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Trabajo Original

Otros

Effects of a low-carbohydrate diet on body composition and performance in road cycling: a randomized, controlled trial

Efectos de una dieta baja en hidratos de carbono sobre la composición corporal y el rendimiento en el ciclismo de carretera: estudio aleatorizado y controlado

Sebastian Sitko[1], Rafel Cirer Sastre[2], Francisco Corbi Soler[2] and Isaac López Laval[1]

[1]Facultad de Ciencias de la Salud y del Deporte. Universidad de Zaragoza. Huesca, Spain. [2]Institut Nacional d'Educacio Física de Catalunya (INEFC). Universitat de Lleida. Lleida, Spain

Abstract

Low-carbohydrate diets are frequently used to improve performance in endurance sports, often with contradictory results. This study aimed to assess whether a low-carbohydrate diet can outperform an isocaloric conventional diet for improving body composition and performance in a sample of twenty-six trained male road cyclists (previous experience in cyclosportive events, 7.6 ± 4.4 years; age, 26.9 ± 4.9 years; weekly training volume, 7.8 ± 2.9 hours; height, 176 ± 7 centimeters; body fat percentage, 9.7 ± 0.8 %; weight, 65.3 ± 2.3 kg). Detraining and pre-treatment periods in which nutrition and training were standardized were followed by an eight-week long intervention in which cyclists consumed either a low-carbohydrate diet (15 % of calories from carbohydrates) or a conventional endurance sports diet while maintaining the same training volumes and intensities. Body composition was assessed through electrical impedance, and performance was evaluated through a twenty-minute time trial performed on a smart bike trainer. The results revealed an overall improvement over time in absolute and relative power, body mass, and body fat for both groups, whilst the improvement in absolute power was comparable. The improvements seen in relative power ($p = 0.042$), body mass ($p = 0.006$), and body fat ($p = 0.01$) were significantly higher in the low-carbohydrate group. We concluded that eight weeks of a low-carbohydrate diet significantly reduced body weight and body fat percentage, and improved 20-minute relative power values in a sample of road cyclists when compared to an isocaloric conventional diet.

Keywords:

Road cycling. Performance. Body composition. Low-carbohydrate diet.

Resumen

Las dietas bajas en carbohidratos se usan con frecuencia para mejorar el rendimiento en los deportes de resistencia, a menudo con resultados contradictorios. Este estudio tuvo como objetivo evaluar si una dieta baja en carbohidratos puede superar a una dieta convencional isocalórica para mejorar la composición corporal y el rendimiento en una muestra de veintiséis ciclistas de carretera masculinos entrenados (experiencia previa en eventos cicloportivos, 7,6 ± 4,4 años; edad, 26,9 ± 4,9 años; volumen de entrenamiento semanal, 7,8 ± 2,9 horas; altura, 176 ± 7 centímetros; porcentaje de grasa corporal, 9,7 ± 0,8 %; peso, 65,3 ± 2,3 kg). Los períodos de desentrenamiento y pretratamiento, en los que se estandarizaron la nutrición y el entrenamiento, fueron seguidos por una intervención de ocho semanas de duración en la que los ciclistas consumieron una dieta de bajo contenido en carbohidratos (15 % de calorías de los carbohidratos) o una dieta convencional para deportes de resistencia, manteniendo los mismos volúmenes de entrenamiento e intensidades. La composición corporal se evaluó a través de la impedancia eléctrica y el rendimiento se evaluó a través de una prueba contrarreloj de veinte minutos realizada en un rodillo de bicicleta inteligente. Los resultados revelaron una mejora general en el tiempo en cuanto a potencia absoluta y relativa, masa corporal y grasa corporal para ambos grupos, mientras que la mejora en potencia absoluta fue comparable. Las mejoras de la potencia relativa ($p = 0,042$), la masa corporal ($p = 0,006$) y la grasa corporal ($p = 0,01$) fueron significativamente mayores en el grupo bajo en carbohidratos. Se concluye que ocho semanas de una dieta baja en carbohidratos redujeron significativamente el peso corporal y el porcentaje de grasa corporal, y mejoraron los valores de potencia relativa de 20 minutos en una muestra de ciclistas de carretera en comparación con una dieta convencional isocalórica.

