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Imbalanced Nutrition of Top-Level Swimmers

Authors **A. Kabasakalis, K. Kalitsis, G. Tsalis, V. Mougios**

Affiliation Physical Education and Sport Science, University of Thessaloniki, Thessaloniki, Greece

Key words
- anthropometry
- dietary supplements
- hemoglobin
- iron
- macronutrients
- micronutrients

Abstract

The aim of the present study was to monitor the nutritional status of 9 Greek national top-level swimmers during a competitive season of eight months. The swimmers were assessed through recording of food and supplement intake, blood sampling, and anthropometry at four landmarks: in the beginning of the season (baseline), after completing a phase of intensive and voluminous training (at 10 weeks), at a minor taper (19 weeks), and during the major taper (32 weeks). Energy and macronutrient intake did not change significantly over time, and only a few significant changes were found in micronutrient intakes. Low carbohydrate and high fat intakes (e.g., 36 and 42% of total energy, respectively, in males), inadequate intake of some micronutrients, and improper use of supplements indicated suboptimal dietary habits. Blood hemoglobin fluctuated significantly during the season. No significant changes in parameters indicative of the iron stores (transferrin saturation and ferritin) were found, although iron intake increased by supplementation with the onset of training. Serum markers of training stress were not significantly altered. In conclusion, Greek top-level swimmers should be guided toward a balanced diet and a rational use of supplements. Monitoring of dietary intakes during a competitive season is highly recommended.

Introduction

Nutrition plays a crucial role in athletic performance. Swimming is a demanding sport, in which nutritional needs can be extraordinary. A balanced intake of macronutrients is essential, as adequate carbohydrate and protein intakes are necessary for maintaining and enhancing glycogen stores and lean body mass, respectively, during training [26]. Sufficient micronutrient intake is also important, as minerals facilitate the development of swimming performance and contribute to the attainment of optimal physiological function [16]. Nevertheless, reports show suboptimal dietary intakes of swimmers [7,11, 24]. Such findings could be partially attributed to the lack of nutritional education and scientific monitoring. Moreover, swimmers do not always adjust their nutrient needs to the training stress [1,11,23], but information about possible modifications of the dietary habits of swimmers during different training phases is limited.

Training of swimmers needs to be accompanied by appropriate evaluation of a variety of parameters, including hematologic and biochemical ones. Variations in these parameters may influence the performance capacity of swimmers [8, 21], and such variations do take place during swimming training, although in diverse directions [3,5,8,10,13,14,17,20,27,33]. Some of these parameters, for instance, parameters of the iron status, are influenced not only by training but also by nutrition [4].

Given the dearth of data on the nutritional status of swimmers during extended training periods, the aim of the present study was to monitor the dietary intakes, along with hematologic and biochemical parameters, of swimmers participating in top-level training during a competitive season of eight months. Anthropometric and performance data were also included in order to provide a thorough picture of the responses to a highly demanding training schedule.

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Correspondence
Vassilis Mougios, PhD
University of Thessaloniki
Physical Education and Sport Science
■Street?
■ Thessaloniki
Greece
mougios@phed.auth.gr

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Material and Methods

Subjects

Nine young healthy swimmers (4 male and 5 female, aged [mean ± SD throughout] 18.4 ± 1.2 and 17.3 ± 1.7, respectively) participated in the study. To ensure a high level of training and performance, we chose swimmers who were members of the Greek national team and medalists in their age category in the previous national championship. Two participants (one male and one female) were also members of the Olympic team. All participated in systematic training and specialized in events of 50, 100, and 200 m. The females had normal menstrual function (menstrual cycle of 21 – 35 days). The swimmers and their parents were informed, orally and in writing, about the design and probable risks of the research, and consented in writing to participate. The study design was approved by the institutional ethics committee.

