Food habits in athletes

Een wetenschappelijke proeve op het gebied van de medische wetenschappen

PROEFSCHRIFT

ter verkrijging van de graad van doctor aan de Katholieke Universiteit Nijmegen, volgens het besluit van het College van Decanen in het openbaar te verdedigen op dinsdag 16 juni 1992
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door

Agnes Maria Josepha van Erp-Baart

geboren op 3 januari 1945
te Hulst

Promotores: prof. dr. ir W.H.M. Saris, Rijksuniversiteit Limburg
prof. dr. R.A. Binkhorst

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Stellingen, behorend bij het proefschrift 'Food habits in athletes'

1. Gezien het huidige voedingspatroon van de nederlandse wedstrijdatleet is aandacht voor de eiwitinneming een achterhaalde zaak.
(Dit proefschrift)

2. Door de relatief lage energieinneming zijn vrouwelijke atleten wat hun vitamine- en mineralenvoorziening betreft, per definitie 'at risk'.
(Dit proefschrift)

3. Vanuit kwalitatief oogpunt bezien dient de sporter niet alleen te letten op hetgeen men aan tafel eet. De tussendoortjes zijn zeker zo belangrijk.
(Dit proefschrift)

4. Bij intensief sporten leidt de optelsom sportactiviteiten + dagelijkse activiteiten vaak tot een te hoge schatting van het totale energieverbruik.
(Dit proefschrift)

5. De regelmatig sportende insulineafhankelijke diabeet verkiest ten onrechte het eten van extra voedsel als middel om de bloedglucosespiegel te reguleren.
(Dit proefschrift)

6. De gestage stroom van nieuwe voedingsmiddelen draagt ertoe bij dat het beheer van een voedingsmiddelenbestand en het uitvoeren van voedselconsumptieonderzoek een schier onmogelijke taak wordt.

7. Zolang de prikkel om te consumeren overvloedig aanwezig is zullen de kosten geinvesteerd in pogingen de bevolking te motiveren minder te eten omgekeerd evenredig zijn aan de opbrengsten.

8. Het gegeven dat in het verleden de man de kostwinner was, leidt er ook nu nog toe dat het kostwinnerschap in historisch gezien specifiek vrouwelijke beroepen economisch en sociaal niet erkend wordt.

9. De recente opleving in de fietsenhandel is niet zozeer het gevolg van een toename in de behoefte zich te bewegen, maar een toegeven aan de behoefte zich een statussymbool te verschaffen.

10. Zolang begeleiding van sporters voor een groot deel in de sfeer van enthousiaste vrijwilligheid ligt, is het een illusie om te denken, dat het opbouwen van deskundigheid op dit terrein mogelijk is.

A.M.J. van Erp-Baart, Nijmegen, 16 juni 1992

Voor Alexis en Natasja

Voor Lambert

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Abbreviations

BM	body mass
BW	body weight
CHO	carbohydrate
CPK	creatine phosphate kinase
CR	creatinine
CV	coefficient of variation
DRDA	dutch recommended daily allowance
E	endurance
EE	energy expenditure
EI	energy intake
En%	relative contribution to total energy intake
F	fat
FFM	fat free mass
FM	fat mass
Hb	haemoglobin
HbA1	glycosylated haemoglobin
HDL	high density lipoprotein
HR	heart rate
HRM	heart rate memory
HPLC	high performance liquid chromatography
Ht	haematocrit reading
IDDM	insulin dependant diabetes mellitus
LDL	low density lipoprotein
MJ	megajoule
P	protein
PI	protein intake
RDA	recommended daily allowance
RMR	resting metabolic rate
S	strength
T	team sport
$\dot{V}O_2$-max	aerobic power
3-MH	3-methylhistidine

CHAPTER 1

Introduction

Nutrition has attracted considerable attention in man's attempt to enhance physical performance. Almost every article or book about nutrition and sport starts with the conclusion that numerous athletes believe that special foods are necessary for optimal performance and that usual food intake is not sufficient to meet the athletes' physiological needs (1, 2, 16, 17, 18, 20). For this reason it is not surprising to see that food supplements are taken and a lot of special foods are regarded as the best for athletic performance (15, 19).

Nutrition is mostly studied from the physiological point of view. From an abundance of studies it is well known that food intake and dietary manipulations are of great importance for the enhancement of athletic performance.

Basic change in food intake is related to the increasing need of energy, but it depends on the intensity, frequency and duration of the training or contest (2) to what extent total daily energy expenditure will increase. Total energy expenditure depends also on whether the exercise serves as a substitute for daily activities or is additional to it.

With regard to the nutrients another physiological fact is the preference in substrate utilization in relation to performance and subsequently the importance of macronutrient intake (8).

Already in the 1930s it was found that carbohydrate intake is important for physical performance at a high level of intensity and long duration. After the introduction of the muscle biopsy technique it became clear from the measurements of energy substrate flux that at exercise intensities of more than 70% of the $\dot{V}O_2$-max the shift towards CHO oxidation becomes increasingly important. At an intensity level of over 95% glucose serves as the only fuel for the exercising muscle. Recommendations are therefore made to increase carbohydrate intake to at least 55% of total energy intake (8).

The second main fuel for muscle metabolism is fat (5). From a practical standpoint the lipid stores in the body are unlimited: 1 kg of adipose tissue is sufficient to supply energy for 10–20 h of exercise. However it should be mentioned that the intensity in which the exercise can be performed is limited. Up to 50% of $\dot{V}O_2$-max the fuel is mainly provided by the oxidation of fatty acids. At higher intensities carbohydrates become increasingly important (2).

Although the value of increased dietary protein as a determinant of athletic performance has been debated for many years, it is now generally accepted that protein is important for the actual athletic performance. A sufficient protein intake is important for the building of muscle mass and the recovery of damaged tissue. It is generally known that an increased need is found in groups like children, adolescents and pregnant women. If an athlete starts with regular physical training muscle mass will be built up.

Nitrogen balance studies, urinary urea excretion studies, urinary 3-methyl histidine studies and metabolic tracer studies have shown that a protein intake of about twice the RDA (0.8 g/kg BM) might be necessary for the maintenance of the nitrogen balance of intensively exercising athletes (11, 18, 19). Another reason for an increased need for protein arises when total energy intake is lower than the energy actually expended. Brouns (6) has found that if energy intake is too low and repeated heavy sustained exercise is performed an intake of 1.7 g/kg BM causes a negative nitrogen balance. Lemon (13) has demonstrated that protein serves as an energy substrate when the glycogen stores are depleted and exercise is continued at a high intensity level. He calculated from urea secretion in sweat that a protein intake of 2 g/kg BM is probably sufficient to keep body protein in balance under these circumstances. On the other hand, if we look at the recommendations for protein intake in relation to athletic performance intakes of 4 to 5 g/kg BM are often advised. It seems, however, that these recommendations are often based on the protein intake usually found in intensively exercising strength athletes. Further investigations are necessary to establish reliable recommendations regarding optimal protein intake for various groups of athletes. In these studies the energy balance must be considered as well.

The subject of vitamin and mineral supplements is perhaps the most intriguing one for athletes. Numerous studies have dealt with this problem (3, 4, 9, 14). The available evidence for vitamin and mineral requirements shows that there is no justification for the opinion that the general recommendations should be higher. Still supplementation is common practice. The main reason for doing so is probably the uncertainty of the athlete as to whether the nutritional value of his/her food intake is adequate.

Summerizing this general information about macro- and micronutrient intake in relation to athletic performance one can conclude that nutrition has become an important aspect of todays ability to compete at an international top-level. Besides talent, training and material one has to take care of his/her nutrition in order to have optimal results. However for adequate nutritional advice information about habitual food intake of athletes performing at top level is needed. Until now a systematic approach to obtain data about food intake of elite athletes was scarce. Analysing these data one can learn about the nutritional needs under these circumstances and the problems athletes are faced to. Therefore we decided to start this project on food habits of different groups of elite athletes in order to analyse the nutrient intake and meal pattern.

From the health point of view it is important to obtain insight into the health risks incurred by the athlete. It is generally known that endurance-trained athletes tend to have higher HDL-cholesterol levels than the general population, a factor associated with a decreased risk for atherosclerosis. The diet of strength athletes is known to containing an abundance of protein. This normally coincides with a high intake of saturated fatty acids and cholesterol, known risk factors for the development of cardiovascular disease. The question may arise whether strength athletes have higher risks for the development of cardiovascular disease because of these food practices. As part of an experimental study on dietary intervention during strength training, we were able to evaluate the food intake and plasma lipid levels of different groups of active sportsmen.

During the years that the actual food intake was studied many athletes came for advice with respect to weight maintenance or weight loss. In such types of sports as body building, rowing, weight-lifting, gymnastics and judo one has to compete in certain weight categories, or a minimum body and/or fat mass is required for optimal appearance and performance.

Weight reduction is not a problem if time is available, and if the excess of weight is caused by an excess of fat mass. However in most cases time is very limited and body fat mass is already very low (9). Nutritionists often have to navigate between Scylla and Charybdis. One option is weight reduction with a concomitant decrease in functional muscle mass and thus the hazard of decreased performance. The other choice is to advice the athlete to take his weight for granted and to compete in another weight class.

We have started to tackle this weight dilemma by addressing some aspects of this complex feature. First, we have assessed actual energy expenditure in female top gymnasts. This special group is often faced with weight problems, and sometimes it seems virtually impossible to decrease food intake. Secondly, the use of 3-methylhistidine (3MH) as an indicator of muscle protein breakdown has been studied in a group of physically active men and women. The question is whether 3 MH can be used as an indicator for muscle protein breakdown. Until now little information on the reproducibility over days was available (21). However weight reduction is usually spread over weeks. Special attention has therefore been given to the reproducibility over a longer period of time.

A group of athletes of special interest are insulin-dependent diabetes mellitus (IDDM) athletes. Because of the lack of insulin response the substrate flow to the muscle is impaired. On the other hand, it is well recognized that exercise improves insulin sensitivity. Therefore IDDM patients are encouraged to take regular exercise to decrease the daily dose of insulin. In some cases diabetics decide to compete at a high athletic level. They are than faced with the problem how to adapt their nutritional habits to a very intensive training regime. Information relevant to this category is scanty and the athletes still have to learn by trial and error (10, 11, 12). Therefore a nationwide study of intensively exercising IDDM athletes has been carried out. Observation of the food habits of adult trained athletes could produce some information on how they deal with this complex problem.

In conclusion, for adequate nutritional advice basic information on actual food intake of intensively exercising athletes is needed. Therefore in **Chapter 2** the results on energy and macronutrient intake of 25 groups of elite athletes are presented. **Chapter 3** answers the question whether supplements are needed to have adequate intakes of calcium, iron and vitamins. In **Chapter 4** the intake of magnesium and zinc is discussed.