Palabras clave:

Ciclismo de carretera. Rendimiento. Composición corporal. Dieta baja en hidratos.

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Correspondence:

Sebastian Sitko. Facultad de Ciencias de la Salud y del Deporte. Universidad de Zaragoza. C/Pedro Alfonso 5, 4.º B. 22005 Huesca, Spain
e-mail: sebastian@sitkotraining.com

INTRODUCTION

During the last few years the scientific interest around different strategies for optimizing sports performance through nutritional interventions has been on a constant rise. The emphasis on macronutrient distribution and calorie balance has been substituted by what is nowadays known as "sport nutrition periodization" (1-4). This approach is based on the fact that, similarly to what is expected during training programs, nutritional interventions must be continuously adapted to the phase of the training cycle, and to the current objectives and body composition of the athlete (5). Among all the strategies described in this approach, the one dubbed "training low" could be highlighted. This concept can be defined as performing training sessions with depleted glycogen stores in order to elicit changes in body composition and optimize fat oxidation (6). This can be achieved with different strategies such as training in a fasted state, limiting carbohydrate intake prior or after training, or following a low-carbohydrate diet on a day-to-day basis, among others (7).

Low-carbohydrate diets are frequently used to improve performance in endurance sports, often with contradictory results. A recent systematic review concluded that, while absolute performance values may be negatively affected, the changes in body composition associated to low-carbohydrate diets may result in positive outcomes in those sports in which the power-to-weight ratio plays a crucial role (8). Road cycling is an endurance sport in which relative power values often determine performance (9), as climbing ability usually decides the overall results (10). Scientific evidence regarding the usefulness of low-carbohydrate diets for improving body composition and performance in road cycling is scarce. A previous study (11) reported improvements in relative VO_{2max} and lactate threshold values mainly due to changes in body composition. The sample, however, was composed of off-road cyclists, and the nutritional intervention restricted carbohydrates even further than what could be normally expected during a traditional low-carbohydrate diet. The effects of a low-carbohydrate diet on trained road cyclists have been studied previously with promising results (12). In this study, eleven highly trained road cyclists trained at submaximal intensities while consuming an isocaloric low-carbohydrate diet for one month. The participants lost weight and body fat while absolute power remained unchanged, thus ameliorating their relative power values. However, the intervention presented several limitations such as reduced sample size, short duration, and lack of a control group.

Taking all the previous evidence into account, the authors of the current study hypothesized that low carbohydrate diets could potentially improve performance in endurance sports in general and in road cycling in particular. As previous research presented several limitations, the objectives of the present study were: a) to assess whether a low-carbohydrate diet can improve body composition and performance in a sample of trained road cyclists, and b) to confirm the findings reported in previous research with a longer intervention, a larger sample size, and the presence of a control group.

MATERIALS AND METHODS

PARTICIPANTS

Twenty-six trained male road cyclists were recruited for the study. The main characteristics of the study participants were: previous experience in cyclosportive events, 7.6 ± 4.4 years; age, 26.9 ± 4.9 years; weekly training volume, 7.8 ± 2.9 hours; height, 176 ± 7 centimeters; body fat percentage, 9.7 ± 0.8 %; weight, 65.3 ± 2.3 kg. The inclusion criteria were the same as for the previously published pilot study (8): a) at least seven years of previous experience in cyclosportive events, and b) at least twelve hours of training volume per week. Absence of lower limb injuries and drug or supplement use in the three months prior to and during the intervention were set as exclusion criteria.

After being informed of the benefits and potential risks of the investigation, each participant completed a health-screening questionnaire (13), 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). Participants were randomized into either low-carbohydrate diet or control group in a 1:1 ratio using a block size of two, created by computerized software (SAS version 9.2). Two sets of sealed envelopes were provided to each investigator and the appropriate set was opened by a third person. Due to the nature of the study (nutritional intervention), blinding was considered inappropriate.