Study design

The duration of the study was 32 weeks, namely from the beginning of the training season (mid-September) to the national championship (mid-May). During this period, the swimmers' coaches kept daily records of the training program. The swimmers were assessed at four landmarks of the yearly program. The first landmark was the beginning of the training season (baseline). The second landmark was the end of a training phase of increased intensity and training volume (at 10 wk), during which the swimmers reached 57 ± 7 km of swimming, 11 ± 1 swimming training sessions, and 5 ± 1 dry-land conditioning sessions per week. The duration of each swimming training session reached 135 min, and the duration of each dry-land conditioning session reached 90 min. The third landmark was the end of a 2-wk minor taper (at 19 wk), during which the training volume was drastically reduced and dry-land training was stopped. The last landmark was at the 3-wk major taper, during which swimmers sought to be at their best physical condition for the national championship (at 32 wk). Training at the major taper consisted of low-training volume and little dry-land training. Training intensity remained high during both tapers, as is customary. Dietary assessment, anthropometric measurements, blood sampling, and performance tests were performed at the aforementioned time points as described below.

Dietary records

All participants recorded their food and supplement intakes for three days (two weekdays and one weekend day) on special forms after having received detailed instructions. Dietary records were analyzed for energy, macronutrients, and micronutrients in Microsoft® Access through the use of a food database created in our laboratory on the basis of published data [9].

Anthropometric measurements

Body mass was measured to the nearest 0.1 kg by an electronic balance (Seca, Hamburg, Germany), and height was measured to the nearest 0.1 cm by a stadiometer fixed to the balance. Body fat was estimated by measuring four-terminal bioelectrical impedance through a Bodystat 1500 apparatus (Douglas, United Kingdom). Because bioelectrical impedance is influenced by the amount of body water, the participants were asked to abstain from any food or fluids for at least 4 h, physical exercise for at least 12 h, and caffeine-containing beverages as well as sauna for at least 24 h before the measurement.

Hematologic and biochemical measurements

Morning fasting blood samples were obtained from an antecubital vein in a seated position. The female subjects provided blood samples at least five days after the beginning of a menstruation. Five mL of blood was drawn in a plain evacuated test tube for biochemical analysis, and 2 mL of blood was drawn in an EDTA-containing evacuated test tube for hematologic analysis. After clotting of the blood in the plain tube, serum was prepared by centrifugation and was stored at – 80 °C until analysis.

Whole blood was analyzed immediately for hematocrit, hemoglobin, erythrocyte count, leukocyte count, and platelet count in a Coulter Microdiff autoanalyzer (Miami, FL, USA). Serum was analyzed for iron, total iron binding capacity (TIBC), ferritin, creatine kinase (CK), cortisol, and testosterone. Iron was determined spectrophotometrically through a reagent kit from Biosis (Athens, Greece). The TIBC was determined likewise after saturation of transferrin with Fe^{3+} and precipitation of the excess Fe^{3+} with a kit from Elitech (Sees, France). Transferrin saturation was calculated as the ratio of iron to the TIBC × 100. Ferritin, cortisol, and testosterone were assayed by enzyme immunoassay with kits from DRG (Marburg, Germany). CK was determined spectrophotometrically with a kit from Dialab (Vienna, Austria).

Performance tests

The performance parameters measured were velocity in a 100-m race in each swimmer's main style and peak blood lactate concentration after the race. For the lactate determination, 14 µL of capillary blood was taken from a fingertip 3, 5, and 7 min after the race and was immediately mixed with 140 µL perchloric acid, 0.3 mol/L. Lactate was measured spectrophotometrically in the supernatant after centrifugation using a kit from Sigma Diagnostics (St. Louis, MO, USA), and the highest of the three values obtained was taken as the peak lactate concentration.

Statistical analysis

Results are reported as means ± SD. Normality of data distribution was ascertained through Shapiro-Wilk tests. Dietary, anthropometric, hematologic, biochemical, and performance parameters were analyzed by two-way (sex × time) ANOVA with repeated measures on time. Significant interactions were followed up by pairwise comparisons through simple main effect analysis. The level of statistical significance was set at $\alpha = 0.05$. Data were analyzed in SPSS 11.0 (SPSS, Chicago, IL, USA).

