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Nutrient intake of endurance runners with ovo-lacto-vegetarian diet and regular western diet

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Nährstoffzufuhr von Ultralangstreckenläufern mit ovo-lakto-vegetarischer und konventioneller Sportlerkost

Summary: During an endurance run (1 000 km in 20 days) it was investigated whether an ovo-lacto-vegetarian diet (OLVD) could cover the nutritional requirements of endurance athletes. A regular western diet (RWD) was used as reference. Both diets were offered with an energy content of 4 500 kcal per day and an energy percentage of carbohydrate:fat:protein of 60:30:10. The runners were divided into two dietary groups according to their usual dietary habits. The results of the 55 participants who completed the race show that runners from both groups had the same intake of energy, carbohydrate, fat and protein. Runners of the OLVD group consumed more dietary fiber and polyunsaturated fatty acids as well as less cholesterol. With the exception of sodium chloride and cobalamine, the intake of the calculated minerals and vitamins was higher in the OLVD and exceeded the official recommendations. This study shows that an OLVD with a high nutrient density is adequate to cover the nutritional requirements of endurance-athletes. The intake and absorption of iron should be monitored closely in all diet groups.

Zusammenfassung: Während eines Ausdauerlaufs (1 000 km in 20 Tagen) wurde untersucht, ob eine ovo-lakto-vegetarische Kost (OLVD) den Nährstoffbedarf von Ausdauersportlern decken kann. Als Vergleichskost diente eine konventionelle Kostform (RWD). Beide Kostformen wurden mit einem Energiegehalt von 4 500 kcal pro Tag und mit einem Nahrungsenergieanteil von Kohlenhydraten:Fett:Protein im Verhältnis von 60:30:10 angeboten. Die Läufer wurden – entsprechend ihrer üblichen Ernährungsgewohnheiten – in zwei Ernährungsgruppen eingeteilt. Die Ergebnisse der 55 Läufer, die das Ziel erreichten, zeigten, daß sich Läufer aus beiden Gruppen prozentual die gleiche Menge an Nahrungsenergie, Kohlenhydraten, Fett und Protein zuführten. Läufer der ovo-lakto-vegetarischen Gruppe nahmen mehr Ballaststoffe und mehrfach ungesättigte Fettsäuren sowie weniger Cholesterin auf. Mit Ausnahme von Natriumchlorid und Cobalamin war die Aufnahme der berechneten Mineralstoffe und Vitamine in der ovo-lakto-vegetarischen Gruppe höher und überschritten die offiziellen Nährstoffempfehlungen. Diese Studie zeigt, daß eine ovo-lakto-vegetarische Kost mit einer hohen Nährstoffdichte den Nährstoffbedarf eines Ausdauersportlers angemessen decken kann. Die Zufuhr und Resorption von Eisen bedarf bei jeder Kostform einer genauen Überwachung.

Key words: Vegetarian diet – endurance run – nutritional requirement – dietary survey

Schlüsselwörter: Vegetarische Ernährung – Ausdauerlauf – Nährstoffbedarf – Ernährungserhebung

Introduction

In recent years is has been found that endurance-athletes have a growing interest in vegetarian diets and that they follow different vegetarian dietary regimens (5, 23, 54,

55, 60, 64). While few endurance-athletes with vegetarian diets avoid all food of animal origin (vegan type), the majority of these athletes include dairy products and/or eggs in their daily diet (ovo-lacto-vegetarian type) (5, 54, 55).

The more restricted a diet, the more important is the knowledge of the athlete of how to make careful food selections for an adequate nutrient intake. For athletes potential problems of a strict vegan diet are a low energy intake, an insufficient intake of riboflavin, cobalamine, calcium, iron and zinc (13, 23, 42, 64). The consumption of dairy products prevents most of these problems, however, iron and zinc remain nutrients where there is a high risk of an inadequate intake for athletes on such diets (27, 32, 55).

For endurance-athletes one of the most important dietary recommendations is a high carbohydrate intake, with up to 70 % of calories derived from carbohydrates (15, 51). Vegetarian diets replace part of the food of animal origin with food of plant origin which results in a higher intake of carbohydrates and could consequently help to reach the recommendation. However, the exclusion of animal food could increase the risk of inadequate iron intake for athletes, especially in female runners (50, 55). In addition, the bulk of plant food in vegetarian diets is expected to cause an insufficient energy intake (11, 13, 42).

