ACES Arquivos de Ciências do Esporte

Artigo Original

Avaliação das escolhas nutricionais pré-treinamento de alta intensidade por nadadores competitivos

Evaluation of High Intensity Pre-Training Nutritional Choices by Competitive Swimmers

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Citação: Pinto, M. G. M.; Franken, M.; Macedo, R. C. O.; Castro, F. A. S.; Martins, N.; C. Evaluation of High Intensity Pre-Training Nutritional Choices by Competitive Swimmers. Arq Cien do Esp.

Recebido: 08/2024
Aceito: 10/2024

Nota do Editor: A revista *"Arquivos de Ciências do Esporte"* permanece neutra em relação às reivindicações jurisdicionais em mapas publicados e afiliações institucionais

Resumo: *Introdução*: O planejamento nutricional é aspeto fundamental para o desempenho em natação. A literatura a avaliar se nadadores de competição adaptam a sua ingestão nutricional de acordo com os treinos realizados é limitada. *Objetivo*: Analisar se nadadores de competição adequam sua dieta para treinos de alta intensidade, especificamente para séries de treino intervalado de alta intensidade, e ainda, se a ingestão nutricional causa influência no tempo até a exaustão. *Métodos*: Catorze nadadores do sexo masculino realizaram séries de 400 m (com 40 s de descanso passivo), em dois dias distintos, a 90% (s90) e 95% (s95) do s400 (velocidade média do teste de 400 m sob máxima intensidade), previamente determinado pelo teste de 400 m nado crawl. As ingestões alimentares foram registadas nas 24 horas anteriores à realização das séries. Os consumos energéticos e de macronutrientes foram calculados e comparados com recomendações. *Resultados*: Os nadadores apresentaram ingestão inadequada de energia (s90 ≈ 64,2% e s95 ≈ 85,7% abaixo das recomendações) e de hidratos de carbono (s90 ≈57,1% e s95 ≈85,7% abaixo das recomendações), quando confrontada com as recomendações específicas para fases de treino de intensidade elevada. Não foram encontradas correlações, para as duas séries, entre desempenho e variáveis nutricionais. *Conclusão*: Foi possível observar inadequação da dieta às necessidades do treino.

Palavras-chaves: natação; nutrição; alta intensidade; energia; hidratos de carbono.

Abstract: *Background*: Nutritional planning is a fundamental aspect for performance in swimming. The literature evaluating whether competitive swimmers adjust their nutritional intake according to the training performed is limited. *Objective*: To analyze the adequacy of dietary intake in competitive swimmers for high-intensity interval training series, and to verify the correlation between nutritional variables and time until exhaustion. *Methods*: Fourteen male swimmers performed 400 m series (with 40 s of passive rest) on two separate days at 90% (s90) and 95% (s95) of the average speed of the 400 m (s400) test under maximum intensity), previously determined by the 400 m front crawl test. Dietary intakes were recorded in the 24-hour period preceding the series. Energy and macronutrient intakes were compared with literature recommendations. *Results***:** Swimmers reported inadequate energy intake (s90 ≈64% and s95 ≈85%, below recommendations) and carbohydrate intake (s90 ≈57% and s95 ≈85%, below recommendations) when compared to specific recommendations for high-intensity training phases. No correlations were found for the two series between performance and nutritional variables. *Conclusion***:** There was an inadequacy of the diet to the needs required by training.

Keywords: swimming; nutrition; high intensity; energy; carbohydrates.

1. Introduction

Swimming is a technically and energetically demanding sport, especially in a competitive context[1]. In competitive swimming, different race distances require specific types of training, depending on swimmers' respective effort times. Attributes such as muscular strength, endurance, speed, aerobic and anaerobic power are required and supported by different combinations of energy systems[2]. During the sessions training, predefined durations and distances help manage the target intensity. For example, the average speed during the 400 m front crawl test (T400) is indicated as the minimum speed to reach the intensity corresponding to maximum oxygen consumption (VO_2max, or the speed of VO_2max) in swimming[3]. Thus, the T400 can be used as an effective parameter for evaluating athletes in swimming and for prescribing intensity in training[4].

