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Original article

Nutritional supplements use in high-performance athletes is related with lower nutritional inadequacy from food

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Abstract

Background: The use of nutritional supplements (NS) among athletes is widespread. However, little is known about the relationship between nutritional adequacy and NS usage. The aims of this study were to evaluate the NS usage and to compare the nutritional intake from food and prevalence of micronutrient inadequacy (PMI) between NS users and non-users.
Methods: Portuguese athletes from 13 sports completed an NS usage questionnaire and a semi-quantitative food-frequency questionnaire assessing information over the previous 12 months. The estimated average requirement cut-point method was used to calculate PMI. General linear models were used to compare nutritional intake and NS usage. Chi-squared tests and logistic regression were performed to study, respectively, relationships and associations between PMI and NS usage.
Results: From the 244 athletes (66% males, 13–37 years), 64% reported NS usage. After adjustment, NS users showed a higher intake from food ($p < 0.05$), for at least 1 gender, for energy, and for 7 of the 17 studied nutrients. The highest PMI were seen for vitamins D and E, calcium, folate, and magnesium. After adjustment, NS users, irrespective of gender, reported lower PMI for calcium (OR = 0.28, 95%CI: 0.12–0.65), and female users for magnesium (OR = 0.06, 95%CI: 0.00–0.98).
Conclusion: Athletes using NS reported a higher nutritional intake from food, and a lower PMI for several nutrients. Perhaps, those who were taking NS were probably the ones who would least benefit from it.

Keywords: Carbohydrates; Minerals; Proteins; Sport; Vitamins

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1. Introduction

Athletic performance can be enhanced by an adequate and individually-adapted dietary intake. Sports nutrition guidelines suggest that protein intake should be between 1.2 g/kg/d and 1.7 g/kg/d,[1] carbohydrates (CHO) ingestion may range from 3 to 12 g/kg/d depending on the duration and type of exercise,[2] and fat should contribute to 20%–35% of total energy value (TEV).[1] Recently, these guidelines—developed for adults—were also considered adequate for adolescents.[3] Moreover, athletes should reach, at least, the dietary reference intakes (DRI) for all micronutrients.[1]

Regardless of the growing body of scientific evidence concerning the sports nutrition impact on performance, and the supposedly easier access to reliable information, athletes are still reporting slightly unbalanced diets. Generally, protein intake tends to be higher than recommended,[4] while that of carbohydrates is sometimes below the recommended range.[5] The adequate consumption of some micronutrients is also a source of concern, with some studies[6,7] showing intakes under the DRI.

The wide usage of nutritional supplements (NS) by athletic populations is largely recognized.[8] Though, in sports field, it has not been appropriately demonstrated if supplementation is advantageous and rationale for those who are taking it. Some studies[8,9] had already shown that the reasons to use certain types of NS, namely multivitamins/minerals and individual micronutrients such as vitamin C and iron, are not always science-based. Moreover, the use of these vitamin/mineral supplements by

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athletes will only result in a performance enhancement if it corrects a nutritionally unbalanced diet.[1] Additionally, epidemiological studies have been shown that NS users tend to have better health-related behaviors, namely a healthier nutritional intake.[10,11] Therefore, those taking NS are potentially the ones who need them less. However, little is known regarding the nutritional adequacy of athletes using NS.

Therefore, the aims of this study were to (1) assess the NS usage among high-performance athletes, (2) evaluate nutritional inadequacy considering the micronutrients from food, (3) compare nutritional intake, and (4) evaluate the prevalence of micronutrient inadequacy (PMI) between NS users and non-users. For this purpose, we used the NS definition suggested by Petróczi and collaborators[9] which considers that NS are products taken orally with the aim to supplement the diet with vitamins, minerals, and/or other substances. Supplements may contain vitamins, minerals, herbs, amino acids and/or a concentrate, metabolite, constituent, extract, or a combination of any of these.

