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VARIATIONS OF NIACIN CONTENT WITH REGARD TO CARBOHYDRATES IN ENERGY-RICH DIETS OF ELITE EUROPEAN ATHLETES AND THEIR RELATION WITH DIETARY RDA

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Abstract

In sport, proper nutrition exerts a significant impact on sporting results. Scientific data about the nutritional habits of elite European athletes is limited and therefore it is unclear whether athletes are following nutritional recommendations and maintaining proper diets. The aim of this study was to determine the content of niacin in the daily diets of elite European athletes with regard to calories and carbohydrate intake, and its relation to dietary RDA. The study included 64 adult athletes of both sexes from sport teams in five European countries. A 24-hour dietary survey was developed based on an "Album of photographs of meals and food products". A microbiologically based method was used for the niacin determination, with enzymatic hydrolysis by a 40 mg mixture of papain and diastase run on every analysed 2 g sample (in accordance with the AOAC). The carbohydrate intake of each subject was obtained with a "Carbohydrate count book", and the energy value determined using a bomb calorimeter. Among the group of elite European athletes surveyed, reconstructed meals provided an average of 28.5 mg of niacin in women, and 22.4 mg in men. The FAO and the WHO recommend daily allowances for niacin in persons over 19 years of age is 15.2 mg 2300 kcal^{-1} for women and 21.1 mg 3200 kcal^{-1} for men. The diets analysed did cover the recommendations in 53% of all diets (54% in women, and 50% in men) but in the endurance sports, which require a high carbohydrate intake, niacin demand may increase up to 23.8 mg and 30.4 mg, respectively. Therefore, the average diet is not sufficient. Only 15% of all diets covered the increased niacin recommendations (27% in group of women, and 0% in men). This was proven to be strongly insufficient as the demand for niacin increases significantly with increased caloric intake which may lead to a niacin deficiency. Thus, in such cases niacin supplementation may be justified. Also, the results indicate that

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daily nutrition does not provide a sufficient amount of energy for athletes. The daily food intake of European sport team members did not fully cover the RDA requirements for niacin due to high daily carbohydrate consumption, and low caloric intake. Thus, daily diets should be better organised to meet the needs of athletes.

Keywords: niacin, carbohydrates, calories, nutrition, endurance sport, physical activity.

INTRODUCTION

Micronutrient deficiencies remain a global health concern. As an example, anaemia has an estimated global prevalence of approximately 25%, affecting over 1.5 billion people worldwide (WHO 2000). Although a poor nutritional status is most common in developing countries, people in developed nations also may experience a suboptimal micronutrient status. Nutritional disorders attributable to deficiencies of vitamins (such as vitamin A, thiamine, riboflavin and niacin) and minerals (calcium, iron and zinc) occur widely in many of these nations (Nishida 2004). The WHO has placed inadequate fruit and vegetable consumption on the list of 10 leading factors for death in middle and high-income countries (Mathers et al. 2009, Crowe et al. 2011). Nutrition and lifestyle, particularly over-nutrition and lack of exercise, promotes the progression and pathogenesis of obesity and metabolic diseases (Mathias et al. 2014). Obesity is one of the leading causes of preventable morbidity and mortality from cardiovascular diseases (CVD), diabetes, cancer, and several other chronic disorders.

It such cases, fitness training may be considered as a non-pharmacological tool to attenuate metabolic programing and to ameliorate the illness provoked by metabolic diseases and reduce the prevalence of obesity, type 2 diabetes, and CVD (Mathias et al. 2014).

The optimum amount of energy supplied by food for an adult is such that it offsets energy expenditure, and thus provides a zero energy balance. According to the principles of proper nutrition, the main source of energy should come from carbohydrates (50 to 70%), especially complex carbohydrates (the percentage of energy from simple sugars should not be greater than 10 to 12%). Lipids should provide 20 to 35% of energy, and proteins 10 to 15%. Various socioeconomic factors influence the amount and composition of diets consumed, leading to obesity in Europe (Gallus et al. 2014) or malnutrition (Black et al. 2008, Lai et al. 2014, Rahe et al. 2014), and hence the level of intake. Intake increases with income and also seasonal differences are of particular importance since many fruits and vegetables are widely available during summer months (Di Maria-Ghalili et al. 2005). Increased consumption of vegetables, fruits and berries is associated with a delayed risk of all-cause mortality in particular due to cancer and stroke (Hjartåker et al. 2014).

