

2.5. Statistical Analyses

One-way Analysis of Covariance (ANCOVA) was applied to examine the impact of a "regular diet and resistance exercise" and "keto diet and resistance exercise" on post-intervention Body Fat Mass, Body Weight, and Lean Body Mass after controlling for pre-intervention Body Fat Mass, Body Weight, and Lean Body Mass, respectively. Moreover, a paired-sample t-test was applied to evaluate the changes from pre-intervention for each individual group. Statistical analyses were done using SPSS for Windows, version 24. $p \leq 0.05$ was considered statistically significant in the interpretation of the results. Moreover, the preliminary assumptions were checked without any serious violations.

3. RESULTS

Adjusted means and standard errors (SE) for post-intervention of measured variables along with their unadjusted means and standard deviation (SD) for pre and post-intervention, are presented in Table **1**. Changes from baseline and their corresponding *p*-value are also reported for each individual group. The KD+RT group showed a statistically significant decrease of 2.90 kg in Body Weight, t (9) =-5.75, $p < .0005$, while the RE+RT group significantly gained weight by 1.29 kg, t (9) = 2.88, p =.018. Bodyweight was greater in the RE+RT group (M = 68.21, SE = 0.48 kg) compared to the KD+RT group (M = 63.93, SE = 0.48 kg) post-intervention after controlling for baseline body weight. There was also a significant difference in post-intervention body weight among the groups, F (1, 17) = 39.19, $p < .0005$, partial η^2 = .697.

Table 1. Unadjusted means and standard deviations (SD) for pre- and post-intervention body composition components, adjusted means and standard errors (SE) for post-intervention body composition components after controlling for their pre-intervention, and changes from baseline measurements.

Variables	Unadjusted Scores Mean (SD)						Post-intervention Adjusted Scores Mean (SE)	
	KD+RT Group			RE+RT Group				
	Pre-intervention	Post-intervention	*P*-value	Pre-intervention	Post-intervention	*P*-value	KD+RT Group	RE+RT Group
Body Weight (kg)	64.91 (16.06)	62.01 (15.76)	*p*<0.0005**	68.83 (12.52)	70.12 (12.31)	0.018**	63.93 (0.48)	68.21 (0.48) (*p*<0.0005)*
Body Fat Mass (kg)	22.57 (10.49)	18.19 (8.95)	*p*<0.0005**	19.62 (6.95)	18.11 (6.55)	*p*<0.0005**	16.91 (0.42)	19.39 (0.42) (*p*=0.001)*
Lean Body Mass (kg)	42.34 (9.24)	43.82 (9.98)	0.033**	49.21 (9.14)	52.01 (9.49)	*p*<0.0005**	47.41 (0.51)	48.42 (0.51) (*p*=0.199)
Body Mass Index	23.59 (4.59)	22.53 (4.43)	*p*<0.0005**	24.12 (3.60)	24.59 (3.46)	0.016**	22.78 (0.18)	24.34 (0.18) (*p*<0.0005)*

* Significant difference with keto-diet group (p<0.05)
** Significant changes from Baseline (Pre-intervention) (p<0.05)
KD+RT: Keto-diet combination with resistance exercise; RE+RT: regular-diet combination with resistance exercise.

Body fat mass elicited statistically significant mean decrease of 1.51 kg, t (9) =-6.05, $p < .0005$, and 4.38 kg, t (9) =-5.96, $p < .0005$ for group on regular diet and group on keto diet, individually. After adjustment for pre-intervention body fat mass, RE+RT group demonstrated higher mean (M = 19.39, SE = 0.42 kg) compared to the KD+RT group (M = 16.91, SE = 0.42 kg). Furthermore, there was a significant difference in post-intervention body fat mass among the groups, F (1, 17) = 17.087, p =.001, partial η^2 = .501.

Regular diet and keto diet groups indicated significant mean increase of 2.8 kg, t (9) =7.21, $p < .0005$ and 1.48 kg, t (9) =2.52, p =.033 in lean body mass, respectively. Although mean of lean body mass was greater in the RE+RT group (M = 48.416, SE = 0.511 kg) compared to the KD+RT group (M = 47.414, SE = 0.511 kg) after controlling for pre-intervention scores, there was not a significant difference in post-intervention lean body mass among two groups, F (1, 17) = 1.788, p =.199, partial η^2 = .095.

4. DISCUSSION

Combination of carbohydrate-restricted diet with resistance exercise led to a greater reduction of body fat mass and body weight compared to the regular diet with similar resistance exercise. The findings are aligned with other studies reporting a considerable decrement of body fat mass and body weight when carbohydrate consumption is sustained at a low level, reduced or restricted altogether [18, 28].

Although our findings are backed by some sources of information from previous researches, there exist some inconsistent conclusions due to the shortage of studies separating the effect of keto diet with and without resistance exercise on muscle hypertrophy and body fat mass. These studies concluded that the decrement in body fat mass during and after KD is accompanied by an incidental reduction in lean body mass [29, 30]. Despite the contrary, it should be highlighted that no physical exercise intervention, in particular resistance training, was applied to the participants in the aforementioned studies.