A comparison between habitual fat intake and plasma serum levels in active sportsmen is made in **Chapter 5**.
In **Chapter 6** the results on energy expenditure in female top gymnasts are given. The reproducibility study of urinary 3-methylhistidine excretion is discussed in **Chapter 7**. Food intake and dietary adaptations in IDDM athletes are presented in **Chapter 8.** Finally in **Chapter 9** the several aspects elaborated in the previous chapters are integrated. Emphasis is laid on the practical consequences of proper nutritional advice. Although the athletes need energy and nutrients (protein, vitamins, minerals) they still eat natural food items and not single nutrients in pills, powders, etc. It is the basics of nutrition that are essential to the well being of athletes. However, this aspect is often underestimated by exercise physiologists and manufacturers of special sport food products.

References

1. Anonymous. Advice concerning sport food supplements (dutch). *Neth J Nutr* 48, 73-97, 1987.
2. Åstrand PO, K Rodahl. *Textbook of work physiology.* Nutrition and physical performance. McGraw Hill Book Company, pp 483-521, 1977.
3. Beek EJ van der. Vitamins and endurance training. Food for running or faddism claims. *Sports Med* 2, 175-197, 1985.
4. Belko AZ. Vitamins and exercise-an update. *Med Sci Sports Exerc* 19, 5, S191-S196, 1987.
5. Bjorntorp P. Importance of fat as a support nutrient for energy: metabolism of athletes. *J Sports Sc* 9, 71-76, 1991.
6. Brouns F. *Food and fluid related aspects in highly trained athletes.* Sportwetenschappelijke onderzoekingen 15. Uitgeverij De Vrieseborch, Haarlem, 1988.
7. Brownell KD, Steen SN, Wilmore JH. Weight regulation practices in athletes: analysis of metabolic effects. *Med Sci Sports Exerc* 19, 546-556, 1987.
8. Costill DL. Carbohydrate for exercise; dietary demands for optimal performance. *Int J Sports Med* 9, 1-18, 1988.
9. Dokkum W van. *The need for minerals and trace elements in athletes* (dutch) In: WHM Saris, M Stasse Wolthuis (eds). Sport en Voeding. Samson Stafleu, Alphen aan de Rijn, 1988.
10. Franz MJ. Exercise and the management of diabetes mellitus. *J Am Diet Assoc* 87, 872-881, 1987.
11. Horton ES. Metabolic aspects of exercise and weight reduction. *Med Sci Sports Exerc* 18, 10-18, 1985.

12. Kemmer FW, M Berger. Exercise and diabetes mellitus; Physical activity as a part of daily life and its role in the treatment of diabetic patients. *Med Sci Sports Exerc* 4, 77-88, 1983.
13. Lemon PR. Protein and exercise: update 1987. *Med Sci Sports Exerc* 9, 5, S179-S190, 1987.
14. McDonald R, Keen CL. Iron, magnesium and zinc nutrition and athletic performance. *Sports Med* 5, 171-184, 1988.
15. Nieman DC, JR Gates, JV Butler et al. Supplementation patterns in marathon runners. *J Am Diet Assoc* 89, 1615-19, 1989.
16. Panel summary statements. First international conference on nutrition and fitness. *Am J Clin Nutr* 49, 5, S931-937, 1989.
17. Position of the American Dietetic Association: Nutrition for physical fitness and athletic performance for adults. *J Am Diet Assoc* 87, 933-939, 1987.
18. Simopoulos PS. Opening address. Nutrition and fitness from the first Olympiad in 776 BC to 393 AD and the concept of positive health. *Am J Clin Nutr* 49, 921-926, 1989.
19. Weight LM, Noakes TD, Labadarios D. et al. Vitamin and mineral status of trained athletes including the effects of supplementation. *Am J Clin Nutr* 47, 186-191, 1988.
20. Williams MH. *Ergogenic aids in Sport*, Champaign Ill. Human Kinetic Publishers 1983.
21. Young VR, Munro HN. N-methylhistidine (3-methylhistidine) and muscle protein turnover. An overview. *Fed Proc* 37, 2291-2300, 1978.

CHAPTER 2

Nationwide survey on nutritional habits in elite athletes.
Part I. Energy, carbohydrate, protein, and fat intake

A.M.J. van Erp-Baart, W.H.M. Saris, R.A. Binkhorst, J.A. Vos and J.W.H. Elvers
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Abstract

Information about habitual food intake was systematically obtained from elite endurance, strength, and team sport athletes. The athletes ($n = 419$) trained at least 1–2 h daily and competed on an international level.

A 4- or 7-day food diary was kept. For analysis of the data, a computerized food table was used. Mean energy intake varied from 12.1–24.7 MJ per day for male and 6.8–12.9 MJ per day for female athletes. Protein intake was in agreement with or higher than the Dutch recommendations. Contribution of carbohydrate intake to total energy intake varied from 40–63%. Fat intake tended to meet the criteria for a prudent diet (<35%).

Snacks contributed about 35% to the total energy intake and the bread/cereals and dairy food groups were the most important energy sources. It is concluded that in general there are two major concerns.

In those sports in which body composition plays an important role, energy and thus nutrient intake is often marginal. In all groups of athletes intake of carbohydrate is insufficient.

Introduction

In nutrition many beliefs and misconceptions exist with respect to athletic performance (35, 9, 21, 15). For example in the old days meat was associated with muscle and strength, and until now many athletes believe they need an abundance of protein-rich food to have an optimal performance. In the nutritional sciences recommendations for adequate nutrient intake are available. Also specific information about the best composition of the athletes' diet has become available in the last 2 decades (32, 33, 16). However, beside information about the needs, knowledge of the athletes' food habits is necessary to give adequate nutritional advice. The question arises whether athletes are properly nourished today? In this respect the available literature about nutrient intake in elite athletes is limited, not covering the whole range of sport types. Describing the dietary patterns of successful competitive athletes may lead to a better understanding of the nutritional habits, which can be used in counselling athletes.

Therefore, we decided in 1978 to start with a project to describe the food selection of athletes competing primarily on an international level. Because the number of athletes at this level who are available and willing to cooperate is limited, the study was extended over an 8-year period.

Methods

Selection of athletes took place on the basis of training daily at least for 1–2 h and competing mostly on an international level. Several European, World, and Olympic medal winners are included. Especially those types of sports popular in the Netherlands were investigated. Endurance, as well as strength and team sport athletes were willing to cooperate. Because we wanted to describe the food habits of elite athletes, the number of athletes per group is sometimes rather small.

Nutritional information was obtained by a 4- or 7-day food diary. At least 3 days, in which 2 week days and 1 weekend day are included, are needed to obtain valid information on a group level (19, 29). Based on a pilot study, it was decided to use a minimum of 4 days (2 week days and 2 weekend days) to minimize biased information within the groups studied. However, if it was possible, a 7-day diary was used.

The food diaries were kept by the athletes themselves. Personal instruction at the laboratory or at home was given in advance by a trained dietitian. After returning the diaries, if necessary a telephone checkup was made to complete the information, and portion sizes and household utensils were checked for weight. To assure comparability in the data, all instructions and coding work was supervised by the same dietitian. If during the year major changes in food habits were to be expected by changes in training or contests, the food diary method was repeated. The running and rowing athletes were therefore questioned twice and the cycling athletes three times.

The other groups of athletes kept a food diary only once. Besides information about the food intake, the athletes were asked to give information about type and duration of training and contests in a sport activity diary.

Food consumption was converted into nutrients using the GVOP computer program (7) based on a nutrient file from the Dutch food table (30). Statistical analysis and plot procedures were done according to SAS (24).

Anthropometric data (body mass en length) were obtained. Fat mass (FM) was assessed by taking four skinfolds (biceps, triceps, subscapula, and supra iliaca) according to Durnin and Womersley (6) with a Holtain calliper.

Table 1. Anthropometric data (mean ± SD) of the different groups of endurance, strength, and team sport athletes.

Type of sport	Sex	*n*	Age (yrs)	Height (cm)	Body mass (kg)	Body fat (%)
Endurance (E)						
1 Tour de France*	M	5	26 ± 3	178.1 ± 3.6	70.8 ± 6.3	11.7 ± 2.2
2 Tour de l'Avenir	M	4	24 ± 2	179.4 ± 7.6	73.7 ± 1.3	10.5 ± 2.0
3 Triathlon*	M	3	26 ± 3	176.2 ± 5.3	70.2 ± 2.5	8.1 ± 1.0
4 Cycling, amateur	M	14	20 ± 1	183.8 ± 7.3	72.3 ± 6.8	9.8 ± 1.8
5 Marathon skating*	M	5	33 ± 5	177.8 ± 3.7	72.3 ± 7.4	11.8 ± 3.0
6 Swimming*	M	20	18 ± 3	182.0 ± 16.0	72.9 ± 8.1	10.7 ± 3.3
7 Rowing*	M	18	22 ± 2	183.8 ± 5.9	77.2 ± 6.7	12.1 ± 1.2
8 Running*	M	56	30 ± 5	179.0 ± 6.1	68.8 ± 6.3	12.7 ± 3.6
9 Rowing*	F	8	23 ± 2	168.3 ± 7.8	69.8 ± 5.8	29.8 ± 4.1
10 Cycling, amateur*	F	21	23 ± 4	168.5 ± 4.4	66.0 ± 6.7	27.8 ± 5.0
11 Running*	F	18	31 ± 5	166.5 ± 5.6	52.1 ± 4.3	15.9 ± 3.1
12 Sub-top swimming	F	50	12 ± 2	155.3 ± 13.5	43.6 ± 11.1	21.4 ± 5.6
Strength (S)						
1 Body building*	M	8	30 ± 7	174.7 ± 7.1	87.3 ± 13.7	15.3 ± 4.2
2 Judo*	M	4	23 ± 1	178.4 ± 6.9	82.5 ± 11.6	10.4 ± 2.4
3 Weight lifting	M	7	27 ± 4	176.4 ± 8.4	76.4 ± 10.0	15.3 ± 3.8
4 Judo*	M	28	18 ± 1	175.6 ± 6.8	68.7 ± 10.0	8.7 ± 2.5
5 Top gymnastics	F	11	15 ± 1	158.0 ± 7.0	46.9 ± 6.3	18.9 ± 2.7
6 Subtop gymnastics	F	41	13 ± 1	150.3 ± 10.2	39.8 ± 11.1	16.0 ± 5.4
7 Body building*	F	4	25 ± 5	161.7 ± 3.1	56.0 ± 6.2	20.5 ± 3.6
Team sport (T)						
1 Water polo*	M	30	24 ± 3	188.9 ± 6.4	85.5 ± 7.4	13.7 ± 3.3
2 Soccer*	M	20	20 ± 3	182.5 ± 6.8	74.5 ± 6.9	11.3 ± 2.1
3 Hockey*	M	8	27 ± 2	180.0 ± 9.0	75.0 ± 7.7	9.6 ± 2.8
4 Volley	F	9	23 ± 3	174.6 ± 4.5	66.0 ± 3.5	22.0 ± 1.8
5 Hockey*	F	9	24 ± 4	166.0 ± 3.6	62.1 ± 7.4	18.6 ± 3.4
6 Handball	F	8	22 ± 2	166.0 ± 6.3	63.2 ± 4.2	25.0 ± 3.8

* Including World, European, and Olympic medal winners

In Table 1 the number of athletes, the type of sport, and the physical data are presented. To express daily physical exercise as a multiple of basal metabolic rate (BMR) according to the WHO/FAO recommendations (34), BMR was calculated from body mass, length, age, and sex according to Schofield (25).