Results

Dietary data

Daily energy and macronutrient intakes displayed no significant changes over time. **Fig. 1** presents the energy intake of the participants, itemized per macronutrient. The daily energy intake averaged 12.95 MJ in males vs. 9.88 MJ in females and did not differ significantly between sexes. The daily carbohydrate intake averaged 4.0 g/kg body mass for males and 4.4 g/kg body mass for females, corresponding to 39 and 46% of the total energy intake, respectively. Forty-two percent of energy for males and 36% for females was derived from fat, displaying a significant difference between sexes. Saturated, monounsaturated, and polyunsaturated fatty acids contributed 19, 18, and 5%, respectively, to the energy intake of males; the corresponding values for females were 16, 15, and 5%. The intake of monounsaturated fatty acids was significantly higher in males. With respect to the daily

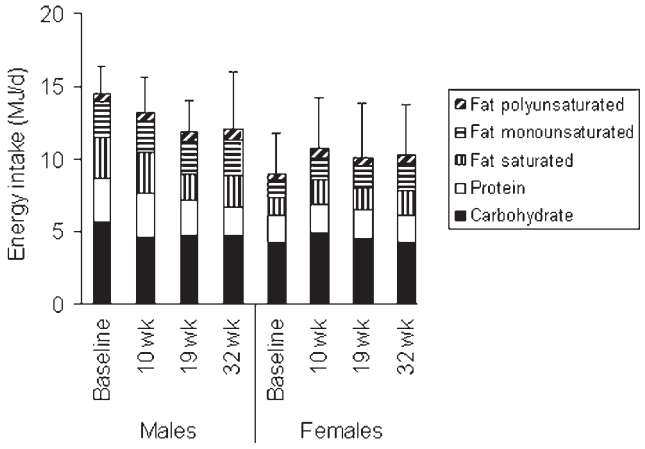

Fig. 1 Mean energy intake of the swimmers during the study period. Error bars denote SD of the total energy intake.

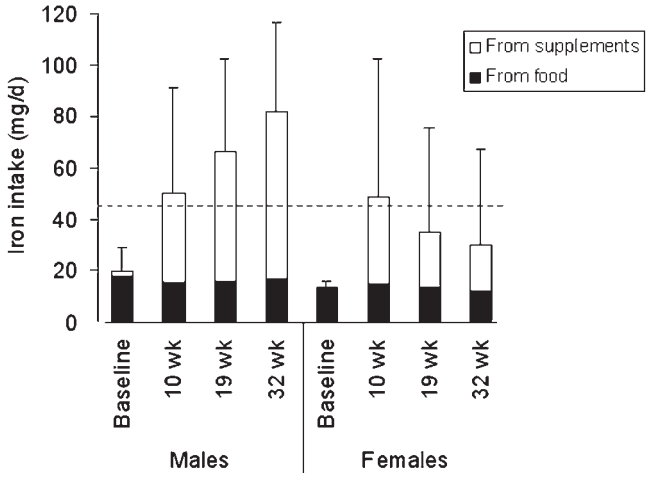

Fig. 2 Mean iron intake of the swimmers during the study period. Error bars denote SD of the total iron intake. The broken line indicates the tolerable upper intake level [30].

Table 1 Daily vitamin intake of the swimmers over the entire study period (mean ± SD of four males and five females)

