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Nutritional status of endurance athletes: what is the available information?

Júlia A. D. Nogueira, Teresa H. M. Da Costa

Faculty of Health Sciences, Department of Nutrition, University of Brasília, Brasília, Brazil

SUMMARY. Nutritional status is a critical determinant of athletic performance. We question whether currently available studies can give adequate information on nutritional status of endurance athletes. This paper is a critical review of articles published from 1989 to 2003 that investigate nutritional status of endurance athletes. The terms, "nutrition", "diet", or "nutrient", were combined with "endurance athletes" to perform Medline and Pubmed electronic database searches. Two inclusion criteria were considered: (a) study subjects should be adults and (b) articles should report gender-specific values for total energy expenditure and intake of energy, macro and micronutrient from food. Only seven studies fulfilled inclusion criteria. In general, the conclusions of these studies are that endurance athletes have negative energy balance, low intake of carbohydrate, adequate to high intake of protein, and high intake of fat. A critical discussion of the articles′ data on vitamins, minerals and trace elements adequacy is conducted using insights and methodology proposed by the newly published assessment and interpretation of Dietary Reference Intakes (DRIs). The studies evaluated give an inappropriate evaluation of the prevalence of adequacy/inadequacy of micronutrient intake among endurance athletes. In this work we indicate potential limitations of existing nutritional data, which reflects the misconceptions found in published literature on nutritional group evaluation. This review stresses the need for a comprehensive and well-conducted nutrition assessment planning to fulfill the existing gap in reliable information about micronutrient adequacy of endurance athletes.
Key words: Endurance athletes, energy balance, nutrient adequacy, DRIs.

RESUMEN. Estado nutricional de los atletas de resistencia: ¿Cuál esla información disponible?. El estado nutricional es un determinante crítico del desempeño de atletas. Nos cuestionamos si los estudios actualmente disponibles pueden dar información adecuada sobre el estado nutricional de atletas de resistencia. Este trabajo es una revisión crítica de artículos publicados desde 1989 hasta 2003 que investigaron el estado nutricional de esos atletas. Los términos "nutrition", "diet" o "nutrient" fueron combinados con "endurance athletes" en las búsquedas por Medline y Pubmed. Dos criterios de inclusión fueron considerados: (a) los sujetos de estudio tenían que ser adultos y (b) los artículos tenían que reportar valores específicos por género para gasto energético total e ingestión de energía, macro y micronutrientes. Apenas siete estudios satisficieron los criterios de inclusión. En general, las conclusiones fueron que atletas de resistencia tienen balance negativo de energía, baja ingestión de carbohidratos, ingestión de proteína adecuada a alta y alta ingestión de grasas. Una discusión crítica de los datos sobre la adecuación de vitaminas, minerales y elementos traza fue conducida usando el enfoque y la metodología propuestos por las Dietary Reference Intakes (DRIs). Los estudios analizados dan una evaluación inapropiada sobre la prevalencia de adecuación/inadecuación de la ingestión de micronutrientes en atletas de resistencia. Las informaciones nutricionales actualmente disponibles reflejan conceptos equivocados sobre la evaluación nutricional de grupos. Enfatizamos la necesidad de planear una evaluación nutricional completa y bien conducida para suplir la falta de conocimiento en el área y contribuir con información confiable sobre la adecuación de micronutrientes de atletas de resistencia.
Palabras clave: Atletas de resistencia, balance de energía, adecuación de nutrientes, DRIs.

INTRODUCTION

Few formal studies have properly assessed nutritional status of athletes despite the fact that optimal nutrition enhances physical activity, athletic performance and recovery from exercise (1-4). Therefore, it is not clear if endurance athletes are maintaining adequate diets. This review encompasses articles published from 1989 to 2003 that investigate nutritional status of endurance athletes. The terms, "nutrition", "diet", or "nutrient", were combined with "endurance athletes" to perform Medline and Pubmed electronic database searches. In order to be considered relevant, there were two inclusion criteria for articles: (a) study subjects should be adults and (b) articles should report gender-specific values for total energy expenditure and intake of energy, macro and micronutrient from food.