Results

Unless otherwise stated, the results presented in the tables and figures include food supplements contributing to the energy intake. To obtain objective criteria for the quantity of the food intake, the Dutch recommended daily allowances (DRDA) for highly active people (31) and WHO/FAO (34) recommendations were used. The DRDAs are according to age, gender, and level of activity of the groups investigated and represent the mean energy intake of the group. The recommendations for protein, fat, and carbohydrate are the general recommendations of a prudent diet for the general population in the Netherlands.

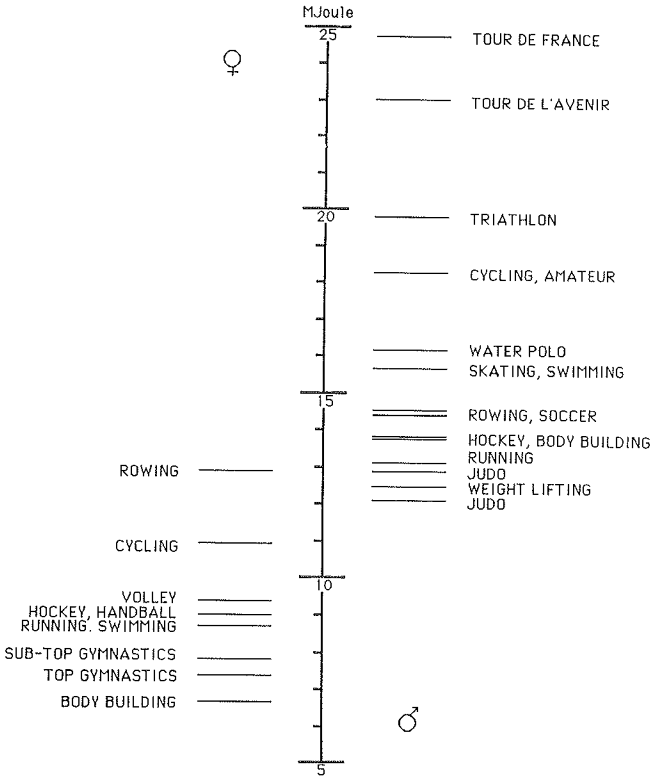

Fig. 1 Daily energy intake per day (MJ) in endurance, strength, and team sport athletes.

In Figs. 1 and 2 the mean total energy intake and the energy intake expressed in BMR units are presented.
Male athletes had a mean energy intake ranging from 12.1–24.7 MJ/day. Female athletes had an energy intake ranging from 6.8 to 12.9 MJ/day.

Expressed in BMR units, the energy intake in men was 1.6–3.3 BMR units and in women 1.2–1.8 BMR units. Highest energy intakes (above 2.0 BMR units) were found in male endurance athletes. Lowest energy intakes (below 1.5 BMR units) were found in female strength athletes.

When energy intake was calculated per kg body mass (BM), male athletes had an intake varying from 157–347 kJ/kg BM and female athletes had an intake ranging from 110–206 kJ/kg BM (Table 2). It was found that within the same group energy intake per kg body mass varied considerably.

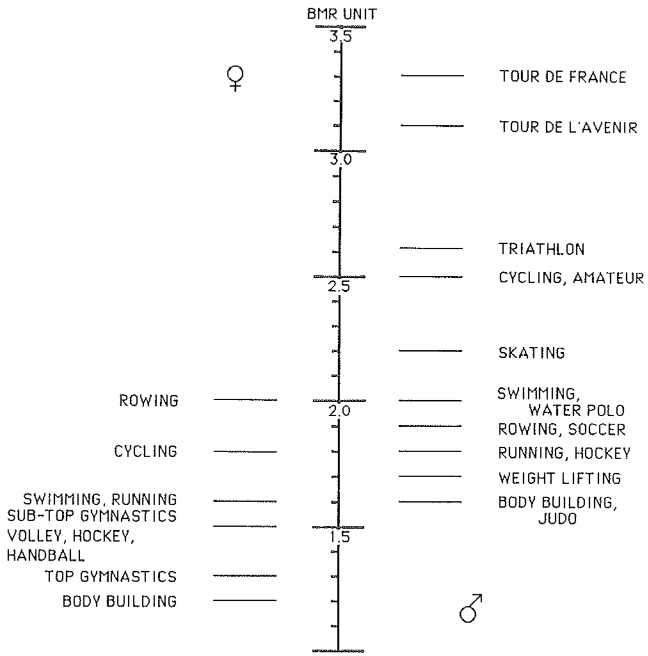

Fig. 2 Daily energy intake (BMR units) in endurance, strength, and team sport athletes.

Table 2. Energy intake (kJ/kg body mass) of the different groups of endurance, strength, and team sport athletes.

Type of sport	Sex	Energy intake ($kJ.kg^{-1}$)	
		Mean	Range
Endurance (E)			
1 Tour de France	M	347	286-388
2 Tour de l'Avenir	M	316	247-378
3 Triathlon	M	272	246-295
4 Cycling, amateur	M	253	207-314
5 Marathon skating	M	222	175-294
6 Swimming	M	221	119-300
7 Rowing	M	189	167-225
8 Running	M	193	127-311
9 Rowing	F	186	140-200
10 Cycling, amateur	F	164	115-215
11 Running	F	168	123-218
12 Sub-top swimming	F	200	92-338
Strength (S)			
1 Body building	M	157	106-183
2 Judo	M	157	76-210
3 Weight lifting	M	167	99-203
4 Judo	M	177	60-325
5 Top gymnastics	F	158	91-216
6 Sub-top gymnastics	F	206	113-334
7 Body building	F	110	91-133
Team sport (T)			
1 Water polo	M	194	92-299
2 Soccer	M	192	118-287
3 Hockey	M	181	167-217
4 Volley	F	140	101-229
5 Hockey	F	145	91-199
6 Handball	F	142	78-271

Protein

In Fig. 3 the mean protein intake, expressed in g/kg BM, of all groups of endurance, strength, and team sport athletes is presented in relation to the mean energy intake. The DRDA for protein intake is 1.2 g/kg BM for men and 1.0 g/kg BM for women. For the adolescent athletes an intake of 1.4 g/kg BM for boys and 1.2 g/kg BM for girls is advised. It is stated that during periods of intensive training or competition DRDA may increase to a maximum of 1.5 k/kg BM. From the results of Fig. 3, it can be seen that the protein intake in most groups was in agreement with these recommendations or higher.

Protein intake per kg BM increases when energy intake increases. In body building men and women (S1 and S7) the protein intake was high in comparison with the other groups of athletes at the same energy level. This can be explained by the use of extra protein supplements. If corrections are made for these supplements, protein intake drops in S1 to 1.6 g/kg BM and in S7 to 1.3 g/kg BM, both above the recommendation.

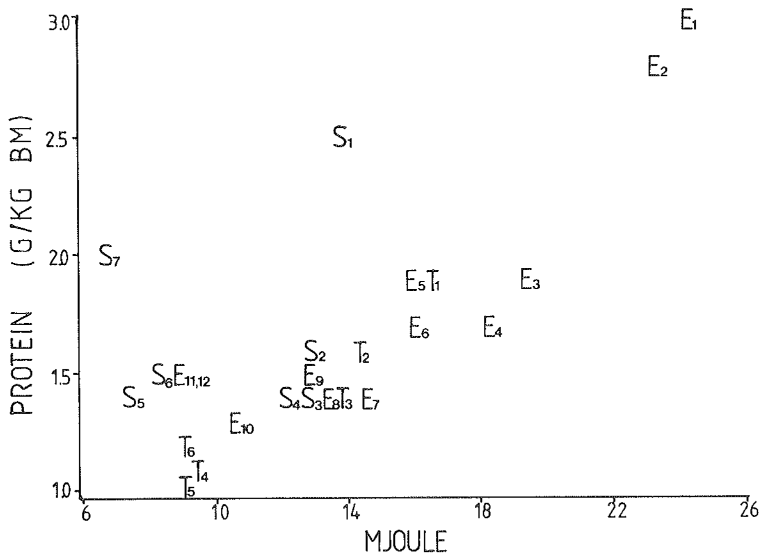

Fig. 3 Daily protein intake (g/kg body mass) in relation to mean energy intake (MJ) in endurance (E), strength (S), and team sport (T) athletes (for corresponding numbers, see Table 1).

Carbohydrate

In Fig. 4 the carbohydrate (CHO) intake, expressed as percentual contribution (En%) in relation to the energy intake is presented. The DRDA for CHO is an energy contribution of 55 En%. Only five groups, all endurance (E1, E2, E4, E5, and E11), reached this level. Especially in endurance sports it is recommended (5) to increase CHO to at least 60 En%. Only two groups exceeded the 60 En% level. In the S and E groups CHO intake varied most. In male S athletes CHO intake dropped to low levels (40 En%). The female S athletes had a CHO intake close to the recommended level. In general the male S athletes had a lower level. The S2 and S3 group results were even lower than 45 En%. The T groups had CHO intake about 46 En%, which is the same as found in the general Dutch population.

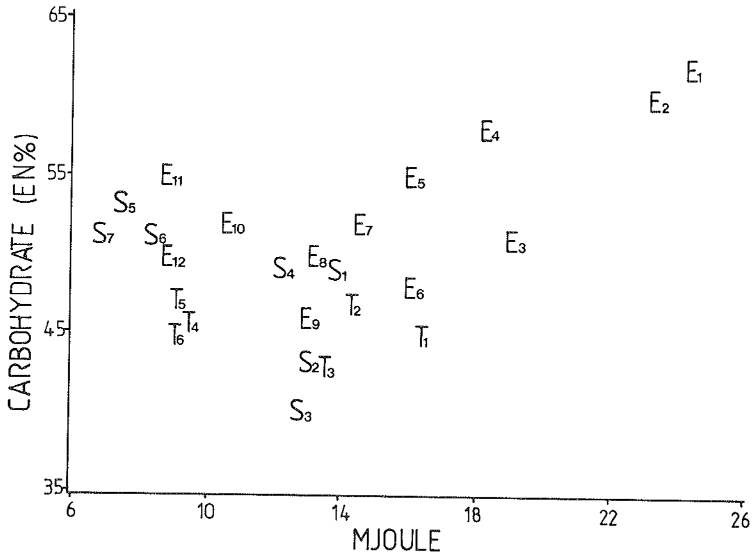

Fig. 4 Daily carbohydrate intake (En%) in relation to energy intake (MJ) in endurance (E), strength (S), and team sport (T) athletes (numbers according Table 1).

Fat

In Fig. 5 the fat intake, expressed in En%, is presented in relation to the mean energy intake. The DRDA for fat intake is 35 En% or less. Compared with the fat intake of the general Dutch population (40–45 En%) the fat intake was low and tended to meet the criteria for a prudent diet. Only in handball (T6) fat intake was on the same level as for the population at large. Extremely low (< 25 En%) intake was found in the Tour de France (E1) and Tour de l'Avenir (E2). Except for these two groups no relation was found with sport type or energy intake.