2. Methods

2.1. Participants and study design

Three hundred and four athletes representing the Portuguese national teams in 13 sports (cycling, athletics, triathlon, gymnastic, rugby, basketball, volleyball, judo, swimming, baseball, handball, boxing, and fencing) volunteered to participate in this study. The sports were conveniently selected for the study. Informed consent was obtained from all athletes. Additionally, formal authorisation from the guardians was required for those <18 years old. The study was approved by the Scientific Council of the Faculty of Nutrition and Food Sciences at the University of Porto, and by each of the 13 national sports federations.

The participants filled out 2 self-administered questionnaires: one about NS usage and one semi-quantitative food-frequency questionnaire (FFQ). Both questionnaires assessed information over the previous 12 months. The questionnaires were completed in the presence of a qualified and trained nutritionist or sent into the respective sport federation (boxing and fencing) throughout the year of 2008.

2.2. Nutritional intake

Dietary intake was obtained by a semi-quantitative FFQ, validated for the Portuguese adult population.[12] The FFQ is an 86-item questionnaire that includes food groups and beverage categories, and a frequency section with 9 possible responses, ranging from “never or less than 1 time per month” to “6 or more times per day”. The food intake was calculated by weighting 1 of the 9 possibilities of frequency of consumption by the weight of the standard portion size of the food-item. A seasonal variation factor was considered for foods in which production and consumption were not regular over the year. Energy and nutrient intake with more sport relevance (proteins, carbohydrates, lipids, vitamins A, C, E, D, B6, and B12, thiamine, riboflavin, folate, magnesium, zinc, calcium, selenium, and iron), without including the NS contribution, were estimated using the software Food Processor SQL® (ESHA Research Inc., Salem, OR, USA) added with Portuguese foods and recipes.

To identify under- and over-reporting, the ratio of energy intake (EI) to basal metabolic rate (BMR) was used.[13] EI was obtained from data analyses whereas BMR was estimated using Schofield equations.[14] The under-reporting cut-off for this study was set at 0.9, as it was used in another study for a similar purpose,[15] and the one for over-reporting at 4.0, which corresponds to the physical activity level (PAL) upper limit for professional endurance athletes.[16]

The PMI was determined by the estimated average requirement (EAR) cut-point method,[17] calculating the proportion of individuals whose intake was below the EAR from the Food and Nutrition Board of the Institute of Medicine, for the respective gender and age group (to consult EAR values please see Ref.18). PMI for iron was not calculated since this method should not be used when requirements are not normally distributed.[17] Age groups were defined according to the Food and Nutrition Board of the Institute of Medicine categories.

2.3. NS usage and other information

A broad definition of NS was used, which included all types of supplements, namely ergogenic aids, sports food, and dietary/nutritional supplements. Thirty closed-ended options for NS were provided with an additional open-ended question.

This questionnaire also assessed information on weight, height, age, gender, years of education (year of attendance or concluded years if the athlete was not currently studying), type of sport, hours of training, and number of international performances, as described in detail elsewhere.[8]

2.4. Statistical analysis

Descriptive data were reported as proportions (%), mean ± SD when data were normally distributed (height, weight, body mass index (BMI)), or as medians (interquartile range) when not (age, number of international performances, hours of training, and energy and nutrients intake).

The Kolmogorov–Smirnov test was used to evaluate normality. Student’s t test for normally distributed variables, Mann–Whitney U test for non-parametric data, and χ^2 test for categorical variables were used to compare groups. For the χ^2 tests with statistically significant results, φ coefficients were also calculated to describe the relationships between the variables.

In order to compare nutritional intake between NS users and non-users, nutritional variables were adjusted for total EI, using the nutrient residual model.[19] In this model, energy-adjusted nutrient intake is computed as the residuals from the regression analysis, with total EI as the independent variable and absolute intake as the dependent variable. Afterwards, univariate general linear models non-adjusted and adjusted for confounders were performed. Non-normal distributed variables (total EI, absolute nutrients intake, and hours of training) were logarithmically transformed to attain normal distribution for the purpose of residual models and univariate general linear models.

The relationships between PMI and NS usage were performed using χ^2 tests. For those with statistically significant

Table 1
Characteristics of nutritional supplements user and non-user athletes according to gender.