From a total of 16, only 7 reviewed articles fulfill both inclusion criteria. The selected articles covered different sports including triathlon (5), running (6,7), swimming (8), cycling (9,10) and track and field (3). All track and field events are not considered to be endurance sports, but since the particular study reviewed (3) separates results between various categories of athletes, we decided to include long-distance runner data.

This review's objectives are the following: (a) to critically evaluate past and present scientific articles on nutrient intake and nutritional status of endurance athletes and (b) to indicate potential limitations in the interpretation of existing nutritional data and (c) to serve as a call for rigorous methodological planning when conducting nutritional assessment of athletes.

Anthropometric characteristics

The foundation of an effective nutrition care plan for active individuals should integrate assessments of psychosocial, biochemical, nutritional and physical status factors (11). Body weight and composition can affect exercise performance so precise nutritional evaluation should begin with anthropometric assessments. And, since the requirements of energy and some nutrients depend on body mass and composition, they may be better e xpressed as kg/body weight (1,11,12).

Measurement of weight, height, and calculation of body mass index (BMI) and percentage body fat are recommended, since each has its clinical limitations. For instance, BMI does not reflect body fat content so muscular individuals may be misclassified as overweight (11). On the other hand, different body fat assessment techniques have inherent variability, thus limiting the precision with which they can be interpreted (1). The various protocols for anthropometric assessments have been previously discussed in detail (13,14).

Most of the selected studies do not report full information on anthropometric characteristics of the athletes (3,7- 9). The reported mean and standard deviation values for age, anthropometric characteristics, training time, and training level of male and female athletes are outlined in Table 1.

TABLE 1
Age, anthropometric characteristics and training hours for male (M) and female (F) endurance athletes (mean values (M), standard deviation (SD)

Ref nº	Sport	Sex	n	Age (yr.)		Height (cm)		Weight (kg)		BMI (kg/m²)		Body fat (%)		Training (h/wk)	Athletes´ level
				M	SD	M	SD	M	SD	M	SD	M	SD	M	
3	Track & field [a]	M	8	25.3	2.7	174.1	7.3	60.5	4.1	20.0	NA	NA	NA	17.0	Elite
		F	7	23.7	2.4	161.9	7.7	46.9	5.2	18.0	NA	NA	NA	17.5	Elite
5	Triathlon	M	50	39.0	7.1	178.0	7.1	74.7	7.8	23.7	2.8	15.2	4.2	10.9	Recreational
		F	21	32.0	9.2	166.0	4.6	60.2	5.5	21.9	1.8	24.2	3.2	12.4	Recreational
6	Running [b]	M	18	35.8	8.0	178.8	5.4	71.2	6.2	22.8	1.8	13.4	3.2	7.0 [e]	Novice
7	Running	M	291	40.1	10.2	177.8	6.8	73.1	8.5	23.1	1.7	NA	NA	3.9 [e]	Amateur
		F	56	37.8	9.0	163.8	6.0	55.6	6.7	20.9	2.2	NA	NA	3.7 [e]	Amateur
5	Swimming [c, d]	M	24	19.4	0.4	180.5	1.3	75.7	2.2	23.2	0.5	NA	NA	7.5	Collegiate
9	Cycling	M	6	27.0	1.9	180.8	3.3	68.6	2.9	21.0	NA	NA	NA	20.0	Professional
		F	9	34.6	5.6	167.1	5.5	58.1	4.9	20.9	1.9	23.6	4.3	7.0 [e]	Novice
10	Cycling	F	8	22.0	5.0	165.0	6.1	60.4	5.0	22.2	NA	23.3	5.6	5.0	Trained

[NA] Not Available [a] long-distance runners values [b] 2 weeks before the marathon event [c] values at season start [d] both long and short distance group means [e] estimated from training schedule

Mean BMI reported by the studies categorize endurance athletes as being in the normal range for BMI (15). Body fat (BF) assessment by skin fold thickness (6, 10) or bioelectrical impedance (5), apart from their intrinsic differences, showed values ranging from 13.4 to 15.2 % for male and from 23.3 to 24.2 % for female athletes. The values for %BF presented in this review are somewhat higher when compared to some studies conducted with elite athletes (16-19). Optimal body-fat levels vary depending upon the sex, age, heredity and the fitness level of the athlete, as well as the sport itself.