Vitamin	Sex	From food	From supplements
Vitamin B_1 (mg)	male	5.5 ± 7.4	0.6 ± 0.5
	female	1.9 ± 0.7	1.6 ± 2.4
Vitamin B_2 (mg)	male	2.9 ± 1.0	0.7 ± 0.6
	female	2.1 ± 0.8	1.6 ± 2.5
Niacin (mg)	male	28 ± 11	7 ± 6
	female	24 ± 9	4 ± 6
Vitamin B_6 (mg)	male	2.9 ± 1.2	0.7 ± 0.6
	female	2.6 ± 1.0	3.7 ± 5.5
Vitamin B_{12} (µg)	male	9.1 ± 3.5	1.1 ± 0.9
	female	6.0 ± 3.5	2.9 ± 5.1
Folate (µg)	male	384 ± 124	133 ± 123
	female	336 ± 153	674 ± 1271
Biotin (µg)	male	35 ± 21	15 ± 12
	female	24 ± 13	76 ± 149
Vitamin C (mg)	male	103 ± 51	80 ± 107
	female	97 ± 77	247 ± 407
Retinol (µg)	male	615 ± 273	none
	female	324 ± 173	none
Carotene (µg)	male	3035 ± 2065	5500 ± 4452
	female	2402 ± 2449	3868 ± 4881
Vitamin A (RE)*	male	1132 ± 261	917 ± 742
	female	729 ± 483	645 ± 814
Vitamin D (µg)	male	3.3 ± 3.4	3.7 ± 3.0
	female	2.1 ± 1.9	2.8 ± 4.9
Vitamin E (mg)	male	8 ± 2	22 ± 18
	female	7 ± 3	74 ± 124

* Vitamin A is expressed in retinol equivalents as the sum of µg retinol and one-sixth µg carotene

Table 2 Mineral intake of the swimmers over the entire study period (mean ± SD of four males and five females)

Parameter	Subjects	From food	From supplements
Na (mg)	male	4038 ± 1788	a1 ± 3
	female	3570 ± 1724	45 ± 87
K (mg)	male	3533 ± 476	7 ± 4
	female	2485 ± 516	2 ± 3
Ca (mg)	male	1619 ± 597	20 ± 14
	female	1189 ± 481	127 ± 214
Mg (mg)	male	333 ± 59	49 ± 43
	female	258 ± 80	57 ± 96
Fe (mg)	male	17 ± 3	41 ± 41
	female	14 ± 3	20 ± 36
Cu (mg)	male	1.9 ± 0.4	0.7 ± 0.6
	female	1.3 ± 0.5	0.6 ± 1.6
Zn (mg)	male	15 ± 7	6 ± 4
	female	11 ± 5	6 ± 13
Mn (mg)	male	2.8 ± 0.7	0.9 ± 0.7
	female	2.2 ± 0.8	0.8 ± 1.9
Cl (mg)	male	6281 ± 2994	0 ± 0
	female	5601 ± 2735	14 ± 34
P (mg)	male	2020 ± 466	74 ± 151
	female	1409 ± 420	65 ± 121
Se (µg)	male	74 ± 32	29 ± 24
	female	69 ± 34	20 ± 35
I (µg)	male	123 ± 48	0 ± 0
	female	72 ± 28	24 ± 106

protein intake, males averaged 2.1 g/kg body mass and females 1.7 g/kg body mass (18% of total energy intake for both sexes).

The daily intake of fiber showed no significant difference and was 23 ± 4 g for the male, and 21 ± 7 g for the female, participants. The daily intake of cholesterol was 480 ± 184 mg for males and 228 ± 85 mg for females, displaying a significant difference between sexes.

Fig. 2 presents the iron intake throughout the study period. While the intake from food remained relatively constant, the total intake changed significantly over time due to an increase in iron supplementation with the onset of training. Moreover, a significant time-by-sex interaction appeared in the total iron intake.

With respect to the intake of other micronutrients through food and supplements, there were only a few statistically significant findings of minor importance. Thus, and for the sake of clarity, we have grouped the corresponding data for each sex across the entire training period in **Table 1** for vitamins and **Table 2** for minerals.

