MEDICINA 51 (2015) 351–362

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: http://www.elsevier.com/locate/medici

Original Research Article

Nutritional habits among high-performance endurance athletes

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ARTICLE INFO

Article history:
Received 16 March 2014
Accepted 8 November 2015
Available online 18 November 2015

Keywords:
Nutritional habits
High-performance
Endurance athletes

ABSTRACT

Background and objective: For athletes, the main purpose of nutrition is to ensure the compensation of increased energy consumption and the need for nutrients in the athlete's body, thereby enabling maximum adaptation to physical loads. The aim of this study was to determine the habits of highly trained endurance athletes depending on sports type, sex and age in order to improve the planning and management of the training of athletes using targeted measures.
Materials and methods: In 2009–2012, the dietary habits of 146 endurance athletes were analyzed. The actual diet of Lithuania endurance athletes was investigated using a 24-h dietary survey method. Data on the athletes' actual diet were collected for the previous day.
Results: It was found that 80.8% of endurance athletes used lower-than-recommended amounts of carbohydrates in their diet, and more than 70% of athletes used higher-than-recommended levels of fat, saturated fatty acids, and cholesterol. The diet of female athletes was low in carbohydrates, dietary fiber, protein, omega-3 fatty acids, B vitamins, potassium, calcium, phosphorus, iron, manganese, and zinc. Athletes aged 14–18 years tended to consume quantities of protein that were either lower than recommended or excessive.
Conclusions: The diet of highly trained endurance athletes does not fully meet their requirements and in this situation cannot ensure maximum adaptation to very intense and/or long-duration physical loads. The diet of highly trained endurance athletes must be

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Peer review under the responsibility of the Lithuanian University of Health Sciences.

Production and hosting by Elsevier

http://dx.doi.org/10.1016/j.medici.2015.11.004

optimized, adjusted and individualized. Particular attention should be focused on female athletes.

1. Introduction

Athletes and their training specialists should pay special attention to the supervision of nutrition because proper diet is an integral part of the optimal physical development of athletes and achievement of optimal results [1]. To improve the planning and management of highly trained athletes using targeted measures, it is no doubt very important to clarify the nutritional hazards of different groups of athletes. The diet of athletes training for major competitions must meet certain requirements. Only with adequate nutrition can an athlete's body compensate for increased energy loss and nutritional needs and thereby facilitate the maximum adaptation to physical loads.

Endurance athletes raise their aerobic capacity to overcome daily intensive and/or long-lasting, onerous physical loads. Physical performance and the fatigue incurred by athletes during aerobic training are partly dependent on endogenous carbohydrate reserves accumulated in the body and/or exogenous carbohydrate availability during physical loads [2]. Therefore, when enduring intense 2–3 h of physical loads on a daily basis, athletes must consume the recommended amount of carbohydrates (7–12 g/kg of body weight) [2]. Meanwhile, the recommended protein intake is 1.2–1.6 g/kg of body weight, and the energy value supplied by fat should not be higher than 35% [1]. In addition, athletes must consume the recommended amounts of vitamins and minerals [1].

Over the past decade, it has been demonstrated that the nutritional habits of athletes depend on sex and age. Due to incomplete growth and maturation, a special focus is required for the diet of young athletes. In 1980–2000, female athletes were placed in the risk group of inadequate nutrition for the lack of carbohydrate intake and insufficient energy value of food rations [3]. Insufficient carbohydrate consumption is associated with low fat mass of athletes and poorer physical performance [3]. In addition, it has been found that the quantities of some vitamins and minerals consumed by female athletes in various countries are below recommended doses [4,5]. Therefore, to prevent anemia and osteoporosis, female endurance athletes are recommended to take iron supplements, and their intake of calcium should be 1.5–2 times higher than the recommended daily intake (RDI) [1,6,7].

Unlike in other countries, the diets of Lithuania high-performance endurance athletes have not yet been fully explored and evaluated. There is no summary data about the eating habits of elite Lithuanian endurance athletes. For these reasons, until now is has not been possible to highlight the characteristics of different groups of athletes. The aim of this study was to determine the actual nutrition habits of high-performance endurance athletes depending on sport, sex and age.

2. Material and methods

2.1. Study population

During general training in 2009–2012, 95% of the endurance sports athletes who were included on the list of athletes approved by orders of the Department of Physical Education and Sports were studied. The highest-performance endurance athletes (n = 146) in Lithuania, engaged in Olympic disciplines such as rowing, cycling, swimming, skiing, biathlon, and long-distance running, were investigated. The highly skilled endurance athletes were tested during the preparatory period before a competition. The scope of the athletes' workout load fully complied with approved training plans. The assessment of the athletes' training plans was based on the plans that are used by highly skilled endurance athletes training for the Olympics and officially approved by the Department of Physical Education and Sports and the National Olympic Committee of Lithuania, plans specified in the London 2012 and Sochi 2014 programs (Table 1).

All the organizational issues regarding the survey were discussed prior to the research with the Lithuanian Olympic Sports Center and with the Bioethics Committee. Permission to carry out the biomedical study was issued by the Bioethics Committee (No. 158200-11-113-25, November 3, 2009).

2.2. Anthropometric measures

The height of the athletes was measured using a stadiometer (±1 cm) at the Lithuanian Sports Medicine Centre. Measurement of the body weight and individual weight components (body mass, lean body mass [LBM] in kg and %, muscle mass [MM] in kg and %, and body fat [BF] in kg and %) were performed at the Lithuanian Olympic Sport Centre using the BIA (bioelectrical impedance analysis) method. Athletes' height and body weight ratios were assessed by calculating the body mass index (BMI). Each athlete's BMI was determined by calculating it as body weight in kilograms (kg) and dividing by height in meters squared (m^2). It was assessed according to the standards that describe insufficient body weight (when BMI is <19 kg/m^2), normal body weight (when BMI is 19–24 kg/m^2), excess weight (when BMI of 24–30 kg/m^2), and obesity (when BMI ≥30 kg/m^2) [8]. BF and the muscle and fat mass index (MFMI) of athletes was assessed according to the standards [8] presented in Table 2.

2.3. Dietary intake

The actual diet of Lithuania endurance training athletes was investigated using a 24-h dietary survey method. Data on the athletes' actual diet was collected for the previous day. The

Table 1 – Endurance training plans for athletes.

Sports	Rowers	Highway cyclists	Swimmers	Skiers	Biathletes	Long-distance runners
Athlete testing month	March	April	May	August	August	June
Time period	Preliminary	Preliminary	Preliminary	Preliminary	Preliminary	Preliminary
Stage	Special training	Special training	Special training	Basic training	Special training	Special training
Days of exercise per month	25	26	27	22	20	27
Exercises per month	41	26	41	32	31	50
Total physical workload, hours per month	105	156	126	70	42	117
Total physical preparation, hours per month	20	–	40	30	16	40
Total physical training, hours per month	85	156	86	40	26	77
The content of the special work (intensity zones)						
Aerobic strength endurance, recovery (blood lactate concentration up to 2 mmol/L, heart rate – 130 ± 10 beats per minute), %	20	20	17	38	24	44
Aerobic strength training (blood lactate concentration is 2–4 mmol/L, heart rate – 150 ± 10 beats per minute), special muscle-power increase at the anaerobic threshold, %	70	50	41	39	49	37
Mixed aerobic and anaerobic glycolytic strength training (blood lactate concentration is 4–12 mmol/L, heart rate – 170 ± 10 beats per minute), VO_2max increase, %	9	30	34	15	19	11
Anaerobic glycolytic strength training (blood lactate concentration up to 21 mmol/l/L, heart rate ≥181 beats per minute), %	–	–	6	4	8	7
Anaerobic phosphocreatine (maximum effort) strength training (blood lactate concentration is 1.5–6 mmol/L), %	1	–	2	4	–	1

VO_2max, maximal oxygen uptake.

survey was performed by a trained interviewer using the direct interview method at the Lithuanian Olympic Sports Centre. The interviewer recorded data on foods and meals consumed by each athlete. In the course of the food recall, the portion sizes in the special *Atlas of Foodstuffs and Dishes* were used. The atlas displays different portions of products and meals, assessed in grams, making it possible to record the amounts of all food products and meals consumed.