Periodized nutrition, which can meet athletes' energy and nutrient needs, respecting the different phases of the competitive calendar and optimizing training adaptations, is an essential aspect for achieving ideal sports performance[5, 6]. Additionally, nutritional goals are not static, being dependent on the athlete's competitive phase and variables such as the duration and intensity of training performed, suggesting that nutritional planning be adapted to the athlete's context, objectives, and needs[7]. Performance during training at high intensities may be limited due to several factors, including nutritional planning[8]. In high-intensity training, it is essential that glycogen reserves are complete, allowing adequate glucose oxidation[8, 9]. Inadequate management of energy and macronutrient intake, related to individual needs and specific training situations, and sports periodization, can result in a decrease in sports performance[7].

In this context, analyzing whether elite athletes adapt their dietary planning according to the type of training becomes important to optimize performance. However, it is not known whether competitive swimmers autonomously adapt their dietary behavior according to the training carried out and their intensity. Thus, the present study aimed to analyze the adequacy of dietary intake in competitive swimmers for high-intensity interval training series (above 80% of VO_2max), and to verify the correlation between nutritional variables and time until exhaustion, an indicator of performance.

2. Methods

This is a cross-sectional observational investigation, performed in Porto Alegre, RS, Brazil. The main outcomes are the energy and macronutrient intakes, and total time to exhaustion (TTE). This investigation was approved by the local Human Research Ethics Committee (17367), in accordance with the Declaration of Helsinki for ethics in research with human beings.

Participants

Fourteen specialists in 400, 800, 1500 m events freestyle, and open water male swimmers (percentage of the current world record in the 400 m freestyle event = 77.4 ± 4.6% in a 25 m pool) participated in this study (a cross-sectional observational investigation). The swimmers had at least four years' experience in the sport, trained around 12 hours a week, between five and eight sessions, completing between 35 and 80 km of swimming per week, and were in a specific preparation phase (high intensity and low volume) of the season. Participants were informed in advance of all procedures and read and signed an informed consent document.

Instruments and Procedures

Swimmers were instructed to reduce their level of physical exercise in the 24 hours before the assessment sessions. Participants abstained from consuming caffeine 12 hours before each of the assessment sessions. The tests were in a 25m pool (water and ambient temperature of 29.5±0.7 and 24.2±0.9°C), between 2pm and 6pm.

Anthropometric Assessments

The height, body mass, arm span, and skinfolds were measured and the body mass index (BMI) of all participants was calculated, prior to the application of swimming protocols. Three non-consecutive measurements of the tricipital, abdominal, suprailiac, and subscapular folds (adipometer Sanny, scientific model, São Bernardo do Campo, Brazil; 0.1 mm) were recorded[10] (Table 1).

Table 1 – Characteristics of participants, n=14.

	Mean	standard deviation	Limits of the mean confidence intervals (95%)
Age (years)	21.1	7.3	[17.3 to 24.9]
Body mass (kg)	72.4	10.6	[66.9 to 78.0]
Height (cm)	179.6	6.7	[176.0 to 183.1]
Arm span (cm)	186.3	8.1	[182.0 to 190.5]
Σ 4 skinfolds* (mm)	48.6	11.7	[42.5 to54.8]

BMI (kg/m²)	22.4	2.5	[20.9 to 23.9]

* Tricipital, abdominal, suprailiac, and subscapular folds; BMI: body mass index

Swimming tests

After a standardized 800 m warm-up (intensity self-selected), the swimmers performed the T400. The average speed (s400, quotient between 400 m and the time, s) was calculated. Two speeds were calculated: 90 (s90) and 95% (s95) of the s400. After 48 hours of the T400, in a random manner, they performed, after the same warm-up, two series of interval training until exhaustion on two different days, respecting an interval of 48 hours between each session: s90 and s95. In both series, participants were asked to perform as many 400 m repetitions as possible at the pre-established speed (40 s of passive rest).