PROTOCOL

The experiment was conducted during the preparatory period of the annual training cycle, when low intensity dominates daily training loads. Training loads with the same frequency, volume, and intensity were adopted by all cyclists during the twelve weeks of the intervention period. The training protocol included high volume and moderate intensity exercise in order to simulate common training practices in road cycling during the preseason. First, participants were asked to abstain from all training and consume their habitual diet for three weeks. This was followed by a four-week conditioning period in which they performed three training sessions per week, and did not change their habitual diet. Later, subjects were randomly allocated to either the low-carbohydrate or conventional diet group. Each one of them performed the same training program and consumed the appropriate diet during an eight-week period. Figure 1 represents the design of the intervention.

TRAINING PROTOCOL

During the conditioning period participants performed three weekly training sessions (Monday, Wednesday and Saturday)

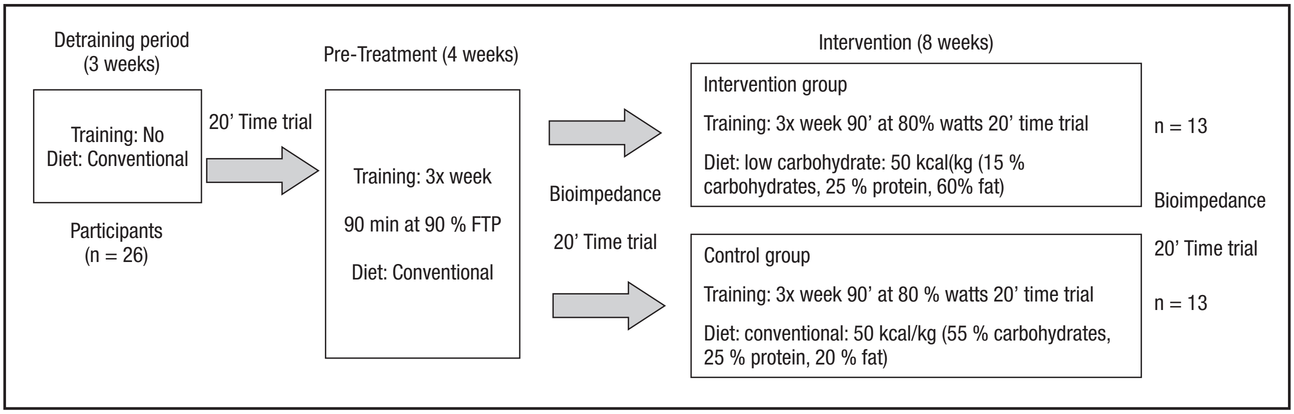

Figure 1.

Design of the intervention protocol.

at a relative power of 90 % of the watts produced during their first 20-minute time trial. Each session lasted 90 minutes. During the intervention period, the intensity was changed to 80 % of the relative power output obtained in the second 20-minute time trial in order to work at intensities in which fat oxidation is enhanced, and to try to create the environment in which theoretically the benefits of a low-carbohydrate diet are largest. The use of 20-minute time trials for the assessment of performance in road cycling is widely accepted both in the scientific and practical fields (9,12,14-18). Participants used a left-sided crank-based power meter for their training sessions (Stages Cycling, Colorado, US). The training files were extracted from the bike computer and sent to the researchers so that adherence to the training program could be monitored. Energy expenditure was assessed with data extracted from the power meter in kilojoules (KJ).

DIETARY INTERVENTION

During the intervention period, participants were instructed to consume either a low-carbohydrate diet (15 % of calorie intake from carbohydrates, 25 % from protein and 60 % from fats) (19,20) or a conventional endurance sports diet (55 % carbohydrates. 25 % protein and 20 % fat) (21), both provided by a certified sports nutritionist. The total caloric intake was provided in relative values (50 kcal/kg/day) for both groups, 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 hours recall (22), which recorded type, quantity, preparation method, and time of each meal and snack to later be analyzed for calorie (kcal) and macronutrient (carbohydrate, fat and protein) distributions (23). Participants were considered as non-adherent when daily macronutrient intake exceeded a 10 % variation of the recommended amounts.