Use of supplements

The swimmers took several nutritional supplements throughout the study period, mainly starting during the first training phase. Iron and multivitamins were the most popular supplements. The average supplemental intake of iron (**Fig. 2**) and vitamin E

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Table 3 Anthropometric data (mean ± SD of four males and five females)

Parameter	Sex	Baseline	10 wk	19 wk	32 wk	Effect of time	Effect of sex	Interaction
Body mass (kg)	male	74.9 ± 9.0	74.5 ± 8.5	75.5 ± 8.5	77.0 ± 9.8	n.s.	p = 0.046	n.s.
	female	62.6 ± 8.2	63.2 ± 6.3	62.7 ± 6.5	63.7 ± 8.1			
Height (m)	male	1.84 ± 0.08	1.84 ± 0.08	1.84 ± 0.08	1.84 ± 0.08	n.s.	n.s.	n.s.
	female	1.76 ± 0.05	1.76 ± 0.05	1.76 ± 0.05	1.77 ± 0.05			
BMI (kg/m^2)	male	22.0 ± 0.8	22.1 ± 0.7	22.3 ± 0.9	22.4 ± 0.6	n.s.	n.s.	n.s.
	female	20.1 ± 2.2	20.4 ± 1.7	20.1 ± 1.9	20.2 ± 2.2			
Body fat (%)	male	10.2 ± 2.1	10.2 ± 1.2	8.1 ± 2.1	10.2 ± 1.8	p < 0 .001	p = 0.020	p = 0.008
	female	18.7 ± 5.0	16.1 ± 3.9	15.1 ± 4.0	14.3 ± 4.2			
Body fat (kg)	male	7.8 ± 2.4	7.7 ± 1.7	6.2 ± 2.2	8.0 ± 2.3	p = 0.003	n.s.	p = 0.028
	female	12.0 ± 4.6	10.4 ± 3.4	9.7 ± 3.5	9.3 ± 3.7			

n.s.: not significant; BMI: body mass index

(**Table 1**) were well above the dietary reference intake (DRI) for both males and females [28,30]. For example, iron supplementation reached 122 mg/d (8 times the DRI) in a female participant, and vitamin E supplementation reached 344 mg/d (23 times the DRI) in another female participant. Iron intake by 6 out of the 9 participants exceeded the tolerable upper intake level (UL) of 45 mg daily [30] at least once. Additionally, females received much more folate and vitamin C than the corresponding DRI [28,29], the most extreme case being a female receiving 13 times the DRI of these vitamins. Iron, calcium, magnesium, zinc, and manganese intake by a female swimmer exceeded the UL of, respectively, 45 mg, 2.5 g, 350 mg from supplement, 34 mg, and 9 mg daily [30,31] during heavy training (assessment at the second landmark)■*please check*. This was also the case for the calcium intake by a male swimmer. Other than that, there was minimal supplemental intake of nutrients such as magnesium and iodine, whose intake from food was also inadequate.

Anthropometric data

Anthropometric data of the participants during the study period are presented in **Table 3**. Percentage body fat remained relatively stable in the males but decreased gradually in the females, resulting in a significant time-by-sex interaction. Females displayed a significant reduction at 32 wk compared to baseline and 10 wk, and males had significantly less body fat percentage than women at baseline, 10 wk and 19 wk.

Hematologic and iron status data

Table 4 presents the data on the iron status parameters. The hematocrit, hemoglobin concentration, and erythrocyte count showed the usual sex-dependent differences. The hematocrit and erythrocyte count did not change significantly over time but hemoglobin did, displaying a consistent fluctuation in both sexes. No differences were found in the leukocyte or platelet counts (not shown), in which males averaged 5.6 and 219 k/µL, respectively; and females 5.1 and 212 k/µL, respectively.

The serum iron concentration and TIBC displayed a significant main effect of time owing to a remarkable peak in iron at 10 wk and a consistent fluctuation in the TIBC that was the reverse of the fluctuation in hemoglobin. No differences in transferrin saturation or the ferritin concentration were found. One male and three female swimmers had ferritin values below the corresponding low reference limits [32] at least once during the study period. The same was the case for the transferrin saturation values of one male and one female participant.

