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Original Article (short paper)

Dietary intake in high-level swimmers A 32-week prospective cohort study

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Abstract — Aims: To determine whether high-level swimmers present adequate energy and macronutrient intake during each training phase of the season. **Methods:** A 32-week prospective cohort study was conducted with 18 elite swimmers (10 men, 20±2 years; 8 women, 20±3 years) from a competitive swimming club. This period comprised two training macrocycles, each one divided in four training phases: general, mixed, specific and competition. Dietary intake, estimated energy expenditure and daily energy requirements were assessed in every training phase. Body composition was evaluated five times throughout the season. Energy and macronutrient consumption were compared with the energy expenditure and the literature recommendations, respectively. **Results:** Athletes maintained a relatively constant dietary intake throughout the season, regardless the different needs of each training phase. The balance between energy consumption and expenditure was negative in all training phases ($p=0.02$; d between 1.5-6.2) for women, while men did so in half of phases ($p<0.01$; d between 0.3-4.1). Swimmers had higher protein intake than recommendations in 73% of the evaluations, while carbohydrate and lipids intake were lower than recommendations in 76% and 69% of the evaluations, respectively. **Conclusion:** Athletes did not meet the energy demands and specific macronutrient requirements of each training phase of the competitive season.

Keywords: swimming; energy intake; food intake; sports nutrition; athletes.

Introduction

The training schedule of high-level competitive swimming teams is planned according to the competitive calendar. Hence, the planning is performed so that athletes can reach their best physical fitness and technique in the most important competition in the season[1]. It is well established that nutrition plays a crucial role in sports performance[2], since a proper diet providing the athlete's nutritional requirements helps to obtain morphological and physiological adaptations and optimizes performance in training and competitions[1,3,4]. In this sense, the current dietary recommendations demonstrate the importance of energy intake and specific nutrients in each training phase[3], as an example, during the general preparation phase (high volume and low intensity) emphasis should be given to high energy ingestion. In the specific phase (low volume and high intensity) carbohydrate availability should be high, but caloric ingestion needs to be controlled; highlighting the need for an individual and continuously adjusted approach[2].

Some narrative review studies have explored important aspects of nutrition in swimming athletes in relation to the supply of energy and nutrients[1,3,4]. Cross-sectional studies examining the adequacy of nutritional parameters in swimmers present conflicting results[5,6,7], while longitudinal studies are scarce[8,9]. Barr & Costill[9] evaluated a North-American collegiate swim team by three times during a 25-week training program, and found that an increase in training volume appears to result in an increased consumption of the athletes' usual diets[9]. In the other hand, Kabasakalis, Kalitsis, Tsalis, Mougios[8] assessed nine Greek national top-level swimmers by four times throughout a competitive season of 32 weeks, and concluded that energy and macronutrient intake did not change significantly over time[8].

In summary, there is no consensus whether competitive swimmers change their energy and macronutrient intake throughout the season. Moreover, there is a lack on the literature regarding the adequacy of dietary intake of these athletes according the specific demands of each training phase of the competitive season. Therefore, the aim of this study was to determine whether high-level swimmers have adequate energy and macronutrient intake during each training phase of a 32-week season. Considering previous findings[8], our hypothesis was that athletes would not change their energy and macronutrient intake patterns throughout the season, and this intake would not meet the specific demands of each phase of training.

Methods

Study design

This was a prospective cohort study conducted from January to August 2015 (32 weeks), a period composed of two macrocycles for the competitive swimming season. Swimmers were evaluated during the four phases of training (general, mixed, specific and competition) of each macrocycle, resulting in a total of eight evaluations (Figure 1). The study was approved by the institutional ethics committee (protocol 882.361).