MEASUREMENT OF BODY COMPOSITION AND POWER OUTPUT

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). Height was measured according to a previously established protocol (24) with a SECA 214 stadiometer, which is graduated up to 1 mm. Two hours after breakfast, a power assessment test was performed following a previously validated protocol (18) on the Tacx Neo Smart bike trainer (Tacx International, Rijksstraatweg, Netherlands), which allows power, cadence, and heart rate measurement. The protocol performed on the participants can be seen in figure 1. All participants performed the test under the same conditions (temperature 20 ºC, humidity 40 %).

STATISTICAL ANALYSIS

Statistical procedures were performed using the R v3.5.3 program (R Core Team, Vienna, Austria). The Shapiro-Wilk test was used to verify that data met parametric assumptions. Descriptive data are presented as mean ± standard deviation. Mean comparisons between groups at baseline were made using a t-test for independent samples. Then, a mixed analysis of variance was calculated to assess the effects of group (control and low-carbohydrate) and time (pre, post), as well as their interaction. Differences were expressed as 95 % confidence intervals (95 % CI), effect sizes were assessed as partial eta squared (η^2_p), and magnitudes rated as follows: $\eta^2_p \geq 0.14$, large effect; $0.14 > \eta^2_p \geq 0.06$, medium effect; $0.06 > \eta^2_p \geq 0.01$, small effect; and $\eta^2_p < 0.01$, trivial effect (25). Statistical significance was assumed when $p < 0.05$.

RESULTS

The daily monitoring of adherence revealed that all participants completed all the expected training sessions. Pairwise group comparisons in baseline data revealed that participants in both groups, low-carbohydrate and control, presented comparable values for age ($p = 0.49$), body height ($p = 0.56$), body mass ($p = 0.47$), body fat percentage ($p = 0.45$), training experience ($p = 0.44$), and training weekly volume ($p = 0.75$).

Absolute power in the 20-min time trial increased after the intervention in all participants: $F(1, 24) = 106.07$, $p < 0.001$, $\eta^2_p = 0.82$ (large), 95 % CI [16.3, 24.4] W (Fig. 2). However, absolute power in the low-carbohydrate group was comparable with that in the control group, in general: $F(1,24) = 0.03$, $p = 0.86$, $\eta^2_p = 0$ (trivial), 95 % CI [-9.9, 8.3] W; and changes in absolute power over time were also comparable between groups: $F(1,24) = 0.05$, $p = 0.83$, $\eta^2_p = 0$ (trivial), 95 % CI [14.2, 25.7] W in the low-carbohydrate group vs 95 % CI [15.0, 26.5] W in the control group. Relative power also increased after the intervention in all participants, $F(1, 24) = 180.8$, $p < 0.001$, $\eta^2_p = 0.88$ (large), 95 % CI [0.41, 0.56] W/kg, and was comparable in the low-carbohydrate vs the control group, in general: $F(1,24) = 1.28$, $p = 0.27$, $\eta^2_p = 0.05$ (small), 95 % CI [-0.08, 0.29] W/kg. However, and contrary to absolute power, time changes for relative power were different between groups: $F(1,24) = 4.61$, $p = 0.042$, $\eta^2_p = 0.16$ (large), higher in the low-carbohydrate group, 95 % CI [0.46, 0.67] W/kg, than in the control group, 95 % CI [0.31, 0.52] W/kg.

Body mass decreased after the intervention in all participants: $F(1, 24) = 71.08$, $p < 0.001$, $\eta^2_p = 0.75$ (large), 95 % CI [-3, -1.8] kg. Body mass in the low-carbohydrate group was not statistically different from that in the control group, in general: $F(1,24) = 4.23$, $p = 0.051$, $\eta^2_p = 0.15$ (large), 95 % CI [-3.1, 0] kg. However, body mass decrease was different between groups: $F(1,24) = 9.08$, $p = 0.006$, $\eta^2_p = 0.27$ (large) and more pronounced in the low-carbohydrate group, 95 % CI [-4.2, -2.5] kg, than in the control group, 95 % CI [-2.4, -0.7] kg. Body fat also decreased after the intervention in all participants: $F(1, 24) = 46.01$, $p < 0.001$, $\eta^2_p = 0.66$ (large), 95 % CI [-1.3, -0.7] %. Further, body fat was lower in the low-carbohydrate group, in general: $F(1,24) = 6.6$, $p = 0.017$, $\eta^2_p = 0.22$ (large), 95 % CI [-1.2, -0.1] %, and the body fat decrease over time was different between groups: $F(1,24) = 7.75$, $p = 0.01$, $\eta^2_p = 0.24$