Proper nutrition is one of the major factors affecting an athletes' development, health and well-being. A healthy balanced diet can help to attain the best fitness and sporting results; moreover, it can protect against injuries. Many sportsmen, sport nutritionists and registered dieticians share the opinion on proper food and drink intake for athletes (Rautiainen et al. 2014). To run a short distance (100 m), runners use glucose reserves and burn them under anaerobic conditions (Beneke et al. 2011). In contrast, marathoners, who cover long distances (20,000 meters), use fat reservoirs as a main source of energy in aerobic metabolism. Aerobic conditions consume oxygen to efficiently produce ATP over long periods of time.

Carbohydrates are the best source of energy with an influence on proper muscle building. Dietary programmes that restore and even super-compensate muscle glycogen levels can enhance activity patterns during training. On the other hand, too low energy intake from food causes disturbances to the proper functioning of the hormonal, metabolic, and the immune system.

Many elite athletes use caffeine as an ergogenic aid to boost performance, and carnitine to help metabolize food into energy. Carnitine better preserves skeletal muscle glycogen and lowers plasma lactate levels, but does not improve physical performance, as Morand et al. proved (2014). It is vital to achieve an energy intake that provides sufficient carbohydrates to fuel the training and competition programme, satisfies all the nutrient requirements, and allows the manipulation of energy or nutrient balance to achieve changes in lean body mass, body fat or growth. The achievement of an ideal physique is a long-term goal that should be undertaken over successive years, and particularly during the off-season and pre-season. An increase in lean body mass or a decrease in body fat is the product of a targeted training and eating programme (Ferramosca et al. 2014). Consultation with a sports nutrition expert can assist an athlete to manipulate energy and nutrient intake to meet desired goals.

Niacin, the common name for both nicotinic acid and nicotine-amide, in the form of co-enzymes, catalyses NAD^+ and $NADP^+$ dependant reactions. NAD^+ takes part in the catabolism of carbohydrates, fat, proteins, and alcohol, as well as cell signalling and DNA repair. $NADP^+$ is mostly engaged in anabolism reactions such as fatty acid and cholesterol synthesis. In Europe, the high level of niacin in the daily diet is derived from the group of food coomposed of meat, fish, eggs (40%), cereals (30%), fruits and vegetables. Nicotinic acid can be found in food of both animal and plant origin. Meat (including fish), baker's yeast, seeds, legumes and parsley root are the best sources of the acidic form of niacin (Majewski, Lebiedzińska 2013, 2014b). The amide form of niacin, on the other hand, predominates in products of animal origin where it is bound in the form of co-enzymes. In the liver, niacin can be synthesized from the essential amino acid, L-tryptophan, yielding 1 mg of niacin from 60 mg of this amino acid.

Tryptophan conversion requires other B group vitamins (riboflavin, pyridoxal 5'-phosphate) and minerals (iron, magnesium, cobalt and zinc) which work as co-enzymes and co-factors in the niacin formation pathway (Ocampo et al. 2014, Majewski et al. 2016). An excess of tryptophan in the daily diet can cause hyperserotonemia in a foetus (Castrogiovanni et al. 2014).

In general, niacin intake in a healthy population is on an adequate level. However, among people within high-risk groups (such as alcoholics, people experiencing decreased food intake, and elite professional athletes where the demands are increased) these amounts may not be sufficient. Hence, cases niacin supplementation might be justified.