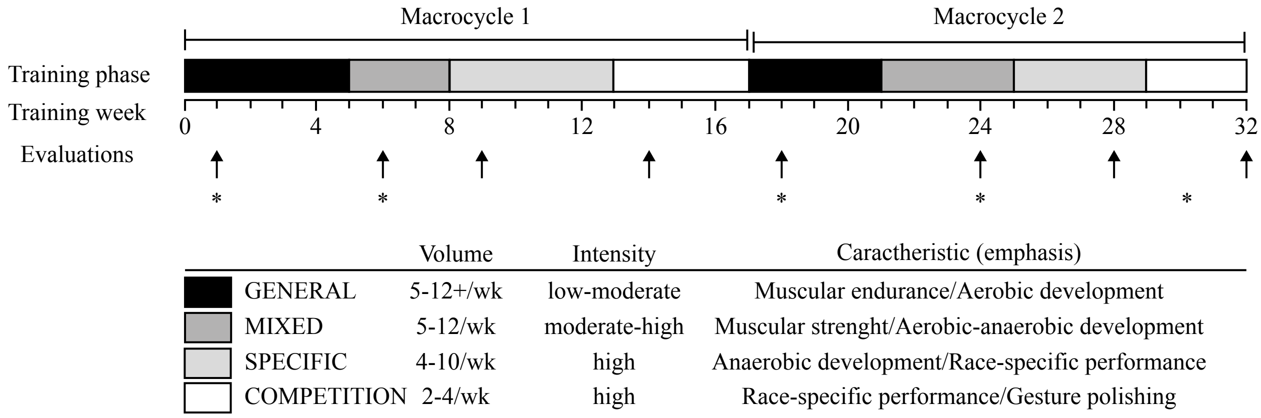

Figure 1. Summary of study design. The black arrows (↑) indicate the assessments of dietary consumption and energy expenditure. The asterisks (*) indicate body composition assessment.

Participants

All members of the main team of a competitive swimming club in Brazil were invited to participate in the study (total of 20 athletes). All athletes and/or their legal sponsor agreed to participate and signed the Informed Consent Form prior to data collection. During the beginning of the season, two athletes left the team and hence were excluded from the study. Thus, 18 swimmers (10 men and 8 women; aged 20.0±2.5 and 19.9±3.0 years, respectively) completed the full study schedule.

All athletes had at least 4 years of experience in competitive swimming training, and competed at the national and international level. Most of athletes (94%) were or had already been part of the Brazilian national swimming team. Three (16.7%) were sprinters, while seven (38.9%) and eight (44.4%) were middle and long distance swimmers, respectively. The predominant stroke was the front crawl (15 athletes, 83.3%).

The swimmers trained at an Olympic-size pool, twice a day, 5-6 days a week, each training session lasting about 2 hours, except for the competition period when the training volume reduced considerably. Moreover, athletes executed a complementary training at a fitness center for 30 to 50 min/d. Researchers had complete access to the training schedule (updated daily) and directly observed most of the training sessions.

Assessment of dietary intake

In the first training phase, a two-day dietary record including food and nutritional supplements was used (referring to 2 typical days of training), while the habitual dietary recall (referring to 1 typical training day) was used in all other training phases. The habitual dietary recall was adopted to maximize the athletes' adherence to the study, since a two-day dietary record is more laborious and can lead to potential biases due to low compliance. Altogether, eight dietary assessments were taken over the course of the study (Figure 1). In order to minimize errors in the reporting of food portions, photographic food material was provided to the athletes. The Avanutri Online® program (Avanutri & Nutrição Serviços e Informática Ltda Me, Brazil) was used to calculate total energy intake (kcal/d), as well as proteins, carbohydrates and lipids intake (g/kg/d). The adequacy of macronutrients consumed at each stage of training was evaluated according to the recommendations preconized by Stellingwerf, Maughan, Burke[2]: 6.0-12.0 g/kg of carbohydrate, 1.5-1.7 g/kg of protein, 1.5-2.0 g/kg of fat.

Estimated Energy Expenditure

The FAO/WHO[10] equation was used to calculate resting energy expenditure, and occupational activity was calculated according to the factorial method. Exercise energy expenditure was calculated according to the metabolic equivalents (MET)[11] from the athletes' weekly training schedule. Details on the training program were collected in each training phase by direct observation to measure time spent on each exercise and series, using a stopwatch, and the weekly training spreadsheet was provided with information about swimming style, distance swam, intensity, and number of repetitions; making possible to choose the best matching MET. The estimated energy expended during weekly training was divided by seven to determine daily exercise energy expenditure. Total energy expenditure (TEE) was determined by summing resting energy expenditure, occupational activity expenditure and exercise energy expenditure. This strategy was repeated in each training phase[12].

