



THE EFFECT OF CARBOHYDRATE DIETS ON AMATEUR RUNNERS' PERFORMANCE

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ABSTRACT

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Carbohydrate (CHO) consumption contributes to minimizing muscular and hepatic glycogen stores during long-distance running. Coinciding with fatigue onset and performance decline, a decrease in the amount of carbohydrates affects performance in runners adversely. Accordingly, the effect of three CHO diets (30%, 60%, and 80%) were each analyzed for seven days on amateur runners' 5 km performance. Ten amateur male runners (36.4 ± 12.7 years, 175 ± 4.5 cm, 70.2 ± 6.31 kg) performed a pretest and three running tests. Body mass was assessed before and after exercise. Pacing and time were measured for each kilometer in all the research phases. Two-way Anova repeated measures were employed to analyze the data. In the pretest, the CHO intake results revealed 4.20 ± 1.86 g/kg. In the 30% diet, CHO consumption was $30.80 \pm 1.07\%$ or 2.20 ± 0.42 g/kg; in the 60% diet, $59.34 \pm 0.82\%$ or 4.24 ± 0.82 g/kg; and in the 80% diet, $77.79 \pm 1.00\%$ or 5.56 ± 4.15 g/kg. All analyses showed no significant difference among the CHO diets. However, in the 80% protocol, time improved by 2.30% in comparison to the 30% diet and the pretest. Our results revealed that changing dietary CHO in comparison to a runner's usual intake did not improve their athletic performance.

Contribution/Originality: This manuscript investigated that different carbohydrate diets in pacing and performance of 5km runners, aiming to identify whether low carbohydrate doses affect sports performance.

1. INTRODUCTION

Performance in endurance sports is determined by the interaction between the energy systems. In middle distance events such as 5 km, there is a dependence on power and aerobic capacity (Guglielmo, Babel, Arins, & Dittrich, 2012). A study has demonstrated that threshold speed is a great predictor of performance in the 5 km (Denadai, Ortiz, & Mello, 2004). Research has also revealed that the more trained a 5 km runner is, the more anaerobic metabolism is utilized and the more important the availability of muscle glycogen is for enhanced performance (Guglielmo et al., 2012).

Carbohydrates (CHO) are one of the two primary sources of energy for skeletal muscle during exercise (Caputo, Oliveira, Greco, & Denadai, 2009). The usage ratio of CHOs is related to the intensity and duration of the activity (Caputo et al., 2009). Scientific research on the use of CHOs during medium-distance events, specifically the 5 km, has revealed that the running speed in this event is above the anaerobic threshold speed (VLan) (Bartlett,

Hawley, & Morton, 2015). Thus, a high percentage of muscle glycogen is used even if the test duration is not very long (Alghannam, Gonzalez, & Betts, 2018; Siahkohian, Farhadi, Baghi, & Valizadeh, 2008).

It was from this premise that science began to investigate the effects of CHO supplementation on performance in high intensity and moderate duration tests (Impey et al., 2018; Sale et al., 2015). The purpose of these tests was to determine whether the diet would increase muscle glycogen concentration and delay muscle fatigue during moderate exercise intensity (Cherif et al., 2018). Previous studies on dietary intake have shown increased muscle glycogen concentration after the consumption of a CHO-rich diet (Couto et al., 2015). Consequently, CHO as an ergogenic aid in sports has been discussed in literature (Earnest, Rothschild, Harnish, & Naderi, 2019). It has been revealed that both moderate and intense exercise nutrient consumption contribute to muscle glycogen replacement (Nielsen, Holmberg, Schröder, Saltin, & Ortenblad, 2011).

To elucidate nutritional benefits in athletic performance, some dietary CHO protocols with high and low percentages were employed before exercise. There is growing consensus that CHO-restricted diets promote adaptive responses to exercise by increasing oxidative enzyme and lipid metabolism activity without improving performance (Burke, Jeukendrup, Jones, & Mooses, 2019). On the contrary, CHO-rich diets enhance performance in competition by extending exercise duration (Marquet et al., 2016). This phenomenon is explained by mechanisms such as increased energy availability for muscle contraction, endogenous glycogen sparing, and high rates of exogenous CHO oxidation. Accordingly, recent research has investigated the effect of CHO load intake on athletic performance (Newell, Wallis, Hunter, Tipton, & Galloway, 2018).