MATERIAL AND METHODS

Dietary assessment

The 24-h dietary recall was used to assess daily food composition. The 24-h dietary interview provides data estimated on the intake of total daily energy, nutrients and the other dietary components, as well as dietary behaviours regarding type, quantity and time of each food and beverage consumption. The protocol with 24-hour food diaries is less burdensome and more challenging for interviewers (Ocké et al. 2014). The group of sportsmen were selected from five European countries: Poland (n = 16), Germany (n = 12), United Kingdom (n = 12), Italy (n = 12) and Czech Republic (n = 12). The anthropometric characteristics of elite European athletes were collected in Table 1. In the interview, respondents (n = 64) reported all foods and be-

Table 1

The anthropometric characteristics of elite European athletes*

Specification	Mean ± SD*	Mean ± SD*
Sex	men (n = 28)**	women (n = 36)**
Age (years)	23.68 ± 0.774 (21 – 24)	22.20 ± 0.892 (21 – 25)
Body weight (kg)	78.33 ± 9.812^a (66 – 84)	53.20 ± 8.921^a (49 – 68)
Height (cm)	179.2 ± 7.551^a (175 – 189)	167.9 ± 4.832^a (160 – 175)
BMI (kg m^{-2})	22.02 ± 2.021^a (21.46 – 25.00)	19.69 ± 2.561^a (18.58 – 24.66)
BMI (%) Normal weight (18.5 ≤ BMI ≤ 25)	100.0	100.0

* values are with the mean ± standard deviation (SD),
** number of samples, ^{a} comparison between sexes: $p < 0.001$

verages consumed in a prior 24-h period (midnight to midnight). The elicited data later allowed us to reconstruct the diets of elite athletes and analyse the niacin concentration, and the carbohydrate with the energy intake.

Determination of nutrients

The concentration of niacin was determined by applying a microbiological method (Majewski, Lebiedzińska 2014a). We isolated niacin from 2 g samples after enzymatic hydrolysis using an enzyme mixture of papain and diastase (40 mg) according to the AOAC method (AOAC 2003). A microbiological method using the *Lactobacillus plantarum* strain ATCC No. 8014 is widely applied to determine niacin concentration (Ndaw et al. 2002). The method is applicable because niacin is one of the most stable water-soluble vitamins and its biological activity is retained following thermal, light, pH or oxidation treatment. Such a procedure releases the free form of niacin from that which is bound in NAD^+ and $NADP^+$ forms. Enzymatic hydrolysis is thus possible for releasing free niacin from its biologically bound forms, where it can be liberated from coenzymes or throughout matrix degradation.

The precision and accuracy of the applied method was established, at highly acceptable level, on samples spiked with known amounts of niacin (Majewski, Lebiedzińska 2014; Table 2).

Table 2

Accuracy and precision obtained during niacin determination*

Niacin content (mg 100 g^{-1})	Enrichment (mg 100 g^{-1})	Recycle (%)	SD (%)	Relative error (%)
7.89 ± 0.15	3	97.87	2.89	- 2.13
	6	103.04	3.13	+3.04

* values are means ± SD (n = 10)

The results were scrutinised to see if levels were sufficient to satisfy the RDA requirements for adult subjects aged over 19 years by their concordance with the amended reference values of nutrition, supplied by the Prinzo WHO report (2000).

The amount of energy from each dried food item was analysed in four aliquots with a bomb calorimeter. The bomb calorimeter was calibrated with benzoic acid. The energy content of each food item was expressed as kilocalories per 100 grams of food sample before drying. Total carbohydrate content of foods was determined using carbohydrate count book.

Statistical analysis

Continuous variables which were normally distributed were presented as means ± SD. Relationships between categorical variables were tested by the calculation of chi-square test. The Student's t-test for independent samples was used to evaluate mean differences of the normally distributed variables (i.e., body mass index) between cases and controls. The tested hypotheses were evaluated using the non-parametric *U* test suggested by Mann and Whitney. The significance level was accepted at $p < 0.05$.

RESULTS AND DISCUSSION

Niacin concentration

There were no significant differences between the analysed diets of elite athletes from different European countries ($p > 0.05$). Analysed meals provided an average of 28.5 mg of niacin for women, whereas in men, analysed meals provided 22.4 mg. The FAO and the WHO recommended daily intake of niacin is 6.6 mg per 1000 kcal, which is 15 and 21 mg per person, respectively and no less than 13 mg at an intake below 2000 kcal. In endurance sports, the demand increases to 22.8 and 30.36 mg, respectively.