For both series, an underwater visual pacer (resolution of 0.01 $m \cdot s^{-1}$), triggering bright flashes, with lamps positioned every meter, at the bottom of the pool, below the swimmer, was used to convey to swimmers the speed they should maintain[4]. The pacer was programmed with individual speeds (s90 and s95). The swimmer's inability to follow the flashing lights was determined as a criterion for the occurrence of exhaustion and the test's end. In each series, the TTE was obtained by adding the effort time according to the number of repetitions, from which the intervals for passive recovery after each repetition were excluded. Each series' TTE was obtained by two experienced timekeepers (digital stopwatch, Casio, model HS-80tw, Japan).

Food Record

Swimmers were instructed to record all food (solid and liquid) consumed in the 24-hours prior to each training series. They were instructed on the correct and standardized way to complete the self-report method. It was emphasized that swimmers made their respective notes, during or immediately after consuming food, to decrease memory bias in the dietary assessment. Meals were described with mealtime, estimated quantities in relation to a common-sized container (measuring spoons) and, when possible, with the food's brand. After, all notes were double-checked, individually. Thus, it was possible to characterize the athletes' food consumption in the 24-hour period prior to the s90 and s95.

The nutritional variables of the 24 hours that preceded the two interval training sessions were considered. Each food record was carefully analyzed by a trained and qualified professional (registered dietitian) from the research team. After review, all foods and mixed dishes consumed according to the athletes' descriptions were converted to their actual weights (in grams), compared and evaluated with the parameters listed in a food composition database[11]. The intake of each nutrient in the analyzed period was estimated by cross-referencing a food database[11], thus establishing the characteristics of athletes' eating habits in the pre-training period (previous 24 hours) of the high intensity sessions. Food attributes referring to total calories (kcal) were obtained; carbohydrates

(CHO, % and g); protein (PROT, % and g); lipids (LIP, % and g); and fasting period (min) before each series. Considering individual body mass, total energy was calculated in kcal/kg/day and macronutrient intake in g/kg/day. Previously published values as nutritional references[12] were used.

Data analysis

Data distribution was checked with the Shapiro-Wilk test. Means, standard deviations, and limits of the mean confidence intervals (95%) were calculated. The % of swimmers who were above or below the recommended macronutrient intake ranges were calculated. The comparison between performance and nutritional variables, obtained in the s90 and s95, was performed using Student's t test for dependent data. Effect size was calculated with Cohen's d: 0 – 0.19 trivial; 0.2 – 0.59 small; 0.6 – 1.19 moderate; 1.2 – 1.99 large; 2.0 – 3.99 very large, and > 4.0 practically perfect[13]. The correlation between nutritional variables and performance in each series was verified using the Pearson Correlation test. The statistical power a posteriori (b) was computed for comparisons between performance and nutritional variables, obtained in the s90 and s95, due to the sample size, in the G*Power v. 3.1.9.7. The SPSS Statistics for Windows (version 27.0. Armonk, NY: IBM Corp.) was used and the level of significance was assumed as $p < 0.05$.

3. Results

The average s400, s90, and s95 were, respectively, 1.45±0.08; 1.30±0.11; and 1.37±0.01 $m \cdot s^{-1}$. For s90 and s95, swimmers performed, respectively, between 4 and 15 repetitions and 2 and 5 repetitions. They reached TTE of, respectively for s90 and s95, 46.14±23.42 and 16.60±9.06 min. The performances are in Figure 1. The effect size and the b of the series on performance were, respectively 2.04 (very large) and 0.99.