Table 2 – Body fat (BF) and muscle and fat mass index (MFMI) among athletes by sex.

	Male athletes	Female athletes
BF, %		
Is too low	<5	<15
Lean	5–9	15–19
Optimal	10–14	20–24
Acceptable	15–19	25–29
Excessive	20–24	30–34
MFMI		
Insufficient	<2	<1.8
Too small	2.1–3.39	1.9–2.89
Moderate	3.4–4.69	3–3.99
Extensive	4.7–6	4–5
Maximum	>6	>5

BF, body fat; MFMI, muscle and fat mass index.

The average daily food intake of athletes was evaluated and the chemical composition and energy value of the food rations were determined using chemical composition tables [9]. Carbohydrate, protein and fat intake was assessed according the recommendations in academic literature [1,2,7]. The recommended carbohydrate content for endurance athletes having moderate or high intensity daily training of 1–3 h must amount to 7–12 g/kg of body weight [2] and protein content must amount to 1.2–1.6 g/kg of body weight [1]. The percentage of energy from fat should be between 20% and 35%, saturated fatty acids (SFA) <10%, polyunsaturated fatty acids (PUFA) from 6% to 10%, omega-3 fatty acids (omega-3 FA) from 1% to 2%, and omega-6 fatty acids (omega-6 FA) from 5% to 8% [7]. In line with these recommendations, the compliance of the average intake of nutrients with the recommended quantities was evaluated and expressed as a percentage of the recommended intake (RDI) (consumption/RDI × 100).

Table 3 – Normative data of basic activities, activity codes and METS (in kcal/kg/h) for activities used in the present study.

2011 Code	METS	Sports	Description
Organized physical activity			
01030	8.0	Bicycling	Bicycling, 12–13.9 mph, leisure, moderate effort
01050	12.0	Bicycling	Bicycling, 16–19 mph, racing/not drafting or >19 mph drafting, very fast, racing general
01060	15.8	Bicycling	Bicycling, >20 mph, racing, not drafting
12070	11.0	Running	Running, 7 mph (8.5 min/mile)
12030	8.3	Running	Running, 5 mph (12 min/mile)
12029	6.0	Running	Running, 4 mph (15 min/mile)
18230	9.8	Water activities	Swimming laps, freestyle, fast, vigorous effort
18260	10.3	Water activities	Swimming, breaststroke, general, training or competition
18270	13.8	Water activities	Swimming, butterfly, general
18240	5.8	Water activities	Swimming laps, freestyle, front crawl, slow, light or moderate effort
02054	3.5	Conditioning exercise	Resistance (weight) training, multiple exercises, 8–15 repetitions at varied resistance
02050	6.0	Conditioning exercise	Resistance training (weight lifting – free weight, nautilus or universal-type), power lifting or body building, vigorous effort (Taylor Code 210)
02074	12.0	Conditioning exercise	Rowing, stationary, 200 W, very vigorous effort
02073	8.5	Conditioning exercise	Rowing, stationary, 150 W, vigorous effort
02010	7.0	Conditioning exercise	Bicycling, stationary, general
02013	8.8	Conditioning exercise	Bicycling, stationary, 101–160 W, vigorous effort
15590	7.0	Sports	Skating, roller (Taylor Code 360)
15592	9.8	Sports	Rollerblading, in-line skating, 17.7 km/h (11.0 mph), moderate pace, exercise training
15593	12.3	Sports	Rollerblading, in-line skating, 21.0–21.7 km/h (13.0–13.6 mph), fast pace, exercise training
19140	13.5	Winter activities	Skiing, cross-country, biathlon, skating technique

Adapted from Ainsworth et al. [12].

Athletes' increased intakes of vitamins and/or minerals have little or no effect on physical performance indicators as long as the dietary intake of vitamins and minerals meets the prescribed RDI for a given country. Thus, athletes should consume diets that provide at least the RDI for all micronutrients [1,7]. Compliance of the intake of vitamins and micronutrients with the recommended daily intake was estimated according to the vitamin and mineral RDI approved in Lithuania [10]. Since the vitamin and mineral RDI depends on age and gender, the intake of these substances was expressed as a percentage of RDI (consumption/RDI $\times$ 100). By the intake of macronutrient and micronutrient levels, athletes were divided into groups: those consuming less than RDI (intake is less than RDI), those consuming the recommended amount (intake meets RDI), and those using more than RDI (intake exceeds RDI).

2.4. *Energy requirements*

Basal metabolic rate (BMR), daily energy expenditure (DEE), and training energy expenditure (TEE) of all subjects were estimated. BMR was calculated using the Harris & Benedict formulas [11]. The physical activity and lifestyle variables considered in this study were the 24-h period spent on regular and non-regular activities, sedentary activities, and sleeping habits as reported by the American Dietetic Association, Dietitians of Canada, and the American College of Sports Medicine [7]. Twenty-four-hour records of physical activity were collected on the same day participants recorded their dietary intake. These measures were supported by the studies of Ainsworth et al. [12] and data were managed according to the specific activity. Some normative data of basic organized physical activities, activity codes, and METS (in kcal/kg/h) for physical activities used in the study are presented in Table 3.

The metabolic equivalent intensity level (MET) was used; it should be understood as the ratio of work metabolic rate to a standard resting metabolic rate of 1.0 (4.184 kJ)/kg/h (or 3.5 mL O_2/kg/min). Participants recorded the 24-h period frequency and duration of the different activities expressed and the rate of energy expenditure for each activity were estimated. The physical activity level (PAL) of all athletes was calculated as the ratio between DEE and BMR as reported by FAO/WHO/UNU [13]. To estimate the total energy requirement (EER), the basal metabolic rate (BMR) was then multiplied by the appropriate activity factor (PAL).

2.5. *Statistical analysis*

Statistical data analysis was carried out using SPSS v. 15.0 statistical software. Conventional methods of descriptive statistics were applied for the analysis of research data: arithmetic means and standard deviation (SD) were calculated. The analysis of variance (ANOVA) method was used for the analysis of variables that met the assumptions of the application of parametric methods. The chi-square (χ^2) test and Fisher exact test were used for the categorical data analysis. The level of significance $\alpha = 0.05$ was used to check the hypothesis. The difference in results was considered statistically significant when a P value obtained was less than or equal to 0.05.

Table 4 – Anthropometric data of endurance athletes.