Analysed diets provided the right amount of niacin in 55% of female athletes and 50% of male athletes ($p < 0.01$; $n = 64$). 75% of the men's diet did cover the required 21.1 mg of niacin per day, but the amount of calories consumed was not within the recommended minimum of 3200 kcal, either. 87.5% of the men's diet complied with the recommended 6.6 mg (1000 $kcal^{-1}$), but in 12.5% of these cases the niacin intake was below the recommended 21.1 mg (Figure 1).

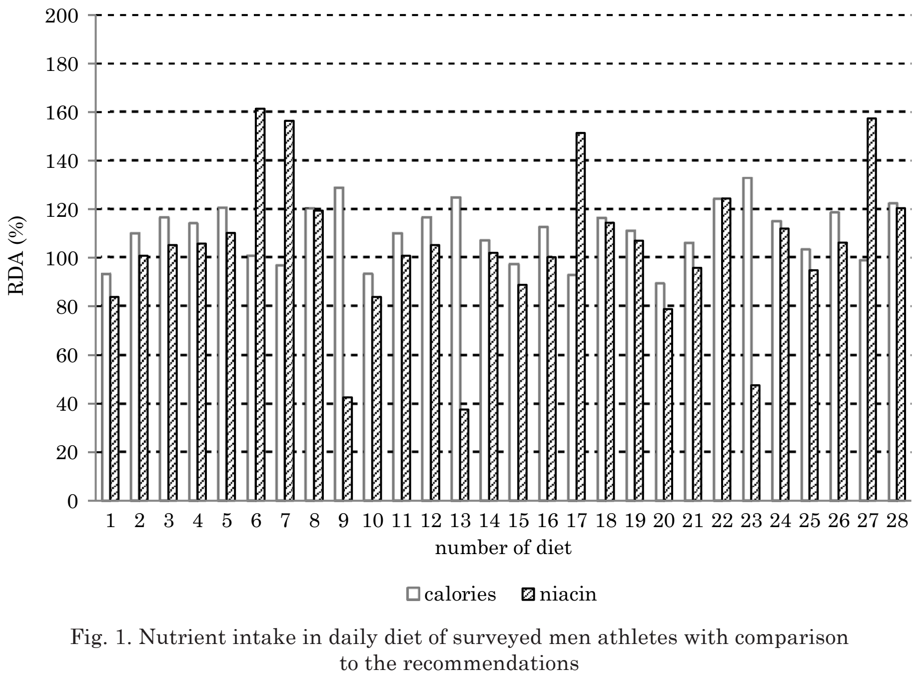

Fig. 1. Nutrient intake in daily diet of surveyed men athletes with comparison to the recommendations

In female athletes, 91% of analysed diets *did* cover both the required daily intake of niacin (which is 15.2 mg day^{-1}) and the recommended 6.6 mg on each 1000 kcal. However, the caloric intake was not within the recommended frames. Only 45% of analysed diets covered the recommended minimum of 2300 kcal (Figure 2).

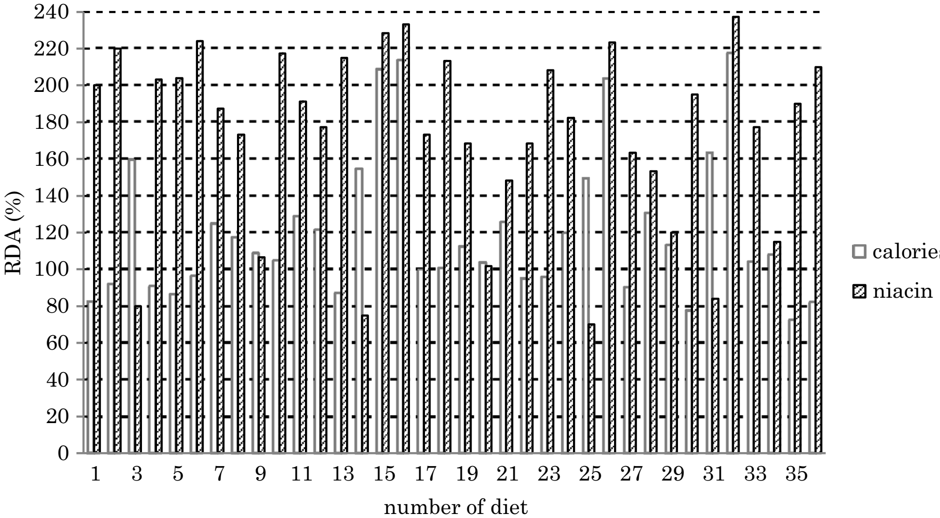

Fig. 2. Nutrient intake in daily diet of surveyed women athletes with comparison to the recommendations