	Male		p	Female		p
	User ($n = 108$)	Non-user ($n = 52$)		User ($n = 45$)	Non-user ($n = 36$)	
Height (cm)[a]	181 ± 9	186 ± 10	<0.001[d,*]	167 ± 8	175 ± 6	<0.001[d,*]
Weight (kg)[a]	74.3 ± 12.0	81.6 ± 10.0	<0.001[d,*]	57.9 ± 7.4	65.6 ± 7.0	<0.001[d,*]
Body mass index (kg/m^2)[a]	22.6 ± 2.3	23.5 ± 1.8	<0.001[d,*]	20.8 ± 1.9	21.4 ± 2.0	<0.001[d,*]
Age (year)[b]	21 (5)	19 (6)	0.012[e,*]	20 (10)	17 (3)	0.029[e,*]
9–13[c]	0	0	0.018[f,*] ($\varphi = 0.225$; $p = 0.018$)	9 (20)	0	<0.001[f,*] ($\varphi = 0.642$; $p < 0.001$)
14–18[c]	21 (20)	20 (38)		10 (22)	31 (86)	
19–30[c]	78 (72)	31 (60)		26 (58)	5 (14)	
31–50[c]	9 (8)	1 (2)		0	0	
Education (year)[c]						
≤9	13 (13)	6 (12)	0.891[f]	12 (29)	4 (12)	<0.001[f,*] ($\varphi = 0.503$; $p < 0.001$)
10–12	36 (37)	20 (41)		11 (26)	26 (76)	
≥13	49 (50)	23 (47)		19 (45)	4 (12)	
Sports[c]						
Team	31 (29)	38 (73)	<0.001[f,*] ($\varphi = -0.420$; $p < 0.001$)	15 (33)	32 (89)	<0.001[f,*] ($\varphi = -0.559$; $p < 0.001$)
Baseball	5 (5)	8 (16)		0	0	
Handball	9 (8)	5 (10)		0	0	
Rugby	0	0		10 (22)	6 (17)	
Basketball	7 (6)	4 (7)		0	0	
Volleyball	10 (9)	21 (40)		5 (11)	26 (72)	
Individual	77 (71)	14 (27)		30 (67)	4 (11)	
Judo	11 (10)	4 (7)		4 (9)	0	
Fencing	3 (3)	5 (10)		0	0	
Boxing	3 (3)	0		0	0	
Cycling	26 (24)	0		2 (4)	0	
Triathlon	6 (6)	0		5 (11)	0	
Athletics	9 (8)	1 (2)		7 (16)	1 (3)	
Swimming	18 (17)	2 (4)		12 (27)	0	
Gymnastics	1 (1)	2 (4)		0	3 (8)	
International performances[b]	9 (28)	7 (27)	0.390[e]	4 (15)	0 (10)	0.066[e]
Hours of training (h/week)[b]	18 (8)	11 (9)	<0.001[e,*]	13 (7)	8 (4)	<0.001[e,*]

[a] Data presented as mean ± SD.
[b] Data presented as median (interquartile).
[c] Data presented as n (%).
[d] t test.
[e] Mann–Whitney U test.
[f] Chi-squared test. For the statistically significant p, the φ coefficients (and their corresponding p) are presented.
* $p < 0.05$.

associations, φ coefficients were calculated and logistic regression was subsequently performed, with and without confounders' adjustment. Odds ratios (OR) and 95% confidence intervals (CI) were calculated by reference with the micronutrient intake ≥ EAR.

Considering the biological plausibility related to dietary intake, age, BMI, education, and total EI were considered as confounders. For this purpose, age was categorized as ≤18 and ≥19 years old to attain similar number of athletes per group, and respect the DRI age–group cut-offs. Moreover, regarding the statistical significance differences between users and non-users by gender for sport and hours of training (Table 1), these variables were also included as confounders.

All statistical procedures were completed using the SPSS Version 20 software (IBM, Armonk, NY, USA). The level of significance was set at $p < 0.05$.