Body Composition Assessment

The athletes were evaluated at five different time points throughout the season, which comprised different phases of training: general (1 wk) and specific (9 wk) during the first macrocycle of the year; and general (18 wk), specific (28 wk) and competition (30 wk) during the second macrocycle. Anthropometric information was collected from the club's medical department, including body mass (kg), height (m), sum of four skinfolds - triceps, subscapular, iliac crest, abdominal (mm) - and body fat (%) estimated using Cescorf® scientific caliper, and the protocol proposed by Faulkner[13].

Statistical Analysis

Data are presented as mean and standard deviation for age and 95% mean confidence interval for anthropometric data, energy expenditure and dietary intake. Total energy expenditure, training energy expenditure, energy intake, and carbohydrate, protein and fat intake were compared between phases of training by Generalized Estimating Equations (GEE) with Bonferroni *post hoc* analysis. Paired t tests were used to compare total energy expenditure with energy intake during each phase of training, as well as to compare macronutrients intake with the literature recommendations during each training phase[2]. Effects size for single-sample *t* test was calculated applying the equation $d = x-x0/s$, where d is the effect size, x the sample mean, $x0$ the null value and s the sample standard deviation; we confederated criteria of classification accordantly Hopkins[14] where: 0 to 0.2 trivial, 0.21 to 0.6 small, 0.61 to 1.20 moderate, 1.21 to 2 large and greater than 2 vary large. When GEE was applied, effects size was identified using statistic η^2 and criteria of classification accordantly Cohen[15] where: 0 to 0.13 small, 0.14 to 0.26 moderate and grater than 0.26 large. The significance level was set at alpha value < 0.05 and SPSS 22.0 was used to run all data analysis.

Results

Body Composition (Table 1)

Men did not change their body weight throughout the season ($p = 0.237$, $\eta^2=0.008$) whereas women significantly reduced their body mass values between the first and last evaluations ($p < 0.001$, $\eta^2=0.007$). Both sexes had the highest average body fat percentages and sum of skinfold thickness at baseline that corresponds to the vacation return. Moreover, it was observed significant reductions in men and women body fat percentage ($p = 0.04$, $\eta^2=0.2$; $p = 0.03$, $\eta^2=0.06$) and skinfold thickness ($p = 0.01$, $\eta^2=0.2$; $p = 0.01$, $\eta^2=0.06$) at the 30th week of training (table 1). On average, men were 1.80 m (1.77-1.83) tall, and women were 1.70 m (1.68-1.72) tall, both men and women without significant changes over the year ($p = 1.00$, $\eta^2=0.08$, $\eta^2=0.05$).

Table 1. Anthropometric data of male (n=10) and female (n=8) swimmers during a competitive season. Data presented as mean (confidence interval).

Parameter	Sex	Baseline (general phase)	6 wk (mixed phase)	18 wk (general phase)	24 wk (mixed phase)	30wk (competition phase)	p-value
Body mass (kg)	Male	72.0 (66.7-77.3)	71.4 (66.7-77.0)	72.3 (66.7-77.9)	72.0 (66.5-77.6)	72.9 (68.5-77.4)	p =0.237
	Female	67.9 (64.8-71.1)^{a}	67.1 (64.3-70.0)^{a,b}	67.8 (64.4-71.2)^{a,b}	66.7 (63.4-69.9)^{a,b}	64.3 (61.0-67.6)^{b}	p <0.001
Body fat (%)	Male	12.0 (10.8-13.3)^{a}	11.0 (10.1-12.0)^{b}	11.1 (10.3-11.8)^{b}	10.7 (9.8-11.5)^{b}	9.8 (8.9-10.6)^{b}	p =0.007
	Female	15.1 (13.2-17.0)^{a}	13.3 (11.9-14.7)^{b}	14.4 (12.3-16.4)^{a,c}	12.7 (11.0-14.4)^{b}	13.5 (11.5-15.6)^{c,b}	p <0.001
∑ 4 skinfold (mm)	Male	40.7 (32.5-48.9)^{a}	34.4 (28.3-40.4)^{b}	34.8 (29.5-40.1)^{b}	33.2 (28.0-38.3)^{a,b}	30.5 (27.1-33.9)^{b}	p =0.008
	Female	60.8 (48.5-73.2)^{a}	48.9 (39.7-58.0)^{b}	56.2 (42.9-69.6)^{a,c}	45.2 (34.2-56.1)^{b}	50.7 (37.2-64.2)^{b,c}	p <0.001

