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ABSTRACT

Previous evidence suggests that low-carbohydrate diets may improve body composition and performance relative to body weight in endurance athletes. This has been the first study that has attempted to evaluate the utility of low-carbohydrate diets in a sample of eleven trained and experienced road cyclists who consumed 10% of their caloric intake in the form of carbohydrates during four weeks while maintaining a neutral energy balance (50 kcal/kg/day). Body composition was evaluated through an electrical impedance assessment before and after the intervention while maximal power output (5 and 20 min) was measured on a bike trainer by following a standardized protocol and in the same room conditions for all the participants. The study was performed during the preseason, when the subjects could abstain from performing high-intensity workouts. The participants, eleven men aged 31 ± 5 years, performed four weekly 150 min training sessions at submaximal intensities and received nutritional support from a certified sport nutritionist. The intervention resulted in reduced total weight (-2.51 kg) and body fat percentage (2.42%), and improved relative power (+0.2 w/kg for 20 min and +0.25 w/kg for 5 min) values while absolute power remained unchanged. The results suggest that low-carbohydrate diets could be used in order to induce changes in body composition and improve relative power during the preseason. However, future research with larger sample sizes and a control group is needed in order to validate the results.

Key words: Road cycling. Performance. Body composition. Low-carbohydrate diet.

RESUMEN

La evidencia científica previa sugiere que las dietas bajas en hidratos de carbono pueden mejorar la composición corporal y el rendimiento relativo al peso en deportistas de resistencia. Este ha sido el primer estudio que ha intentado evaluar la utilidad de este tipo de dieta en una muestra de once ciclistas de carretera entrenados y experimentados que consumieron un 10% de sus calorías diarias en forma de hidratos de carbono durante cuatro semanas mientras mantenían un balance energético neutro (50 kcal/kg/día). La composición corporal se evaluó con bioimpedancia eléctrica antes y después de la intervención mientras que la potencia máxima (5 y 20 min) se evaluó siguiendo un protocolo estandarizado sobre un rodillo de ciclismo en las mismas condiciones ambientales para todos los participantes. El estudio se realizó en la pretemporada, cuando todos los sujetos podían abstenerse de realizar entrenamientos de alta intensidad. Los participantes, once hombres con edades de 31 ± 5 años, realizaron cuatro sesiones de entrenamiento de 150 minutos de duración semanales y recibieron apoyo de un nutricionista deportivo titulado. La intervención resultó en una disminución del peso (-2,51 kg) y el porcentaje de grasa corporal (-2,42%), así como en un aumento de la potencia relativa (+0,2 w/kg en potencia 20 min y +0,25 w/kg en potencia 5 min) mientras que los valores de potencia absoluta no se modificaron. Los resultados sugieren que las dietas bajas en hidratos de carbono podrían utilizarse durante la pretemporada para inducir cambios en la composición corporal y mejorar la potencia relativa. Sin embargo, hacen falta estudios con una muestra más grande y un grupo de control para poder validar estos resultados.

Palabras clave: Ciclismo de carretera. Rendimiento. Composición corporal. Dieta baja en hidratos de carbono.

INTRODUCTION

Sport nutrition periodization has been one of the most popular research topics in the field of sports performance during the last years (1). Among the strategies commonly described in nutrition periodization, a strategy called “training low” may be highlighted (2). This strategy comprises several different approaches with a common point: training with low glycogen stores due to insufficient carbohydrate feeding (3). Besides other interventions, this effect can be achieved by following a low-carbohydrate diet on a day-by-day basis.

Low-carbohydrate diets are frequently used to induce changes in body composition in obese individuals with great results and no long-term side effects (4). It has been speculated that some of the main benefits of these dietary interventions are the filling properties of the commonly consumed food items and appetite suppression (5). These properties would allow an ad-libitum character of the intervention, with no calorie counting needs and similar adherence rates to those observed in low fat calorie reducing interventions (6). The ability of these diets to induce changes in body composition in non-athletic populations could also play a role in sport disciplines in which power to weight ratio is one of the determinants of performance, such as road cycling.