3. Results

From the 304 athletes, 44 were excluded due to incomplete information, and 19 due to miss-reporting (16 for under-reporting and 3 for over-reporting). Therefore, the final sample comprised 241 athletes (66% males, 13–37 years, 71.5 ± 13.0 kg, 178 ± 11 cm). Similar NS prevalence of use ($p = 0.370$) and EI ($p = 0.842$) were reported by athletes regardless the method of data collection. An overview of basic characteristics of supplement users and non-users, by gender, is given in Table 1.

The majority of athletes (64%) were reported to have used NS in the previous 12 months. The top 8 reported supplements were multivitamins/minerals (71%), sport drinks (59%), magnesium (58%), protein (47%), glutamine (28%), vitamin C (28%), iron (24%), and sport gels (21%).

A significant difference of consumption between users and non-users from food intake was detected for 8 of the 17 studied nutrients (Table 2). In all of these situations, users showed a higher intake of the respective nutrient than non-users. Regarding the crude values, differences were found for proteins in males, and for proteins, CHO, vitamins D and B12, and selenium in females. After adjustment for EI, age, education, sport, hours of training, and BMI, male users showed a higher ingestion of

Table 2
Comparison of energy, macronutrients, and micronutrients intake from food between nutritional supplements users and non-users according to gender.

	Male				Female			
	User ($n = 108$)	Non-user ($n = 52$)	Crude *p*[a]	Adjusted *p*[b]	User ($n = 45$)	Non-user ($n = 36$)	Crude *p*[a]	Adjusted *p*[b]
Energy (kcal/d)	2798 (1344)	2756 (996)	0.898	0.815[c]	2663 (1057)	2598 (1214)	0.185	0.016[c]*
Proteins (g/kg/d)	1.8 (0.8)	1.3 (0.6)	0.011*	0.067[d]	2.1 (1.1)	1.6 (0.9)	<0.001*	0.028[d]*
Proteins (g/d)	126 (50)	116 (45)	0.315	0.236	120 (56)	104 (55)	0.023*	0.075
Carbohydrates (g/kg/d)	4.8 (2.8)	4.2 (1.9)	0.170	0.040[d]*	5.6 (2.8)	5.2 (3.2)	0.042*	0.595[d]
Carbohydrates (g/d)	351 (163)	337 (143)	0.938	0.260	327 (144)	345 (201)	0.503	0.290
Lipids (g/d)	94 (49)	96 (46)	0.511	0.077	86 (50)	78 (44)	0.144	0.691
Vitamin A (μg/d)	2549 (1708)	2543 (1986)	0.609	0.083	2863 (1822)	2110 (2312)	0.489	0.987
Vitamin C (mg/d)	164 (139)	163 (113)	0.179	0.053	223 (184)	188 (162)	0.899	0.684
Vitamin E (mg/d)	10.7 (7.1)	11.1 (4.8)	0.494	0.479	11.2 (6.7)	9.9 (6.3)	0.148	0.735
Vitamin D (μg/d)	5.5 (3.5)	5.0 (3.4)	0.460	0.768	5.4 (4.4)	3.4 (2.9)	<0.001*	0.036*
Thiamine (mg/d)	2.3 (1.1)	2.2 (1.1)	0.975	0.181	2.2 (1.2)	2.1 (1.3)	0.449	0.990
Riboflavin (mg/d)	3.3 (1.8)	2.9 (1.3)	0.509	0.026*	3.0 (1.9)	3.0 (1.8)	0.300	0.341
Vitamin B6 (mg/d)	3.3 (1.5)	2.8 (1.3)	0.308	0.205	3.2 (2.2)	2.9 (2.2)	0.207	0.381
Vitamin B12 (μg/d)	13.4 (8.3)	11.5 (9.2)	0.818	0.109	13.5 (11.6)	8.3 (7.0)	0.002*	0.076
Folate (μg/d)	510 (299)	461 (237)	0.334	0.032*	525 (279)	382 (384)	0.266	0.630
Magnesium (mg/d)	453 (220)	417 (164)	0.532	0.160	447 (205)	425 (229)	0.079	0.382
Zinc (mg/d)	17.0 (7.7)	15.7 (6.6)	0.584	0.293	16.4 (7.3)	14.4 (8.9)	0.116	0.165
Calcium (mg/d)	1388 (845)	1149 (738)	0.090	0.019*	1280 (827)	1285 (714)	0.508	0.335
Iron (mg/d)	22.4 (10.6)	21.0 (13.7)	0.853	0.225	20.1 (12.3)	16.8 (13.3)	0.155	0.931
Selenium (μg/d)	130 (60)	114 (73)	0.622	0.122	131 (83)	105 (56)	0.009*	0.020*