Different letters indicate significant difference between training weeks (a, b, c)

Energy Intake and Energy expenditure (Figure 2)

The energy expended in training by men and women accounted respectively for 29-37% and 30-38% the total energy expended in the phases of general preparation (1 wk and 18 wk), 35% and 37-38% in the phases of mixed preparation (6 wk and 24 wk), 37% and 37-40% in specific phases (9 wk and 28 wk) and 24-22% and 26-25% in the competition phases (14 wk and 32 wk) *(Figure 2)*.

In the competitive phases (14 wk and 32 wk), both TEE ($p < 0.001$, $\eta^2=0.4$, $\eta^2=0.3$, results of effect size for men and women, respectively) and in training energy expenditure ($p < 0.001$, $\eta^2=0.5$, $\eta^2=0.6$) were lower than the ones in other phases of training, in both sexes. However, energy intake was kept constant over all phases for both men ($p = 0.261$, $\eta^2=0.4$) and women ($p = 0.522$, $\eta^2=0.2$), with mean values of 3079 (2959-3206) kcal/d and 1756 (1634-1876) kcal/d respectively.

When comparing TEE with energy intake, we found that women expended more energy than it was ingested in all training phases ($p = 0.02$ for all phases; d between 1.5-6.2). Similar results were seen in men in the mixed phase of the macrocycle 1 (9 wk), and in the general phase (18 wk), mixed phase (24 wk) and specific phase (28 wk) of the macrocycle 2 ($p < 0.01$ for all comparisons; d between 0.3-4.1). These data represent an average energy deficit of 670 kcal/d for men and 1220 kcal/d for women.