Anthropometric data	Sex	Rowers (n = 24)	Highway cyclists (n = 40)	Swimmers (n = 43)	Skiers (n = 14)	Biathletes (n = 20)	Long-distance runners (n = 5)
Age, years	M	17.4 ± 1.5	18.6 ± 2.6	16.9 ± 2.5	18.2 ± 3.0	16.9 ± 1.5	22.0 ± 1.4
	F	23.7 ± 1.5	17.0 ± 1.2	16.3 ± 2.7	15.6 ± 1.5	16.0 ± 1.0	27.3 ± 5.5
Height, cm	M	191.8 ± 6.1	179.8 ± 6.5	185.0 ± 7.4	179.2 ± 11.7	177.7 ± 6.8	174.6 ± 0.6
	F	176.8 ± 7.3	168.0 ± 4.0	166.7 ± 6.2	168.0 ± 6.6	163.8 ± 2.9	167.5 ± 8.8
Weight, kg	M	88.1 ± 8.8	70.7 ± 7.7	75.3 ± 10.5	71.6 ± 12.7	66.8 ± 8.6	64.0 ± 1.2
	F	71.4 ± 7.2	57.3 ± 3.4	56.7 ± 8.8	57.3 ± 9.5	58.1 ± 2.0	55.4 ± 7.4
LBM, kg	M	70.4 ± 5.0	59.0 ± 5.2	62.6 ± 7.1	59.8 ± 9.2	57.1 ± 5.6	55.2 ± 1.6
	F	54.6 ± 4.1	44.6 ± 3.4	44.7 ± 5.1	44.5 ± 6.0	43.8 ± 1.5	43.9 ± 5.8
LBM, %	M	80.0 ± 3.4	83.8 ± 3.8	83.5 ± 3.6	84.0 ± 5.2	85.9 ± 3.8	85.8 ± 0.1
	F	76.7 ± 4.0	77.7 ± 3.3	78.9 ± 5.1	78.0 ± 3.7	75.5 ± 0.2	79.3 ± 1.5
BF, kg	M	17.7 ± 4.7	11.6 ± 3.4	12.8 ± 4.0	11.8 ± 4.3	9.7 ± 3.6	8.8 ± 0.4
	F	16.8 ± 4.3	12.8 ± 2.0	12.0 ± 4.1	12.8 ± 3.9	14.2 ± 0.5	11.5 ± 1.8
BF, %	M	19.8 ± 3.6	16.2 ± 3.8	16.6 ± 3.7	16.0 ± 5.2	14.1 ± 3.8	13.7 ± 0.8
	F	23.3 ± 4.0	22.3 ± 3.3	20.7 ± 4.5	22.0 ± 3.7	24.5 ± 0.2	20.7 ± 1.5
BMI, kg/m^2	M	23.9 ± 1.9	21.8 ± 1.6	21.9 ± 1.9	22.2 ± 2.5	21.1 ± 1.9	21.0 ± 0.3
	F	22.8 ± 2.3	20.3 ± 0.8	20.3 ± 2.4	20.2 ± 1.9	21.7 ± 1.0	19.7 ± 0.9
MFMI	M	3.9 ± 1.0	5.3 ± 2.1	5.0 ± 1.7	6.8 ± 3.9	6.3 ± 2.4	5.9 ± 0.4
	F	3.1 ± 0.7	3.3 ± 0.8	3.8 ± 1.1	3.4 ± 0.8	2.9 ± 0.1	3.6 ± 0.4

Values are expressed as mean ± standard deviation.
LBM, lean body mass; MM, muscle mass; BF, body fat; BMI, body mass index; MFMI, muscle and fat mass index; M, males; F, females.

3. Results

3.1. *Characteristics of respondents*

The mean age of the athletes was 17.7 ± 2.9 years and the training status corresponded to 7.32 ± 3.4 years. The athletes were divided into groups by age and sex. There were 74% (n = 108) of men and 26% (n = 38) of women. The 14–18-year-old group was represented by 71.9% (n = 105) of the athletes, and the 19–31-year-old group, by 28.1% (n = 41) of the athletes. The research subjects were involved in the following sports: rowing (16.4%; n = 24), cycling (27.4%; n = 40), swimming (29.5%; n = 43), skiing (9.6%; n = 14), biathlon (13.7%; n = 20), and long-distance running (3.4%; n = 5). Athletes trained 6 days per week. The time of one workout was 130.0 ± 34.7 min and total exercise time was 174.9 ± 34.7 min per day.

Table 4 shows the characteristics of body weight, height and body mass components of the endurance athletes by the sport type and gender. The evaluation of athletes' body composition by sport and sex showed that the BMI of all athletes was within the normal range. Body composition indicators show that regardless of the gender and sport, the LBM of the athletes fell within normal limits.

In all female endurance athletes, fat mass was assessed as "optimal," but the assessment of MFMI showed that "average" is typical for female rowers, cyclists, swimmers, skiers and long-distance runners. Meanwhile, the MFMI of female biathletes is "low" due to relatively lower LBM and increased fat mass, which in professional sports is considered suboptimal body composition. In contrast to female athletes, the body composition of Lithuanian male endurance athletes corresponds to the requirements for highly trained athletes. "High" MFMI was specific to cyclists, swimmers, and long-distance runners, and "very high" MFMI was specific to skiers and biathletes.

3.2. *Dietary intake and energy expenditure*

Table 5 describes the estimated energy requirement (EER) and energy intake (EI) of athletes involved in different sports. The mean EER of endurance athletes was 4287.2 ± 949.6 kcal/day, and EI was 3396.8 ± 1027.5 kcal/day. In 77.4% of the athletes, EI did not fully cover energy expenditure. The assessment of EI in

Table 5 – Energy intake and energy expenditure of endurance athletes.

	Rowers (n = 24)	Highway cyclists (n = 40)	Swimmers (n = 43)	Skiers (n = 14)	Biathletes (n = 20)	Long-distance runners (n = 5)
EI, kcal Total	3833.2 ± 955.6	3372.2 ± 1073.3	3402.8 ± 1012.7	3080.2 ± 1216.6	3329.2 ± 879.9	2603.9 ± 477.0
M	3952.2 ± 945.7	3641.8 ± 879.8	3707.1 ± 748.9	3638.9 ± 908.6	3538.0 ± 759.3	2730.0 ± 667.8
F	2999.6 ± 605.6	2563.3 ± 1236.1	2772.5 ± 1212.7	2074.5 ± 1092.0	2145.8 ± 520.8	2519.9 ± 453.5
EER, kcal Total	5172.5 ± 698.7	3876.4 ± 674.6	4261.5 ± 960.2	3913.9 ± 1036.1	4269.1 ± 903.1	4661.9 ± 1155.3
M	5303.1 ± 637.6	4106.1 ± 618.4	4725.3 ± 749.4	4333.8 ± 1055.5	4338.9 ± 929.3	5414.3 ± 657.1
F	4258.0 ± 338.9	3187.5 ± 192.0	3300.8 ± 543.6	3158.2 ± 388.0	3873.6 ± 751.1	4160.3 ± 1228.8

Values are expressed as mean ± standard deviation.
EI, energy intake; EER, estimated energy requirement; M, males; F, females.

Table 6 – Macronutrient intake of endurance athletes.

Nutrients	Rowers (*n* = 24)	Highway cyclists (*n* = 40)	Swimmers (*n* = 43)	Skiers (*n* = 14)	Biathletes (*n* = 20)	Long-distance runners (*n* = 5)
PRO, g/kg	1.6 ± 0.4	1.8 ± 0.6	1.8 ± 0.6	1.6 ± 0.6	1.8 ± 0.6	1.6 ± 0.7
CHO, g/kg	4.6 ± 1.3*	6.4 ± 2.6*	5.6 ± 2.2	5.4 ± 1.9	5.7 ± 1.8	4.7 ± 1.5*
Dietary fiber, g	37.1 ± 14.0	32.1 ± 16.5	32.7 ± 16.6	32.6 ± 11.5	31.7 ± 13.7	29.7 ± 10.2
FAT, g/kg	2.3 ± 0.8	2.0 ± 0.7	2.3 ± 0.8	2.0 ± 0.8	2.4 ± 0.8	2.1 ± 0.5
FAT, %	44.8 ± 9.8**	35.9 ± 7.1**	41.0 ± 6.9**	38.1 ± 7.3	41.8 ± 4.6	43.1 ± 5.6**
SFA, %	15.1 ± 4.7	12.7 ± 3.3	13.1 ± 3.4	12.8 ± 4.1	14.5 ± 3.2	15.5 ± 0.9
PUFA, %	6.6 ± 2.5	5.1 ± 1.7*	6.6 ± 2.4	6.0 ± 1.2	6.6 ± 2.3	8.5 ± 4.0*
Omega-3 FA, %	0.4 ± 0.1	0.3 ± 0.1	0.4 ± 0.3	0.3 ± 0.1	0.3 ± 0.1	0.5 ± 0.2
Omega-6 FA, %	6.0 ± 2.4	4.7 ± 1.6*	6.1 ± 2.2	5.4 ± 1.3	6.1 ± 2.3	7.2 ± 4.4*
Cholesterol, mg	1045.3 ± 480.4*	703.3 ± 369.8*	785.0 ± 402.6	608.6 ± 367.4*	890.1 ± 403.1	752.0 ± 172.4

Values are expressed as mean ± SD.
PRO, protein; CHO, carbohydrates; FAT, fat; FA, fatty acids; SFA, saturated fatty acids; PUFA, polyunsaturated fatty acids.
* $P < 0.05$, significant differences by ANOVA.
** $P < 0.01$, significant differences by ANOVA.