Despite the increasing number of athletes consuming vegetarian diets, there is to our knowledge only one study published which investigated the adequacy of the nutrient supply of vegetarian regimens for endurance-athletes (46). In order to assess the efficacy of an ovo-lacto-vegetarian diet in covering the nutritional requirements of runners, the nutrient intake by an ovo-lacto-vegetarian diet and that by a regular western diet were measured during an endurance run. In contrast to most studies which have concentrated on the nutrient intake of self-selected diets by athletes, this study focuses on the adequacy of a supplied vegetarian diet for the nutrient requirements of vigorously exercising athletes. Since there are no nutritional recommendations for athletes the RDA (41) were employed as well as the specific statements of the American Dietetic Association (3) and results of the literature as standard for having reached the nutritional requirements.

Methods and materials

The total distance of the run was 1000 km, crossing Germany from the north to the south in 20 days. The daily stages varied from 47–57 km and averaged 50 km. The runners started at 7 a.m. and had to complete the distance by 5 p.m. Runners were recruited by advertisements in various sport magazines. After a physical and medical examination, 110 runners were accepted to participate in this study.

Diet groups

Interviews and questionnaires were used to assess the usual dietary habits of the runners before the start of the study, because their normal diets were the basis for the inclusion in one or the other study group. The criteria for this differentiation included the total consumption of whole-grain-products, vegetables, salads, and fruits which was expected to be high (2–3 servings each per day) to be accepted into the ovo-lacto-vegetarian diet (OLVD) group. The consumption of about one serving of meat per week was tolerated within the criteria for the vegetarian group, because the intention of the study was not to investigate the nutritional *status* of vegetarian versus omnivorous endurance runners, but to focus on the problems of the vegetarian diet *during* the run. According to these results, runners were divided into either the regular western diet (RWD) group or the OLVD group.

During the study both diets were offered with an energy content of 18.8 MJ/d (4 500 Kcal/d) and a ratio of carbohydrate:fat:protein of 60:30:10 in energy percent. The diets had been composed and calculated in advance and were prepared according to these plans by trained personnel during the run. Runners were free to choose the amount and kind of food within their dietary group. There was no consumption of special "sport foods" high in energy and/or carbohydrates nor any supplementation.

Conventional recipes were used for the RWD. In order to reach the goal of the low-fat percentage only small servings of meat, cheese and sausages were offered, as well as breakfast cereals, fruits, salads, vegetables, juices and other low-fat foods. Processed foods like instant soups and desserts, candy bars, soft drinks and refined cereal products such as white bread and rice, etc. were included according to the dietary habits of the general population.

The main dishes within the OLVD consisted of freshly prepared soups, desserts, salads, pasta, rice and potato dishes in combination with vegetables. All cereal products, bread, pasta and rice were served as whole-grain products. Tea was not allowed in this group because of its known interference with the bioavailability of iron.

Assessment of nutrient intake

Trained personnel controlled the prescribed servings, served the food, and recorded the food intake of each runner on protocol sheets. After the run the protocols were coded for nutrient assessment. The data were calculated for macronutrients, vitamins, minerals including iron and zinc, using the microcomputer dietary analysis program "diet 2000w" (7) with Souci- Fachmann-Kraut as data base (56). In addition to the 700 food items listed in the program, it was supplemented with approximately 150 additional nutrient values and about another 150 new food items from different food tables (2, 14, 19, 26, 37, 44, 46). The nutrient contents of all processed foods were calculated from manufacturer's specifications and were also included in the microcomputer dietary analysis program.

Blood samples

On days 0 and 19, fasting blood samples were obtained for the determination of vitamin parameters. Immediately after collection, blood samples were packed in dry ice and sent to Hoffmann-LaRoche, Basel, where further analysis was kindly conducted (12, 61, 62).

Statistical analysis

The Mann-Whitney U-test for unpaired samples was used to determine statistically significant differences between the two groups. Although the Mann-Whitney U-test is calculated with the medians instead of the means, results are presented as means. Since it was assured that no major differences exist between the medians and the means, too much confusing data and an unclear presentation were avoided. All analyses were carried out using the SPSS-X statistical package (48).