However, a gap exists in dietary CHO recommendations for long-distance running (over 3000 m) among amateur runners. Thus, it is crucial to analyze the effect of dietary CHO protocols with low (30%), average (60%), and high (80%) CHO percentages on performance (time, pacing) in 5-km amateur runners. Accordingly, the effects of three CHO diets (30%, 60%, and 80%) on the performances of 5-km runners were analyzed in this study.

2. METHODS

2.1. Subjects

Ten male amateur runners (mean $\pm$ SD, age: 36.4 ± 12.7 years; height: 175 ± 4.5 cm; weight: 70.2 ± 6.31 kg, V_{peak} 17.51 ± 1.52 km/h⁻¹) performed running tests for four weeks. The participants who volunteered to take part in the study were non-smokers, had not suffered an osteoarticular lesion within the six months before the experiment, did not have cardiovascular diseases or diabetes, had not consumed any ergogenic and dietary supplements, and had run 5 km in 25 minutes or less. During the research, all the participants were in the preseason and had not yet competed. They also performed a standardized training program to avoid the influence of exercise on performance outcomes. The study was approved by the Research Ethics Committee (CAAE: 94926618.9.0000.5148). All the participants provided written informed consent before participating in the experiment.

2.1.1. Experimental Design

We conducted a quantitative, crossover study. Tests were conducted once a week for five weeks (Figure 1). There were five stages of data collection, one each week, during which a pretest and four running tests were conducted. The first phase of the research was a pretest. During this stage, the runners' food consumption was evaluated by means of the 24-hour recall (Rec24h). Body mass and a maximum progressive test on a treadmill were also assessed during this stage. During the second stage, a 5000 m running test performed on an athletics track was conducted to confirm whether the athletes could run the distance in less than 25 minutes and to collect each participant's last race time. Time, average speed, and RPE were evaluated for each kilometer run. There was an interval of four weeks after the pretest. During this period, normocaloric diets containing 30%, 50%, 60% and 80% CHO based on the average intake of Rec24h were prepared. During the fifth week, the runners were required to eat

an adaptation diet with 50% CHO for seven days. During the following 21 days, the athletes were submitted to three different CHO intake protocols (30%, 60%, and 80 %). They followed each of these diets for seven consecutive days. The participants were selected randomly to distribute these diets. On the last day of each diet, 5 km running tests were performed on the athletics track. During the tests, time and pacing data were collected every kilometer the athletes ran to assess their performance. The running tests took place in the third, fourth, and fifth week, which corresponded to the third, fourth, and fifth stages of the experiment, respectively. All the running tests were conducted under the same conditions, specifically, the time of day, day of week, and location. As noted previously, the first phase was a pretest and the other phases involved three running tests. The pretest and running tests spanned five weeks.