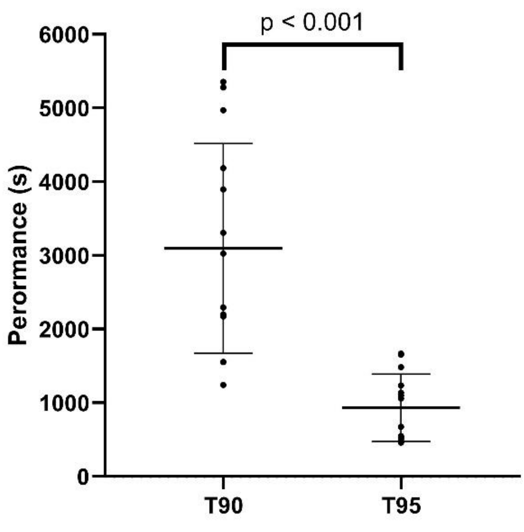

Figure 1 – Performance(s) in the 90 and 95% series of the s400; n = 14.

Table 2 presents data on nutritional variables. Table 3 presents the relative frequencies of swimmers who were below or above the recommendations for energy, carbohydrates, proteins, and lipids, in both series.

Table 2 – Nutritional variables, in means ± standard deviations, and limits of confidence intervals (95%) of the means, the comparisons between s90 and s95 (p, d, and b values); n = 14.

	s90 mean ± sd [limits of confidence intervals]	**s95 mean ± sd [limits of confidence intervals]**	**p;** b **d (effect)**
Energy (kcal)	3701 ± 1270 [2968 to 4435]	3070 ± 1215 [2368 to 3771]	0.037*; 0.82 0.50 (small)
Energy (kcal/kg)	52.0 ± 20.9 [40.0 to 64.0]	43.4 ± 19.8 [32.0 to 54.9]	0.051; 1.00 1.87 (large)
Carbohydrates (%)	48.3 ± 7.1 [44.2 to 52.4]	50.7 ± 9.3 [45.3 to 56.2]	0.211; 0.44 0.29 (small)
carbohydrates (g)	436.6 ± 132.2 [360.2 to 513.0]	382.3 ± 157.2 [291.5 to 473.1]	0.193; 0.60 0.37 (small
Proteins (%)	19.2 ± 4.9 [16.3 to 22.0]	20.7 ± 5.2 [17.7 to 23.7]	0.231; 0.44 0.29 (small)
Proteins (g)	175.4 ± 71.3 [134.2 to 216.6]	155.4 ± 70.0 [115.0 to 198.8]	0.012*; 0.64 0.39 (small)
Proteins (g/kg)	2.45 ± 1.12 [1.81 to 3.1]	2.19 ± 1.13 [1.54 to 2.81]	0.016*; 0.99 0.23 (small)
Lipids (%)	32.4 ± 5.8 [29.0 to 35.7]	28.5 ± 7.5 [24.1 to 32.8]	0.016*; 0.91 0.58 (small)
Lipids (g)	138.7 ± 68.0 [99.4 to 178.0]	101.3 ± 61.5 [65.8 to 136.9]	0.016*; 0.99 0.85 (moderate)
Fasting period (min)	154.6 ± 53.9 [123.5 to 185.7]	159.8 ± 58.2 [125.6 to 192.9]	0.733; 0.12 0.092 (trivial)

* Statistically significant differences between series s90 and s95. Fasting period: fasting period before each session

Table 3 – Relative frequency of swimmers below or above the recommend intake, n = 14.

	s90	**s95**
Energy (% below recommendation*)	64.2%	85.7%

Carbohydrates (% below recommendation*)	57.1%	85.7%
Proteins (% above recommendation*)	71.4%	64.2%
Lipids (% below recommendation*)	57.1%	28.5%

* In accordance with published values as nutritional references[12].

Figure 2 presents, respectively, in panels A, B, C, and D the individual intakes, the averages for each intensity, and the daily recommendations for calories, carbohydrates, proteins and lipids.