One of the main characteristics of road cycling is the importance of the power to weight ratio during the key moments of the competitions such as mountain stages (7). Modifying body composition at the expense of losses of fat mass and maintenance or increases in lean mass has been shown to improve cycling performance (8), and slight increases in body mass at the expense of muscle mass have no detrimental effects on performance (9). Low-carbohydrate diets have been studied in sports that are highly dependent on relative power such as powerlifting and Olympic weightlifting (10) with weight-reducing results and no detrimental effects on strength, therefore improving the power-to-weight ratio. Only one previous study has investigated the effects of a low-carbohydrate intervention in cycling but it was conducted on off-road cyclists (11). In that study, the dietary manipulation resulted in increased relative values of maximal and threshold oxygen consumption due to changes in body composition associated to reductions in body fat. The authors speculated that a low-carbohydrate or ketogenic diet could be useful during the preseason in this sport discipline. It has also been previously speculated that low carbohydrate-adapted cyclists may compensate the reduced dietary carbohydrate availability by altering whole body substrate utilization (12), mainly by improving fat oxidation rates (13).

To the authors' knowledge no previous research has been conducted with highly trained road cyclists and low-carbohydrate diets. Therefore, this study attempted to verify and quantify the effects of these interventions on road cycling performance. The authors hypothesized that a low-carbohydrate diet could potentially reduce body fat while maintaining lean mass and peak power (5 and 20 min) levels in highly trained cyclists, therefore improving the power-to-weight ratio in this sport discipline as well as overall performance. According to all of this, the main objectives of the study were: a) to assess the efficacy of a low-carbohydrate diet in inducing body composition changes in a sample of trained cyclists, and b) to measure the changes in relative power values produced by the above-mentioned changes in body composition.

MATERIAL AND METHODS

Participants

Eleven highly-trained male road cyclists were recruited for the study. The main characteristics of the study sample were: age 31 ± 5 years; experience 9.4 ± 1.9 years; training 15 ± 3 hours per week; height 177.1 ± 4.8 cm, and weight 73.7 ± 3.2 kg. The inclusion criteria for the participants were: a) at least seven years of previous experience in cyclosportive events, and b) at least twelve hours of training volume per week. After being informed of the benefits and potential risks of the investigation, each participant completed a health-screening questionnaire (14) and provided his written informed consent prior to participation in the study. The study followed the ethical guidelines of the Declaration of Helsinki and received approval from the Research Ethics Committee of the autonomous region of Aragon, Spain (PI18/398).

Training Protocol

The experiment was conducted during the preparatory period of the annual training cycle, when low intensity dominates the daily training loads. Training loads of the same frequency, volume and intensity were adopted by all cyclists during the four weeks of the intervention period. The training protocol included high volume and moderate intensity in order to simulate common training practices in road cycling during the preseason. Participants performed four weekly (Monday, Wednesday, Friday and Saturday) training sessions at an intensity of 70 to 80% of their functional threshold power (FTP), and a duration of two and a half hours. The FTP results from subtracting 5% to the maximal power achieved during a 20-minute time trial. Participants used a left-side crank-based power meter for their training sessions (Stages Cycling, Colorado, USA). Participants extracted their training files from the bike computer and sent the data so the researchers could monitor the adherence to the training program. Energy expenditure was monitored with data extracted from the power meter in kilojoules (KJ).

Dietary Intervention

Participants were instructed to consume a low-carbohydrate diet (10% of calorie intake from carbohydrates, 25% from protein and 65% from fats) provided by a certified sports nutritionist. The distribution of macronutrients matched the definition of a low-carbohydrate diet accepted in the scientific literature (15). The total caloric intake was provided in relative values (50 kcal/kg/day), a quantity that was chosen in order to match the daily energy expenditure and avoid negative energy balances. An informative sheet with recommended foods and foods to be avoided was given to all participants. Intake was assessed with a previously validated once-weekly 72 h recall (16). Participants were considered as non-adherent when daily consumption of carbohydrates exceeded 15% of total daily calories.