Notes: Data are presented as the median (interquartile range). Energy and nutrients are presented as unadjusted variables.

[a] General linear model.

[b] General linear model adjusted for energy, age, education, sport, hours of training, and body mass index.

[c] General linear model adjusted for age, education, sport, hours of training, and body mass index.

[d] General linear model adjusted for energy, age, education, sport, and hours of training.

* $p < 0.05$.

CHO, riboflavin, folate, and calcium, and female users of energy, proteins, vitamin D, and selenium.

A huge percentage of the sample (92%) showed an inadequate intake for vitamin D, and more than half of the sample (58%) for vitamin E. A high PMI level was also found for folate (22%), magnesium (20%), and calcium (22%), as shown in Table 3. The PMI magnesium (20%), for the other nutrients was lower or non-existent. Female users reported a significantly lower PMI for magnesium and calcium, and male users for calcium. Regardless of gender, NS users showed to have lower PMI for folate and calcium.

Additionally, female non-users were significantly more likely to present magnesium (crude OR = 0.12, 95%CI: 0.03–0.60) and calcium (crude OR = 0.35, 95%CI: 0.13–0.94) inadequacy than users. When adjusted for EI, BMI, education, sport, and hours of training, the PMI for calcium (OR = 0.18, 95%CI: 0.28–1.11), but not for magnesium (OR = 0.06, 95%CI: 0.00–0.98), ceased to be associated with supplement usage. Male users were less likely to have an inadequate calcium intake (crude OR = 0.40, 95%CI: 0.18–0.90; adjusted OR = 0.29, 95%CI: 0.10–0.82). Furthermore, NS users (irrespective of gender) were less likely to have an inadequate calcium intake (crude OR = 0.36, 95%CI: 0.19–0.67; adjusted OR = 0.28, 95%CI: 0.12–0.65). No association was observed for folate (crude OR = 0.56, 95%CI: 0.30–1.05; adjusted OR = 0.69, 95%CI: 0.30–1.60).

4. Discussion

One of the main findings of this study was that elite Portuguese athletes who consumed NS reported a better nutritional intake from food than non-users. Moreover, the athletes who did not use NS reported a higher PMI for several nutrients. Additionally, taking NS showed to be associated, independently of confounders, with lower odds of inadequate intake from food sources of calcium, irrespectively of gender, and of magnesium, for female athletes.

The tendency for healthier food choices and better dietary intakes for several nutrients by NS users compared to non-users have been systematically described in non-athletic populations.[10,20] In the sports field, there is 1 study[21] with female master (≥35 years) cyclists and runners which also shows that supplemented female athletes reported higher intakes of some micronutrients. However, the dietary information included both food and NS making it difficult to compare with the present data. Nevertheless, if one takes into account that health and performance issues were the most chosen reasons to justify NS consumption among Portuguese athletes,[8] it seems that there is a propensity, also among athletes, for NS use by those who are more self-concerned.

When comparing the ingestion of macronutrients from food between NS users and non-users, the higher weight-adjusted protein intake found in both male and female users for crude values, and in females for adjusted ones, is of special interest. Moreover, the users groups' intake was above the upper recommendation limit, whereas the intake of the non-users groups was within the recommended range (1.2–1.7 g/kg/d [1]). Regarding CHO intake, male users showed to have higher weight-adjusted ingestion after confounders' adjustment compared to non-users, with both groups showing median ingestions under the minimum recommended for the studied sample: 5 g/kg/d.[2]

Table 3
Comparison of PMI between nutritional supplements users and non-users according to gender.