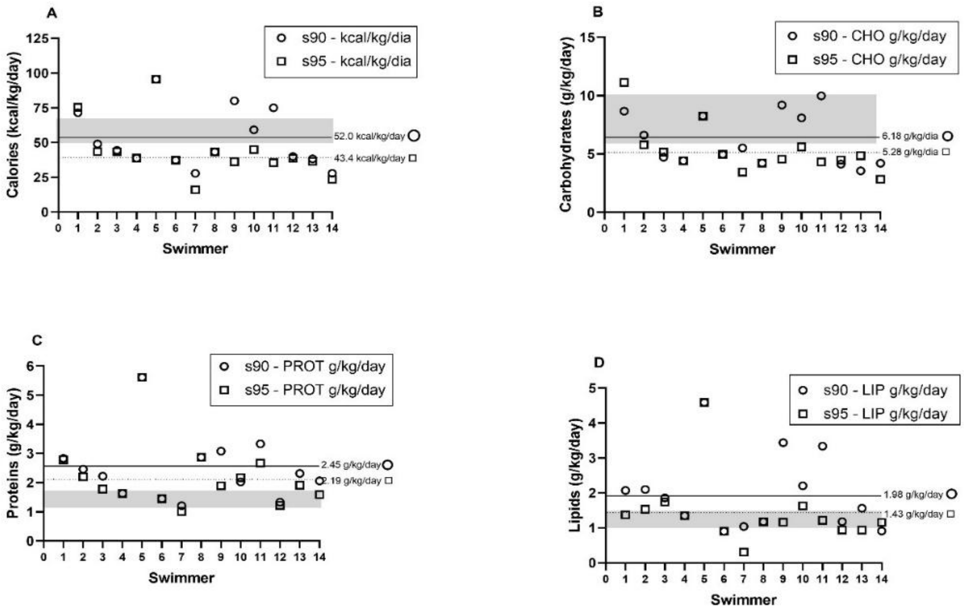

Figure 2 – Panel A: Energy intake. In gray the daily recommendation range, from 50 to 64.3 kcal/kg/day. Panel B: Carbohydrate intake. In gray the daily recommendation range, from 6 to 10 g/kg/day. Panel C: Protein intake. In gray the daily recommendation, from 1.2 to 1.7 g/kg/day. Panel D: Lipid intake. In gray the daily recommendation is 1.0 to 1.5 g/kg/day [12]. In the four panels, the circles indicate the 90% series, and the squares indicate the 95% series. The solid line indicates the mean at 90% and the dotted line the mean at 95%; n = 14.

The correlations between performance and nutritional variables were not significant for both series ($p > 0.05$). The correlation values between the TTE at each intensity and the nutritional variables are in Table 4.

Table 4 – Correlation matrix between TTE at s90 and TTTE and s95 and nutritional variables, n = 14.

	Energy (kcal)	Energy (kcal/kg)	Carbohydrates (%)	Carbohydrates (g)	Carbohydrates (g/kg/day)	Proteins (%)	Proteins (g)	Proteins (g/kg/day)	Lipids (%)	Lipids (g)	Lipids (g/kg/day)
TTE s90 (s)	r = -0.50 p = 0.06	r = -0.46 p = 0.09	r = 0.17 p = 0.55	r = -0.44 p = 0.10	r = -0.45 p = 0.09	r = -0.14 p = 0.62	r = -0.50 p = 0.09	r = -0.49 p = 0.07	r = -0.08 p = 0.76	r = -0.41 p = 0.14	r = -0.41 p =0.13
TTE s95 (s)	r = 0.20 p = 0.47	r = 0.10 p = 0.73	r = 0.29 p = 0.30	r =-0.24 p = 0.40	r = 0.36 p = 0.19	r = -0.24 p = 0.40	r = -0.09 p = 0.75	r = 0.025 p = 0.93	r = 0.04 p = 0.87	r = -0.55 p = 0.85	r = -0.026 p = 0.92

4. Discussion

The objective of the present study was to analyze the adequacy of dietary intake in competitive swimmers for high-intensity series, and to verify the correlation between nutritional variables and TTE, indicator of performance. We highlight that: (i) swimmers reported inadequate energy (s90 ≈64% and s95 ≈85% below recommendations) and carbohydrate intake (s90 ≈57% and s95 ≈85% below recommendations), when compared with specific recommendations[12] for high-intensity training; and (ii) no significant correlations were found, for the two series, between performance and nutritional variables.