Assessment of Body Composition and Performance

Body mass and body fat percentage were evaluated barefoot in the morning hours (7-8 am) after an overnight fast with the electrical impedance method (BC-602, Tanita Co., Tokyo, Japan) before and after the 4-week intervention period. Height was measured according to a previously established protocol (17) with a SECA 214 stadiometer, which is graduated up to 1 mm.

Two hours after breakfast, a power assessment test was performed following the protocol established by Hunter and Coggan (18) on the

Tacx Neo Smart bike trainer (Tacx International, Rijksstraatweg, The Netherlands), which allows power, cadence and heart rate measurement. The protocol performed on the participants can be seen in table I. All participants performed the test in the same conditions (temperature, 20 ºC; humidity, 40%).

Statistical Analysis

The statistical analysis was performed with the R v3.5.3 (R Core Team, Vienna, Austria). Normality assumptions were verified using the Shapiro-Wilk test with Bonferroni correction. Statistics are presented as mean ± standard deviation (range) and estimates of parameters are stated as mean [95% confidence interval]. Mean comparisons were made using the t-test for paired samples, and statistical significance for confidence intervals was set at $\alpha = 0.05$. Effect size estimates were provided by calculating Hedge's *g* for paired samples, and interpreted according to Cohen (19): small, g ≤ 0.20; medium, g ≤ 0.50; large, g ≤ 0.80.

RESULTS

The descriptive statistics may be seen in table II. Absolute power (AP) was comparable between measurements for both tests, 5 and 20 min (95% CI = -10.29 to 12.47 w, t(10) = 0.21, p = 0.835; and 95% CI = -1.56 to 6.27 w, t(10) = 1.35, p = 0.208, respectively). On the contrary, when adjusting power relative to body weight (RP) an increase of 95% CI = 0.04 to 0.46 w/kg was observed for the 5 min test (t(10) = 2.7, p = 0.028), corresponding to a small to medium effect size (95% CI = -0.14 to 1.7); and an increase of 95% CI = 0.12 to 0.28 w/kg in the 20 min test (t(10) = 5.61, p < 0.001), which corresponds to a medium to large effect according to Cohen (95% CI = 0.6 to 2.65). Participants lost a 95% CI = -1.71 to -3.9 kg after the intervention (t(10) = -5.71, p < 0.001), which corresponds to a medium to large effect size (95% CI = -0.63 to -2.69). Body fat was 95% CI = -1.29 to -3.54% lower after the intervention (t(10) = -4.79,

$p < 0.001$), which corresponds to a small to large effect according to Cohen (95% CI = -0.4 to -2.38). Individual responses can be seen in figure 1. None of the 72 h recalls showed lack of compliance with the dietary intervention.

DISCUSSION

To the authors' knowledge, this has been the first study that has attempted to assess the effects of a low-carbohydrate diet on body composition and performance in trained road cyclists. The main findings of the study were: a) a low-carbohydrate diet did not have any influence on the absolute 5 and 20 min power output; b) body mass and body fat percentages were significantly reduced after four weeks on a low-carbohydrate diet in a sample of trained road cyclists; and c) as a consequence of the previous finding, the power-to-weight ratio expressed as w/kg was significantly increased after the dietary intervention.

These results are in accordance with the evidence provided by a previous systematic review (20), which found that low-carbohydrate diets typically had positive effects on body composition of endurance athletes and, therefore, improved relative power values. The only previous study performed on cyclists (11) also reported improvements in body composition and relative performance values, although the study sample was slightly different (off-road cyclists) and the dietary intervention limited even more the allowed quantity of carbohydrates (ketogenic diet).