Markers of training stress

No differences between sexes or over time were found in the serum CK or cortisol concentrations. In CK, males averaged 200 U/L (at 37 °C) and females 161 U/L (at 37 °C). Cortisol averaged 202 and 223 µg/L in males and females, respectively. Half of the cortisol values were above the upper reference limit [32]. Finally (regarding the biochemical parameters), the serum testosterone concentration showed the known difference between sexes but did not change significantly over time, averaging 5.1 µg/L in the males and 0.7 µg/L in the females.

Performance data

Performance data are presented in **Table 5**. Swimming velocity in the 100-m race improved gradually and significantly with training. The peak blood lactate concentration after the race increased by 64 % at 10 wk of training and remained relatively constant thereafter.

Discussion

▼

In the present study, we monitored nutritional, hematologic, biochemical, anthropometric, and performance variables of national top-level swimmers during an extended period (eight months) of training in an attempt to pinpoint possible weaknesses of the swimmers' diet in relation to their responses to training. A limitation of our study is the small sample size, which was dictated by our wish to include only swimmers who participated in systematic top-level training.

No significant changes over time were found in the daily energy and macronutrient intakes. The swimmers seemed not to adjust their nutritional habits to the demands of the training load. This does not seem to be an appropriate practice, especially in terms of energy balance, and has been reported for female swimmers by other authors [1,23]. Noland et al. [22] reported a reduction in the energy intake of male swimmers during voluminous training, while female swimmers displayed no significant changes. Barr and Costill [2], on the other hand, found increased energy intake with increased training volume in swimmers, which seems more reasonable and fitting to a carefully scheduled diet.

Underreporting is always a concern when dietary intakes are reported by participants in a study. Since body mass did not change significantly during this study, energy intake should match energy expenditure. Because measuring the latter was

Table 4 Iron status data (mean ± SD of four males and five females)

Parameter	Sex	Baseline	10 wk	19 wk	32 wk	Effect of time	Effect of sex	Interaction
Hematocrit (%)	male	46.9 ± 2.4	46.9 ± 1.9	46.8 ± 1.7	47.8 ± 0.8	n.s.	p < 0.001	n.s.
	female	41.3 ± 1.2	41.3 ± 2.3	42.2 ± 1.2	42.2 ± 1.6			
Hemoglobin (g/dL)	male	16.0 ± 0.9	15.6 ± 0.7	16.1 ± 0.4	15.4 ± 0.2	p = 0.007	p < 0.001	n.s.
	female	14.1 ± 0.3	13.8 ± 0.8	14.5 ± 0.4	13.6 ± 0.6			
Erythrocyte count (M/μL)	male	5.3 ± 0.2	5.2 ± 0.3	5.1 ± 0.2	5.2 ± 0.2	n.s.	p = 0.001	n.s.
	female	4.5 ± 0.2	4.4 ± 0.3	4.5 ± 0.2	4.5 ± 0.4			
Iron (μg/dL)	male	99 ± 29	121 ± 23	84 ± 36	79 ± 27	p = 0.021	n.s.	n.s.
	female	63 ± 10	103 ± 43	72 ± 30	77 ± 19			
TIBC (μg/dL)	male	305 ± 83	354 ± 45	276 ± 33	333 ± 40	p = 0.003	n.s.	n.s.
	female	299 ± 65	305 ± 76	233 ± 63	310 ± 54			
Transferrin saturation (%)	male	28 ± 5	34 ± 4	30 ± 10	24 ± 10	n.s.	n.s.	n.s.
	female	23 ± 9	36 ± 21	36 ± 28	26 ± 10			
Ferritin (μg/L)	male	25 ± 12	27 ± 12	24 ± 14	23 ± 8	n.s.	n.s.	n.s.
	female	17 ± 16	20 ± 18	24 ± 22	19 ± 12			

n.s.: not significant; TIBC: total iron binding capacity

Table 5 Performance data (mean ± SD of four males and five females)