Training and energy expenditure

The studies reviewed (3,5-10) refer to weekly training schedules as presented in Table 1. Although most subjects were reported to be experienced and serious endurance competitors, training data, reflected by the mean number of hours per week (from 3.7 to 20h/week), and athletes´ level refer mostly to non-professional athletes.

Before 2002, total energy expenditure (TEE) was commonly estimated through the factorial method, using equations to estimate basal energy expenditure (20) and then multiplying them by the time devoted to different activities and the energy cost of each activity throughout a 24-hour period. However, there are recognized problems with the factorial method and the validity of energy requirement predictions based on it have been questioned (21). The IOM (2002) has developed more accurate prediction equations of TEE based on doubly labeled water (DLW) database through non-linear regression, which takes into account age, weight, height and physical activity level.

Therefore, it is necessary to estimate the amount of time and intensity of training sessions in order to calculate energy expenditure (22). Only one study reported the training schedule and intensity used to calculate energy expenditure (5). Three studies (3,7,8) did not calculate the energy cost by the intensity or duration of the training session but, instead, referred to RDA approximated total energy expenditure (TEE). And, three other studies (6,9,10) did not give any information about the TEE of the athletes (Table 2). Reported mean total energy expenditure ranged between 11.3 and 14.9 MJ (2690 to 3550 kcal) for male and 8.4 and 11.8 MJ (2000 to 2800 kcal) for female athletes (Table 2).

TABLE 2

Total energy expenditure (TEE), total energy intake (TEI), and food intake values for carbohydrate, protein and fat

Ref n°	Sport	n	TEE (MJ) Mean	TEI (MJ) Mean	TEI (MJ) SD	CHO g	CHO SD	CHO %	CHO g/kg/day	Protein g	Protein SD	Protein %	Protein g/kg/day	Fat g	Fat SD	Fat %	Fat g/kg/day
	MALE																
3	Track & field [a]	8	14.9 [b]	15.2	1.9	429	48	52	7.1	139	37	15	2.3	131	25	32	2.2
5	Triathlon	50	12.0	11.6	2.9	372	106	54	5.0	102	28	15	1.4	92	35	30	1.2
6	Running [b]	18	NI	11.3	2.8	346	NI	51	4.9	81	NI	12	1.1	111	NI	37	1.6
7	Running	291	11.3 [d]	10.6	3.1	327	119	52	4.5	105	34	17	1.4	87	36	31	1.4
8	Swimming [c]	24	12.1 [d]	15.3	3.9	501	141	54	6.6	121	28	13	1.6	134	42	33	1.7
9	Cycling	6	NA	22.4	1.7	770	44	57	11.3	176	16	13	2.6	178	31	30	2.6
	FEMALE																
3	Track & field [a]	7	11.8 [d]	11.4	1.5	337	59	51	7.2	109	18	16	2.4	98	15	33	2.1
5	Triathlon	21	9.4	9.1	2.2	290	78	54	4.8	84	32	15	1.4	73	23	30	1.2
6	Running [c]	9	NA	8.5	1.7	283	NA	54	4.9	76	NA	15	1.3	72	NA	31	1.2
7	Running	56	8.4 [d]	7.8	2.5	246	82	52	4.4	74	37	16	1.3	66	34	32	1.2
10	Cycling	8	NA	7.5	3.0	264	107	60	4.4	64	28	14	1.1	57	41	26	0.9

[NA] not available [a] long-distance runners [b] values estimated from figure [c] values at start season [d] RDA values

The FAO/WHO/UNU Expert Consultation (20) adopted the principle of relying on estimates of TEE rather than on energy intake from dietary surveys to estimate energy requirements of adults. As a result, reporting TEE has become a necessary practice. Therefore, it is extremely important that energy expenditure is assessed correctly to determine energy intake requirements (23). Inaccurate information on TEE may lead to spurious conclusions regarding energy needs and true dietary contribution to the maintenance of good health and maximum performance. Future research on dietary practices of athletes should include precise information on training schedules and intensities, TEE calculations based on Dietary Reference Intakes for Energy (21), and, as often as possible, include the use of an external and independent marker of energy expenditure for comparison, e.g., doubly labeled water.