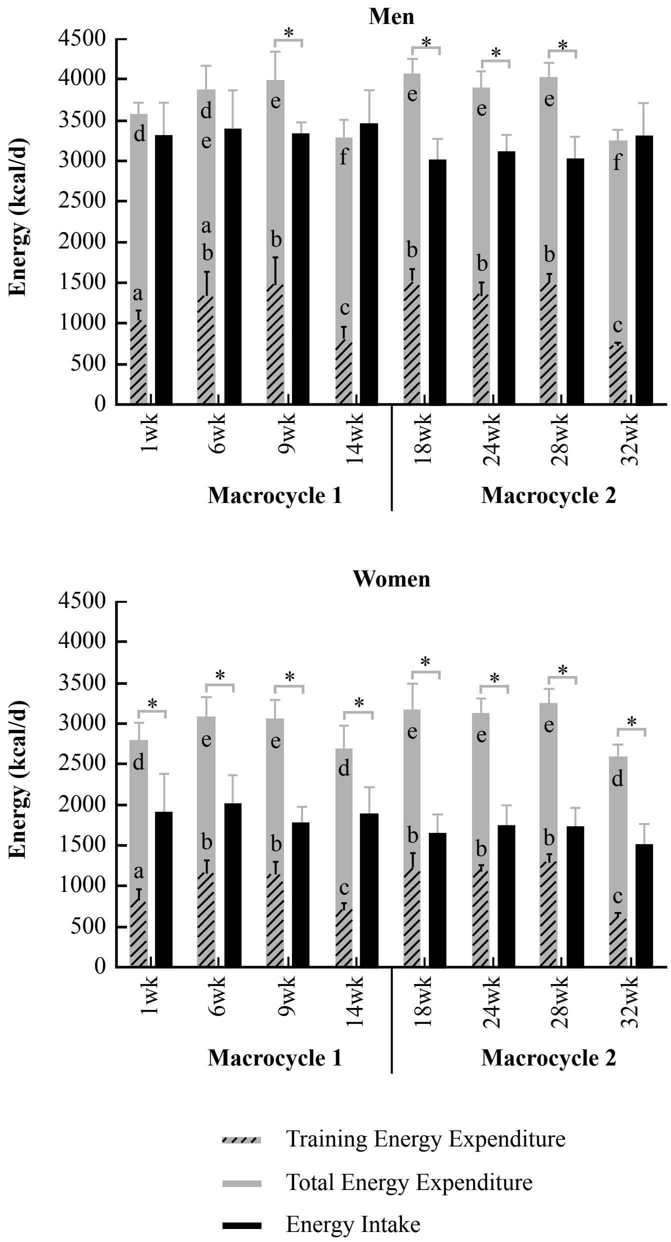

Figure 2. Total energy expenditure, training energy expenditure and energy intake for each training phase (in two macrocycles) by male (n=10) and female (n=8) swimmers (Data presented as mean ± standard deviation). Different letters indicate significant difference between training weeks for training energy expenditure (a, b, c) or total energy expenditure (d, e, f). The asterisk (*) indicate significant difference between total energy expenditure and energy intake.

Macronutrient intake (Figures 3-5)

Among all swimmers (men and women), carbohydrate intake (Figure 3) was below the recommendation[2] for the respective training phase in 76% of the evaluations. This represents that 95% of female evaluations were below the recommended range. There was a significant reduction in carbohydrate intake by women between week 9 [3.7 (3.0-4.4) g/kg/d] and week 18 [3.0 (2.4-3.7) g/kg/d] ($p < 0.001$, $\eta^2=0.1$), and also by men when comparing week 14 [5.5 (4.5-6.6) g/kg/d] to week 18 [4.8 (4.0-5.6) g/kg/d], week 24 [5.0 (4.3-5.7) g/kg/d] and week 28 [5.0 (4.2-5.8 g/kg/d] ($p < 0.001$, $\eta^2=0.3$). Over the course of the study, average carbohydrate intake was 5.4 (5.0-5.9) g/kg/d for men and 3.5 (3.0-3.9) g/kg/d for women.

Protein intake (Figure 4) was above recommendation[2] in 73% of swimmers, with men consuming above the reference values in 86% of the evaluations. There were differences in protein consumption by women between week 1 [1.4 (1.1-1.7) g/kg/d] *vs* week 14 [1.9 (1.5-2.3) g/kg/d], week 24 [2.0 (1.6-2.3) g/kg/d] and week 28 [2.0 (1.7-2.3) g/kg/d] ($p < 0.001$, $\eta^2=0.4$). There was no difference in protein intake between phases of training for men ($p = 0.104$, $\eta^2=0.1$). Over the course of the study, mean protein intake was 2.5 (2.3-2.6) g/kg/d for men and 1.8 (1.6-1.9) g/kg/d for women.

Lipid intake (Figure 5) was lower than recommendation[2] in the first two phases of training (general and mixed) of the two macrocycles in 68% of evaluations for men and 100% of evaluations for women. In other phases of training (specific and competition), men did not reach the recommended values in 35% of the evaluations, and women in 75% of the evaluations. There was no difference in lipid intake between training phases by men ($p = 0.356$, $\eta^2=0.2$) or women ($p = 0.911$, $\eta^2=0.1$). The average of lipids consumed throughout the study was 1.2 (1.2-1.3) g/kg/d for men and 0.75 (0.7-0.8) g/kg/d for women.