Table 7 – Dietary intake of vitamins and minerals of endurance athletes.

Vitamins and minerals	Rowers (*n* = 24)	Highway cyclists (*n* = 40)	Swimmers (*n* = 43)	Skiers (*n* = 14)	Biathletes (*n* = 20)	Long-distance runners (*n* = 5)
Vitamin A, mg	1.3 ± 0.8	1.0 ± 0.4	1.0 ± 0.4	1.0 ± 0.8	1.3 ± 0.6	1.6 ± 1.4
% of RDI	139 ± 77	111 ± 46	109 ± 48**	109 ± 99	135 ± 62	205 ± 170**
Vitamin D, μg	3.4 ± 3.1	2.8 ± 2.2	3.2 ± 3.1	3.7 ± 2.5	3.7 ± 3.0	3.4 ± 2.7
% of RDI	69 ± 62	56 ± 45	64 ± 63	75 ± 50	75 ± 60	67 ± 55
Vitamin E, mg	23.9 ± 9.4	18.0 ± 9.1	24.7 ± 11.1	19.7 ± 8.4	23.5 ± 9.0	20.8 ± 7.4
% of RDI	239 ± 94	190 ± 103*	267 ± 115*	213 ± 81	240 ± 89	208 ± 74
Vitamin B_1, mg	2.1 ± 0.8	2.5 ± 1.6	2.3 ± 1.1	2.1 ± 1.5	2.0 ± 0.8	1.5 ± 0.5
% of RDI	136 ± 67	154 ± 88	164 ± 92	144 ± 113	136 ± 58	71 ± 26
Vitamin B_2, mg	2.7 ± 0.9	2.9 ± 1.5	2.9 ± 1.3	3.0 ± 1.8	2.7 ± 0.8	2.0 ± 0.4
% of RDI	163 ± 53	183 ± 94	188 ± 87	187 ± 115	164 ± 49	129 ± 16
Vitamin B_6, mg	3.8 ± 1.2	3.6 ± 1.5	3.9 ± 1.5	3.6 ± 1.3	3.8 ± 1.3	3.0 ± 0.8
% of RDI	205 ± 54	200 ± 80	226 ± 84	204 ± 67	208 ± 74	213 ± 68
Vitamin B_{12}, μg	5.4 ± 2.6	5.4 ± 2.6	5.3 ± 3.0	5.0 ± 3.5	4.9 ± 2.2	5.5 ± 3.6
% of RDI	180 ± 87	179 ± 89	176 ± 99	168 ± 116	165 ± 72	185 ± 120
Vitamin C, mg	102.0 ± 45.3	146.6 ± 102.9	152.7 ± 100.2	131.5 ± 126.6	130.3 ± 97.7	201.0 ± 213.4
% of RDI	170 ± 76	244 ± 172	269 ± 183	223 ± 210	217 ± 163	335 ± 356
Vitamin PP, mg	26.9 ± 9.1	30.6 ± 16.6	29.6 ± 11.5	27.4 ± 11.3	25.5 ± 9.1	25.9 ± 5.1
% of RDI	136 ± 54	155 ± 82	169 ± 65	151 ± 58	133 ± 45	108 ± 29
Folic acid, μg	251.7 ± 69.4	317.2 ± 183.5	273.4 ± 98.7	262.7 ± 143.4	253.6 ± 95.2	308.6 ± 63.3
% of RDI	113 ± 41	136 ± 72	141 ± 59	122 ± 62	118 ± 50	103 ± 21
Calcium, mg	1398.3 ± 399.1	1163.4 ± 484.2	1000.4 ± 503.9	1117.1 ± 543.2	1066.0 ± 406.7	1532.4 ± 1341.7
% of RDI	165 ± 54	135 ± 57	120 ± 58	133 ± 66	129 ± 53	153 ± 44
Magnesium, mg	493.1 ± 163.3	447.7 ± 190.8	502.5 ± 221	480.3 ± 225.6	464 ± 149.7	594.9 ± 334.6
% of RDI	134 ± 40	132 ± 61	144 ± 64	141 ± 63	128 ± 41	198 ± 112
Zinc, mg	18.8 ± 6.3	14.6 ± 5.1	15.9 ± 5.9	13.8 ± 5.6	15.2 ± 4.3	12.5 ± 2.2
% of RDI	133 ± 41	109 ± 37	112 ± 43	102 ± 38	109 ± 30	104 ± 18
Iron, mg	26.5 ± 7.4	27.1 ± 11.5	26.9 ± 10	26.4 ± 11.4	23.5 ± 6.9	19.9 ± 4.3
% of RDI	224 ± 65	228 ± 118	212 ± 95	209 ± 106	199 ± 72	156 ± 34
Potassium, mg	5389.5 ± 1759.4	4620.4 ± 2022.3	5137.6 ± 2179.5	5060.9 ± 2053.9	4756.8 ± 1638.8	5586.4 ± 3085.9
% of RDI	216 ± 70	185 ± 81	206 ± 87	202 ± 82	190 ± 66	223 ± 123
Phosphorus, mg	2102.5 ± 546.4	1816.1 ± 552.0	1864.7 ± 650.3	1740.0 ± 732.1	1841.0 ± 520.1	1646.4 ± 321.4
% of RDI	191 ± 43	168 ± 58	166 ± 65	157 ± 71	164 ± 49	183 ± 36
Sodium, mg	5910.8 ± 2324.3	3750.6 ± 1504.2	3909.3 ± 1409.1	4332.7 ± 2228.1	4162.0 ± 1089.2	5536.4 ± 3481.2
% of RDI	394 ± 155**	250 ± 100**	261 ± 94**	289 ± 149	277 ± 73**	369 ± 232
Cooper, mg	2564.0 ± 858.6	2410.6 ± 894.6	2722.2 ± 969.2	2397.6 ± 816.0	2324.7 ± 659.5	2450.3 ± 375.7
% of RDI	128 ± 43	121 ± 45	136 ± 48	120 ± 41	116 ± 33	123 ± 19
Manganese, mg	6.0 ± 2.8	4.9 ± 2.0	6.2 ± 3.1	5.1 ± 1.9	5.3 ± 2.1	3.9 ± 0.9
% of RDI	121 ± 55	98 ± 40	124 ± 63	102 ± 39	105 ± 41	78 ± 18

Values are expressed as mean ± standard deviation.
* $P < 0.05$, significant differences by ANOVA.
** $P < 0.001$, significant differences by ANOVA.

different groups of athletes showed that there were no differences ($F = 1.770$, $P = 0.123$). EI that is too low is specific to long-distance runners, rowers, swimmers, biathletes, skiers, and cyclists.

Table 6 shows the carbohydrate, protein and fat levels consumed by the athletes. The mean carbohydrate intake of the athletes was 5.6 ± 2.1 g/kg; protein, 1.7 ± 0.6 g/kg; and fat, 2.2 ± 0.8 g/kg. Energy values from carbohydrates, proteins, and fats in the diet accounted for 45.5% ± 8.3%, 14.3 ± 2.9% and 40.1 ± 7.8%.