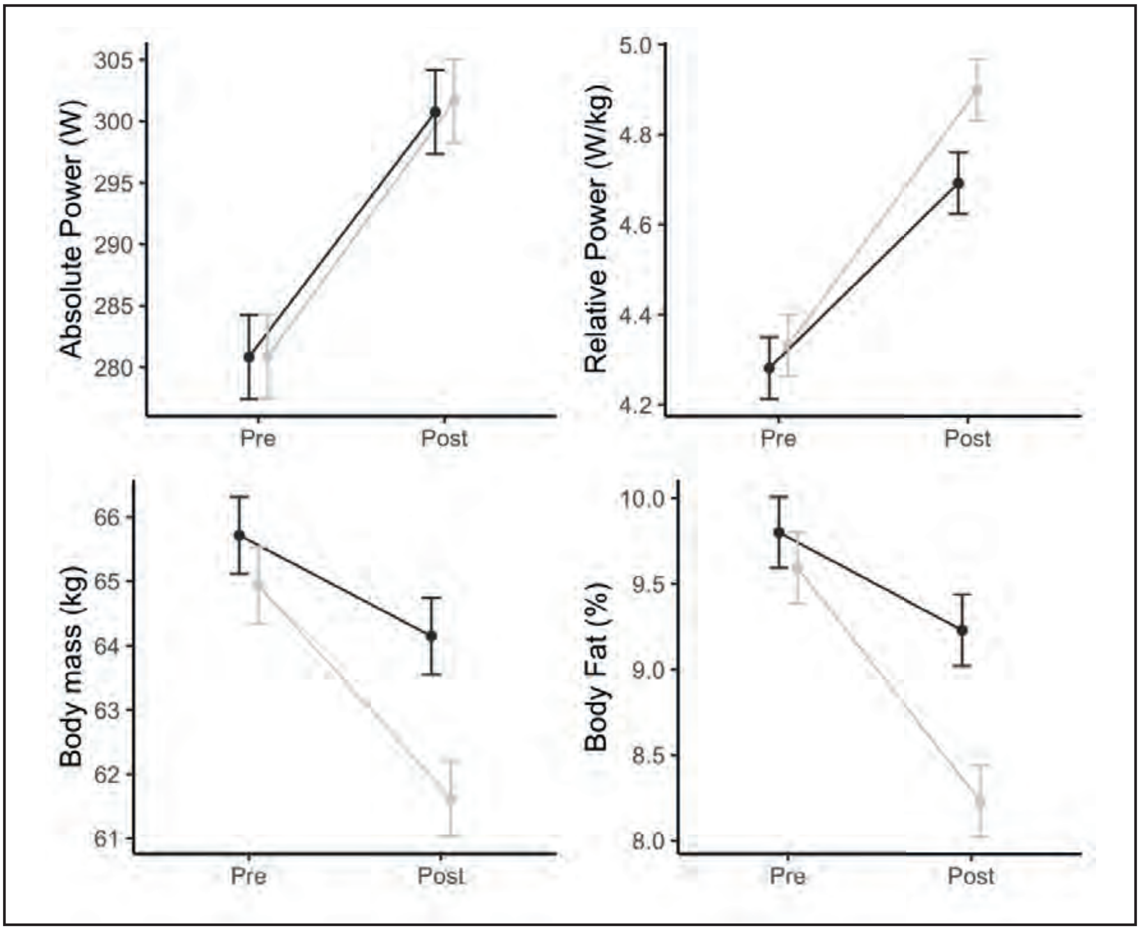

Figure 2.

Effects of the intervention by group, time, and variable. The control group is represented in dark gray, and the low-carbohydrate group in light gray. Horizontal lines represent within-group time changes. Dots and vertical whiskers represent group means and standard errors for each group and time point.