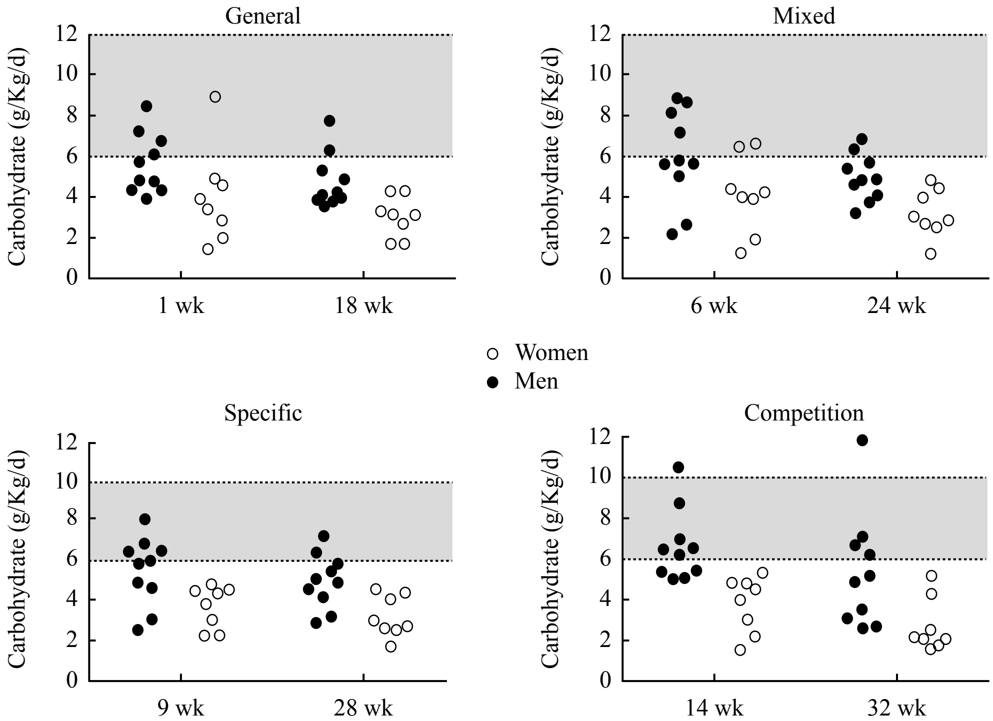

Figure 3. Individual carbohydrate intake and recommendation (grey band) for each training phase (in two macrocycles) by male (n=10) and female (n=8) swimmers.

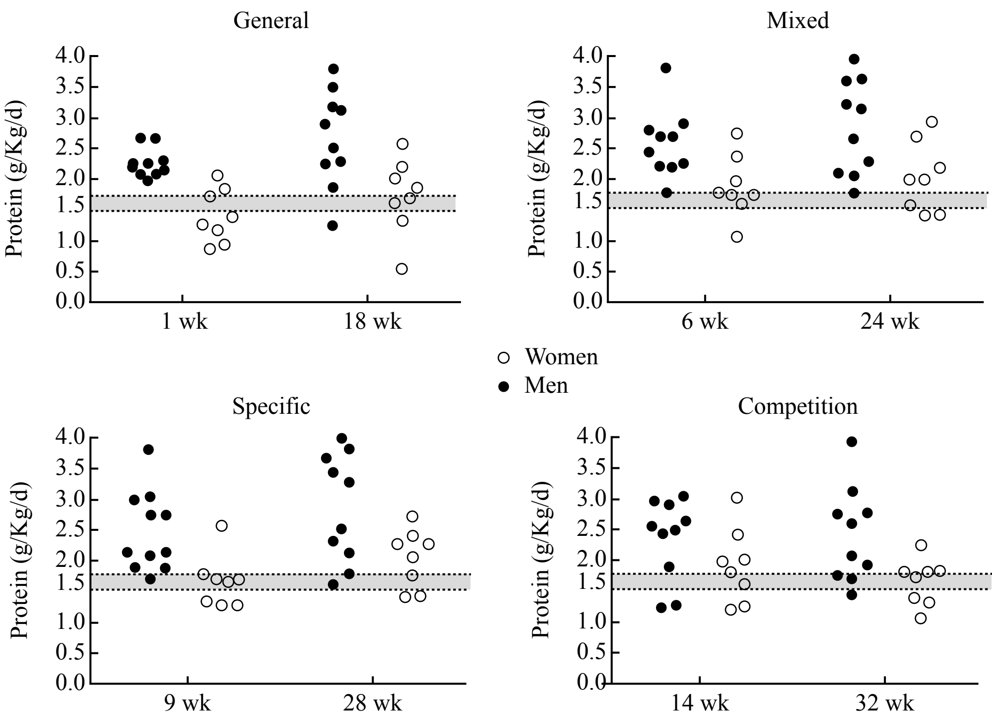

Figure 4. Individual protein intake and recommendation (grey band) for each training phase (in two macrocycles) by male (n=10) and female (n=8) swimmers.