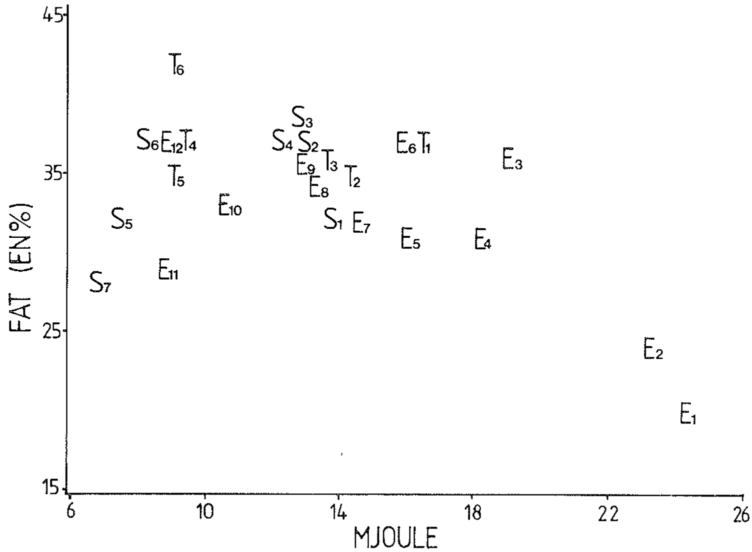

Fig. 5 Daily fat intake (En%) in relation to mean energy intake in endurance (E), strength (S), and team sport (T) athletes (numbers according Table 1).

Alcohol

Mean alcohol intake was, respectively, 2.9, 2.0, and 10.0 g/day in female E, S, and T athletes. In the male E, S, and T athletes, daily intake was, respectively, 10.9, 17.2, and 19.2 g. These figures were calculated for the adult groups because the adolescen groups had a negligible alcohol consumption. Mean alcohol intake in the Dutch population is 23.5 g/day. Considering the type of sport, team sport athletes had the highest alcohol consumption.

Patterns of Eating

In Fig. 6 the mean contribution of breakfast, dinner, lunch, and snacks to the total energy and macronutrient intake for all athletes is presented. Snacks are defined as all food eaten outside the three major meals. Highest intake values were found in snacks, ranging from 32% to 37% of the total energy intake. Lowest energy intake was found in breakfast. Meal patterns were in general the same for all the groups of sport types. With respect to the nutrient intake, it was shown that in breakfast and lunch/supper the contribution was, respectively, ca. 15% and 20% of the daily intake

Dinner provided ca. 40% of the protein intake and about 30% of the fat intake, while snacking led to about 30% carbohydrate and ca. 30% fat intake.

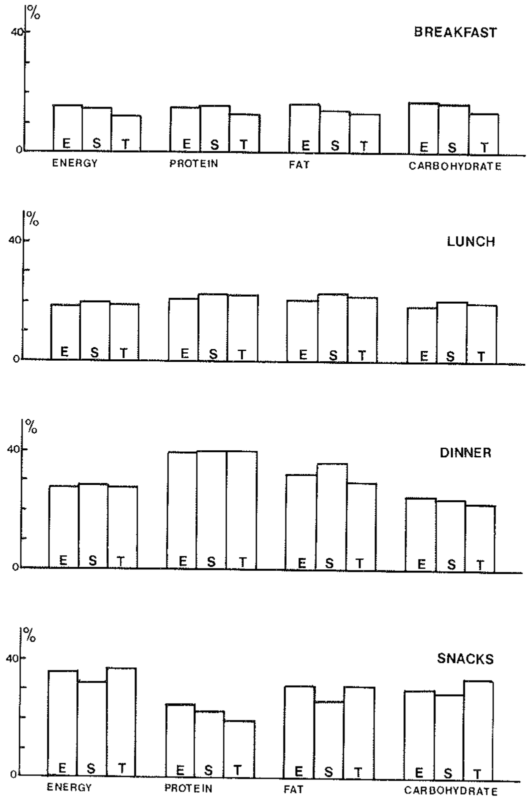

Fig. 6 Contribution of breakfast, lunch/supper, dinner, and snacks to the energy and macronutrient (protein, fat, carbohydrate) intake in endurance (E), strength (S), and team sport (T) athletes.

In Fig. 7 the mean contribution of the most important food groups to energy intake is presented for the three types of sport groups. The food group bread/cereals was the most important energy source. Also dairy products contributed about 10% to the energy intake. It is interesting to note that meat and poultry products were relatively important for the energy intake of S and T sport athletes, while in E athletes the contribution was below 2%. With respect to food supplements, cyclists in the Tour de

France frequently used CHO supplements (18.8 En%) and in body building protein supplements were often taken (14 En% in men, 6 En% in women).

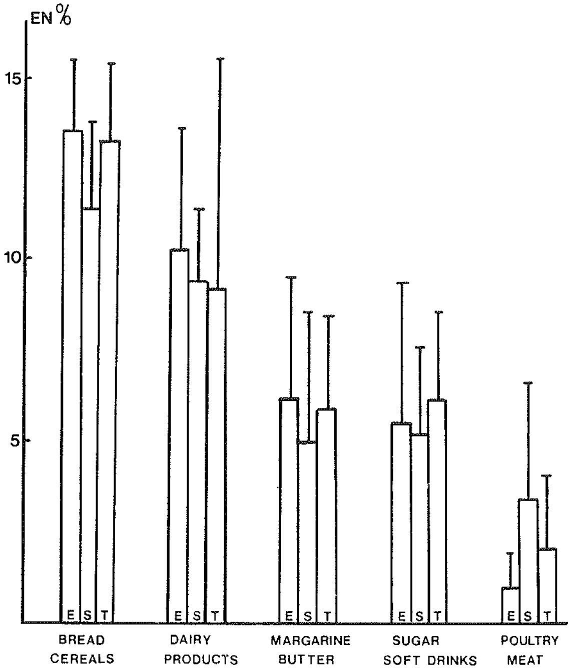

Fig. 7 Contribution of food groups to total energy intake in endurance (E), strength (S), and team sport (T) athletes.

Discussion

While interpreting the data found on energy and nutrient intake, the validity of the method chosen to assess food consumption should be taken into account. There are many sources of error and several authors have pointed out that the method often fails to produce accurate results on the individual level (20). For instance, to classify an individual correctly with a reliability of 90% for carbohydrate intake, it is necessary to obtain information about the actual food intake for a whole month. Thus, the validation has to be seen in the context of the conclusions that have to be drawn from the research carried out. For this study it was necessary to gather valid data on a group level to make group-to-group comparisons. The weighed record method has been considered the golden standard, and valid group estimates may be obtained with this method (19). The precision of the estimated group mean, as expressed by its variance, depends on the number of subjects, the number of daily records provided by each respondent, between-subject variance, and within-subject variance (28). Chalmers et al. (4) pointed out that on a group level a 24-h recall gives the same information as a 3-day record.

From a pilot study in a group of athletes we estimated that the minimum sample size of 4 days including the weekend gives better information than a 24-h recall. The main reason was the small number of athletes. Therefore, in this study the 4-day record was chosen as a minimum length of data collection and if practically possible the 7-day record was applied.

Besides the number of record days, the validity of mean group values depends on the number of subjects. Due to the fact that we stressed the criteria of elite in a certain sport, the number of athletes per group was sometimes small. Therefore, the results of these groups have to be considered with caution.

However, it should be emphasized that by being so strict with respect to the level of performance in entering the study, it was possible to collect data about food habits of a unique group consisting almost only of athletes competing on an international level as can be seen in Table 1 including several European, World, and Olympic medal winners.

Energy

The need for energy to balance energy expenditure is the primary concern of an athlete. From the research on energy expenditure, it is well known that the energy expenditure per time unit is directly proportional to the intensity level of the exercise task.

One of the often used parameters to express exercise intensity is the multiple of the basal metabolic rate (Mets or BMR units). Values during short periods of maximal exercise can be about 14–20 BMR units (26). However, on a 24-h basis, the duration of the exercise period is more important. Moderate exercise at a 6 BMR unit level can be tolerated for prolonged periods of time (8 h or more) while intensive exercise of 10–15 BMR units may last only for 1–3 h.

Therefore, it is not surprising to see that in Fig. 2 especially those sports in which the emphasis is on the endurance have the highest energy intake over 24 h. In these sports the BMR units exceed the value 2 with the highest recorded level for the Tour de France (BMR unit; above 3.0). It was surprising to see that this phenomenon on increasing BMR levels was only seen in male athletes. None of the female endurance groups exceeded the 2.0 BMR level. Several explanations for this difference are possible. For instance, competing at top level in cycling means shorter distances for female cyclists. Another important difference is the fact that while professional male cyclists are well aware of the need to eat enough while performing in long-lasting and intensive events, the female cyclists had problems in maintaining their energy balance. They all inclined to lose weight during the contest period, while the male cyclists maintained their weight. Brownell et al. (3) suggested that in endurance female athletes energy efficiency is high compared with nonactive subjects, in order to save energy as a protective response to exercise because of the reproductive function.

For the remaining male athlete groups, BMR units per day varied from 1.6 to 2.1 with the lowest values for weight lifting, judo, and body building (1.6 and 1.7). In the female groups the values were centered around 1.5 BMR units, except for top gymnastics and body building. Their values of 1.4 and 1.3 can be considered as unrealistically low, assuming they trained for at least 1.5–2 h daily.

The question arises whether these energy intakes are in agreement with the energy expenditure. In female top gymnasts and in the male Tour de France cyclists, we assessed energy expenditure. In the professional cyclists, energy intake balanced energy output very well (22) over the same period. The energy balance in the top gymnasts showed a different picture. The energy expenditure was 180 kJ/kg BM/day (SD 28 kJ) while the intake accounted only for 158 kJ/kg BM/day (SD 43 kJ). This group trained 5 days/week for 3 h daily of which only 15% of the time was physically active. For the rest of the day, they were completely inactive. This partly explains the low energy expenditure value of 180 kJ/day. However, the lower intake value still needs an explanation. Although only one girl indicated that she attempted to lose weight, still 90% of the group had an energy intake lower than the energy expenditure (8). It is our impression that these girls are continuously on a weight-reducing diet since a low weight is preferable for the performance. Hickson (11) and Loosli (15) found an energy intake in female gymnasts of 180 kJ/day. This is lower than in our sub-top gymnasts but at the same level as in our top gymnasts. Also in judo 10 out of 28 males indicated that they were on a weight-reducing diet because they had to compete in weightclasses.