In addition, we carried out an assessment of the implementation of the daily requirements for niacin in relation to increased physical activity of professionals in all analysed diets. As reference values, we adopted standards proposed by the FAO and the WHO for women and men aged 19-25 years with high physical activity. The recommended niacin intake level is 22.8 mg for women and 30.4 mg for men, after caloric calculation. We found that 72.7% of female diets and 12.5% of male diets minimally covered the increased niacin needs. On the contrary, the caloric consumption was not within the recommended frames. Only 27.3% of analysed female diets *did* cover both the recommended niacin intake and the caloric consumption. None of the diets of their male counterparts covered both the recommended niacin intake and the caloric consumption (Figure 3).

Carbohydrates and energy

The results are presented in Table 3. The figures are given in ranges since they differ widely from one to another. The analysed diets were rich in carbohydrates, and the consumption was within the range of 386-720 g day^{-1} in women and 420-567 g day^{-1} in men. Current recommendations suggest that, when undertaking endurance sports, the daily intake should include

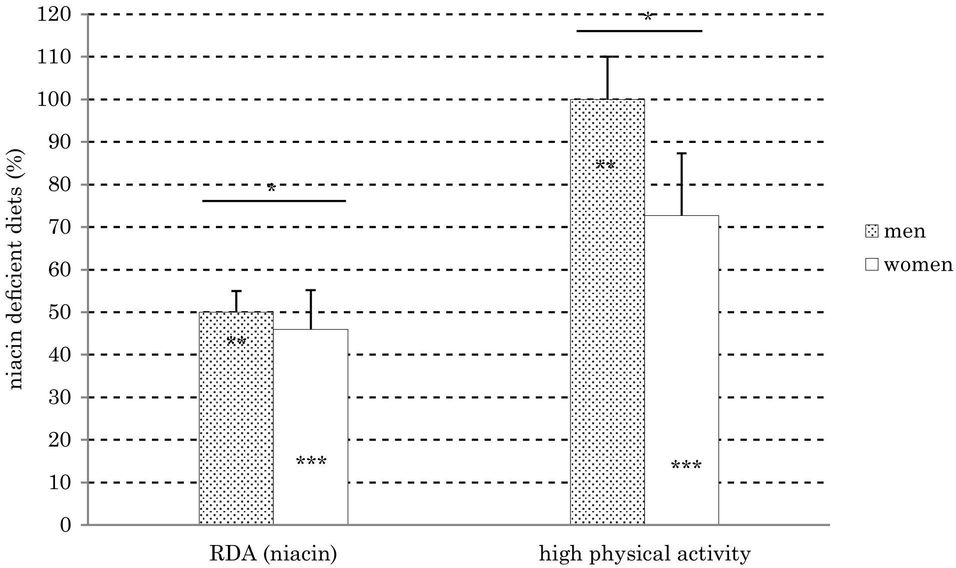

Fig. 3. The percentage of niacin deficient diets in European athletes including both standard recommendation (RDA) and high physical activity

Comparison of the same nutrition standards for niacin within different gender, $^{*}p < 0.05$; Comparison of different nutrition standards for niacin within the same gender, $^{**}p < 0.001$; *** $p < 0.001$. Asterisks indicate differences in groups.
Error bars represent the standard error of the mean (n = 64)

Table 3

The nutrients intake in daily diets of elite European athletes and Nutritional Standards for women and men over 19 years of age[1]