In the present study, it has been found that participants in the KD+RT group decreased body fat mass, whereas preserving LBM, comparable findings have additionally been reported when an ordinary energy-restricted diet had been combined with resistance exercise [13]. Nonetheless, the hunger curb associated with the increased levels of ketone bodies in a carbohydrate-restricted diet [31] is an edge to the other low-fat or regular diets. Carbohydrate restriction lowers levels of insulin due to the reduction of glucose availability; this, in turn, increases the concentration of counter-regulatory hormones like catecholamines and glucagon, encouraging the lipolysis of adipose tissues [32]. According to reports, the loss of body fat is inversely related to serum insulin levels in a 6-week carbohydrate-restricted diet [33]. Majority of the variability in fat loss (circa 70%) in the study was explained by lower serum insulin levels due to the change in metabolism from fat storage to oxidation and fatty acid release.

Excess energy is stored as triacylglycerol (TAG) in the liver and other tissues with lack of exercise and over-nutrition. In theory, carbohydrate-restriction should result in a diminished hepatic formation of TAG and very-low-density lipoproteins [34]. This is consistent with our findings wherein a substantial loss of body fat mass was observed in participants on the very-low-carbohydrate diet.

Even though there was no considerable increase in mean lean body mass in the KD+RT group, notwithstanding the incorporation of 8-week resistance exercise, there was no reduction in LBM in contrary to the findings of other weight loss studies [35]. Some reduction of LBM is more or less expected with a low carbohydrate diet [18], and as Merra *et al.* [19], has concluded that very-low-carbohydrate diets do not promote catabolism of LBM provided a sufficient amount of protein is consumed.

The increase in or maintenance of lean body mass attributed to resistance workout has also -already been expressed in calorie- limited diets in females [17]. It is then possible to associate the incorporation of resistance exercise with the maintenance of LBM in the KD+RT group.

The lower insulin levels and lower energy intake may in part be the reason behind a lower increase in lean body mass in the KD+RT group. Theoretically, the formation of TAG, glycogen and proteins in anabolic processes are stimulated by the higher insulin levels induced by higher carbohydrate consumption [36]. Another possible explanation for the non-significant increase in LBM within the KD+RT group might be the use of skeletal muscle protein as fuel. Amino acids may become a part of glucose production *via* gluconeogenesis in dietary-induced ketosis when excessive amounts of protein (above the recommended 25% to 30% of an approximately 2,000 kcal diet) are consumed [37]. The association between the reduction of LBM and low protein consumption has been found in low-calorie diets [38].

The average increase in LBM is established to be 0.06 kg of LBM for each session of exercise (derived from 2 kg gain in 14 weeks) from the outcomes of 29 researches evaluating changes in LBM following resistance training in untrained individuals as outlined by Fleck & Kraemer [24]. The KD+RT group in our study experienced an increase of 1.48 kg in mean LBM within 8 weeks of three sessions per week (0.06 kg increase in each exercise session), which is consistent as discussed in previous studies.

Exercise, in particular resistance exercise, is an effective standalone intervention in a weight loss strategy as it is able to increase one's metabolic rate. As such, resistance exercise is a beneficial addition to weight loss diets due to their synergistic effects. Meckling & Sherfey [39] reported that the best weight loss results were achieved through a combination of exercise and low-carbohydrate high-protein diet. The aforementioned findings were also in line with those of Krebs *et al.* [40], who also demonstrated improved body composition with a similar strategy. It is therefore probable to conclude from these studies that the combination of carbohydrate-limitation and resistance training trumps both low-fat diets with exercise and low-carbohydrate diets without exercise in improving body composition.

A handful of participants in this present study experienced substantial alterations in body composition for a short time period. If more information about the individual differences in response to resistance training combined with carbohydrate-limitation diet could be further examined, this approach may confirm to be important over the overweight and obesity management.

There are several limitations to this study that should be considered. First, limited variables were determined and measured with a minimal intervention time of eight weeks. Second, only body composition measurements were investigated without any record of blood measures. Finally, Habitual dietary intake was also not assessed; therefore, there is a possibility of some disparities in energy consumption, although participants were asked to pursue particular dietary guidelines.

CONCLUSION

According to the study findings, we can conclude that resistance training performed three times per week in untrained participants on a ketogenic diet might decrease body fat mass without notable changes in LBM, whilst resistance training combined with a normal diet may increase LBM without meaningful altering body fat mass.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The research was reviewed and approved by University Malaya advisory panel for research involving human participants on 05/09/2019 Malaysia.

HUMAN AND ANIMAL RIGHTS

No animals were used for this study. All humans research procedures performed in the current study were followed in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later mendments or comparable ethical standards.

CONSENT FOR PUBLICATION

All participants were informed about the protocol and gave their written informed consent before participating in the study.

AVAILABILITY OF DATA AND MATERIALS

The data that support the findings of this study are available from the corresponding author, [HM], upon reasonable request.

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CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

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