Energy intake and energy balance

Although, athletes tend to be high-energy consumers due to high-energy expenditure during training, the range of total energy intake (TEI) among athletes is wide. The results of TEI from the studies reviewed are summarized in Table 2. Reported mean total energy intake ranged between 10.6 and 22.4 MJ (2520 to 5330 kcal) for male and 7.5 and 11.4 MJ (1790 to 2720 kcal) for female athletes.

Maintaining energy balance (where TEE equals TEI) is extremely important to athletes since it affects, not only body weight, but also the proportion of fat to fat-free mass, glycogen stores, vitamin and mineral status, bone health, menstrual status in women, and physical performance (1,17,24). Some of the studies (6,10) did not present values for TEE but do cite data for energy balance.

For male athletes, one study (3) reported higher energy intake compared to energy expenditure. Two studies presented energy intake lower than energy expenditure (5,7). And two studies (6,8) had adequate values for energy intake compared to energy expenditure at the start of the season, but as the training volume increased, an associated increase in energy and carbohydrate (CHO) intake occurred. This increase in energy and CHO intake did not fully compensate for increased energy expenditure since the swimmers and runners lost body fat during the training season. The authors (6,8) did not report a significant change in body weight over the season. It is theoretically possible that body composition had changed (loss of body fat *vs.* gain of lean body mass), a question that is not fully addressed in the articles. Interestingly, for female athletes, all the articles reported lower energy intake values compared to energy expenditure (3,5-7,10).

As seen above, some studies suggest a negative energy balance for athletes (18,25). However, mean percent body fat and BMI values reported in the various studies indicate that athletes were not abnormally lean. The use of the factorial approach to estimates energy expenditure and, thus, energy needs, may have led to overestimation. Moreover, perhaps aerobic training tends to reduce resting metabolic rate. Resting heart and respiratory rates are known to be lower in athletes than in the average population (14). Also, individuals who exercise may compensate for increased energy expenditure due to exercise by performing more low-level activities or performing less overall activity outside actual exercise sessions (24).

The question of how athletes are able to train and compete successfully while consuming what appears to be inadequate energy is still unanswered and open to future research. Dietary assessment methodologies are undoubtedly a factor for data precision. Development of reliable methods to track dietary energy intakes in different populations is needed (21).

Dietary surveys

Dietary intake studies are often used for assessing dietary adequacy because they are inexpensive and noninvasive. However, accuracy and precision of methods for assessing typical food intake in different population groups is of major concern to nutritional research scientists and are open to several criticisms (26-28). All studies reported in this review collected dietary data by food records except two (9,10) that used weighed food records. The duration of food record collection varied between two (8), three (3, 5,7,9,10) and seven days (6).

It is commonly believed that adults underestimate or under-report food intake (23, 29). Thus, the dietary information contained in this review may reflect the limitations that result when dietary records are used. None of the articles reviewed reported the use of any controls, such as food intake levels, for under-reporting of food intake (30).

Nutrients

An adequate diet for athletes should cover energy, macronutrient, micronutrient, and hydration needs (1,31). The mechanisms by which exercise influences nutrient needs are currently under investigation (32-35). Theoretically, exercise may increase or alter the need for some nutrients through increased biochemical and metabolic demands, increased turnover of nutrients, and increased needs for repair and maintenance of lean tissue mass in athletes (1). On the other hand, athletes reach their level of excellence by progressive training, which might also progressively improve the efficiency of nutrient absorption and utilization (1). Currently, the consensus in the literature is that endurance athletes need higher energy, (CHO) and protein intake (1,4,5,20,25), compared to non-athletes. However, in general, available data are not sufficient to set specific reference values of nutrient intake for athletes (21,32- 36). Thus, it is assumed that the newly published Dietary Reference Intakes (DRIs), a set of four nutrient-based reference values (Estimated Average Requirement (EAR), Recommended Dietary Allowance (RDA), Adequate Intake (AI), and Tolerable Upper Intake Level (UL)), are appropriate for athletes unless otherwise stated (21,32- 36).