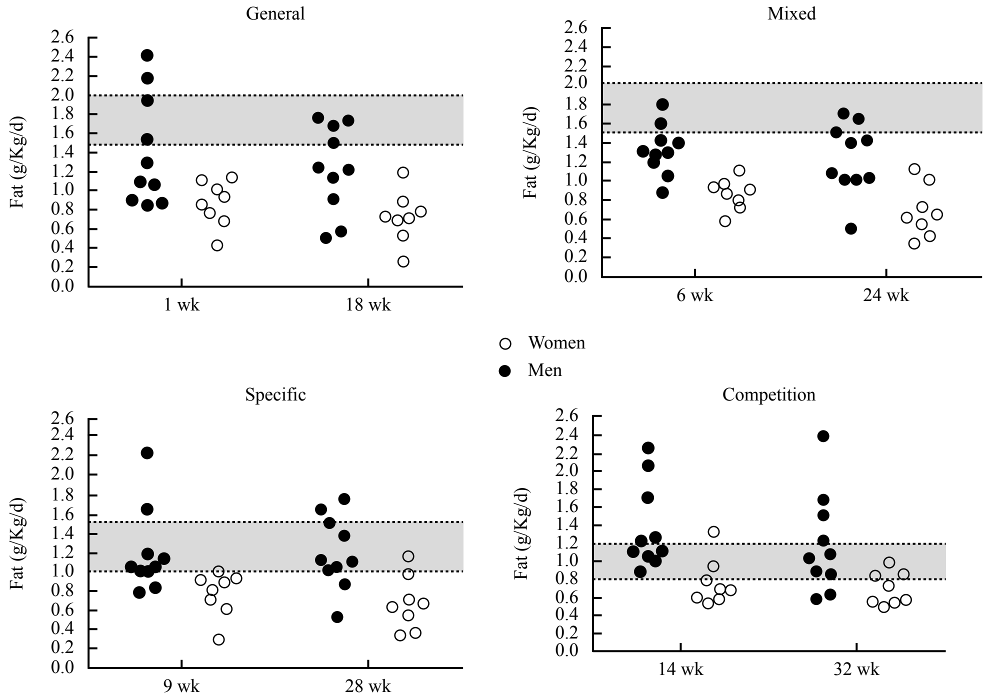

Figure 5. Individual fat intake and recommendation (grey band) for each training phase (in two macrocycles) by male (n=10) and female (n=8) swimmers.

Discussion

The main findings of the study were: (1) athletes maintained a relatively constant dietary intake throughout the season, regardless the different needs of each training phase; and (2) the athletes, especially women, reported inadequate energy and macronutrient intakes when compared to the specific demands of the training phases.

Our findings corroborate previous cross-sectional studies regarding low energy intake by swimmers[5,6,7] although an adequate energy consumption has been reported by other trials[16,17]. In the 90's decade, a longitudinal study encompassing a 25-week training program also found low energy intakes among male college swimmers[9]. However, our results show that female athletes require greater attention from the sports team, coaches and staff as their reports of energy intake are dramatically lower than their needs in all training phases. Since energy expenditure was not estimated in the only longitudinal study involving top-level swimmers[8], this previous study was not able to determine the athletes' adequacy of energy intake. Thus, our study seems to be the first one to call attention for this reduced energy intake among high-level swimmers throughout the season.

Male and female participants of our study exceeded a deficit of 600 kcal·d in 50% and 100% of the training phases, respectively. Although men presented no changes in body mass, women lose ~3.6 kg throughout the season. Specially when looking to the mean energy deficit found for the female athletes (~1220 kcal ·d), one might suspect of the participants' underreporting in dietary records, as already mentioned by previous studies[8,18]. Nonetheless, even considering an underreporting of 16%[19], the findings suggest a low energy intake by high-level swimmers throughout the season. This marked low energy availability may compromise exercise performance[20] and can also be harmful to one's health. Consequently, it increases the chance of athletes developing the RED-S syndrome (Relative Energy Deficiency in Sport), characterized by the insufficient energy to support body functions[21].

Cross-sectional[22] and longitudinal[8] studies support our findings that swimmers have low values of daily carbohydrate intake and that men consume larger amounts of carbohydrates than women. Even though the mean values reported here are higher than those reported for elite Greek swimmers[8], our results show that athletes' carbohydrate intake was below the recommendation[2] for the respective training phase in 76% of evaluations, and this percentage increased to 95% among women. Moreover, even though this study did not intend to report individual data, we observed that several athletes presented a chronic deficit in carbohydrate consumption throughout the season. Thus, although some studies suggest that carbohydrate restriction in specific situations can enhance adaptations to training[22], carbohydrates are traditionally considered as the fundamental source to energy supply[23] and post-exercise recovery[1]. In other words, it is likely that a chronically low carbohydrate diet has negative effects on conditioning and sports performance.