The study found that the athletes used less than recommended amounts of carbohydrates (80.8%), PUFA (50.0%), omega-6 FA (41.8%), omega-3 FA (99.9%), and dietary fiber (33.6%). At the same time, they consumed too much fat (76.7%), SFA (84.9%), cholesterol (71.9%), and protein (48.6%). The athletes did not optimally supply their body with vitamins and minerals in food. Endurance athletes used 84.2% less vitamin D than the RDI, 47.3% less vitamin A, 33.6% less folic acid, 33.6% less vitamin B_1, 21.2% less vitamin B_{12}, 43.8% less manganese, 40.4% less zinc, 33.6% less calcium, and 29.5% less copper.

3.3. *Effects of sports type*

As indicated in Tables 6 and 7, differences were determined according to sport. Unlike rowers and long-distance runners, cyclists more often consumed the recommended amount of carbohydrates ($F = 2.471$, $P = 0.035$), less fat ($F = 5.340$, $P < 0.0001$), and insufficient PUFA ($F = 3.595$, $P = 0.004$) and omega-6 FA ($F = 3.131$, $P = 0.010$). Regardless of the excess fat found in the diets of swimmers, the amount of fat-soluble vitamin A they consumed was lower than the RDI ($F = 2.582$, $P = 0.029$). It should be noted that almost all athletes exceeded the recommended intake of cholesterol and sodium, but rowers were remarkable for the consumption of cholesterol (1045.3 ± 480.4 mg) exceeding the recommended rate by over 2 times ($F = 3.143$, $P = 0.010$) and sodium intake (5910.8 ± 2324.3 mg) being almost 4 times higher ($F = 5.766$, $P < 0.0001$).

3.4. *Effects of gender and age*

Table 8 shows the intake of EI and nutrients of athletes according to gender and age. Male athletes compared with

Table 8 – Distribution of athletes depending on energy and macronutrient intake (by sex and age).

Nutrients	Sex			Age		
	Males, % (*n*)	Females, % (*n*)		14–18 years % (*n*)	19–31 years % (*n*)	
EI, kcal						
Less than RDI	76.9 (83)	78.9 (30)	$\chi^2 = 0.071$,	73.3 (77)	87.8 (36)	$\chi^2 = 3.530$,
Meets RDI	23.1 (25)	21.1 (8)	P = 0.791	26.7 (28)	12.21 (5)	P = 0.060
PRO, g/kg						
Less than RDI	23.1 (25)	47.4 (18)	$\chi^2 = 8.687$,	30.5 (32)	26.8 (11)	$\chi^2 = 13.427$,
Meets RDI	22.2 (24)	21.1 (8)	df = 2,	14.3 (15)	41.5 (17)	df = 2,
Exceeds RDI	54.6 (59)	31.6 (12)	P = 0.012	55.2 (58)	31.7 (13)	P = 0.001
CHO, g/kg						
Less than RDI	81.5 (88)	78.9 (30)	$\chi^2 = 1.852$,	76.2 (80)	92.7 (38)	$\chi^2 = 5.175$,
Meets RDI	13.9 (15)	10.5 (4)	df = 2,	16.2 (17)	4.9 (2)	df = 2,
Exceeds RDI	4.6 (5)	10.5 (4)	P = 0.396	7.6 (8)	2.4 (1)	P = 0.075
Dietary fiber, g						
Less than RDI	23.1 (25)	63.2 (24)	$\chi^2 = 20.180$,	32.4 (34)	36.6 (15)	$\chi^2 = 2.233$,
Meets RDI	76.9 (83)	36.8 (14)	P < 0.0001	67.6 (71)	63.4 (26)	P = 0.628
FAT, %						
Less than RDI	0.9 (1)	2.6 (1)	$\chi^2 = 0.731$,	1.0 (1)	2.4 (1)	$\chi^2 = 0.484$,
Meets RDI	21.3 (23)	23.7 (9)	df = 2,	21.9 (23)	22.0 (9)	df = 2,
Exceeds RDI	77.8 (84)	73.7 (28)	P = 0.693	77.1 (81)	75.6 (31)	P = 0.784
SFA, %						
Meets RDI	12.0 (13)	23.7 (9)	$\chi^2 = 2.979$,	14.3 (15)	17.1 (7)	$\chi^2 = 0.179$,
Exceeds RDI	88.0 (95)	76.3 (29)	P = 0.084	85.7 (90)	82.9 (34)	P = 0.672
Cholesterol, mg						
Meets RDI	20.4 (22)	50.0 (19)	$\chi^2 = 12.219$,	31.4 (33)	19.5 (8)	$\chi^2 = 2.073$,
Exceeds RDI	79.6 (86)	50.0 (19)	P < 0.0001	68.6 (72)	80.5 (33)	P = 0.149
PUFA, %						
Less than RDI	47.2 (51)	57.9 (22)	$\chi^2 = 1.903$,	49.5 (52)	51.2 (21)	$\chi^2 = 4.064$,
Meets RDI	45.4 (49)	39.5 (15)	df = 2,	46.7 (49)	36.6 (15)	df = 2,
Exceeds RDI	7.4 (8)	2.6 (1)	P = 0.386	3.8 (4)	12.2 (5)	P = 0.131
Omega-6 FA, %						
Less than RDI	41.7 (45)	42.1 (16)	$\chi^2 = 0.750$,	41.9 (44)	41.5 (17)	$\chi^2 = 0.526$,
Meets RDI	45.4 (49)	50.0 (19)	df = 2,	47.6 (50)	43.9 (18)	df = 2,
Exceeds RDI	13.0 (14)	7.9 (3)	P = 0.687	10.5 (11)	14.6 (6)	P = 0.768
Omega-3 FA, %						
Less than RDI	99.1 (107)	100.0 (38)	P = 0.739	100.0 (105)	97.6 (40)	P = 0.280
Meets RDI	0.9 (1)	0.0 (0)		0.0 (0)	2.4 (1)	

PRO, protein; CHO, carbohydrates; FAT, fat; FA, fatty acids; SFA, saturated fatty acids; PUFA, polyunsaturated fatty acids; RDI, recommended daily intake.

Table 9 – Distribution of athletes (in percent) depending on vitamin intake (by sex and age).

Vitamins	Sex			Age		
	Males, % (*n*)	Females, % (*n*)		14–18 years % (*n*)	19–31 years % (*n*)	
Vitamin A						
Less than RDI	42.6 (46)	60.5 (23)	χ^2 = 3.627,	49.5 (52)	41.5 (17)	χ^2 = 0.769,
Meets or exceeds RDI	57.4 (62)	39.5 (15)	P = 0.057	50.5 (53)	58.5 (24)	P = 0.381
Vitamin D						
Less than RDI	83.3 (90)	86.8 (33)	χ^2 = 0.261,	84.8 (89)	82.9 (34)	χ^2 = 0.075,
Meets or exceeds RDI	16.7 (18)	13.2 (5)	P = 0.610	15.2 (16)	17.1 (7)	P = 0.789
Vitamin E						
Less than RDI	4.6 (5)	13.2 (5)	P = 0.083	4.8 (5)	12.2 (5)	P = 0.111
Meets or exceeds RDI	95.4 (103)	86.8 (33)		95.2 (103)	87.8 (36)	
Vitamin C						
Less than RDI	17.6 (19)	15.8 (6)	χ^2 = 0.064,	17.1 (18)	17.1 (7)	χ^2 < 0.0001,
Meets or exceeds RDI	82.4 (89)	84.2 (32)	P = 0.800	82.9 (87)	82.9 (34)	P = 0.992
Vitamin B_1						
Less than RDI	28.7 (31)	47.4 (18)	χ^2 = 4.392,	21.9 (23)	63.4 (26)	χ^2 = 22.786,
Meets or exceeds RDI	71.3 (77)	52.6 (20)	P = 0.036	78.1 (82)	36.6 (15)	P < 0.0001
Vitamin B_2						
Less than RDI	6.5 (7)	31.6 (12)	P < 0.0001	17.1 (18)	2.4 (1)	χ^2 = 5.632,
Meets or exceeds RDI	93.5 (101)	68.4 (26)		82.9 (87)	97.6 (40)	P = 0.018
Vitamin B_6						
Less than RDI	0.9 (1)	13.2 (5)	P = 0.005	5.7 (6)	0 (0)	P = 0.133
Meets or exceeds RDI	99.1 (107)	86.8 (33)		94.3 (99)	100 (41)	
Vitamin B_{12}						
Less than RDI	12.0 (13)	47.4 (18)	χ^2 = 20.981,	23.8 (25)	14.6 (6)	χ^2 = 1.484,
Meets or exceeds RDI	88.0 (95)	52.6 (20)	P < 0.0001	76.2 (80)	85.4 (35)	P = 0.223
Folic acid						
Less than RDI	27.8 (30)	50.0 (19)	χ^2 = 6.225,	24.8 (26)	56.1 (23)	χ^2 = 12.985,
Meets or exceeds RDI	72.2 (78)	50.0 (19)	P = 0.013	75.2 (79)	43.9 (18)	P < 0.0001