Results

Of the initial 110 runners, 55 finished the complete distance of 1 000 km. General characteristics of the finishers show that in each dietary group 50 % of the participants completed the run (Table 1). Orthopedic problems were the most common reason for dropping out of the run. The kind of nutrition was not a reason to cause a cessation of the

run. Orthopedic problems, training condition, motivation and will-power played the major role in decisions to quit, and were independent of the dietary group of the runners.

Table 1. General characteristics of the 55 runners who finished the run (mean ± SD)

Characteristics	RWD	OLVD	RWD, male	OLVD, male	RWD, fem.	OLVD, fem.
Runners, n	30	25	23	19	7	6
Age, years	40.8 ± 11.2	46.2 ± 12.9	38.4 ± 12.8	46.2 ± 13.1	49.0 ± 7.7	46.5 ± 12.6
Weight, kg	68.4 ± 6.9	65.2 ± 5.2	271.4 ± 6.9	66.8 ± 5.7	58.2 ± 7.1	60.3 ± 4.4
Height, cm	172.6 ± 6.8	171.1 ± 5.4	175.6 ± 7.5	173.7 ± 6.0	162.9 ± 5.3	162.8 ± 3.9
VO_2max, ml O_2/kg/min	50.5 ± 7.9	49.5 ± 6.7	53.7 ± 5.8	51.7 ± 7.2	40.5 ± 6.4	43.6 ± 6.5
Training per week, km	82.5 ± 25.2	84.4 ± 21.9	85.0 ± 27.8	86.6 ± 26.8	74.3 ± 17.2	77.5 ± 7.6
Running time, min/d	354.8 ± 68.6	349.3 ± 65.8	333.3 ± 64.2	348.8 ± 66.1	425.4 ± 470.7	350.6 ± 66.4

RWD: regular western diet; OLVD: ovo-lacto-vegetarian diet

Nutrient intake

Energy: There was no difference in the energy intake between runners of the two diet groups (Table 2). The energy intake of about 4200 Kcal for the men of both groups and 3000 Kcal for the women was not enough to supply the energy requirements for the run, which resulted in an average weight loss of 1.7 kg for men and 2.1 kg for women corresponding to a reduction of body fat from 13.1 % to 10.5 % for men and 19.8 % to 17.1 % for women. Weight loss was similar for RWD and OLVD. Over the 20 days a gradual increase of the energy intake was observed in both groups. Divided into 5-day intervals, the energy intake of the RWD group rose significantly from 3385 Kcal (14.2 MJ) as a mean of the first 5 days, to 4421 Kcal (18.5 MJ) of the last 5-day interval ($p \leq 0.001$). The corresponding values for the OLVD group are 3325 Kcal (13.9 MJ) and 4671 Kcal (19.5 MJ), respectively ($p \leq 0.001$).

Table 2. Daily energy intake (mean ± SD)

Energy intake	RWD (n=30)	OLVD (n=25)	RWD, male (n=23)	OLVD, male (n=19)	RWD, fem. (n=7)	OLVD, fem. (n=6)
kcal	3968 ±565	3973 ±636	4273 ±876	4247 ±598	2967 ±599	3089 ±419
MJ	16.59 ±2.36	16.61 ±2.66	17.89 ±3.66	17.75 ±2.50	12.40 ±2.51	12.91 ±1.75

RWD: regular western diet; OLVD: ovo-lacto-vegetarian diet

Carbohydrate, fat and protein: The intake of the macronutrients indicated no significant difference between the two dietary groups (Table 3). For both groups, the energy percentage of carbohydrate:fat:protein was 57:31:12. Also, in both groups about 54 % of the total carbohydrate intake was derived from simple sugars and 41 % from polysaccharides. A more detailed analysis of the macronutrient intake revealed expected differences (Table 3). In the OLVD group intakes of dietary fiber, polyunsaturated fatty acids and plant protein were higher than in the RWD group, whereas the intakes of saturated fatty acids, cholesterol and animal protein were higher in the RWD group (Table 3). The P:S ratio in the RWD group was significantly lower (0.39) than the quotient of the OLVD group (0.63) ($p \leq 0.001$).