Another way to get information about energy balance is by looking at changes in body mass and body fat mass. In running and rowing, BM and FM were assessed in contest and training periods. In cycling this was done in training, contest, and resting periods. It was found that in the male runners and cyclists no changes in BM or FM appeared. In male rowers and female cyclists BM and FM decreased during the contest period. In rowers this decrease can be explained by the fact that they have to compete in weights. The female cyclists indicated they had problems in maintaining BM and FM during the year. In the resting season BM and FM increased, sometimes by more than 5 kg. Therefore, during the training season and not seldom during the contest period athletes had to follow a weight-reducing diet. Also in water polo this phenomenon was noticed. From these results it becomes clear that in all weight sports and in sports where body shape is of the most importance dieting is common the whole year round, while athletes taking a rest period often restrict their food intake during the active season.

Especially in young athletes this practice is one of the major concerns with respect to nutrition (23). Some interesting questions which cannot be adequately answered from this study can be posed. For instance, what is the effect of these starvation periods on growth and development? As for the present it is far too easy to conclude that a tendency toward a lower stature in female gymnasts exists as a result of the apparent deficiency in nutrients and energy.

Protein

No nutrient has received more attention in relation to athletic performance than protein. In his review on the role of protein, Williams (32) used the term magical super nutrient to describe the beliefs of the athletes and the claims of advertisements. Although it is true that a certain amount of dietary protein is essential, it is very difficult to explain to the athletes that with a normal variety of food this need can be covered. In comparison with the recommendations, it is clear that all groups meet the DRDAs. Even in the endurance groups where CHO content of food items is the main diet selection criterium protein is well above the DRDA levels.

In recent years it was argued that during intensive long-lasting exercise, when glycogen stores are depleted, protein is used as energy source (14). Values have been reported of a 5%–15% increase in protein oxidation (10). However, the increase in energy intake and thus protein intake as found in all E groups prevents a long-term negative nitrogen balance. Even in the extreme situation of cycling the Tour de France protein intake in all athletes was above 2.5 g/kg BM/day. This is far more than the 1.0 g/kg BM/day found by Butterfield (2) who demonstrated an increase in protein utilization during a period of physical activity. Lemon (14) suggested that because of the extra need of certain essential amino acids during exercise, an intake 1.5–1.8 g/kg/day is necessary. Only in body building protein was taken as a pure supplement in high doses. These athletes persist in this type of supplementation despite all arguments (32).

Carbohydrate

In the last 2 decades, an impressive number of studies have been conducted resulting in better understanding of the important role of carbohydrates to maximize performance. Excellent reviews have been published in recent years about this topic (27,5). There is a general conclusion that a high-carbohydrate diet (70 En%) benefits aerobic endurance. Although most research is focussed on endurance sports, it is reasonable to conclude that also team and strength athletes who train intensively daily need a carbohydrate-rich (55–65 En%) diet. In a study with athletes in explosive types of sports, it was found that glycogen is used as energy source (13). Data of the present study show that carbohydrate intake expressed as En% is low. However, in comparison with their nonactive peers, athletes do increase their carbohydrate intake. The highest values were found for endurance athletes (50–60 En%) but all these values are relatively low. The team sport athletes increased the CHO intake only by a few percent over the values for the population at large, while in strength athletes CHO intake ranged from no change (40 En%) to an increase by about 10% (50 En%).

Fat

The moderate increase of carbohydrate intake in all groups resulted in a moderate decrease of fat intake from 40–45 En% for the general population to 35–40 En% indicating a more prudent diet. During low-intensity exercise, fat is the major substrate source (1). Furthermore, it is generally glycogen (12). However, fat as energy substrate is less economical than carbohydrate in terms of ATP yield per unit of oxygen utilized. Compared with high-carbohydrate diets, endurance performance of moderate intensity is significantly impaired when fat is the main nutrient in the diet. There seem to be no arguments to increase fat intake. On the contrary, a higher fat intake affects carbohydrate intake. The major part of the total fat consumption was taken during dinner (30%) and in between (30%). In the high-carbohydrate low-fat sport groups, fat intake from snacks was considerably lower. This might suggest that for an improvement of carbohydrate intake special attention must be given to the quality of the snacks. In-between meals are important in the diet of the athlete, about 35% of the energy intake is derived from snacks outside the three main meals. In fact athletes eat the whole day. This nibbling pattern must be considered as an adaptation to circumstances, where bulky meals are not beneficial to performance. Kirsch and Von Ameln (17) found the same pattern in cyclists and runners.

It is interesting to note that the number one food item for all sport groups is bread. The major differences in food choices between the three major sport types was found in the meat intake. Endurance athletes tend toward a vegetarian diet. This is in line with the dietary guidelines in the Western countries, where a shift from protein and fat-rich foods to carbohydrate-rich foods is advised.

For many years it was argued that alcohol intake decreases cardiovascular and neuromuscular efficiency in athletic performance, but presently the detrimental effects are found to be small in moderate alcohol consumption (18). One effect is the increase of lactic acid in the blood because alcohol degradation by the liver will interfere with the degradation of lactic acid (1). However, alcohol consumption is mostly at dinner or/and in the evening. Therefore, this negative effect is not likely.

Based on the energy content of alcohol, a daily intake of 10–20 g will increase intake by 280–560 kJ/day, not taking the extra intake of the carbohydrates in the drinks into account. If maintaining or reducing BM is one of the major concerns this aspect might be important.

Summarizing the results of this study leads to the following conclusions:

1. On a group level energy intake is lower than recommended. Especially in types of sport where low BM is needed for competing in weights or for esthetic reasons, athletes restrict their energy intake temporarily or continuously.
2. Snacking contributes 32%-37% to the total energy intake. Therefore, the nutrient quality of the snacks needs special attention.
3. The intake of protein was according to the recommendations. In body building protein supplements were used. If protein intake with food is taken into consideration, no justification can be found for these protein supplements.
4. The intake of carbohydrate was higher in endurance athletes than in strength and team sport athletes. However, the recommended intake of 60–70En% especially in endurance-type activities was not found.
5. Related to the intake of energy, carbohydrate, and protein, bread appeared to be the most important single food item in the athlete's diet.

References

1. Åstrand P, Rodahl K: *Textbook of Work Physiology.* New York, McGraw-Hill, 1978.
2. Butterfield GE, Calloway DH: Physical activity improves protein utilisation in young men. *Br J Nutr* 51: 171-184, 1984.
3. Brownell KD, Steen SN, Wilmore JH: Weight regulation practices in athletes: analyses and metabolic and health effects. *Med Sci Sports Exerc* 19: 546-556, 1987.
4. Chalmers FW, Clayton MM, Gates L et al.: The dietary record - how many and which days? *J Am Diet Assoc* 28: 711-717, 1952.
5. Costill DL: Carbohydrates for exercise: dietary demands for optimal performance. *Int J Sports Med* 9: 1-18, 1988.
6. Durnin JVGA, Womersley J: Body fat assessed from total body density and its estimation from skinfold thickness: measurements of 481 men and women aged from 16 to 72 years. *Br J Nutr* 32: 22-97, 1974.
7. Elvers JWH: *GVOP, Food Coding Software Packet* (dutch). GVO Reports (Health Education Project), University of Nijmegen, 1980.
8. Erp-Baart AMJ van, Fredrix LWHM, Binkhorst RA et al.: Energy intake and energy expenditure in top female gymnasts, in Binkhorst RA, Kemper HGC, Saris WHM (eds): *Children and Exercise XI.* Champaign, IL, University Park Press, pp. 218-223, 1985.
9. Fröleke H von, Nilles M: Untersuchungen zum Ernährungswissen und Ernährungsverhalten von Fußball- und Handballspielern. *Deutsch Z Sportmed* 9: 277-290, 1979.
10. Goodman MN, Ruderman NB: Influence of muscle use on amino acid metabolism. *Exerc Sport Sci Rev* 10: 1-26, 1982.
11. Hickson JF, Schrader J, Cunningham Trischler L: Dietary intakes of female basketball and gymnastics athletes. *J Am Diet Assoc* 2: 251-253, 1986.
12. Hurley BF, Nemeth PM, Martin WH et al.: Muscle triglyceride utilisation during exercise as an effect of training. *J Appl Physiol* 60: 562-567, 1986.
13. Jacobs I, Westlin N, Karlsson J et al.: Muscle glycogen and diet in elite soccer players. *Eur J Appl Physiol* 48: 297-302, 1982.
14. Lemon PWR, Nagle FJ: Effects of exercise on protein and amino acid metabolism. *Med Sci Sports Exerc* 13: 141-149, 1981.
15. Loosli AR, Benson J, Gillien DM et al.: Nutrition habits and knowledge in competitive adolescent female gymnasts. *Physician Sports Med* 14: 118-130, 1986.

16. Katch FI (ed.): *Sport, Health and Nutrition.* Champaign, IL, Human Kinetics Publ., 1986.
17. Kirsch KA, von Ameln H: Feeding pattern of endurance athletes. *Eur J Appl Physiol* 47: 197-208, 1981.
18. McNaughton L, Preece D: Alcohol and its effect on sprint and middle distance running. *Br J Sports Med* 20: 56-59, 1986.
19. Marr JW: Individual dietary surveys: purposes and methods. *World Rev Nutr* 13: 105-164, 1971.
20. Marr JW, Heady JA: Within - and between - person variation in dietary surveys: number of days needed to classify individuals. *Hum Nutr Appl Nutr* 40A: 347-364, 1986.
21. Parr RB, Porter MA, Hodgon SC: Nutrition knowledge and practice of coaches, trainers, and athletes. *Physician Sports Med* 12: 127-138, 1984.
22. Saris WHM, Van Erp-Baart AMJ, Brouns F, Westerterp KR, Hoor ten F: Study on food intake and energy expenditure during extreme sustained exercise: the Tour de France. *Int J Sports Med* 10, S1, S26-S31,1989.
23. Saris WHM, Brouns F: Nutritional Concerns for the young athlete, in Rutenfranz J, Mocelin R, Klimt F (eds): *Children and exercise XII.* Champaign, IL, University Park Press, pp. 11-18, 1986.
24. *Sas Users Guide*, ed. 5. Cary, N.C., Sas Institute Inc., pp. 27511-8000, 1985.
25. Schofield WN: Predicting basal metabolic rate. New standards and review of previous work. *Hum Nutr Clin Nutr* 39c (suppl 1): 5-41, 1985.
26. Seliger V: Energy metabolism in selected physical exercises. *Int Z Angew Physiol Eindschl Arbeitsphysiol* 25: 104-120, 1968.
27. Sherman WM: Carbohydrates, muscle glycogen, and muscle glycogen supercompensation, in Williams M.H. (ed): *Ergogenic Aids in Sport.* Champaign, IL, Human Kinetics Publ., 1983, pp. 3-27.
28. Staveren WA van, Hautvast JGAJ, Katan MB et al.: Dietary fiber consumption in an adult population. A methodological study using a seven-day record. *J Am Diet Assoc* 80: 324-330, 1982.
29. Staveren WA van: *Food Intake Measurements: Their Validity and Reproducibility*, thesis. Agriculture University Wageningen, 1985.
30. UCV Food Table (dutch), Voorlichtingsbureau voor de Voeding, Den Haag, 1984.
31. Voedingsraad: *Recommended Daily Allowances for Energy and Nutrients* (dutch), The Hague, The Netherlands, Dutch Nutrition Board, 1988.
32. Williams MH: *Ergogenic Aids in Sport.* Champaign, IL, Human Kinetics Publ., 1983.
33. Wilmore JH, Freund BF: Nutritional enhancement of athletic performance. *Nutr Abstr Rev* 54: 1-16, 1984.
34. WHO/FAO/UNU Expert Consultation: *Energy and Protein Requirements.* Technical Report Series 724. Geneva, World Health Organization, 1985.
35. Wolf EMB, Wirth JC, Lohmann TG: Nutritional Practices of coaches in the big ten. *Physician Sports Med* 7: 113-124, 1979.