RDI, recommended daily intake.

female athletes (54.6% vs. 31.6%; *P* = 0.012) and 14–18-year-old athletes compared with 19–31-year-old athletes (55.2% vs. 31.7%; *P* = 0.001) more often consumed an amount of protein that exceeded the recommended levels (>1.6 g/kg of body weight). The recommended amount of protein (1.2–1.6 g/kg of body weight) was more often consumed by all the athletes than young athletes (41.5% vs. 14.3%). In addition, the diets of female athletes (47.4%) and athletes 14–18 years old (30.5%) often lacked protein.

While excess fat was found in the diets of both men and women, in contrast to male athletes, the diets of female athletes rarely exceeded the recommended intake of cholesterol (79.6% vs. 50.0%; *P* < 0.0001). It was found that more women than men (63.2% vs. 23.1%; *P* < 0.0001) consumed less than the recommended amount of dietary fiber.

Tables 9 and 10 evaluate the consumption of vitamins and minerals according to the gender and age of athletes. It was found that female athletes more often than male athletes consumed quantities of vitamins and micronutrients lower than the RDI: B_1 (47.4% vs. 28.7%; *P* = 0.036), B_2 (31.6% vs. 6.5%; *P* < 0.0001), B_6 (13.2% vs. 0.9%; *P* = 0.005), B_{12} (47.4% vs. 12.0%; *P* < 0.0001), folic acid (50.0% vs. 27.8%; *P* = 0.013), potassium (26.3% vs. 1.9%; *P* < 0.0001), calcium (55.3% vs. 25.9%; *P* = 0.001), phosphorus (34.2% vs. 1.9%; *P* < 0.0001), iron (36.8% vs. 0.0%; *P* < 0.0001), manganese (68.4% vs. 35.2%; *P* < 0.0001), copper (55.3% vs. 20.4%; *P* < 0.0001) and zinc (71.1% vs. 29.6%; *P* < 0.0001). According to age, it was found that older athletes were more likely than younger athletes to use quantities of vitamin B_1 (63.4% vs. 21.9%; *P* < 0.0001) and folic acid (56.1% vs. 24.8%; *P* < 0.0001) lower than the RDI. Meanwhile, 14–18-year-old athletes more often than 19–31-year-old athletes consumed quantities of vitamin B_2 (17.1% vs. 2.4%; *P* = 0.018), phosphorus (14.3% vs. 0.0%; *P* = 0.005) and magnesium (31.4% vs. 12.2%; *P* = 0.017) lower than the RDI.

4. Discussion

The evaluation of the body composition of athletes by sport and sex showed that the BMI and LBM of all athletes varied within the normal range. Athletes having fat mass that was too low were not found. The body composition of male athletes fully complies with requirements. Meanwhile, the fat mass of female athletes was assessed as "optimal/sufficient," but their MFMI was assessed as "moderate" and did not completely meet the requirements for the body composition of elite athletes.

Proper diet is a key factor for adaptation to physical loads. One of the most important dietary requirements for endurance athletes is an optimum supply of carbohydrates. Carbohydrate intake per day should amount to 7–12 g/kg of body weight [7]. The average carbohydrate consumption of the Lithuanian endurance athletes was only 5.6 g/kg of body weight. According to the sport, cyclists stood out as consuming a greater amount of carbohydrates with food (6.4 g/kg of body weight). Differences were observed when comparing our findings with the carbohydrate consumption of endurance athletes in other countries. Highly trained Lithuanian swimmers consume

Table 10 – Distribution of athletes (in percent) depending on mineral intake (by sex and age).

Minerals	Sex			Age		
	Males, % (n)	Females, % (n)		14–18 years % (n)	19–31 years % (n)	
Sodium						
Less than RDI	0.0 (0)	5.3 (2)	P = 0.066	1.0 (1)	2.4 (1)	P = 0.484
Meets or exceeds RDI	100 (108)	94.7 (36)		99.0 (104)	97.6 (40)	
Potassium						
Less than RDI	1.9 (2)	26.3 (10)	P < 0.0001	10.5 (11)	2.4 (1)	P = 0.099
Meets or exceeds RDI	98.1 (106)	73.7 (28)		89.5 (94)	97.6 (40)	
Calcium						
Less than RDI	25.9 (28)	55.3 (21)	χ^2 = 10.850,	29.5 (31)	43.9 (18)	χ^2 = 2.734,
Meets or exceeds RDI	74.1 (80)	44.7 (17)	P = 0.001	70.5 (74)	56.1 (23)	P = 0.098
Magnesium						
Less than RDI	25.0 (27)	28.9 (11)	χ^2 = 0.227,	31.4 (33)	12.2 (5)	χ^2 = 5.665,
Meets or exceeds RDI	75 (81)	71.1 (27)	P = 0.633	68.6 (72)	87.8 (36)	P = 0.017
Phosphorus						
Less than RDI	1.9 (2)	34.2 (13)	P < 0.0001	14.3 (15)	0.0 (0)	P = 0.005
Meets or exceeds RDI	98.1 (106)	65.8 (25)		85.7 (30)	100.0 (41)	
Iron						
Less than RDI	0.0 (0)	36.8 (14)	P < 0.0001	11.4 (12)	4.9 (2)	P = 0.188
Meets or exceeds RDI	100 (108)	63.2 (24)		88.6 (93)	975.1 (39)	
Manganese						
Less than RDI	35.2 (38)	68.4 (26)	χ^2 = 12.612,	41.0 (43)	51.2 (21)	χ^2 = 1.262,
Meets or exceeds RDI	64.8 (70)	31.6 (12)	P < 0.0001	59.0 (62)	48.8 (20)	P = 0.261
Cooper						
Less than RDI	20.4 (22)	55.3 (21)	χ^2 = 16.471,	30.5 (32)	26.8 (11)	χ^2 = 0.189,
Meets or exceeds RDI	79.6 (86)	44.7 (17)	P < 0.0001	69.5 (73)	73.2 (30)	P = 0.664
Zinc						
Less than RDI	29.6 (32)	71.1 (27)	χ^2 = 20.030,	44.8 (47)	29.3 (12)	χ^2 = 2.939,
Meets or exceeds RDI	70.4 (76)	28.9 (11)	P < 0.0001	35.2 (58)	70.7 (29)	P = 0.086

RDI, recommended daily intake.

more carbohydrates than athletes in other countries [14]. On the other hand, cyclists and long distance runners in Lithuania consume fewer carbohydrates than endurance athletes in other countries [15,16]. Regardless of this, compliance with recommended carbohydrate consumption was found only among endurance athletes in South Africa, Spain, Australia and Poland [4,17–20].