Parameter	Sex	Baseline	10 wk	19 wk	32 wk	Effect of time	Effect of sex	Interaction
Velocity at 100 m (m/s)	male	1.57 ± 0.12	1.61 ± 0.10	1.65 ± 0.13	1.67 ± 0.12	p < 0.001	n.s.	n.s.
	female	1.55 ± 0.07	1.59 ± 0.09	1.60 ± 0.07	1.64 ± 0.10			
Lactate (mmol/L)	male	9.8 ± 1.3	16.1 ± 2.8	18.2 ± 1.9	17.4 ± 2.1	p < 0.001	n.s.	n.s.
	female	9.8 ± 4.1	17.4 ± 1.5	16.1 ± 4.5	17.1 ± 1.4			

n.s.: not significant

not included in our aims, we compared the energy intake calculated from the dietary records to an estimation of the resting metabolic rate [6], based on the suggestion that a ratio of energy intake to resting metabolic rate below 0.9 indicates underreporting [7]. All participants were well above this value (males and females averaging 1.6 and 1.3, respectively), except for one female swimmer, who, however, was the only one that consistently lost weight during the observation period. On the basis of these data, we believe that no serious underreporting occured in this study.

A major finding of our study was that our subjects consumed high amounts of fat and low amounts of carbohydrate (although fat intake in terms of g per kg body mass was not too high, 1.5 in the females), a result also found in other studies on swimmers [7, 24]. This imbalance was especially pronounced in males, in agreement with a study on athletes of a variety of sports including swimming [12]. The low carbohydrate intake may have had consequences on the glycogen storing capacity and the ability of the athletes to train hard. In addition, the quality of fat was poor, as evidenced by the facts that saturated fatty acids were the major fatty acid category in the diet of both sexes and cholesterol intake exceeded the recommendation for no more than 300 mg per day or 100 mg per 4.184 MJ [34] in males. Finally, protein intake met or exceeded the current recommendations for athletes [15] in both males and females.

Percentage body fat of the female swimmers decreased rapidly during the first 10 weeks of training and at a slower rate until 32 weeks. This may be due to a fat gain during the preceding off-season, as found in a study with female swimmers [1]. The combination of training effects and an energy balance may explain why percentage body fat decreased while body mass did not change. The average percentage body fat was within the optimal ranges [35], except for the baseline value of females, which was slightly above. Both in the present and in other studies, regular swimming training seems to influence percentage body fat. Meleski and Malina [18] also reported a decrease in body fat of female swimmers during a competitive season (primarily in the early part), which, however, was accompanied by a decrease in body mass. Noland et al. [22] found very similar results to ours, i.e., stable body mass but reduced fat mass in female swimmers and no change in body mass or fat mass in male swimmers with training. Additionally, Barr and Costill [2] reported stable body mass but decreased the sum of skinfold thickness in male swimmers during a 25-week training period.

Micronutrient intake through the diet remained relatively stable during the study period. Since we are not aware of scientifically documented micronutrient reference intakes for athletes, we compared our data to the DRI for the general population [28–31]. On average, the swimmers met the DRI for most micronutrients. Nevertheless, the swimmers received some of these micronutrients in excess through supplements (i.e., vitamins of the B complex, vitamin C, and vitamin A in both males and females, as well as iron in males). On the other hand, the swimmers were able to meet the DRI of other micronutrients only with the aid of supplements (i.e., folate and vitamin E in males and females, as well as biotin, calcium, and iron in females). Thus, the use of these supplements may be considered justified. Finally, the swimmers (both males and females) failed, on average, to meet the DRI for magnesium and iodine even with the aid of supplements.

It seemed that the swimmers tried to prevent possible dietary inadequacies by consuming supplements but this attempt did not always match their actual needs. Although top-level training increases the nutritional needs of athletes and there may be a re-

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duction in performance capacity in cases of serious dietary deficiencies, uncontrolled supplementation should be avoided, as excessive intakes of certain micronutrients (e.g., iron and vitamin E) may be toxic [34]. The most serious case that arised in this study was the one of iron (taken in excess of the UL by two-thirds of the participants). Routine supplementation of iron is common practice in sports [33], and overdoses may cause serious adverse effects [36].