All nutrient needs of endurance athletes can generally be met by an adequate, well-balanced, and varied diet. Furthermore, the timing and frequency of food intake has implications for metabolism and nutrient availability and can be manipulated to achieve specific nutrition goals (37). Supplementation might be advised only in situations of dietary energy restriction (below 65% estimated energy requirement), elimination of one or more food groups, and intake of high-carbohydrate diets with low micronutrient density (1,7,8,38,39).

Carbohydrates

Endurance athletes should consume a high-carbohydrate diet that provides 60% to 70% TEI (4). However, rather than providing guidelines for routine CHO intake in terms of TEI, it is preferable to measure carbohydrates in terms of grams per body mass per day because it 1) assures adequate total CHO intake with respect to total energy intake and 2) allows flexibility for the athlete to meet these targets within the context of his/her energy needs and other dietary goals. CHO intake of 6 to 10 g/kg/day is suggested for the augmented needs of endurance athletes (1,40).

During successive strenuous daily exercise periods, consumption of a low-CHO diet, in combination with low energy intake relative to the activity level, results in progressive decrease in muscle glycogen and reduction of endurance (41). Frentsos & Baer (18) showed that, through diet intervention, adequate energy and CHO intake improved athletes´ performance.

The groups of athletes reviewed consumed CHO at levels of 51% to 57% TEI or 4.5 to 11.3 g/kg/day for males, and of 51% to 60% TEI or 4.4 to 7.2 g/kg/day for females (Table 2). These somewhat low values may result in gradual declines in performance over periods of sustained training. One of the reviewed studies (9) presented CHO intake relative to body weight above 10g/kg/day. In this study, professional cycling athletes were monitored during high intensity training periods and had high-energy consumption and dietary patterns similar to those observed during competition.

Relative CHO intake is generally below the recommended guidelines for endurance athletes (3,5,7,8,10,17,27,38,40).

This disturbing prevalence of inadequate CHO intake begs for elucidation into causes and solutions of athletes' dietary needs.

Protein

Protein intake levels can also be expressed as grams per body mass per day or as percent of total energy intake and should account for 10 to 15% TEI. Recent research suggests that active people require more than the RDA of 0.8 g/kg/day (21) and endurance athletes may need between 1.2 and 1.4 g/kg/day (42). Interestingly, the general population currently consumes at least 1.0 g/kg/day, and most athletes routinely consume 1.2 to 2.0 g/kg/day as an outcome of their high total energy intake (1). On top of that, some classes of athletes commonly use protein supplements (42).

As shown in Table 2, reported mean intakes were between 12% and 17% TEI or 1.1 and 2.6 g/kg/day for males and between 14% and 16% TEI or 1.1 and 2.4 g/kg/day for females. Therefore, as long as energy intake is adequate, protein insufficiency should not be a problem amongst most athletes, including those covered in this review. Nonetheless, there are certain subgroups of athletes that may be at risk of consuming inadequate amounts of protein. These subgroups include athletes who restrict their energy intake, are vegetarians, or those who have eating disorders (42).

Fat

Fat, in addition to CHO, is a main source of energy during exercise. Fat provides essential fatty acids and fat-soluble vitamins and should complement energy needs by providing 20-30% TEI (21,43). In contrast to glycogen stores which are limited, body reserves of fat are, practically, unlimited (17). The goal of lipid utilization during exercise is to transport lipids to the site of oxidation in muscles where it is used in the oxidative process to furnish energy, thereby sparing limited CHO stores.