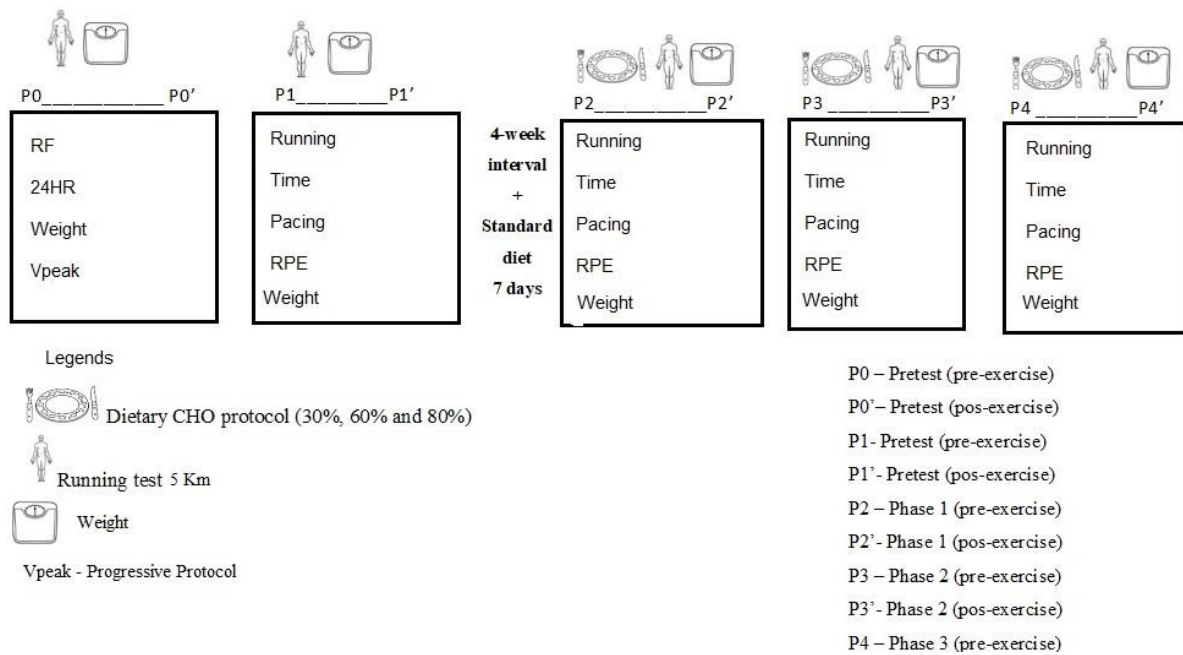


Figure 1. Experimental design.

2.2. Height and Weight Measurements

Body mass was measured before and after the pretest and all the running tests. To assess pre- and post-exercise, body mass was employed as a digital scale (Filizola®, São Paulo, Brazil) with a maximum capacity of 180 kg and a precision of 0.1 kg. During the evaluation, all the participants wore sneakers and sportswear that were not embellished. Height was measured only in the pretest with a stadiometer (HR-200, TANITA, Arlington Heights, IL) during which the athletes were barefoot in an orthostatic position.

2.3. Dietary Assessment and Dietary Protocol

Food intake was evaluated by a 24-hour recall (24HR) for three consecutive days, specifically, two weekdays and one day of the weekend on the pretest and running days. A nutritionist conducted a face-to-face interview with each participant. Macronutrient and energy intakes were assessed with DietSmart® software. At the 5th-week interval before the running tests commenced, all the runners followed a standard diet (50% CHO) for seven consecutive days so they could adapt to the dietary protocols that followed.

At the same time, diets with 30%, 60%, and 80% CHO were calculated based on their average 24-hour intake. All the participants followed three CHO intake protocols, namely, 30%, 60%, and 80% (Table 1) for seven consecutive days each. The participants were assigned to three groups of three or four members according to their running times to distribute dietary protocols. They were all required to have an evening meal three to four hours before their race tests, depending on their allocated dietary group.

Progressive exercise test to determine peak velocity (V_{peak}). The PV test was evaluated on a motorized treadmill (Lion Fitness® model X4). The progressive test started with a warm-up of 5 min at 6 km/h⁻¹, subsequently which the progressive protocol initiated with a a velocity of 8 km /h⁻¹, and increased by of 1 km/h⁻¹, with 3-minute stages. with the gradient set at 1% until the participants reached volitional exhaustion (Bentley, Newell, & Bishop, 2007; Kuipers, Rietjens, Verstappen, Schoenmakers, & Hofman, 2003). To identify the V_{peak} , the velocity was used of the last complete stage, added to the fraction of the incomplete stage (Machado, Kravchychyn, Peserico, Da Silva, & Mezzaroba, 2013), The equation $V_{pico} = V_{complete} + t / T$ in wich $V_{complete}$ is the running of the last complete stage, T the time in seconds sustained during the incomplete stage and T the time in seconds required to complete a stage.

2.4. Running Tests

Running tests were performed on the 5000 m track of the Federal University of Lavras. It was 400 m long and 9.36 m wide and had eight lanes that were approximately 1.25 m wide. In the pretest, we confirmed the maximum running time required for athletes to participate in the study. All the running tests were performed on the seventh day of the diet, which corresponded to the last day of each dietary protocol.

2.5. Running Time and Pacing

The final time in the 5 km run and each athlete's time per kilometer were measured with a digital chronometer (model S141, Seiko® Tokyo, Japan). Running time per kilometer was collected during tests. The data, pacing, and average speed were analyzed to evaluate performance.