Table 3. Daily intake of nutrients and other food components (mean ± SD)

Components g	RWD	OLVD
Carbohydrates, total	559.2 ± 70.7	556.4 ± 90.2
Simple sugars	290 ± 87	306 ± 50
Fat	136.6 ± 33.9	135.8 ± 26.7
Protein, total	116.7 ± 17.3	118.1 ± 19.3
Animal protein	68.7 ± 12.6***	48.4 ± 9.8
Plant protein	48.7 ± 10.2***	67.6 ± 12.9
Dietary fiber	34.0 ± 6.2***	74.2 ± 7.6
Saturated fatty acids	52.2 ± 12.8	48.2 ± 10.9
Monounsaturated fatty acids	40.3 ± 10.2	40.3 ± 7.5
Polyunsaturated fatty acids	18.3 ± 8.0***	29.5 ± 9.4
Cholesterol, mg	424.7 ± 140.4***	278.5 ± 97.8

RWD: regular western diet; OLVD: ovo-lacto-vegetarian diet
* $p \leq 0.05$, ** $p \leq 0.005$, *** $p \leq 0.001$

Table 4. Daily intake of vitamins (mean ± SD)

Vitamins	RWD	OLVD	RWD[1)]	OLVD[1)]
Retinol, µg	513 ± 359**	645 ± 496	–	–
Carotenoids, mg	7.15 ± 5.91***	11.6 ± 7.27	–	–
Retinol equiv., µg	1124 – 1744**	1642 – 2636	144	215
Vitamin E, mg	18.0 ± 7.75***	42.1 ± 9.51	180	420
Thiamine, mg	1.98 ± 0.23***	2.85 ± 0.27	132	190
Riboflavin, mg	2.74 ± 0.39***	3.30 ± 0.47	161	194
Pyridoxine, mg	3.33 ± 0.51***	5.20 ± 0.61	167	260
Niacin equiv., mg	46.1 ± 3.8	46.1 ± 4.0	243	243
Biotin, µg	58.1 ± 10.9***	101 ± 14.0	100[2]	100[2)]
Pantothenic acid, mg	7.19 ± 1.08***	11.1 ± 1.39	100[2]	157[2)]
Folic acid, mg	335 ± 97.5***	530 ± 55.0	168	265
Cobalamine, µg	6.22 ± 1.75***	3.89 ± 1.16	311	195
Ascorbic acid, mg	301 ± 187***	446 ± 98.0	502	744

RWD: regular western diet; OLVD: ovo-lacto-vegetarian diet
* $p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$
[1)] % RDA, males, 25–50 years
[2)] estimated safe and adequate daily dietary intake

Vitamins: With the exception of niacin and cobalamin, all vitamins were consumed in higher amounts by the OLVD group (Table 4). For niacin there was no difference between the two dietary regimens, and cobalamin was the only vitamin which was supplied in higher amounts through RWD than through the OLVD (Table 4).

Based on the data derived from the analysis of serum vitamin levels in both groups the levels stayed within the normal range and showed no drastic changes neither through the extreme performance nor through the different dietary regimens.

Minerals: Of all minerals analyzed, only the intake of sodium and chloride was higher in the RWD group (Table 5). The salt (NaCl) intake calculated from these data resulted in 15.4 g/d for the RWD and 8.1 g/d for the OLVD. The OLVD led to a significant higher intake of all other measured minerals, including potassium, magnesium, calcium, phosphorus, as well as total iron and zinc (Table 5). The amount of total iron analyzed from animal and plant origin shows the characteristics for gender and the two diets (Table 6).

Table 5. Daily mineral intakes (mean ± SD)

	RWD	OLVD	RWD[1]	OLVD[1)]
Sodium, g	6.8 ± 1.6***	3.5 ± 0.6	–	–
Chloride, g	8.2 ± 1.2***	4.4 ± 0.9	–	–
Potassium, g	6.4 ± 0.8***	8.2 ± 0.6	183[2)]	234[2)]
Magnesium, mg	731 ± 75.1***	1126 ± 95.6	209	322
Calcium, g	1.97 ± 0.33***	2.77 ± 0.30	246	346
Phosphorus, g	2.41 ± 0.40***	3.24 ± 0.49	301	405
Iron, mg	26.2 ± 3.7***	33.6 ± 3.4	262	336
Zinc, mg	13.9 ± 2.6***	23.2 ± 3.8	93	155

RWD: regular western diet; OLVD: ovo-lacto-vegetarian diet
* $p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$
1) % RDA, males, 25–50 years
2) estimated safe and adequate daily dietary intake

Table 6. Daily iron intake and calculated iron absorption (mean ± SD)