When an insufficient amount of carbohydrates is continuously received with the diet, this may slow adaptation to lengthy physical loads [21] and weaken the immune system [2]. Muscle glycogen stores that are not fully replenished between training sessions require more effort from the central nervous system during physical exercise and are an overtraining risk factor [2]. In addition, endurance athletes overcome physical loads every day and are trained in high-intensity work for longer than 3–4 h a day. During high-intensity workloads and/or long-term physical exercise, the main source of muscle energy is the glycogen reserves in the muscles. Insufficient carbohydrate consumption can lead to a quick onset of a feeling of fatigue during exercise and poorer aerobic performance [22].

Protein deficiency is found quite rarely in the diet of endurance athletes of other countries [23]. We have received conflicting results showing that as many as one-third (29.5%) of Lithuanian endurance athletes use less than the recommended amount of protein. An amount of protein corresponding to the recommended 1.2–1.6 g/kg of body weight is used by only 22.0% of Lithuanian endurance athletes. On the other hand, 49.0% of our surveyed athletes consume more protein than 1.6 g/kg of body weight. Similarly, excessive protein (>1.6 g/kg of body weight) consumption was found among many other endurance athletes in different countries [14,15,17–19,23,24]. Protein intake greater than 1.6 g/kg of body weight can be considered rational since during long-term intensive physical loads the oxidation of branched-chain amino acids covered 1–6% of energy expenditure [1]. In addition, after endurance exercises muscle protein synthesis is associated with muscle restoration processes and at the same time with mitochondrial and sarcoplasmic protein synthesis when muscle hypertrophy is not encouraged [25].

We found that protein intake depends on the gender and age of the endurance athletes. Males (54.6%) and 14–18-year-old athletes (55.2%) consumed more than the recommended protein content (>1.6 g/kg of body weight), but the protein content in the diet of Lithuanian female athletes (47.4%) was frequently below recommended levels (<1.2 g/kg of body weight). According to some authors, the demand of the bodies of highly trained female athletes for protein is 15%–20% lower than the demand of the bodies of such male athletes, but separate protein recommendations according to the age or sex of athletes have not been published [3].

Due to the excessive dietary intake of fat in 70% of Lithuanian endurance athletes, the consumption of fat, cholesterol, and SFA is higher than recommended. The most fat is consumed by rowers and long-distance runners. Excessive fat consumption leads to large amounts of SFA and cholesterol levels in the diets of the athletes surveyed. A cholesterol level exceeding recommended intake as much as 2 times was found in the diet of rowers. However, it is male athletes more often than female athletes who consume quantities of cholesterol higher than those recommended.

In comparing the fat consumption of the athletes training their aerobic capacity of Lithuanian endurance athletes with athletes from other countries, one can see that the fat content in the diet of swimmers and rowers of other countries is higher than recommended and is similar to the fat content in the diets of the athletes we analyzed [4,26]. Compared with our study, significantly lower fat intake was found among triathletes [5] and cyclists of other countries [17]. Unlike in foreign countries [5,27], higher than recommended cholesterol content was found in the diets of the athletes we tested. It should be noted that increased fat intake accompanied by insufficient physical activity is associated with the risk of cardiovascular diseases and obesity. Meanwhile, when experiencing daily intensive physical loads and/or long-term aerobic training, the higher consumption of fat, SFA, and cholesterol is not linked with a higher fat mass or cholesterol levels in the blood of athletes but has a relationship with the body's levels of homocysteine, which has been linked to cardiovascular diseases [28]. It should be also noted that the diet of Lithuanian endurance athletes does not have enough PUFA. Less than half (42%) of athletes receive an insufficient amount of omega-6 FA with their diet, and the majority of athletes (99.4%) receive an insufficient amount of omega-3 FA.

On the other hand, although well-trained highly skilled endurance athletes' bodies adapt better to oxidize more fat content, a higher fat/very low-carbohydrate diet is not recommended for athletes. Research shows that in order to improve the entire body's fat oxidation and reduce glycogen utilization during exercise, longer (1.5–2 months) and shorter (4–7 days) high fat and very low-carbohydrate diets disrupt athletes' stamina and recovery after exercise and slow the adaptation to physical workloads [21].

Besides that, it was determined that changes at the cellular level are encouraged in athletes' bodies when athletes train on the special Train Low exercise regimen for 3–10 weeks with low muscle glycogen or low exogenous glucose in the body, i.e., many genes responsible for the body's adaptation to physical workloads, transcription, mitochondrial biogenesis, and the promotion of the oxidation of fat in the body [21]. However, the relationship between changes taking place in an athlete's cells and functional changes in the entire body is not always determined. Functional changes in the entire body are not always dependent on the changes in an isolated muscle. Muscle function is only one of the factors that determine the physical performance indicators of athletes. Muscle work clearly influences other systems of the body, including the central nervous system (CNS). The speed and intensity of athletic performance and how much CNS effort exercise takes to overcome fatigue during sports activities depend on CNS activity [29]. Therefore, lack of endogenous and/or exogenous carbohydrate availability in an athlete's body can disrupt CNS adaptation to intense and/or long-term exercise and should not result in rapid CNS fatigue. Hence, at this time there is not enough scientific evidence to make useful recommendations for what exercises would be useful for athletes with insufficiently restored glycogen levels in their muscle or with insufficient availability of exogenous carbohydrates in the body. In addition, athletes training with small quantities of endogenous carbohydrate stores do not achieve better sports performance [29]. Hence, it is irrational to recommend low-carbohydrate diets to highly skilled Lithuanian endurance athletes, except in special cases and only at the beginning of the workout cycle, when physical workloads are more manageable with lower intensity work and under the supervision of health professionals [29]. In summary, highly skilled Lithuanian endurance athletes need to reduce fat intake and increase dietary carbohydrates in the main preparatory period before a competition.

In Lithuania, as in other countries, regardless of the sports in which athletes are involved and the sex and age of athletes, their diet has an insufficient quantity of vitamin D [30]. The specific risk group is female endurance athletes because of improper nutrition. A large number of the female athletes we investigated do not receive the recommended dietary vitamins B_1, B_2, B_6, B_9 and B_{12} and the minerals potassium, calcium, iron and zinc. The results of our study coincide with research on athletes' nutrition in other countries. Like the athletes we observed, the athletes of other countries do not consume the recommended levels of micronutrients with their food: calcium [4,5,30], iron [5,24,31], vitamin E [5,32], vitamin B_1 and folic acid [4,5,24,30]. In order to optimize the nutrition of Lithuanian endurance sports athletes, it is necessary to take into account International Olympic Committee recommendations [6]. To prevent osteoporosis, Lithuanian female athletes are recommended to consume additional calcium and vitamin D. In order to strengthen the immune system and to compensate for the loss of copper with sweat [1], the use of additional amounts of zinc and copper is recommended. Iron deficiency in the body is associated with the inadequate nutrition of female endurance athletes, and therefore they are recommended to consume 70% more iron than the RDI [6]. In addition, Lithuanian female endurance athletes more often than males receive insufficient dietary intake of some B group vitamins. Without receiving enough vitamin B_1 with food, the body accumulates pyruvate and produces more lactate, which results in faster onset of fatigue during daily workouts [1]. Even though physical work capacity indicators do not improve with the additional use of vitamin B_1, B_2, B_6 and B_{12} food supplements, there is an increase in the level of the neurotransmitter serotonin in the brain, improving mood and alertness. Using complex supplements of vitamins B_6, B_{12}, and folic acid reduces the levels of the biomarker homocysteine, which increases due to high physical loads in the body of athletes and lead to cardiovascular diseases [1].