2.6. Statistical Analysis

The mean and standard deviation of all the results were calculated in Microsoft Excel® 2010. For analysis of control and performance parameters (time per km and total time), two-way Anova of repeated measures (diet x time) were employed in the Statistical Package for Social Sciences version 21.0. The significance level was set at $p < 0.05$.

3. RESULTS

Dietary intake data are displayed in Table 1. According to the dietary intake analysis, athletes consumed $30.80 \pm 1.07\%$ or 2.20 ± 0.42 g/kg in the 30% diet, $59.34 \pm 0.82\%$ or 4.24 ± 0.82 g/kg in the 60% diet, and $77.79 \pm 1.00\%$ or 5.56 ± 4.15 g/kg in the 80% diet. These data suggest high adherence to all the diets.

Table 1. Dietary intake assessment, mean $\pm$ SD.

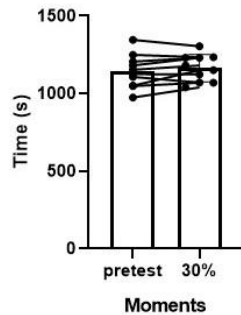
	Pretest	30%	60%	80%
Body mass (kg)	70.43 $\pm$ 6.09	69.06 $\pm$ 6.07	68.49 $\pm$ 5.52	69.12 $\pm$ 5.80
Carbohydrate (g)	290.91 $\pm$ 122.51	154.24 $\pm$ 28.97	296.57 $\pm$ 54.07	388.86 $\pm$ 77.28
Carbohydrate (g/Kg)	4.20 $\pm$ 1.86	2.20 $\pm$ 0.42	4.24 $\pm$ 0.82	5.56 $\pm$ 1.15
Carbohydrate (%)	55.20 $\pm$ 11.69	30.80 $\pm$ 1.07	59.34 $\pm$ 0.82	77.79 $\pm$ 1.00
Fibre (g)	25.66 $\pm$ 13.89	10.81 $\pm$ 3.26	26.74 $\pm$ 4.11	29.24 $\pm$ 6.98
Protein (g)	78.50 $\pm$ 37.80	149.39 $\pm$ 32.01	80.80 $\pm$ 19.02	52.06 $\pm$ 10.39
Protein (g/kg)	1.09 $\pm$ 0.58	2.14 $\pm$ 0.52	1.16 $\pm$ 0.29	0.74 $\pm$ 0.15
Protein (%)	15.61 $\pm$ 6.59	29.79 $\pm$ 2.09	16.05 $\pm$ 1.28	10.42 $\pm$ 0.50
Lipid (g)	70.21 $\pm$ 40.79	88.73 $\pm$ 16.26	56.02 $\pm$ 10.71	27.13 $\pm$ 4.48
Lipid (g/Kg)	1.02 $\pm$ 0.63	1.27 $\pm$ 0.22	0.80 $\pm$ 0.14	0.39 $\pm$ 0.07
Lipid (%)	29.08 $\pm$ 8.05	39.89 $\pm$ 1.91	25.03 $\pm$ 1.79	12.27 $\pm$ 0.93
Kilocalories (Kcal)	2112.29 $\pm$ 872.33	2002.5 $\pm$ 370	2001.9 $\pm$ 376.13	1997.4 $\pm$ 385.61
Kilocalories (Kcal/Kg)	30.51 $\pm$ 13.52	28.64 $\pm$ 5.49	28.62 $\pm$ 5.56	28.56 $\pm$ 5.70

An analysis of running time by kilometer revealed a non-significant difference among the dietary protocols in comparison to the first kilometer in which we observed that the 60% protocol revealed the best time (Table 2). In Km2, while the athletes showed no significant differences, the 60% diet showed the greatest increase. The Km3 running time control revealed the shortest time in contrast to the 30% diet that showed an increase of 7.73% in comparison to the control ($p = 0.338$). In Km4, the 30% and 80% groups demonstrated similar running times. In contrast, although there was no statistical difference, those in the 60% diet took more time compared to those in the 80% diet ($p = 0.137$). On the last kilometer (Km5), those on the 80% CHO diet ran a faster time compared to those on the other diets, but also without any significant difference.