Fe, mg	RWD (30)	OLVD (25)	RWD, male (23)	OLVD, male (19)	RWD, fem. (7)	OLVD, fem. (6)
Total iron	26.2 ± 3.7***	33.6 ± 3.4	28.2 ± 4.0***	35.7 ± 3.7	19.9 ± 3.3*	26.9 ± 3.0
Iron, plant sources	17.6 ± 2.9***	28.9 ± 3.3	18.5 ± 3.2***	30.8 ± 3.7	12.8 ± 2.6**	23.1 ± 3.0
Iron, animal sources	5.12 ± 1.73***	1.40 ± 0.43	5.29 ± 1.64***	1.47 ± 0.43	4.38 ± 1.58**	1.09 ± 0.30
calculated values (39):						
Heme iron	2.1	–	2.1	–	1.8	–
Non-heme iron	24.1	33.6	26.1	35.7	18.1	26.9
Absorbed iron	1.7	1.7	1.8	1.8	21.3	1.4

RWD: regular western diet; OLVD: ovo-lacto-vegetarian diet
* $p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$

Discussion

Dietary surveys always call for some compromises with regard to the exact recording of nutrient intakes (53, 58). However, because of the design of this study, a very high validity of the food-intake-data could be achieved. The composition of the recipes, the preparing of the meals, the serving sizes and the recording on prepared protocols were all carried out under controlled conditions by trained personnel, not by the participants in the study, as is usually the case. The effort put into the improvement of the data base of the nutrient program and the 20-day duration of the study also contribute to the high level of accuracy of the results. Nevertheless, there remain limitations due to incorrect human assessment and to insufficient data of nutrient tables. The results are as exact as possible and present the closest approach based upon the best information available (5).

The primary purpose of this study was to investigate whether an ovo-lacto-vegetarian diet can cover the nutritional requirements for endurance-athletes under the physical and mental stress of a 20-day endurance run. One of the unexpected results was that there was no difference between the two diets in the total energy intake, considering that the volume of the OLVD was larger than that of the RWD. Also no differences were observed in the total intake of fat, protein and carbohydrates.

The loss of body weight and the increasing *energy* intake towards the end of the race signify that the runners, irrespective of their diet, neglected the energy requirements in the beginning and then tried but could not make up for the former losses. The energy intake of the last 5-day interval can be regarded as in balance with the energy output and is similar to other study results (45). A further discussion of anthropometric results and the energy metabolism during the run is described in detail elsewhere (45). The data show that the consumption of an ovo-lacto-vegetarian diet up to 4 500 Kcal/d is not necessarily complicated by the high volume of plant food, as was speculated by others (11, 13).

No runner reported stomach upsets or other problems of the digestive tract. The fact that the participants were selected according to their usual high intake of plant food and dietary fiber was important in this regard. The intake of dietary fiber of the OLVD group with 19 g/1 000 Kcal is in agreement with results from other dietary surveys in the range of 14–23 g/1 000 Kcal by ovo-lacto vegetarians (1, 21, 22, 28, 29, 36). Because of the high energy intake the runners of the OLVD group consumed about 80 g/d of dietary fiber which, with regard to mineral absorption, should not be increased.

The American Dietetic Association recommends an intake of complex *carbohydrates* of about 50–55 % of the total energy intake, and only 10 % of the energy intake in form of simple carbohydrates for athletes (3). This corresponds to a ratio of complex to simple carbohydrates of about 80:20. In both groups of this study 54 % of the total carbohydrate intake resulted from simple carbohydrates, which agrees with the results of other studies describing relations of 40–50 % complex carbohydrates and 50–60 % refined and natural simple carbohydrates (8, 18, 47). All runners irrespective of their diet group consumed, on average, two servings of fruits and at least one serving of milk per day, with both food groups contributing to the high amount of simple carbohydrates but also having a high nutrient density. Desserts and candy bars within the RWD were less nutrient dense than those of the OLVD.

The overall *fat* intake of both groups has to be considered as low, compared to the fat intake of athletes as described in review articles (5, 9, 16, 43). The recommended dietary allowances of the USA (RDA) for the intake of polyunsaturated fatty acids (PUFA) is 7–10 % of the total energy intake (41). The PUFA intake of 7.8 energy percent of the OLVD group was within that range, whereas the RWD group reached 4.6

energy percent (Table 3). With 11.5 energy percent (OLVD) and 11.8 energy percent (RWD) in form of saturated fatty acids (SFA), both groups consumed more than the recommendation which calls for less than 10 % of total calories in form of SFA (41).