5. Conclusions

One-third of Lithuanian endurance athletes did not get the recommended amount of protein, and 80% did not consume sufficient carbohydrates with their meals. In fact, excessive fat intake leads to an excess of saturated fatty acids and cholesterol in the diet of endurance athletes. The nutritional profile of athletes was more determined by gender and age than by the type of sports. Particular attention should be paid to female athletes because the quantities of carbohydrates; dietary fiber; protein; omega-3 fatty acids; vitamins B_1, B_2, B_6, B_9 and B_{12}; potassium; calcium; phosphorus; iron; manganese; and zinc in their diet were lower than the RDI.

6. Recommendations

Lithuanian high-performance endurance athletes do not meet the nutritional recommendations and thus cannot adapt to large-scale, long-term endurance exercise. The diet of highly trained endurance athletes must be optimized, adjusted and individualized.

Conflict of interest

The authors declare that they have no competing interests.

Acknowledgments

We hereby express our acknowledgment to the Lithuanian Olympic Sports Centre and Lithuanian Sports Medicine Centre for their assistance in performing the athlete body composition and nutritional survey.

REFERENCES

[1] Kreider RB, Wilborn CD, Taylor L, Cambel B, Almada AL, Collins R, et al. ISSN exercise and sport nutrition review: research and recommendations. J Int Soc Sports Nutr 2010;7:7. Available from: http://www.jissn.com/content/7/1/7.
[2] Burke LM. Fueling strategies to optimize performance: training high or training low? Scand J Med Sci Sports 2010;20:48–58.
[3] Tarnopolsky M. Females and males: should nutritional recommendations be gender specific? Schweiz Z Med Traumatol 2003;51:39–46.
[4] Łagowska K, Jeszka J. Are young female athletes at risk of amenorrhea? An analysis of body composition and nutritional and endocrine factors. Acta Sci Pol Technol Aliment 2011;10:223–32.
[5] Bam S. Body composition, dietary intake and supplement use among triathletes residing in the Western Cape region. S Afr J Sports Med 2011;23:3.
[6] International Olympic Committee (IOC). Position stand: female athlete, triad; 2009, Available from: http://www.olympic.org/documents/reports/EN/en_report_917.pdf.
[7] American Dietetic Association, Dietitians of Canada, American College of Sports Medicine, Rodriguez NR, Di Marco NM, Langley S. American College of Sports Medicine position stand. Nutrition and athletic performance. Med Sci Sports Exerc 2009;41:709–31.
[8] Skernevičius J, Raslanas A, Dadelienė R. Sporto mokslo tyrimų metodologija [Methodology of sports science research]. In: Skurvydas A, Skarbalius A, Milašius K, editors. Fizinio išsivystymo tyrimai. Antropometrija. 1st ed. Vilnius: Lithuanian University of Educational Sciences Press; 2004. p. 51–8.
[9] Sučilienė S, Abaravičius A. Maisto produktų sudėtis [Composition of food products]. Vilnius: Ministry of Health of the Republic of Lithuania; 2002.
[10] Rekomenduojamos paros maistinių medžiagų ir energijos normos [Recommended daily intakee of nutrients and energy]. Valstybės žinios, vol. 102–2936. Vilnius: Ministry of Health of the Republic of Lithuania; 1999.
[11] Harris J, Benedict F. A biometric study of basal metabolism in man. Philadelphia, PA: Lippincott; 1919.
[12] Ainsworth BE, Haskell WL, Herrmann SD, Meckes N, Basset DR, Todor-Locke C, et al. Compendium of physical activities: a second update of codes and MET values. Med Sci Sports Exerc 2011;43:1575–81.
[13] FAO/WHO/UNU. Human energy requirements: principles and definitions. Report of a Joint FAO/WHO/UNU Expert Consultation; 2001, Available from: ftp://ftp.fao.org/docrep/fao/007/y5686e/y5686e00.pdf [accessed 05.03.15].
[14] Papadopoulou S, Xyla E, Grammatikopoulou M, Hassapidou M. Nutrition intakes and practices of marathon swimmers. Br J Sports Med 2011;45:e1.
[15] Vogt S, Heinrich L, Schumacher YO, Grosshauser M, Blum A, König D, et al. Energy intake and energy expenditure of elite cyclists during preseason training. Scand J Med Sci Sports 2010;20:609–18.
[16] Barrack MT, Van Loan M, Rauh MJ, Nichols JF. Physiologic and behavioural indicators of energy deficiency in female adolescent runners with elevated bone turnover. Am J Clin Nutr 2010;92:652–9.
[17] De Sousa MV, Altimari LR, Okano AH, Coelho CF, Altimari JM, Teixeira O, et al. Pre-exercise high concentration carbohydrate supplementation impairs the performance on high intensity cycling exercise. Rev Andal Med Deporte 2010;3:133–7.
[18] Beis LY, Willkomm L, Ross R, Bekele Z, Wolde B, Fudge B, et al. Food and macronutrient intake of elite Ethiopian distance runners. J Int Soc Sports Nutr 2011;8:7.
[19] Bajerska J, Jagowska K, Jeszka J. The evaluation of nutritional habits, nutritional status triathlon's with and without menstrual disorders. Med Sport 2010;14:204–8.
[20] Cox GR, Snow RJ, Burke LM. Race-day carbohydrate intakes of elite triathletes contesting Olympic-distance triathlon events. Int J Sport Nutr Exerc Metab 2010;20:299–306.
[21] Hawley JA, Burke LM, Phillips SM, Spriet LL. Nutritional modulation of training-induced skeletal muscle adaptations. J Appl Physiol 2011;110:834–45.
[22] Jeukentrup AE. Nutrition for endurance sports: marathon, triathlon, and road cycling. J Sports Sci 2011;29:S91–9.
[23] Heaney S, O'Connor H, Gifford J, Naughton G. Comparison of strategies for assessing nutritional adequacy in elite female athletes' dietary intake. Int J Sport Nutr Exerc Metab 2010;20:245–56.
[24] Anschuetz S, Rodgers CD, Taylor AW. Meal composition and iron status of experienced male and female distance runners. J Exerc Sci Fit 2010;8:25–33.
[25] Burd NA, Tang JE, Moore DR, Philips SM. Exercise training and protein metabolism: influences of contraction, protein intake, an sex-based differences. J Appl Physiol 2009;106:1692–701.
[26] Compagnolo PBD, Gama CM, Petkowicz R. Dietary intake adequacy of adolescent athletes of 4 sports. R Bras Ci e Mov 2008;16:33–40.
[27] Martins MI, Rocha A. Caracterização antropométrica e consumo alimentar em atletas de remo. Aliment Hum 2010;16:37–46.
[28] Czajkowska A, Lutosławska G, Mazurek K, Ambroszkiewicz J, Żmijewski P. Plasma homocysteine levels, physical activity and macronutrient intake in young healthy men. Pediatr Endocrinol Diabetes Metab 2011;17:30–4.

[29] Hawley JA. Nutrition to manipulate adaptation to endurance type exercise training. Proc. 2011 MALLORCA sport nutrition conference; 2011. Available from: www.PowerBar.com and www.nestlenutrition-institute.org [accessed 05.03.15].
[30] Gábor A, Kovács VA, Fajcsák Z, Martos E. From guidelines to practice – nutritional habits of Hungarian elite athletes compared with the data from the 3rd National dietary survey. Acta Aliment 2010;39: 27–34.
[31] Łagowska K, Jan Jeszka J. The evaluation of nutritional habits and nutritional status of female athletes using and not using nutritional supplements. Med Sport 2011;15:51–5.
[32] Garcin M, Doussot L, Mille-Hamard L, Billat V. Athletes' dietary intake was closer to French RDAs than those of young sedentary counterparts. Nutr Res 2009;29:736–42.