CHAPTER 3

Nationwide survey on nutritional habits in elite athletes
Part II. Mineral and vitamin intake

A.M.J. van Erp-Baart, W.H.M. Saris, R.A. Binkhorst, J.A. Vos and J.W.H. Elvers
(published in Int J Sports Med 10, S11-S16, 1989)

The nutritional habits of elite athletes competing at a national and international top level were determined. Groups of endurance, strength, and team sport athletes participated. All athletes trained at least 1–2 h daily. The purpose of the study was to quantify the mineral and vitamin intake and to identify the magnitude of the nutrient supplementation use.

Information on food intake was obtained by a 4- or 7-day food diary. It was found that calcium and iron intake was positively related to energy intake. In low energy intakes (< 10 MJ) iron intake might be insufficient.

In general, vitamin intake with food was in agreement with the Dutch recommendations. However, if energy intake is high (> 20 MJ) the amount of refined carbohydrate is increased. Consequently , the nutrient density for vitamin B-1 drops. Therefore, under these conditions, supplementation for vitamin B-1 must be considered. The low vitamin intake found in lower energy intakes can be improved by proper nutritional advice.

In body building and in professional cycling, high dosages of vitamins are used. The other groups of athletes used only moderate quantities of vitamin supplements.

It is concluded that vitamin and mineral intake is sufficient, when energy intake ranges between 10 and 20 MJ/day.

Introduction

Athletes look for any competitive edge through training, material, and dietary manipulation. In this process many coaches and athletes apparently believe that supplementation of vitamins and minerals is essential to improve performance. The thought behind this practice is: Little is good, so more must be even better. Therefore, athletes are great consumers of nutritional supplements, despite the opinion among researchers that micronutrient supplementation is only beneficial if intake is marginal (4, 18, 2).

Information about how well-balanced the athlete's diet is, is limited. Especially elite athletes competing on an international level are mostly not involved in studies to quantify nutritional intake. On the other hand, this particular group may be at risk because of the high intensity and duration of the exercise and the fact that by travelling from one match to another, food intake depends on local restaurant facilities.

The purpose of this investigation was to quantify micronutrient intake of elite athletes involved in different types of sports and to identify the magnitude of supplementation practice of vitamins and minerals in relation to the diet.

Methods and Materials

From 1978 to 1986 the nutritional habits of different elite sport groups were determined. In each of the three major types of sports, endurance, strength, and team sport, groups or individual athletes were asked to participate. Criteria for selection of the type of sport was based on its popularity in the Netherlands. Furthermore, stress was laid on being an elite athlete competing on an international level. The minimal amount of training hours had to be 1–2 h daily for 5 days/week.

To increase the number of young athletes, two groups of sub-top athletes competing on a national level were included (swimming and gymnastics).

To obtain information on nutritional habits, the athletes kept a food diary for 4 days, and if possible this was extended to 7 days. Descriptions of the methods and the characteristics and anthropometric data of the different groups are given in detail in Van Erp-Baart et al. (7).

Results

Unless otherwise mentioned, the tables and figures represent vitamin and mineral intake without supplements. To obtain objective criteria, the Dutch recommended daily allowances (DRDA) are used (15, 16). These recommendations are safe levels of intake for a group. To indicate that certainly some individuals of the group have a less than adequate intake, the 80% level was chosen as the cut-off point to consider a group at risk.

Mineral Intake

In Fig. 1 the mean calcium (Ca) intake is presented in relation to the mean energy intake. A significant relation was found between the mean Ca intake (in mg) and the mean energy intake (in MJ): $Y = 102.87\,X + 141.38$, where Y = Ca and X is energy ($r = 0.85$, $P < 0.05$). The DRDA for Ca is 700–900 mg/day for adults and female adolescents. For adolescent boys it is 900–1200 mg/day. If we take the lowest recommendations into consideration, all groups of athletes exceeded the DRDA.

Also the iron (Fe) intake is significantly related to the energy intake: $Y = 1.13 X + 3.09$, where Y = Fe in mg and X is energy in MJ ($r = 0.86$, $P<0.05$) (Fig. 1). The DRDA for iron is 9 mg/day for male adults, 15 mg/day for female adults and male and female adolescents. Fe intake was in agreement with or higher than DRDA in male adults and in female runners, rowers and cyclists. Low iron intakes were found in the female S and T athletes and the swimming girls.

The extremely high intake in female cyclists (E10) was the result of nutritional advice for extra intake of iron-rich food items because some women suffered from iron-deficient anemia. As a result foodstuffs such as liver, apple syrup, and iron-enriched rose hip syrup were frequently chosen in this group.

Results of the contribution of heme- and non-hemebound iron and supplementation to the total iron intake is given in Table 1. In top cycling the largest amount to iron supplements were taken. The female athletes took supplements on medical advice.

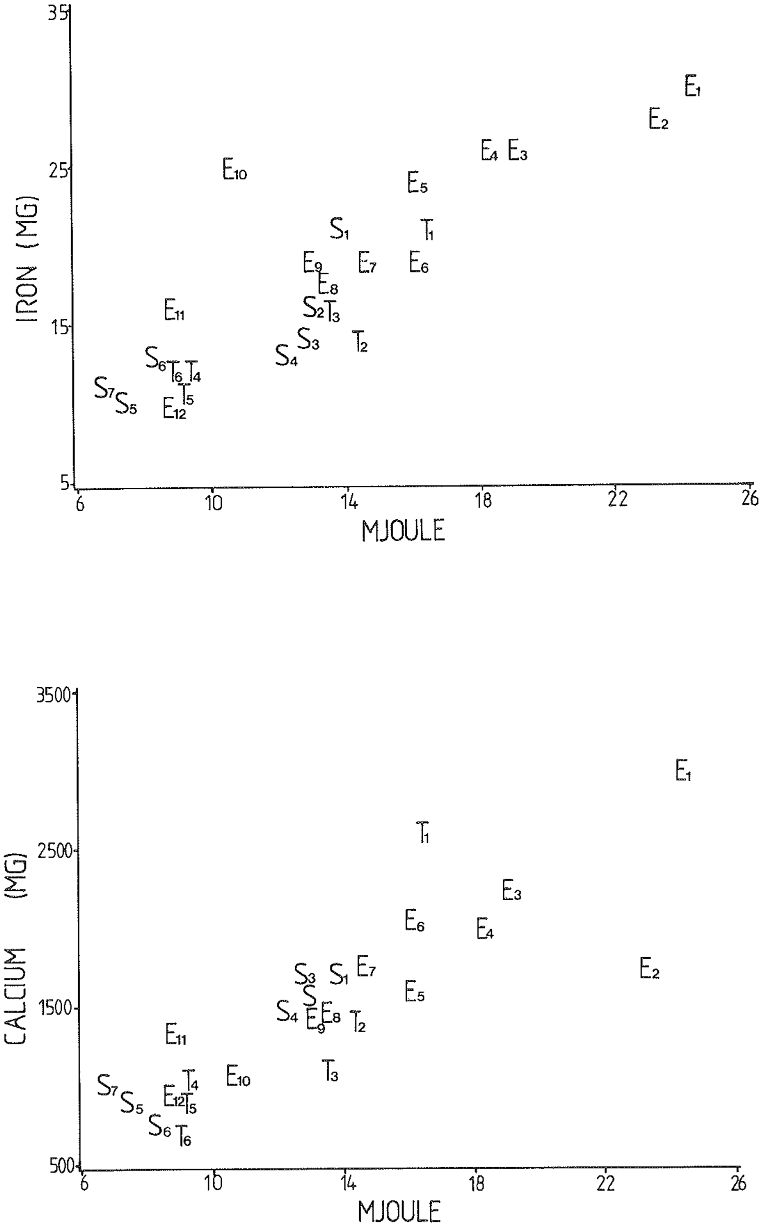

Fig. 1 Daily mean iron and calcium intake in relation to mean energy intake in endurance, strength, and team sport athletes (for explanation of group numbers, see Table 1).

Table 1. Daily mean iron intake (total, heme-bound, non-heme-bound, and from supplements) in endurance, strength, and team sport athletes.

Type of sport	Sex	Iron intake (mg)			
		Total	Heme	Non-heme	Supplement
Endurance (E)					
1 Tour de France	M	353.0	5.3	24.9	324.0
2 Tour de l'Avenir	M	151.8	9.0	19.4	123.4
3 Triathlon	M	26.2	1.3	24.9	0
4 Cycling, amateur	M	37.0	2.2	25.4	9.4
5 Marathon skating	M	38.0	4.0	20.7	13.3
6 Swimming	M	24.2	4.9	14.4	4.9
7 Rowing	M	18.5	3.0	15.5	0
8 Running	M	17.8	2.5	15.3	0
9 Rowing	F	16.2	2.0	14.2	0
10 Cycling, amateur	F	48.0	2.7	22.0	22.3
11 Running	F	22.5	1.6	14.2	6.7
12 Sub-top swimming	F	9.5	1.9	7.6	0
Strength (S)					
1 Body building	M	20.7	4.5	16.2	0
2 Judo	M	16.1	5.4	10.4	0
3 Weight lifting	M	14.2	4.2	10.0	0
4 Judo	M	13.1	3.0	10.1	0
5 Top gymnastics	F	9.9	2.3	7.6	0
6 Sub-top gymnastics	F	14.8	4.8	6.7	3.3
7 Body building	F	11.3	2.3	9.0	0
Team sport (T)					
1 Water polo	M	30.7	5.1	15.6	0
2 Soccer	M	14.0	4.3	9.7	0
3 Hockey	M	15.5	4.6	10.9	0
4 Volley	F	12.3	2.5	9.8	0
5 Hockey	F	52.4	3.1	8.4	40.9
6 Handball	F	12.0	3.2	8.8	0

In Figs. 2–6 the intake of vitamin A, B-1, B-2, B-6, and C are presented. The total intake from food and supplements is depicted as percentage of the DRDA level.

The intake of vitamin A is presented in Fig. 2. The DRDA is 0.85 mg/day. Taking the 80% level of DRDA into account, female gymnasts (S5, S6) and female body builders (S7) had a low vitamin A intake.

The intake of vitamin B-1 is presented in Fig. 3. The DRDA for vitamin B-1 is 0.4 mg/4.2 MJ. Intake of vitamin B-1 with food was low in E1 and E2 (professional cyclists).