In both groups the mono-unsaturated fatty acids (MUFA) portion covered almost the emphasized third of the total fat consumption. With the daily energy intake of about 4 000 Kcal the OLVD group consumed less than 300 mg of cholesterol, while cholesterol intake in the RWD group exceeded the recommendation (425 mg/d). This could still be considered as low compared to other studies (6, 8, 52, 57). Because those reference values do not directly apply for athletes the small discrepencies should not be overestimated. The overall distribution of fatty acids in both groups can be regarded as good compared to the dietary habits of non-athletes as well as other athletes (16). The tendency of the OLVD to get closer to the recommendation than the RWD is noteworthy.

Changes in serum lipid levels depend on the intensity of the performance rather than on different dietary regimens. The serum lipid levels did not exceed the normal range nor were there significant differences between the two groups; these data are discussed elsewhere (40).

Of the food groups, snacks (candy bars, biscuits and other sweets) played an important role as a source for refined carbohydrates and fat. SARIS et al. (47) also found cakes, sweet pies, and cookies to be a major contributor to the total fat intake. The consumption of snack foods needs to be controlled carefully to assure a high nutrient quality and nutrient density of the athletes diets.

In both groups the intake of the measured *vitamins* exceeded the RDAs (41) (Table 4). The higher vitamin intake (exceptions: niacin and cobalamin) within the OLVD group indicates that the consumed foods had a higher nutrient density for most vitamins. In the case of thiamine, the consumption of whole-grain-products, with a high concentration of this vitamin, led to a higher thiamine intake than that resulting from the consumption of meat as the major thiamine source in the RWD group. Compared to studies investigating the vitamin intake of athletes with self-selected diets, the vitamin supply with the RWD was equal and with the OLVD exceeded the average vitamin intake by these athletes (25, 33, 43, 47, 59, 63, 66).

As with the vitamins, all measured *mineral* intakes in both groups surpassed the recommendations (41) (Table 5). With the exception of sodium chloride, the nutrient density for minerals of the OLVD was always higher than that of the RWD. Considering the loss of 2–4 l/d of sweat including 5–10 g sodium chloride (49), the overall intake of sodium chloride of 13–17 g/d (RWD) and 7–9 g/d (OLVD) cannot be regarded as high but did not cause obvious problems. The intake of potassium, magnesium and calcium reached the highest levels in the OLVD group, but was also higher in the RWD group than compared with the results of studies focusing on the nutrient intake of self-selected diets of endurance runners (33, 43, 52, 59, 66). The consumption of whole grain products and the high intake of vegetables and salads caused the significantly higher mineral supply in the OLVD.

Iron deficiency is a common problem for endurance-athletes, especially for female runners (17, 38, 50, 65). While inadequate blood levels of parameters of iron metabolism are often a problem even in athletes who include red meat in their diet, the risk for vegetarian athletes is even greater. In this study the intake of iron was higher in the OLVD group by men and women compared with the RWD group (Table 6). The main sources of iron in the vegetarian diet consisted of legumes, dried fruits, nuts, vegetables and whole grain products; any heme iron was excluded from the diet of these runners.

The high intake of vitamin C (446 mg/d) of the OLVD as well as the avoidance of tea

should have enhanced the absorption of non-heme iron, while phytates and dietary fibers may have reduced it. Assuming a 5 % iron absorption from plant food (39), the higher intake of iron by the vegetarians could have made up for the higher bioavailability of heme iron, knowing that bioavailability was probably disturbed by the physical exercise (Table 6).

Different data were obtained in a study by Snyder et al. (55), who investigated the dietary intake and iron status of female runners. They found that the vegetarian and non-vegetarian runners had about the same total intake of iron. The vegetarian group of that study could not compensate the decreased bioavailability of iron from plant food. This explains the lower concentrations of iron parameters for the vegetarian runners of the study by Snyder et al. (55).

In the study reported here similar results of the iron parameters were obtained for the two diet groups (49).

The concentrations of serum iron and serum ferritin, the most valid parameters of iron stores of the body, varied considerably during the race because of the physiological effects of the exercise (hemolysis, acute phase response, interleukin-1 action) (49). Therefore, these data do not contribute to the information about the iron status of the runners. The evaluation of biochemical parameters concerning the iron metabolism is discussed elsewhere in detail (49).