	Male PMI			Female PMI			PMI			Total PMI ($n = 244$)
	User ($n = 108$)	Non-user ($n = 53$)	p^a	User ($n = 47$)	Non-user ($n = 36$)	p^a	User ($n = 155$)	Non-user ($n = 89$)	p^a	
Vitamin A	2 (2)	0	NV	0	0	NV	2 (1)	0	NV	2 (1)
Vitamin C	6 (6)	4 (8)	NV	1 (2)	1 (3)	NV	7 (5)	5 (6)	NV	12 (5)
Vitamin E	62 (57)	30 (58)	0.555	23 (51)	24 (67)	0.118	85 (56)	54 (61)	0.229	139 (58)
Vitamin D	102 (94)	46 (89)	NV	38 (84)	36 (100)	NV	140 (92)	82 (93)	0.422	222 (92)
Thiamine	0	0	NV	0	0	NV	0	0	NV	0
Riboflavin	0	0	NV	0	0	NV	0	0	NV	0
Vitamin B6	0	0	NV	0	0	NV	0	0	NV	0
Vitamin B12	0	0	NV	0	0	NV	0	0	NV	0
Folate	21 (19)	13 (25)	0.272	7 (16)	12 (33)	0.054	28 (18)	25 (28)	0.049* ($\varphi = 0.118$; $p = 0.068$)	53 (22)
Magnesium	25 (23)	12 (23)	0.580	2 (4)	10 (28)	0.004* ($\varphi = 0.326$; $p = 0.003$)	27 (18)	22 (25)	0.116	49 (20)
Zinc	4 (4)	1 (2)	NV	0	3 (8)	NV	4 (3)	4 (5)	NV	8 (3)
Calcium	15 (14)	15 (29)	0.022* ($\varphi = 0.179$; $p = 0.023$)	9 (20)	15 (42)	0.030* ($\varphi = 0.236$; $p = 0.034$)	24 (16)	30 (34)	0.001* ($\varphi = 0.213$; $p = 0.001$)	54 (22)
Selenium	1 (1)	0	NV	0	1 (3)	NV	1 (1)	1 (1)	NV	2 (1)

Note: Data are presented as n (%).

[a] χ^2 test. For the statistically significant p, the φ coefficients (and their corresponding p) are presented.

* $p < 0.05$.

Abbreviations: NV = non-valid χ^2 test; PMI = prevalence of micronutrient inadequacy.

Female users also reported higher CHO intake (crude values), but median ingestion for both groups was slightly above 5 g/kg/d. Taking into account that the increased intake of proteins and CHO through the use of NS was already seen in high-performance athletes from 38 different modalities,[22] and that protein supplements, sport drinks, and sport gels were amongst the most consumed NS, it is reasonable to expect that the combined intake of food and supplements would result in a higher median-group intakes for NS users. This is especially relevant for proteins since a higher ingestion would lead to a greater deviation from the recommended range. Higher protein intakes than the recommendation are frequently seen among athletes.[4,23] Over the years, the negative impact of high protein intake on bone mass and renal function in healthy individuals has been demystified.[24,25] The excess of protein seems to lead to urea production, resulting in a higher need of water, and to oxidation of the carbon skeletons.[26] Concerning the athletic performance, protein intakes higher than recommendations may have a negative impact if the extra protein is achieve at the expense of CHO.[26] Regarding our data, this seems to be the case since the median of CHO intake for NS users was below the lower limit for males and marginally above for females, and the lipid consumption was within the recommendation values (30.8% ± 6.3% TEV and 31.7% ± 5.4% TEV for female and male users, respectively). Therefore, these athletes might benefit from specific nutritional guidance in order to increase CHO ingestion, and to implement strategies to adjust protein intake.