On the basis of our results regarding the dietary intakes of the swimmers, we highly recommend nutritional monitoring and counseling as an integral part of the swimmers' scientific support during training seasons. In this way, imbalances in energy, macronutrient intakes, and micronutrient intakes may be detected, and decreases in performance capacity as a result of improper nutrition may be prevented. Moreover, a justified and rational use of supplements will be possible.

The hematocrit and erythrocyte count did not change significantly, while the blood hemoglobin concentration displayed a fluctuation over time, as shown in **Table 2**. Alterations in training volume and intensity may have caused this fluctuation. In a study employing similar protocol and duration, Mujika et al. [21] reported similar responses of the hematocrit and erythrocyte count in swimmers but an increase in hemoglobin during a phase of intensified training. On the other hand, Pizza et al. [25] found that not only the hematocrit and erythrocyte count, but also hemoglobin did not change during different phases of swimming training. In the present study, the serum iron concentration increased markedly at 10 wk, evidently as a result of intense iron supplementation. Additionally, the TIBC displayed a fluctuation that was the reverse of hemoglobin's fluctuation. Tsalis et al. [33] reported inverse changes in serum iron and TIBC in adolescent swimmers and attributed them to adaptations to training. Transferrin saturation and ferritin did not change significantly during the study period, in agreement with reports of no significant variations in ferritin during swimming training [21,25,33], but in contrast with the finding of significant variations in transferrin saturation in adolescent swimmers [33]. Thus, the present findings may indicate that the iron stores of adult swimmers are not affected by training or that supplementation protects the iron stores from depletion by training. The leukocyte and platelet counts did not display any significant changes, suggesting that the yearly training of top-level swimmers does not affect these parameters. Mujika et al. [19] also found no variations in the leukocyte and platelet counts with training and taper.

Serum CK, cortisol, and testosterone did not change during the training season. This may indicate that swimmers coped with training stress successfully and/or that the structure of practices was such that prevented the athletes from suffering excessive muscle fiber damage and stress. Considering that during the season the swimmers improved their performance in 100-m events and enhanced their anaerobic metabolism (as testified by the increase in the peak blood lactate concentration), it seems that proper training of swimmers competing in such events does not have to cause undesirable elevations in serum CK or cortisol, or reductions in testosterone. Although our results are in accordance with those of other authors [10,13,20], the same markers of training stress varied with changes in swimming training volume and intensity during a season in other studies [5,8]. A possible explanation for this discrepancy is the difference in training contents in conjunction with the different competitive levels of the participants.

Summary and Conclusion

Monitoring dietary intakes together with the hematologic and biochemical status, as well as anthropometric and performance data of top-level swimmers during an eight-month competitive season with a variety of modalities, provided useful and practical findings. Low carbohydrate and high fat intakes, needless supplementation of several micronutrients, and inadequate intake of other micronutrients (even with the aid of supplements) indicated suboptimal dietary habits of the swimmers. Thus, and in accordance with Farajian et al. [7] and Paschoal and Amancio [24], the need is evident for proper nutritional education and guidance of swimmers who participate in top-level training. In particular, swimmers should be encouraged to consume more carbohydrates and less fat, and try to meet the DRI of all micronutrients through the diet. Additionally, monitoring of dietary intakes throughout a sports season is recommended, as it may reveal imbalances in nutrient intakes and may aid in the prescription of nutritional supplements, where needed. Percentage body fat decreased in females with training. Blood hemoglobin was sensitive to training, as it fluctuated significantly during the entire season. Parameters indicative of the iron stores (transferrin saturation and ferritin) did not change significantly in the face of a large increase in iron intake by supplementation with the onset of training. Markers of training stress, such as serum CK, cortisol, and testosterone, were not affected by the variation in training parameters and the peak blood lactate concentration following an 100-m race increased in both males and females, primarily in the early part of the season.

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