Table 2. Time for km, mean $\pm$ SD.

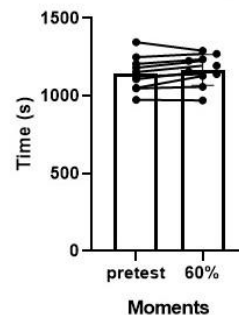
Diets	1Km (Seconds)	2Km (Seconds)	3Km (Seconds)	4Km (Seconds)	5km (Seconds)
Control	212.10 $\pm$ 19.33	225.50 $\pm$ 24.81	229.00 $\pm$ 27.86	239.70 $\pm$ 24.54	237.50 $\pm$ 24.19
30%	215.30 $\pm$ 18.49	226.90 $\pm$ 20.97	251.60 $\pm$ 36.73	233.00 $\pm$ 22.78	236.30 $\pm$ 18.23
60%	206.00 $\pm$ 16.99	232.30 $\pm$ 29.32	242.90 $\pm$ 23.30	246.70 $\pm$ 23.57	239.00 $\pm$ 23.50
80%	211.80 $\pm$ 20.70	226.00 $\pm$ 17.78	235.30 $\pm$ 25.11	232.40 $\pm$ 18.96	230.80 $\pm$ 22.80
p					
Con-30%	0.980	0.980	0.338	0.955	0.981
Con-60%	0.826	0.975	0.402	0.967	0.979
Con-80%	0.987	0.978	0.950	0.982	0.588
30%-60%	0.669	0.992	0.962	0.733	0.965
30-80%	0.980	0.995	0.747	0.972	0.763
60%-80%	0.978	0.983	0.522	0.137	0.974
Δ					
Con-30%	+1.30%	+1.17%	+7.73%	-1.26%	+0.88%
Con-60%	-2.41%	+2.67%	+5.51%	+1.72%	-2.20%
Con-80%	-0.63%	-0.53%	+7.92%	-3.56%	-3.45%
30%-60%	-3.66%	+1.48%	-2.06%	+3.02%	-3.05%
30-80%	-1.90%	-1.69%	+0.18%	-2.33%	-4.30%
60%-80%	+1.63%	-3.12%	+2.29%	-5.19%	-1.28%

Final time in the 5km in the pretest and 30%



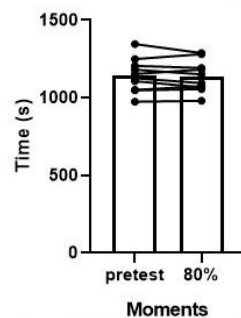
a) comparison of the final 5km time between the pre-test and the 30% diet

Final time in the 5km in the pretest and 60%



b) comparison of the final 5km time between the pre-test and the 60% diet

Final time in the 5km in the pretest and 80%



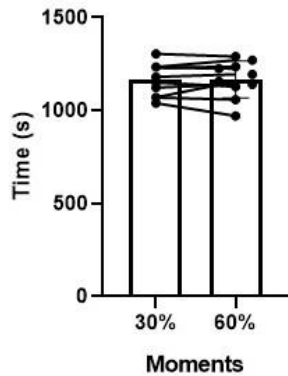
c) comparison of the final km time between the pre-test and the 80% diet

Figure 2. Comparison the time pre test and diets.

The final 5 km time of the three diets is depicted in Figure 2. The results revealed: control-30 diet (1143 ± 34.26 s - 1163.00 ± 27.68 s - $p = 0.975$); control-60% (1143 ± 34.26 s - 1166.90 ± 31.22 s - $p = 0.449$); and control-80% (1143 ± 34.26 s - 1136.30 ± 31.72 s - $p = 0.981$). No significant differences emerged in any of the analyses.

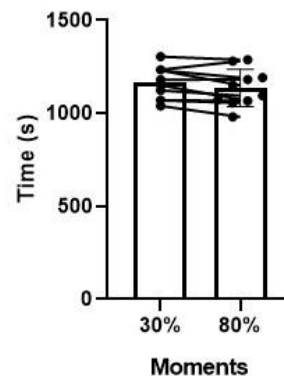
When comparing the final 5 km times between the 30-60% and 30-80% diets (Figure 3), we did not identify any significant difference in the analysis: 30-60% (1163.00 ± 27.68 s - 1166.90 ± 31.22 s - $p = 0.986$); and 30-80% (1163.00 ± 27.68 s - 1136.30 ± 31.72 s - $p = 0.328$).