Although macronutrient ingestion was near the recommended values, probably reflecting an adequate EI, a high PMI was reported for several micronutrients. Intakes below the DRI of folate,[21,27,28] vitamin E,[21,27,28] calcium,[6,15,27] and magnesium[6,15,28] were also found in other athletic groups, namely triathletes,[6] female master (≥35 years) cyclists and runners,[21] swimmers and water polo players,[15] female junior soccer players,[27] and adolescent soccer players.[28] Moreover, compared to non-users, supplement users (irrespective of gender) had 3.6 times lower odds to have inadequate calcium intake, and female users had 16.7 times lower odds to have inadequate magnesium intake, with confounders' adjustment in both situations. Concerning vitamin D, its insufficient ingestion within athletic populations has been a hot topic in the sports nutrition field, due to its possible negative impact on bone health, immune function, inflammatory modulation, and also on muscle function and performance.[29,30] Regarding our participants, they also seem to show the same tendency concerning vitamin D insufficient intake. Notwithstanding the huge prevalence of inadequate intake, vitamin D supplement was not between the most taken supplements in our study and in others.[31,32] Nevertheless, beyond food and supplementation, vitamin D can also be obtained by endogenous synthesis in the skins' dermis after ultraviolet B radiation activation.[33] Surprisingly, deficient intakes of the mentioned micronutrients are still a reality, albeit their insufficient supply can lead to performance impairments.[1] This may be a result of an ineffective transmission of knowledge from nutritionists and other health professionals to athletes, a resistance to change to a healthier dietary behavior, and/or a lack of care regarding these particular nutrients. Macronutrients, especially proteins, are frequently the primarily nutritional concern for athletes, which might lead to forgetfulness of CHO and micronutrients.

Some limitations regarding the NS questionnaire have already been discussed elsewhere.[8] Considering that our aim was to compare users with non-users, both punctual and habitual users were considered as NS users which may constitute a limitation. Additionally, the time extent of data gathering did not permit to assess biochemical parameters, namely vitamin D status. Future studies may opt to evaluate shorter periods of time in order to be feasible to collect information regarding nutritional status, and more specific data regarding NS usage and nutritional intake. Concerning the used FFQ, although it has an acceptable validity,[34–36] the interpretation of results should be done with caution. Even though FFQs are often used to estimate absolute intakes, results should be cautiously evaluated since multiple food records are a preferred method for more precise estimates.[37] Nevertheless, this study allowed the collection of information regarding long-term NS usage and the athletes' dietary intake during the same period of time. Studies performing a simultaneous approach are scarce, and the information that arose from these combined questionnaires is of great and emerging interest. Moreover, this study was performed with a considerable high number of high-level athletes from several different sports, which gave the opportunity to add some novel information about this particular group of sportsmen and sportswomen.

In conclusion, high-performance athletes that used NS reported a generally higher nutritional intake from food and a lower PMI for some micronutrients. Considering the dietary results comparing NS users with non-users, professionals working with athletes should review and question NS use. Perhaps, the athletes who are using or want to use NS, might be the ones who are already more concerned about nutrition-related aspects and with least need to supplement their diet with macro- and/or micronutrients. On this, athletes seem to follow the tendency of general population.[10,38] Moreover, one should bear in mind that supplements cost money and may result in inadvertent doping.[39] Therefore, attention and care should be given to the type of NS that an athlete is taking, in order to prevent unnecessary supplementation. Moreover, this study shows that athletes using NS might benefit from general dietary adjustment, since the amount of ingested proteins seemed higher than recommendations whereas the intake of CHO was near the lower borderline. Furthermore, and given the high PMI for several micronutrients, these athletes would probably benefit not only from a quantitative nutritional approach, but also from a qualitative one focusing on nutritionally-dense foods.

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Authors' contributions

MS was the main researcher and writer; MJF participated in data collection; PC and JS helped to draft the manuscript; PM helped conceiving of the study, and participated in its design and statistical analysis; VHT conceived of the study, and participated in its design and coordination and helped to draft the manuscript. All authors have read and approved the final version of the manuscript, and agree with the order of presentation of the authors.

Competing interests

None of the authors declare competing financial interests.

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