The iron status before the race (Table 7) shows the well known differences between males and females. The only significant difference between the two diet groups in regard to serum ferritin, is due to the self-selected diet of the participants before the study and indicates lower iron stores of the OLVD group.

Compared to the recommendations for non-athletes of about 5 mg iron/1 000 Kcal for men (41) the iron intake of the male participants with 6.6 mg/1 000 Kcal (RWD) and 8.4 mg/1 000 Kcal (OLVD) can be considered as satisfactory, although it is not known whether these concentrations are sufficient for optimal performances. The is close to the iron intake of 8.7 mg/1 000 Kcal of the female runners of the OLVD group recommendation of 9 mg iron/1 000 Kcal for women. The 6.7 mg/1 000 Kcal of the RWD group is definitely too low to cover the additional losses by hematuria, gastrointestinal bleeding and sweat caused by this intense physical exercise.

Judging the iron requirement and its metabolism remains difficult because of the various factors influencing absorption, interactions with other elements (like competition

Table 7. Hematological data of all runners before the race

	All runners (males)		All runners (females)	
	RWD (n=52)	OLVD (n=39)	RWD (n=8)	OLVD (n=11)
Erythrocytes, x10^6/µl	4.47 ± 0.24	4.51 ± 0.25	4.29 ± 0.31	4.38 ± 0.37
Hemoglobin, g/dl	14.2 ± 1.1	14.3 ± 0.8	13.7 ± 1.1	13.6 ± 1.4
MCH (HbE), pg	31.7 ± 1.7	31.7 ± 1.2	32.0 ± 1.8	31.1 ± 1.5
Hematocrit, %	42.5 ± 3.2	42.6 ± 2.2	40.8 ± 1.8	41.0 ± 3.9
Iron, µg/dl	83.6 ± 27.7	76.9 ± 20.4	96.0 ± 20.5	102.4 ± 62.4
Ferritin, ng/ml	93.0 ± 84.6*	56.2 ± 41.7	67.4 ± 93.0*	19.0 ± 18.8
Transferrin, mg/dl	325 ± 57	327 ± 67	360 ± 64	373 ± 101
TRF-saturation, %	21.0 ± 7.9	19.9 ± 9.2	21.3 ± 5.7	22.8 ± 12.6

(mean ± SD); * $p < 0.05$

for absorption and transport mechanisms) and the homeostatic regulation of the organism's nutritional status, all of which are affected by physical exercise. It remains important, therefore, to closely watch factors influencing iron metabolism in sports nutrition. The preferential consumption of foods high in iron (like legumes, grains and nuts) combined with an intake of foods rich in vitamins C is essential even if red meat is included in the diet, and it is crucial if runners consume vegetarian diets. The same considerations apply to other trace elements.

As with iron, the absolute intake of *zinc* was unexpectedly higher in the vegetarian group compared to the RWD group despite the consumption of red meat which is an excellent source of zinc. Milk and milk products as well as the high nutrient density for zinc in whole-grain-products account for the higher intake of zinc in the vegetarian group. Although factors like dietary fiber and phytates can disturb and reduce zinc absorption, there is evidence that an adaption to high fiber intake and its interference with zinc absorption is possible (20, 34). On this basis of the data obtained, the recommendation to eat meat in order to assure an adequate zinc intake (4, 35) has to be amended by the recommendation to include milk products and whole grain products.

The goal of this study was to investigate if an ovo-lacto-vegetarian diet covers the nutritional requirements during strenuous physical exercise. The reference diet (RWD) set a high standard, since it proved to be quite a bit more nutrient dense than the general average diet (30, 31). In spite of this, the OLVD exceeded the reference diet *and* the recommendations for most vitamins and minerals. There were no difficulties obtaining a high concentration of carbohydrates with the dominantly plant food diet, and delivering the necessary energy supply caused no volume problems with this diet (OLVD).

Dietary surveys of athletes with self-selected diets showed a higher intake of fat, protein, sodium and cholesterol, and lower intakes of carbohydrates, dietary fiber and almost every vitamin and mineral (reviews: 5, 9, 16). The OLVD served to the runners in this study fullfilled the demands of sport nutrition and, in addition, it did not contribute to nutritional health problems but could help to establish better dietary habits.

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