(large), higher in the low-carbohydrate group, 95 % CI [-4.2, -2.5] %, than in the control group, 95 % CI [-2.4, -0.7] %.

DISCUSSION

To the authors' knowledge, this has been the first randomized 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 absolute power output; b) body mass and body fat percentages were significantly reduced after eight weeks on a low-carbohydrate diet; and c) as a consequence of the previous finding, the power-to-weight ratio expressed as w/kg increased significantly.

These results are in accordance with the findings reported in a previous systematic review (8), which stated that low-carbohydrate diets typically had positive effects on body composition in endurance athletes and, therefore, improved relative power values. There is a dearth of studies related to the effects of low-carbohydrate diets on cycling performance, and the available evidence is limited to two previous interventions with both off-road (11) and road (12) cyclists. In both studies the limitation of carbohydrates produced reductions in fat mass and improvements in relative performance factors such as peak and threshold oxygen consumption, relative power values, and increased fat oxidation.

As both groups reduced their weight and body fat, and increased absolute power values, the effect of training alone must be considered. However, both groups of participants maintained a neutral energy balance during the study, which suggests that the changes in body composition seen in the low carbohydrate group must be related to the dietary intervention. Furthermore, both groups performed the same training sessions, and energy expenditure deviations were avoided with kilojoule monitoring through power meter data. The theory suggests that low-carbohydrate diets are more effective when implemented in training periods in which moderate exercise intensities are predominant (26). This combination would theoretically allow for improvements in fat oxidation capacities (27), and could help in the management of body composition of endurance athletes (5). According to all of this, the current study attempted to verify whether the low-carbohydrate diet could pose benefits when implemented in the correct contextual framework.

Several issues arise when attempting to use low-carbohydrate diets for performance enhancement in endurance sports. In the first place, evidence suggests that training at high intensities with depleted carbohydrate stores can result in low energy availability and a drop in performance (28). Secondly, 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 (4), achieve higher rates of protein synthesis, and maintain desirable levels of muscle mass (29). With all these concerns in mind, it is suggested that low-carbohydrate diets should not be used during training periods in which high intensities are predominant. Regarding the current study, and based on previous evidence, the authors chose the preseason as the preferable period for implementing this strategy, as low relative intensities and high-volume work are the main characteristics of this part of the competitive year.

The current study was designed to overcome the limitations observed in previous research regarding low-carbohydrate diets and cycling performance. The authors consider that this was achieved only partially. First, sample size was increased considerably. Although the number of participants enrolled in the current study may be commonly seen in similar research, the authors still consider that future studies should attempt to recruit larger sample sizes. Randomization of participants is another significant advantage, as it has not been done previously in studies regarding cycling and low-carbohydrate diets. The inclusion of blinding could have potentially increased the quality of the study, although the challenges associated with conducting placebo-controlled food interventions and dietary advice interventions are both well known and difficult to overcome (30). The length of the study has also increased considerably when compared with previous research, although it must be considered that adaptations to low-carbohydrate and ketogenic diets normally occur after several weeks or even months (26). Finally, the tool chosen for the assessment of body fat percentage is well known for estimating this variable from total body water, and therefore is not a direct method. Therefore, although this estimation method is commonly used in road cyclists (31,32), its results should be interpreted with caution. Future studies should attempt to incorporate both blinding and laboratory markers such as intensities at which fat oxidation is maximal and changes in maximal oxygen consumption, lactate and ventilatory thresholds in order to further explore the physiological changes associated to low-carbohydrate interventions.

CONCLUSIONS

Eight weeks of a low-carbohydrate diet (15 % of calories from carbohydrates) significantly reduced body weight and body fat percentage, and improved 20-minute relative power values in a sample of road cyclists as compared to an isocaloric conventional diet. Future studies should attempt to incorporate both blinding and laboratory markers, such as intensities at which fat oxidation is maximal and changes in maximal oxygen consumption, and lactate and ventilatory thresholds, in order to further explore the physiological changes associated to low-carbohydrate interventions.

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