In Fig. 4 the intake of vitamin B-2 is presented. The DRDA for vitamin B-2 is 1.6 and 1.7 mg/day for adult and adolescent males, respectively. An intake of 1.3 mg and 1.4 mg/day for adult and adolescent females is advised.
Compared with these recommendations intake of vitamin B-2 with food was sufficient for all groups of athletes.

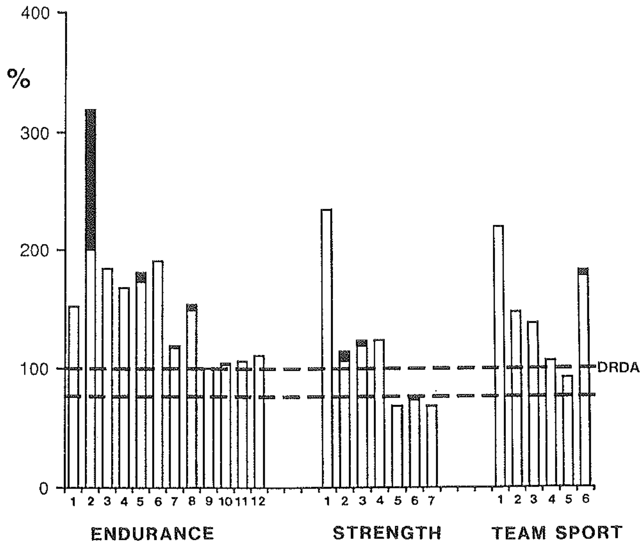

Fig. 2 Daily mean vitamin A (mg) intake (food [] and supplements ▮) in endurance, strength, and team sport athletes (for explanation of group numbers, see Table 1).

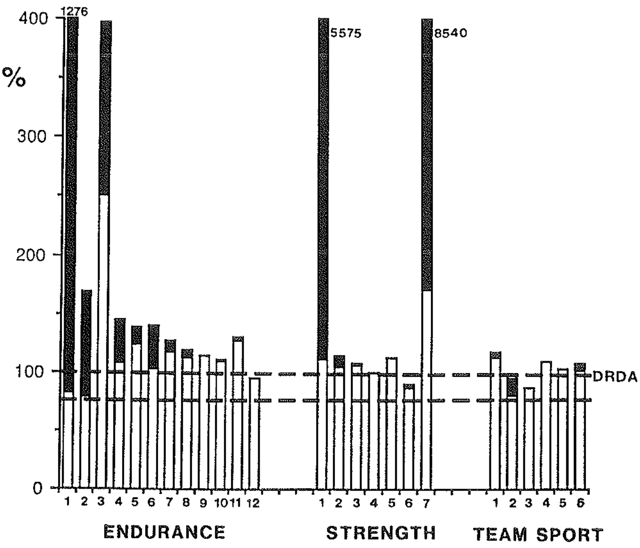

Fig. 3 Daily mean vitamin B-1 (mg) intake (food [] and supplements ▮) in endurance, strength, and teamsport athletes.

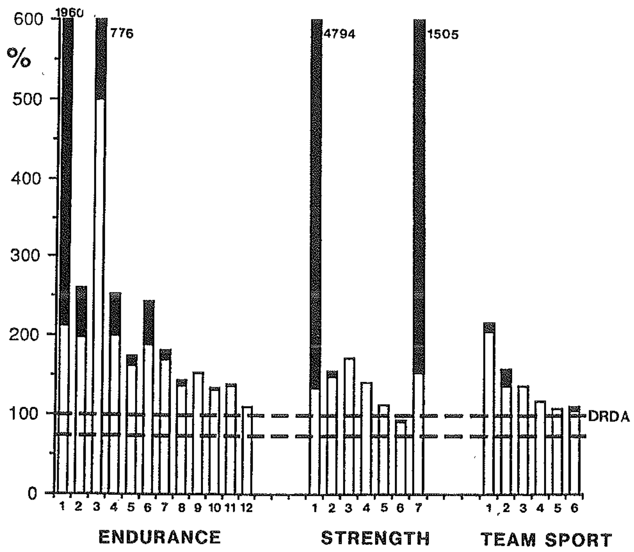

Fig. 4 Daily mean vitamin B-2 (mg) intake (food [] and supplements ▮) in endurance, strength, and team sport athletes.

In Fig. 5 intake of vitamin B-6 is presented. The DRDA for vitamin B-6 is 0.02 mg/g protein. Taking the 100% level into account, it is surprising to see that only triathletes (E3) exceeded that level. Taking the 80% level, vitamin B-6 intake with food was low in professional cyclists (E1, E2), in team sport athletes (except handball), and in adult strength athletes.

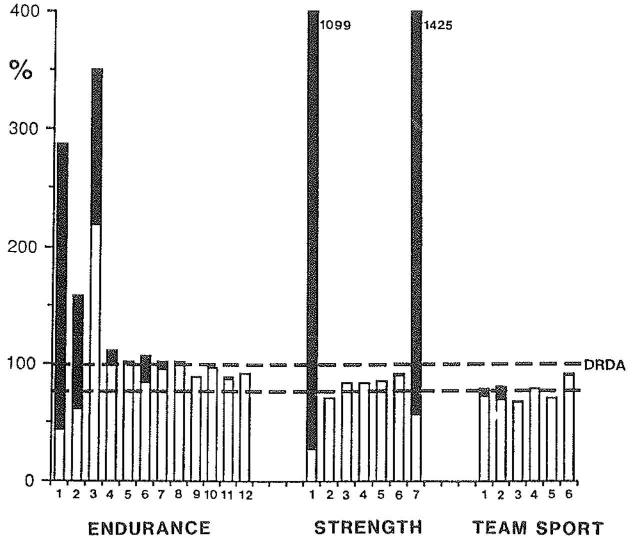

Fig. 5 Daily mean vitamin B-6 (mg) intake (food [] and supplements ▮) in endurance, strength, and team sport athletes.

In Fig. 6 vitamin C intake is presented. Intake of vitamin C with food was sufficient for all the groups (DRDA for vitamin C 70 mg/day) except for young female swimmers and gymnasts and adult female handball players.

With respect to the intake of supplements, vitamin B complex and vitamin C supplements are frequently used by a great number of athletes.

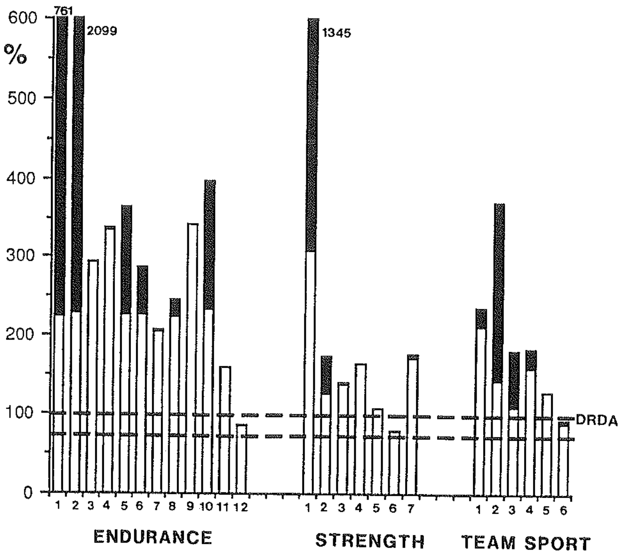

Fig. 6 Daily mean vitamin C (food [] and supplements ▮) in endurance, strength, and team sport athletes.

Discussion

Obviously it is not certain that when the average nutrient intake of a group is equal to the recommended daily allowances, no individual will be deficient. It depends on the range of intake and individual requirements. Waterlow (17) calculated on the basis of known individual intake and requirements that when 50% of the subjects within a group have an intake less than the DRDA (that means median intake of the group meets the DRDA), about 6% of the group will have an intake less than their requirements.

However, the scientific basis for estimates of requirements is uncertain. The information about individual variation in the requirements is unknown in most cases. The information of requirements during hard physical work is even more scarce.

Therefore, it is extremely difficult to judge the adequacy of the individual's intake based on the mean intake of the group, especially if one takes the methodological problems into account, as pointed out in the previous paper by van Erp-Baart et al.

(7). On the other hand, it is likely that when the mean intake is below a certain cut-off point some individuals will be at risk. In this respect the chosen 80% level as a cut off point is a purely pragmatic approach.

Based on these considerations, it is of interest to study the nutritional intake and to analyze whether possible inadequate intakes can be improved by proper food intake or supplementation if necessary.

Minerals

Ca intake was in comparison with the lowest DRDA level sufficient for all groups of athletes. Our results indicate that the lower intake in female athletes can partly be explained by the low energy intake in these groups. To answer the question of whether an increased need for Ca exist in intensively training athletes, Drinkwater et al. (6) have recently found that female runners with secondary amenorrhea have lower bone density than their nonactive peers. The reason for this phenomenon is not yet known. It is hypothesized that the estrogen level might be responsible for this (9). Therefore, they advised a Ca intake of 1500 mg/day for these athletes. It is however uncertain whether such intake will prevent low bone density. From our regression analysis, a calculated energy intake of a least 13.2 MJ/day is needed to meet such a high Ca intake. In none of our female athlete groups was this energy intake recorded.

In comparison with the DRDA iron intake is low in some young, female athletes. It is well established that athletes, especially female endurance athletes, suffer from low Hb and ferritin levels, which is a marker for iron storage. Beside the plasma volume expansion as a physiologic adaptation to regular exercise (10), increased losses or reduced dietary intake can explain the so-called sports anemia. In addition to the normal menstruation iron loss, Haymes (8) pointed out that in sweat iron can be lost up to 4 mg/liter. Another important factor in our opinion, especially in endurance types of sports, is the negative influence on iron absorption of vegetarian food habits. It is well known that iron in food is present in two chemical structures, as hemebound (H) and non-hemebound (NH) iron. H iron is better absorbed by the body than NH iron. An increased intake of iron is therefore advised when NH iron in combination with fiber-rich food is consumed (5). Athletes with vegetarian food habits usually eat more NH iron in combination with fiber-rich food.

Based on the food selection, it was concluded that the endurance athletes in our study tended to a vegetarian diet (7) with a NH iron intake of 60–80% of the total intake. In this light recommendations of 9–15 mg iron/day may be inadequate. On the other hand, there is no evidence that a safe level of intake of 30 mg iron as proposed by Colgan (4) is necessary.

In general vitamin intake was satisfactory except for vitamin B-6. This finding is of interest in light of the knowledge that in The Netherlands legislation forbids vitamin fortification of food except for vitamin A and D in margarine. Only for a strict number of dietary food products, as for instance the iron and vitamin C enriched rose hip syrup, does legislation permit fortification. Therefore, the levels of vitamin intake from food found in these groups can be considered as the 'natural' intake. This is in contrast to most of the other industrialized countries where a more liberal policy concerning vitamin fortification is applied. Based on these considerations, it is concluded that this study confirms the general opinion that the athlete on a well-balanced diet meets the vitamin requirements and further supplementation is unnecessary (18).