Daily intake	Women (n = 36)$^{\#}$			Men (n = 28)$^{\#}$		
	minimum – – maximum	mean ± SD	recommendations	minimum – – maximum	mean ± SD	recommendations
Carbohydrate (g)	386 - 720	425 ± 170	327***	420 - 567	493 ± 152	407***
Energy (kcal)	1899 - 4908	2870 ± 1176**	2300 / 2900-3150***	2988 - 4120	3552 ± 439**	3200 / 4200-4600***
Niacin (mg)	12.5 - 36.3	28.5 ± 8.5*	15.2 / 22.80***	9.0 - 32.9	22.4 ± 5.8*	21.10 / 30.36***
Niacin (mg kcal^{-1})$^{\#\#}$	7.52 - 36.33	25.60 ± 9.11		6.93 - 33.91	19.80 ± 8.60	

* $p < 0.05$; ** $p = 0.08$ – asterisks indicate difference between groups: $^{\#}$ number of surveys,
*** recommendations for women and men aged 19-25 years with high physical activity (proposed by the FAO/WHO expert group),
$^{\#\#}$ niacin conversion per consumed calories (2300 in women and 3200 in men)

327 g day^{-1} and 407 g day^{-1} of carbohydrate, for women and men respectively. This indicates that the carbohydrate consumption was higher than the recommendations.

The analysis of daily food intake in elite European athletes of both genders showed that the consumption of calories was within the daily recommendations but below the increased needs. Daily recommendations for women are 2300 kcal at the minimum and increases to between 2900 and 3150 kcal day^{-1} during endurance training. Women typically consumed 2870.8 ± 1176 kcal a day. Only 45.4% of all analysed diets from this group met the daily requirement. Just 18.2% of analysed meals provided the increased caloric intake.

Male diets provided on average 3552.6 kcal day^{-1}, which is above the recommended 3200 kcal day^{-1}, but below the increased values, the increased recommended intake for men is from 4200 to 4600 kcal day^{-1} (FAO/WHO/UNU 2007). In this group, 62.5% of diets were within the recommended intake. None of the analysed meals covered the increased caloric consumption.

Scientific data about the nutritional habits of elite athletes are scarce. Hence, it is not clear whether elite athletes are following nutritional recommendations and maintaining proper diets. In sport, proper nutrition exerts a significant impact on sporting results, which depend on excellent concentration and motor skill coordination. An adequate vitamin and mineral status is essential for optimal human health and performance. Dietary issues in maintaining an adequate micronutrient status due to the consumption of a very low energy diet (VLED) or having a diet with inadequate nutrients may impair the nutritional status due to strenous heavy physical effort. Moreover, the VLED affects the faecal microbiota, in particular *Bifidobacteria (*Simões et al. 2014) which can lead to gastro-intestinal disorders and inflammation. The most common micronutrients that may be low due to inappropriate diet are the B vitamins with niacin, the bone-building nutrients, especially calcium and vitamin D (Monjardino et al. 2015), iron and zinc (Zhao et al. 2015). Intensive training lasting for many weeks is a factor that increases the demand for all nutrients (including niacin), and the proper energy supply is necessary, as has been shown in this study.

During our study, we discovered differences in niacin concentrations in the analysed diets. As it was proven, women consume higher amounts of niacin in their meals in comparison to their male colleagues. The analysed daily intake provided the right amount of niacin only in 53% of all cases (55% – women, 50% – men), and during intense exercise, which necessitates high carbohydrate consumption, this is insufficient, as the demand for niacin increases significantly. An adequate intake of analysed niacin is important to ensure adequate energy production and the building and repair of muscle tissue.

The analysed diets complied with the 6.6 mg (for 1000 kcal) recommendations (87% – men and 91% – women). However, due to the low energy intake, the results were below the daily niacin intake.

Another nutritional issue was the poor energy intake, with high carbohydrate consumption. This can be linked to poor food selection coupled with inadequate intakes of proteins and essential fatty acids.

CONCLUSIONS

Improved energy balance together with a sufficient amount of niacin in the daily diet will correct the overall nutritional status and may reverse some dysfunctions, thus restoring the normal functiononing of an athlete's body. Obviously, there is a great need for collecting more information on the long-term nutritional status of European athletes.

CONFLICT OF INTERESTS

None of the authors of this paper has a financial or personal relationship with other people or organisations that could inappropriately influence or bias the content of this paper.

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