Reported mean total fat intake ranged from 30% to 37% TEI for male and from 26% to 33% TEI for female athletes (Table 2). Athletes should focus on maintaining daily fat consumption to between 20-25% of total energy (1,17) and to consume CHO in adequate quantities. Fat intake should have a proportion of 1:1:1 of saturated, monounsaturated and polyunsaturated fatty acids (1,21).

In summary, endurance athletes have low CHO intake, adequate to high protein intake, and high fat intake. A better selection of foods such as that obtained by following a food guide pyramid adapted for endurance athletes (44) should help athletes consume adequate diets in terms of macro and micronutrient composition. It is imperative that nutritionists act urgently to correct dietary deficiencies by emphasizing the importance of adequate CHO intake. In some cases, nutritionists may need to evaluate possible use of carbohydrate supplements for athletes who have difficulty meeting CHO intake needs through food.

Micronutrients

Adequate intake of micronutrients (vitamins, minerals and trace elements) is essential for a number of physiological functions, including energy metabolism and maintenance and repair of body tissues (1,38). Micronutrients should be consumed through selecting varied foods. Also, adequate intake of fluids and electrolytes is of fundamental importance and athletes should attempt to remain well hydrated before, during and after exercise. A discussion of adequate fluid and electrolyte intake is beyond the scope of this review. Fluid replacement for athletes has been previously discussed (45,46).

Evaluating the nutritional status of some vitamins, minerals and, in particular, trace elements is certainly not easy. Apart from the difficulty of accurately measuring all losses, there is a continuing debate as to whether micronutrient levels found in serum represent body reserves (47). At present, daily requirements for some micronutrients have not been clearly established for population sub-groups. Consequently, the Recommended Dietary Allowances (RDA) has been used and, currently, the Dietary Reference Intakes (DRIs) are used for athletes (36).

Dietary micronutrient adequacy analysis

Dietary micronutrient adequacy analysis is presented in Table 3 which showsss the characteristics and duration of dietary surveys conducted in the articles reviewed. Also displayed are comments addressing validity of conclusions regarding adequacy or inadequacy of micronutrient intake. These comments take into account nutrition assessment methodology available today (36).

All studies, with the exception of one (6), present analysis for micronutrient adequacy by comparing mean intake to either the RDA (3,5,8,9,10) or to a calculated cut-off point derived from the RDA (7). Some studies used other forms of analysis such as comparing mean intake to data from previously published studies (6,7,10) or by comparing intake of food items and food groups (7,9,10). This approach estimates diet variety which, in turn, indicates micronutrient density. However, though common, it is a mistake to compare mean nutrient intake with RDAs (36) when ivaluating dietary survey data. This form of comparison leads to inappropriate conclusions about mutrient adequacy and, hence, any results derived from such comparisons are also questionable.

The results reported reflect the widespread mistake perpetuated in the literature for nutritional group evaluation. Although the claim of a better interpretation of nutritional assessment has long been published in the literature (48), few have since addressed correct interpretation of dietary research data until 2000, when the Institute of Medicine (36) published comprehensive and effective methodology to assess food intake by individuals and groups.

TABLE 3
Previously published dietary assessment studies of vitamins and minerals in endurance athletes

Year	Ref N°	Dietary survey Type	Dietary survey Duration (days)	Intake comparison Mean to RDA	Intake comparison to food groups	General comments on conclusions drawn from results
1989	6	FR	7	No	No	Determination of micronutrients adequacy is not possible using the methods and results provided. Study conclusions are well-supported by comparing dietary intake during the period of study.
1989	7	FR	3	Yes	Yes	Determination of micronutrients adequacy is not possible using the methods and results provided Study conclusions are based on well-conducted analysis. It shows that, with training-related behavioral changes, dietary intake is improved as compared to the general population.
1989	10	WFR	3	Yes	Yes	Determination of micronutrients adequacy is not possible using the methods and results provided Good evaluation of marginal consumption of micronutrients through intake of some food items was performed.
1990	5	FR	3	Yes	No	Determination of micronutrients adequacy is not possible using the methods and results provided Conclusions of inadequacy cannot be drawn from percentage of athletes with intake below RDA.
1992	8	FR	2	Yes	No	Determination of micronutrients adequacy is not possible using the methods and results provided
1999	3	FR	3	Yes	No	Determination of micronutrients adequacy is not possible using the methods and results provided, especially since extremely high micronutrient intake biased average intake. Conclusions of inadequacy cannot be drawn from percentage of athletes with intake below RDA.
2000	9	WFR	3	Yes	Yes	Determination of micronutrients adequacy is not possible using the methods and results provided A well-structured analysis of food choices is presented which illustrates variability of food intake.