Comparing the average energy intake between the two sets, participants ingested on average a smaller amount of energy (3070 kcal) for the higher intensity set (s95), compared to the lower intensity set (s90; 3701 kcal). A total of ≈64% of the swimmers fell below energy recommendations for the s90, while, for the s95 series, ≈85% did not meet energy intake recommendations. The average intake for s95 training was below recommendations for swimmers in a specific preparation period[12, 14]. The results obtained in the present study are in line with previous cross-sectional studies on low energy consumption by swimmers[15, 16].

One aspect to be considered is the possibility of underreporting highlighted by some studies in relation to athletes' dietary records[17]. However, even if a possible underreporting by athletes can be find, the results suggest an energy intake lower than expected in the preparation phase for high-intensity training. A disparity between energy expenditure and intake is a frequent observation in swimming, a circumstance that is aggravated in situations of sudden increase in training volume and/or intensity[14]. The presence of a negative energy balance or a low energy availability can affect the recovery capacity during and between training sessions and can also contribute to the emergence of the condition Relative Energy Deficiency, impairing health and sports performance[18].

Regarding carbohydrate consumption, the athletes ingested 48.3% and 50.7%, for the s90 and s95 training sessions, respectively. This result is in line with the recommendations[6, 8]. However, with a low total energy intake, the total carbohydrate content, in grams, may continue to be insufficient. However, for the s90, we observed that 57% of the swimmers consumed below the recommended recommendations; and for the s95, 85% ingested carbohydrates in an amount lower than suggested[12, 14]. These results are in line with other studies that demonstrated that swimmers may have a low consumption of this macronutrient[16, 17].

Limited pre-exercise muscle glycogen reserves can restrict performance during high-intensity exercise[5, 19, 20]. On the other hand, some authors[21, 22] suggest that activity performed with low availability of carbohydrates could favor adaptations to training, such as improved enzymatic activity, increased proteins involved in oxidative metabolism, mitochondrial biogenesis, and increased lipolysis. Increasing maximal oxygen consumption is one of the key factors for performance, and energy production will depend first on the intensity of the exercise and then on the duration of the exercise, and it is essential that the muscular and hepatic glycogen reserves are filled to support the demand for glucose and energy[9].

Regarding the period of fasting before training, supported by athletes, it is suggested to ingest 1 to 4 g/kg of carbohydrates in the period of 1-4 hours before performing high intensity activity[23]. In the present investigation, the occurrence of more than 4 hours of fasting was observed in ≈14.2% of swimmers in the s90 training and ≈7.1% in the s95 training, noting that most swimmers ate during the period between 1-4 hours before training.

Regarding protein intake, considering the total macronutrients in the diet, athletes on average ingested 19.2% for the s90 and 20.7% for the s95. These results indicate that the athletes reached the recommended general protein target, and in the case of s95, they were above recommendations[5]. However, a significant number of swimmers exceeded the recommended in the guidelines. In the s90 ≈71% ingested above 1.7 g/kg, and in the s95 ≈64% consumed above that suggested for athletes in a specific preparation period[12, 14]. This finding seems to be a common characteristic for male swimmers, possibly related to the concern with gaining and maintaining fat-free mass, even in situations in which there is a need to lose total body mass. It is important to note that the time, type, and amount of protein intake influence recovery and adaptation post-exercise and between training sessions[14]. The substrate is mainly responsible for promoting tissue adaptation and regeneration and maintaining nitrogen balance, thus preventing protein catabolism, and helping to recover after intense activities[5]. In some situations of hypocaloric dietary behavior, aiming to retain lean body weight, hyper protein intakes are suggested[23].