It should be highlighted that the participants maintained a neutral energy balance during the study period, therefore a negative energy balance as the cause of the changes in body composition can be excluded. The study sample was composed of already trained cyclists who did not alter their physical activity substantially during the study period. Furthermore, the duration and intensity at which the workouts were performed were oriented to an environment in which, theoretically, a low-carbohydrate diet is more effective (13). It has been speculated that a low-carbohydrate diet can improve fat oxidation rates during exercise performed at moderate intensities (21), intensities that are commonly incorporated into the preseason of endurance athletes. It has also been reported that the “training low” strategy (workouts performed with low glycogen stores) could have beneficial effects on body composition (1), effects that are normally sought by endurance athletes during the preseason. According to all of this, the present study attempted to verify the utility of this dietary intervention in the most logical environment for its implementation.

In contrast, several concerns may arise when using a low-carbohydrate diet for performance enhancement. First, when training at high intensities with depleted carbohydrate stores there is a risk for low energy availability and drop in performance (22). Furthermore, although body composition changes associated to low-carbohydrate diets seem useful for attaining an appropriate power- to-weight ratio, carbohydrates are needed in order to optimize recovery (23), achieve higher rates of protein synthesis, and maintain desirable levels of muscle mass (24). With all these concerns in mind, preliminary evidence may suggest that a low-carbohydrate diet may not be an advisable nutritional intervention for endurance athletes training at high intensities. The authors chose the preseason as the preferable time for implementing this strategy, when low relative intensities and high-volume work are used. These training characteristics could combine well with this type of intervention.

The authors acknowledge that the study had several limitations. First, the study sample was relatively small. Although eleven subjects may be a common sample size in similar studies, the number of participants and the lack of a control group make it difficult to isolate the role that the dietary intervention alone played in the results. Furthermore, the study period was relatively short for a dietary intervention as adaptations to low-carbohydrate and ketogenic diets normally occur after several weeks (25). The specificity of the study sample, that needed to incorporate high-intensity workouts into the schedule as soon as possible in order to be competitive, was one of the limiting factors when considering the duration of the intervention. The tool chosen for the assessment of body fat percentage is known for estimating this variable from total body water, and therefore is not a direct method. In summary, although the study provides preliminary results that suggest that a low-carbohydrate diet may be useful for road cyclists during the preseason, the conclusions should be interpreted with caution and further studies with larger sample sizes and a control group are needed in order to validate the results reported by the present study. Among other variables that could be of interest in future studies, intensities at which fat oxidation is maximal and changes in maximal oxygen consumption should be included.

CONCLUSIONS

A four-week intervention with a low-carbohydrate diet (10% of calories from carbohydrates) reduced body weight and body fat percentage, and improved relative power values (5 and 20 min) in a sample of eleven trained road cyclists. On the contrary, no effects were seen on absolute power values. Further research with larger sample sizes and a control group is needed in order to validate these results.

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Table I. Power assessment performed on the subjects, based on the work of Hunter & Coggan (2019)

Time (min)	**% of functional threshold power**
15	56-75
5	Max
10	56-75
20	100
15	56-75

Table II. Participant characteristics and performance variables before and after the race

	Pre	Post
Age (years)	31 ± 5 (24-41)	
Experience (years)	9.5 ± 1.9 (7-13)	
Training (h/week)	15.1 ± 3 (12-20)	
Height (cm)	177.1 ± 4.8 (169-184)	
Weight (kg)	73.7 ± 3.2 (67.7-77.9)	70.9 ± 2.2 (66.8-74.5)
Body Fat (%)	12.3 ± 1.4 (9.8-14.6)	9.9 ± 2 (7.8-13.9)
AP 5 min (w)	435 ± 68 (321-511)	436 ± 70 (325-503)
RP 5 min (w/kg)	5.89 ± 0.85 (4.51-7.15)	6.14 ± 0.93 (4.58-6.96)
AP 20 min (w)	314 ± 31 (272-377)	316 ± 31 (275-371)
RP 20 min (w/kg)	4.25 ± 0.33 (3.83-4.92)	4.45 ± 0.36 (3.88-5.12)

Results are presented as mean ± standard deviation (range). AP: absolute power; RP: relative power.