Final time in the 5km in the 30% and 60%



a) comparison of the final 5km time between the 30% and 60% diet

Final time in the 5km in the 30% and 80%

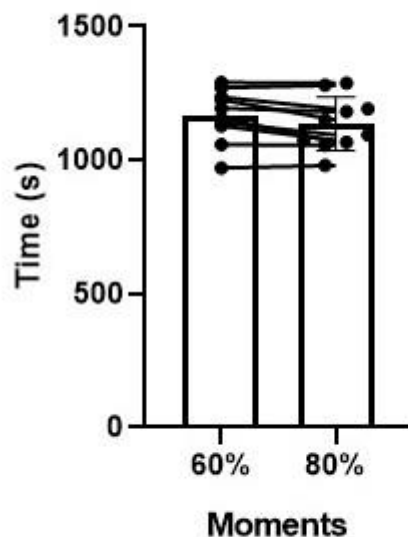


b) comparison of the final 5km time between the 30% and 80% diet

Figure 3. Comparison 30% diets and the 60% and 80% diets.

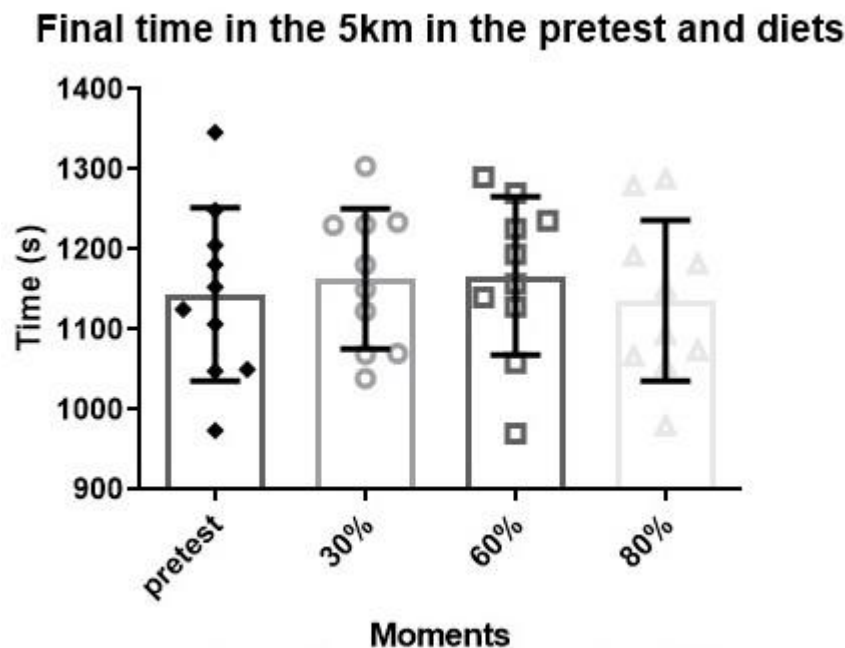
No significant difference in the analyses were revealed in the final 5 km time between the 60-80% diets (Figure 4): 60-80% (1166.90 ± 31.22 s - 1136.30 ± 31.72 s - $p = 0.150$). The general analysis of the comparison between the final 5 km times is depicted in Figure 5.

Final time in the 5km in the 60% and 80%



a) comparison of the final 5km time between the 60% and the 80% diet

Figure 4. Comparison 60% and 80% diets



a) comparison of the final 5km time between the pre-test and diets

Figure 5. Comparison pre teste and diets.

4. DISCUSSION

In this study, the effect of three CHO diets (30%, 60%, and 80%) on 5-km amateur runners' performances was analyzed. No significant differences among dietary CHO protocols were revealed in the results. However, we found that by stabilizing diet, an important improvement in performance was achieved.