In the panorama regarding lipid consumption, for the expected average in relation to the division of macronutrients, in the s90, the athletes exceeded the recommendations (30%), with an intake of 32.4%, while for the s95 they were below the recommendations[5], with a consumption of 28.5%. In s90, ≈57% of athletes had a fat intake above the recommended level (1-1.5 g/kg), and in s95 ≈28% exceeded recommendations. Moreover, ≈14%) in s90 and ≈28% in s95 did not reach 1 g/kg, achieving an intake lower than those predicted in the recommendations[12]. However, another study[17] found high fat consumption by swimmers. In regular high-volume training, endurance athletes can assume a proportion of up to 50% fat in the macronutrient division[5]. The synthesis of hormones, absorption of fat-soluble vitamins, signaling, transport, nervous function, and replenishment of intramuscular triglyceride stores are reasons for consuming lipids for exercisers who aim to improve their performance[19].

The requirements regarding an athlete's energy and macronutrient needs can be linked to the characteristics of the activity practiced, the time of day of the sport, the individual's particularity (gender, body mass, age and dietary preferences), the type of environment (water sports, outdoor, indoor), the periodization of the season, the properties of the day's training (intensity, volume), and sporting objectives[6, 14]. In the context of preparing for high-intensity training, or one that leads to a situation of exhaustion, it is important that the athlete's nutritional status is assessed[20]. An adequate energy intake relative to the energy cost of training[6] and sufficient availability of carbohydrates is directly linked to performance in high-intensity activities[9]. However, in the present study, swimmers' suitability in this sense was not observed.

Additionally, no significant correlations were found between nutritional variables and TTE. This result may be related to the recording of just 24 hours prior to the tests. Energy and macronutrient needs must be met diligently during the competition season, dietary periodization must consider not only the preparation for the session to be developed, but also the general seasonal goals of mesocycles and macrocycles[6]. Hydration, maintenance of body composition, replenishment of glycogen reserves (muscle and liver), adequate consumption of protein (availability of amino acids) for tissue construction and repair, intake of lipids that must provide essential fatty acids (important for immunity and circulating hormone concentrations) and fat-soluble vitamins are strategies for optimal health, support of cognitive function, and improved exercise performance[5].

Food recording methods are being used in nutrition research[24]. Such methods do not need to be carried out personally, are easy to apply, can be carried out at the time of the meal, and are also less expensive. Previous study[25] indicated that some respondents may improve their eating habits unintentionally through self-reflection. However, these methods may present some characteristic limitations, such as short-term intake analysis, limited to a few days/observations and a potential underestimation in reported quantities[26]. It is essential that athletes, coaches, nutritionists and sports scientists adapt athletes' eating habits to the specific demands of training. It is essential that athletes, coaches, nutritionists and sports scientists adapt athletes' eating habits to the specific demands of training. Checking other sports and other intensities of training effort are suggestions for future investigations. The results of this study can be an opportune instrument in observing the eating behavior of athletes and in the form of their preparatory behaviors for intense training.

5. Conclusion

The results of the present study indicate that swimmers reported an inadequate intake of energy and carbohydrates when compared to specific recommendations for high-intensity training, thus resulting in an inadequacy of the diet to the needs required by training. Therefore, it is essential that there is rigorous and personalized monitoring so that athletes adapt their nutritional intakes, specifically to the needs inherent in high-intensity training.

Author Contributions: MGMP: concepção, coleta, análise dos dados e redação final; MF: concepção, coleta, redação final; RCOM: coleta, análise dos dados e redação final; FASC: concepção e redação final; NCM: concepção e redação final.

Financial Support: CAPES, número 001.

Ethics Approval: Esta investigação foi previamente aprovada pelo Comitê de Ética em Pesquisa da Universidade Federal do Rio Grande do Sul (número 17.367) e foi realizada de acordo com a Declaração de Helsinque para Ética em Pesquisa.

Conflict of interest: The authors declare there are no competing interests.

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