As shown in some previous studies[8,16], our findings indicate that most swimmers consume excessive amounts of protein. The average values reported in this study are similar to those found in another longitudinal study with top-level swimmers[8], suggesting this excessive protein intake seems to be a common feature of this category of athletes. Despite recommendations to increased protein intake (~35% total energy intake) by watersport athletes who need to lose total body mass with minimal muscle loss[21], the excessive consumption increases the protein oxidation rates, and long-term effects are unknown[24].

Lipid consumption was largely below the recommendations[2] in all phases of training. Inadequate intake of lipids reduces the intake of essential fatty acids and can negatively affect the absorption of fat-soluble vitamins, hormone synthesis and the composition of cell membranes and myelin sheaths[25]. Other swimming studies have reported high levels of lipid consumption[6,8], but the values were presented in total grams and/or in percentage. Food consumption data should preferentially show considering the individual's body mass (g/kg/d) than the total energy intake percentage[12]. These dissimilar forms of data presentation make impossible the comparison between our findings with those reported by previous longitudinal studies[8,9].

A reduction in the athletes' body fat during the competitive season has been supported by findings from previous studies with swimmers[8]. The mean values of fat reduction found in this study may seem negligible to a population of non-athlete individuals, but can interfere in the athletes' performance when it comes to high-level competitive sports[26]. The discrete changes in body composition of athletes throughout the 32-week training period might be related to the high level of their physical conditioning, as a result of years engaged in a demanding sport training routine.

Different phases of training have particular intensity, volume and types of exercises, which lead to different nutritional requirements[3]. General preparation phase has high volume and low intensity, so it is expected sufficient energy intake to support training; at the same time, it is the best time to lose weight[2]. However, it cannot be assert that athletes were intentionally consuming less calories to adequate their body composition. Mixed phase has moderate to high intensity and high volume so a habitual high carbohydrate diet helps to maintain glycogen storage necessary in high intensity demands[2]; however, no change was seen in carbohydrate intake trough phases. Competition phase, which has high intensity and moderate volume, needs high carbohydrate availability[4]; but energy intake should be carefully adapted to avoid weight gain. Competition phase have less energy expenditure compared to other phases, so it necessary supply energy (especially from carbohydrate) for the high intensity races demands and protein to recovery and be careful with lipid intake to avoid weight gain[2]. However, lipid intake was shown to be constant throughout the season; and only clinically negligible differences between training phases were found in carbohydrate and protein consumption; total energy consumption was affected by both, the low fat and low carbohydrate, intakes. It means that athletes did not change their dietary intake throughout the competitive season, leading to energy and macronutrient consumption patterns that were inconsistent with the specific demands of some phases of training. Dietary record and habitual dietary recall are assessment methods routinely used by clinics and researchers[5,7]. However, a methodological limitation of the present study should be pointed out: it was used only two-day dietary record in the first phase and one habitual dietary recall in all other training phases. It is recommended a minimum of three days diet monitoring (including a weekend day) in order to adequate estimation of habitual energy and macronutrient consumption[27], however, it was prioritized an increased adherence since dietary record is more laborious, and swimmers were followed by a long period of 32 weeks. Nevertheless, the bias induced from participants' underreporting dietary intake is an important factor to consider. To minimize errors inherent to this method, we provided printed materials with pictures of food portions and utensils. Moreover, athletes were encouraged to take pictures of their meals to facilitate the determination of the portion sizes. Therefore, despite some limitations in terms of accuracy, the dietary intake assessment methods used in this study provide reliable data and consist in an accessible tool for nutritionists in the sports field.

Conclusions

To our knowledge, this is the pioneer longitudinal study on the inadequacy of high-level swimmers' diets during the different training phases of a competitive season. The main findings of this study allow us to conclude that the athletes did not adjust their eating pattern according to the specific energy and macronutrient demands of each phase of training during the competitive season. Based on these results, it is advisable that dietitian, coach and other team members work together to ensure an individualized and sustained nutritional counseling to athletes, frequently taking into account the specific dietetic needs of each training phase since the energy and macronutrient deficit maybe could lead to reduction in performance and/or perhaps over-training.

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ERRATUM

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