The average macronutrient intake in pretest CHO consumption (4.20 g/kg) was below the minimum value (5 g/kg/day) of the national recommendations proposed by the American College of Sports Medicine suggested for athletes in moderate exercise. Only the intake of kilocalories (30.51 kcal/kg) met nutritional recommendations (25 to 35 kcal/kg/day) (Thomas, Erdman, & Burke, 2016). In relation to high-performance endurance athletes' eating habits, 24HR has confirmed that 80.8% of runners consumed less CHO (5.6 ± 2.1 g/kg) than that recommended (Baranauskas et al., 2015). When the macronutrient's importance for medium- and long-duration exercise is considered, low CHO intakes might not meet energy needs. Furthermore, the runners' susceptibility to muscle glycogen depletion and premature fatigue increased. The accurate representation of actual food intake may be questioned by the limited self-reported dietary data (Marquet et al., 2016). This information supports research that revealed 24HR could not reflect a chronic intake of a low CHO (LCHO) diet of non-sedentary individuals throughout a period of three years (Pilis et al., 2018). It is possible that the sample size and short duration of diets influenced the outcome. Furthermore, the athletes retained their energy balance even though their dietary data suggested an insufficient food intake to meet energy needs.

An analysis of total running times in seconds revealed no significant difference among diet protocols. The slowest time was in the diet of the 60% diet (1166.9 s) compared to those of the 30% (1163.1 s) and 80% diets (1136.3 s) as well as that of the pretest phase (1143.8 s). However, a reduction of 2.3% and 0.66% in running time was found in the 80% diet in comparison to the 30% diet and pretest. This difference must consider that one second can decide the winner among elite runners. Similarly, another study revealed that two diets with high CHO (9.3 g/kg/day) and LIP (4.3 g/kg/day) administered for five days resulted in similar times in submaximal exercise (cycling) (25.53 ± 0.67 min versus 25.45 ± 0.96 min) (Burke et al., 2002).

When the pacing was analyzed, it was verified that there was maintenance in all diets thus emphasizing that the dietary manipulations did not interfere in the performance. We identified that there was a clear strategy change in the 60% diet where the first was slower than the other kilometers in the different diets. Thus, Km2 of the 60%

diet had the slowest time. Similar behavior was revealed in the other kilometers. A negative strategy has been found in most medium and long-distance studies. While the latter was evident in the 30% and 60% diets, in the 80% diets the strategy was more constant, which may be justified by the supply of glycogen made available by CHO overload (Earnest et al., 2019). The 5 km is considered to be a medium duration test, which could be regarded as a limitation of the study because of the use of muscle glycogen reserves (Leckey, 2018). However, it is noteworthy that the relative intensity of the 5 km tests made greater use of the glycolytic system (Guglielmo et al., 2012) above 75% of VO_{2max} or V_{peak} (the average speed in the 5 km was 89% of V_{peak}) (Emhoff et al., 2013). This increases the use of this substrate thus justifying this distance and procedure adopted for the prescription of diets. Accordingly, they realized and concluded that in races of a longer duration or intensity, the running strategy is controlled to ensure that energy is maintained to ensure an increase in speed at the end of the race (Couto et al., 2015; Pruitt & Hill, 2017b). Finally, the concept that these strategies are grounded in advance through a central governor, which is a complex and intelligent system that controls effort to optimize the kinetic and energetic performance of the athlete, was supported (Pruitt & Hill, 2017a).

A strong feature of this study was the reproduction of actual competitive conditions. It is recommended that future studies employ muscle biopsies to confirm if glycogen concentration in the muscle changes after CHO dietary manipulation. Accordingly, other hypotheses will be able to be explored by comparing runners' performances in relation to their diets. However, the study was limited by its small sample size and convenience sampling. The experimental design precluded answering questions about the effects of dietary protocols on athletes with lower training levels for a different period.

5. CONCLUSION

Knowledge about the most adequate CHO dietary recommendations will allow health practitioners such as nutritionists and coaches to decide and elaborate on strategies jointly to benefit long-distance amateur runners' performances. Our findings revealed that seven-day CHO diets did not lead to more enhanced performances than a runner's normal diet. Nevertheless, for long-distance amateur runners, CHO dietary manipulation appears to have the potential to improve athletic performance.

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Competing Interests: The authors declare that they have no competing interests.

Authors' Contributions: All authors contributed equally to the conception and design of the study.

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