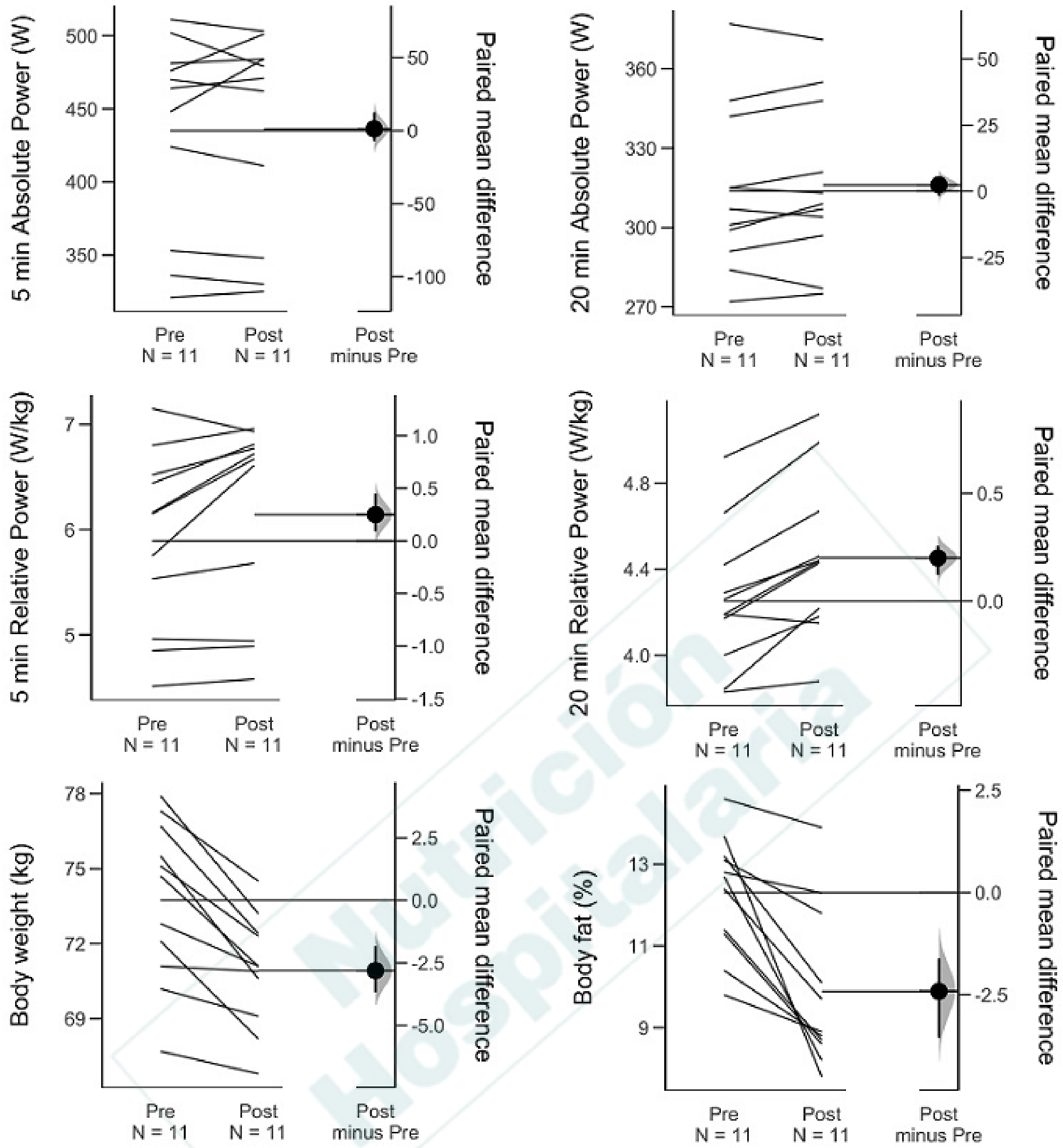

Fig. 1. Individual responses to the intervention.