FR – Food Record WFR – Weighed Food Record

In short, any comparison of nutrient intake to reference values should consider the characteristics of the distribution of usual intake and requirement distributions. The prevalence of nutrient inadequacy depends on the shape and variation of usual intake distribution, not on mean intake. For most nutrients, to have an acceptably low prevalence of inadequate nutrient intake, group mean intake must exceed the RDA. Moreover, in any group, the greater the variability in usual intake relative to the variability in requirements, the greater the mean usual intake must be relative to the RDA to ensure that only a small proportion of the group has inadequate intake (36). If group mean intake equals or even exceeds the RDA, there could still be a substantial proportion of subjects with inadequate intake. This can be true for athletes, especially when supplement usage is counted towards total usual nutrient intake calculations, since extremely high nutrient intake levels by a minority of subjects may bias the average intake of the population due to the large variability of usual intake (3). Comparing mean or median intake either to EAR or RDA or simply looking at mean intake levels is not an adequate approach to assess or imply relative nutrient adequacy of a population group. For this reason, close examination and appropriate utilization of the methodology described in the IOM report (36) is now required by nutrition scientists.

As discussed, to compare mean group intake to the RDA does not determine adequacy of intake. From the results published in the literature, it is not possible to know what proportion of athletes is consuming an adequate amount of vitamins, minerals and trace elements.

As a consequence, there is widespread unease among athletes and coaches when it comes to micronutrient intake. It is advisable to regularly assess athletes' diets and other measures of nutritional status to prevent accumulated seasonal deficiencies (10,17). Certainly, inadequate food intake may cause deficiency in one or more nutrients resulting in deleterious effects, such as impaired physical performance. Possibly, for this reason, there is widespread use of nutrient supplementation, a habit that is prevalent among this population (5,9). Until present, there is no evidence that this practice can improve athletic performance in individuals eating a well-balanced diet (39).

In this regard, the introduction of the Tolerable Upper Intake Level - UL (36) is a new contribution to nutritional evaluation, especially for population groups, such as athletes, that use nutrient supplements on a daily basis over a long period. The UL will help ensure that usual micronutrient intake levels are not so high as to pose adverse health risks to an individual or group of individuals (36). Improved knowledge in this area is certainly important to control supplement abuse.

As with the RDA, it is not correct to compare mean or median intake to the UL since it will not give the true prevalence of the proportion of athletes at risk of toxicity. The variability of intake distribution must be taken into consideration. Many of the studies reported here were done in the beginning of the 1990's, so it is possible that today's greatly amplified offering of food supplements may result in higher intake of some nutrients in detriment to others. This question is still open for research.

Concluding remarks

There is limited information available on dietary intake and nutrient adequacy of athletes. At present, the studies reporting dietary intake and nutritional status of endurance athletes are insufficient to resolve whether these athletes are maintaining nutritionally adequate diets (3,5-10). This review is directed to the nutrition-minded sport researcher as a call for well-designed research on nutritional needs and habits of male and, particularly, female athletes.

A good model for studying nutrient intake of athletes should integrate dietary assessment methods, physical activity questionnaires, physical performance indicators, body composition measurements and, if possible, the use of an external and independent marker for comparison. Such studies, together with better knowledge of the principles and application of reference intakes (DRIs) for assessing dietary nutrient adequacy would fill the existing gap in reliable information about food intake and nutrient adequacy of athletes. This would allow for more fruitful conclusions and would make possible the establishment of conclusive nutritional recommendations for athletes. The future holds an exciting new perspective in this area.

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