Analyzing the data in more detail, it seems that in some groups specific vitamin intake was at risk. In professional cyclists vitamin B-1 and B-6 intake was low. Under these extreme circumstances athletes almost daily need a very large energy intake in combination with a high CHO intake. Therefore their food choice can be considered as well-balanced in this respect. However, in general, carbohydrate-rich food with an acceptable nutrient density is also voluminous. Therefore, refined food items such as sweet cakes or soft drinks are chosen. Especially when the contribution of these products to the total energy is high, micronutrient density drops. For energy-related vitamins such as vitamin B-1, this can lead to an intake below the RDA. In such a situation supplementation is necessary (12). Another interesting observation was the relationship between housing facility and food consumption. For instance, during the Tour de France and Tour de l'Avenir only white bread (French baguette) was eaten. Consequently, the major source of vitamin B-1 as found in most of the other groups eating wholemeal bread was missing.

Selective abstention from food items can have an important effect on nutrient intake. In female top gymnastics and body building intake of butter or margarine was low or not selected at all to reduce energy intake. Consequently, vitamin A intake was low. Other important sources of vitamin A such as vegetables did not compensate for the diminished intake. Still the diets of these groups were well-balanced, taking into account that energy intake had to be reduced. Vitamin A intake then reaches low levels and again in such situations extra attention is necessary to cover adequate vitamin intake.

Vitamin B-6 metabolism is linked directly to protein intake. Taking the abundant protein intake into account, in general the low levels of vitamin B-6 intake are to be considered as marginal and may hasten the onset of insufficient intake. In a report of the Dutch Nutritional Council on the rationale of vitamin fortification, it was concluded that in several population groups vitamin B-6 intake is marginal (16). However, the analytical methods to measure B-6 concentrations in food are questionable. The vitamin B-6 values based on the microbiological or the new HPLC method differ considerably. In a comparison of 24 food items, the new HPLC technique gave a mean 81% higher value for vitamin B-6 compared with the food table values based on the microbiological method (13). In addition, the number of newly detected biochemical vitamin B-6-deficient subjects in different population groups do not show a higher frequency compared with the other B vitamins in the Netherlands. Based on these considerations, the Nutritional Council in the Netherlands decided to advise not to fortify food with vitamin B-6.

With respect to vitamin supplementation, it is not surprising to see that in most sport groups vitamin supplements are taken. However, the amount and type of vitamin pills varies considerably. In most groups only small dosages, equal to the recommended level, are taken. In a study of Stewart et al. (14) among the general adult population of the United States, it was found that about 50% of the subjects questioned used mostly single vitamin components. Furthermore, vitamin C was the most widely used supplement (90%). Parr (11) found in athletic groups a percentage of users of 40%–60%. In our study, the same pattern of vitamin supplementation was found, except for the professional cyclists and the body building groups, where the level was sometimes 15 times the recommendations.

As mentioned before supplementation might be necessary if energy intake is high, but the reason why in body building such high intakes are used, remains unanswered.

In the literature, early studies on the need of vitamins deal with the clinical deficiencies observed in relation to low intakes. Nowadays attention must be given to high levels of vitamin intake. Although in a clinical situation megadoses of vitamins are used to treat neurologic or psychiatric diseases, only in some vitamin-dependent inborn errors of metabolism it is beneficial (3). On the other hand a high vitamin B-6 dose can cause neurologic complications such as sensory neuropathy in apparently healthy persons. Also interaction between micronutrients can result in increasing needs when there is an unbalanced intake, as have been found in the use of vitamin B (1).

The consumption of vitamins in the general population in the Netherlands is far less than what is known about the use in the United States. Nevertheless, in Dutch athletes the use of extra vitamin supplement is comparable. Therefore, it can be concluded that despite the scientific evidence this belief in extra possibilities to improve performance is strong and further research is needed to gather more arguments for proper advice to athletes.

Summarizing the results of this study leads to the following conclusions:

1. Calcium and iron intake is positively related to energy intake. Therefore, with low energy intakes Ca and iron can become marginal. Thus, intake might be problematic for female athletes and in weight reducing diets.
2. In general, vitamin intake was according to the recommendations and in the literature no indications have been found yet to increase the recommended level. However, if energy intake is high (> 20 MJ) supplementation for vitamin B-1 must be considered. The low vitamin intake we found in lower energy intake can be improved by proper nutritional advice.
3. The widespread use of vitamin supplements among athletes compared with the general population in the Netherlands confirms the strong beliefs among these groups that supplementation is essential to improve performance.

References

1. Aldaheff L, Gualtieri T, Lipton M: Toxic effects of watersoluble vitamins. *Nutr Rev* 42: 33-40, 1984.
2. Beek EJ van der: Vitamins and endurance training. Food for running or faddism claims. *Sports Med* 2: 175-197, 1985.
3. Blom W, Van den Berg GB, Huijsmans JGM et al.: Neurologic action of megadoses of vitamins. *Bibl Nutr Dieta* 38: 120-135, 1986.
4. Colgan M: Effects of multinutrient supplementation on athletic performance, in: Katch FI (ed): *Sports, Health and Nutrition*. Champaign, IL, Human Kinetics Publ., pp. 21-51, 1986.
5. Dokkum W van: *Dietary Recommendations and Mineral Utilization*, thesis, University of Amsterdam, 1984.
6. Drinkwater BL, K Nilson, CH Chesnut et al.: Bone mineral content of amenorrheic and eumenorrheic athletes. *N Engl J Med* 31: 277-280, 1984.
7. Erp-Baart AMJ van, Saris WHM, Binkhorst RA et al.: Nationwide survey on nutritional habits in elite athletes. Part I. Energy, protein, carbohydrate, and fat intake. *Int J Sports Med* 10, S3-S10, 1989.
8. Haymes EM: Proteins, vitamins and iron, in M.H. Williams (ed): *Ergogenic Aids in Sports*. Champaign, IL, Human Kinetics Publ., 1983, pp. 27-55.
9. Martin AD, Houston CS: Osteoporosis, calcium and physical activity. *Can Med Assoc J* 136: 587-593, 1987.
10. Magnusson B, Hallberg L, Rossander L et al.: Iron metabolism and sports anaemia. *Acta Med Scand* 216: 149-163, 1984.
11. Parr RB, Porter MA, Hodgon SC: Nutrition knowledge and practice of coaches trainers and athletes. *Physician Sports Med* 12: 127-138, 1984.
12. Saris WHM, Schrijver J, Van Erp-Baart AMJ et al.: Adequacy of vitamin supply under maximal sustained work loads; The Tour de France, in Walter P, Brubacher G, Stähelin HB (ed): *Elevated dosages of vitamins*. Bern, Huber Verlag, 1989.
13. Schrijver J, Van Schoonhoven J, Speek AJ: The analysis of the individual B6 vitamins in foodstuffs by high-performance liquid chromatography with fluorometric detection. 1989, in preparation.
14. Stewart ML, McDonalds JT, Leny AS et al.: Vitamin/mineral supplement use: a telephone survey of adults in the United States. *J Am Diet Assoc* 85: 1585-1590, 1985.
15. Voedingsraad: *Advice Concerning Sport Food Supplements* (dutch). The Hague, The Netherlands, Dutch Nutrition Board, 1988.

16. Voedingsraad: *Recommended Daily Allowances for Energy and Nutrients* (dutch). The Hague, The Netherlands, Dutch Nutrition Board, 1988.
17. Waterlow JC: Uses of recommended intakes. *Food Policy* May: 107-115, 1979.
18. Williams MH: *Ergogenic Aids in Sports*. Champaign, IL, Human Kinetics Publ., 1983.

CHAPTER 4

Magnesium and zinc intake of 25 groups of elite athletes

A.M.J. van Erp-Baart, W. van Dokkum, W.H.M. Saris, R.A. Binkhorst and J.W.H. Elvers
(submitted for publication)

Abstract

The magnesium and zinc intake of 25 groups of elite athletes was determined. Endurance, strength and team sport athletes were involved. All athletes trained at least 1–2 h daily.
The magnesium and zinc intake was calculated from a 4- or 7- day food diary. For analysis a computerized food table was used.
Mean magnesium intake varied from 209–651 mg/day and zinc intake from 8–31 mg/day. A positive correlation was found between energy intake and magnesium and zinc intake. Magnesium as well as zinc intake was in most groups equal or higher than the recommended level in the Netherlands. Therefore it was concluded that magnesium as well as zinc intake will be sufficient if energy intake is adequate.

Introduction

Magnesium (Mg) and zinc (Zn) are essential nutrients for the human body in general and for the athlete in particular.
Magnesium plays a key role as an essential ion in many fundamental enzymatic reactions in intermediary metabolism. These enzymes include those that transfer phosphate groups, acylate coenzyme A and activate the hydrolysation of phosphate and pyrophosphate. Magnesium is involved in protein synthesis and it is essential for the formation of cyclic AMP. It also plays an important role in neuromuscular transmission and activity. Especially important for the athlete are the studies in which a significant relation has been found between oxygen consumption and plasma magnesium levels. So, a low magnesium status of the body may have an impact on exercise capacity (1, 22, 29).

Zinc is essential for the activity of several enzymes in energy metabolism and because of its role in the synthesis of DNA, RNA and protein. Zinc deficiency may result in a reduction of endurance capacity and impairs growth and repair of damaged tissues. The interest for zinc in sports nutrition originates from animal experiments, where an effect has been found on muscular fatigue and endurance (1, 22, 27). However these effects have only been found in a limited number of studies and further research is needed to confirm these results.

Several studies have demonstrated abnormal magnesium and zinc serum levels in athletes (1, 3, 4, 13, 14, 18, 18, 20, 22). The explanations for these very low blood levels diverge and are still subject for debate (30, 31, 32, 33). Some authors state that substantial losses are found in the sweat of the athlete. It is also stated that internal shifts might occur towards other more active parts of the body involved in exercise; even expansion of the blood serum levels is mentioned, resulting in low blood Mg concentrations.

An interesting question remains, i.e. whether dietary intake of magnesium and zinc is sufficient to restore these losses and to maintain blood levels in balance under prolonged severe exercise.

Until 1989 it was difficult to calculate magnesium and zinc intake from food diaries in the Netherlands because the Dutch Food Composition Table missed overall information on the magnesium and zinc content of common foods. However, in 1989 the Dutch Nutrient Databank has implemented nutrient values for magnesium and zinc. This information, mainly based on analyses in weighed food samples, has been used to evaluate the intake of Mg and Zn in several groups of Dutch elite athletes.

Subjects and methods

In 1978 to 1985, data on food consumption in 25 groups of elite athletes were obtained. The total group of athletes consisted of endurance, strength and team sport athletes, varying in age from 12 to 33 years. All groups participated in competitive sports on a national and international level. They all trained at least 1–2 h per day.

Food consumption intake was assessed with a 4- or 7-day food diary. All participants were instructed in advance. The completeness of the diaries was checked and supervised by the same dietitian. Detailed information about types of sports, body mass, fat mass and fat free mass and macro- and micronutrient intake has been published elsewhere (8, 9).

For the calculation of nutrient intake the VEVES food calculation program (16) and BMDP statistical procedures (5) were used. The basis for the calculations was the 1989/90 Dutch Food Composition Table . Because information on magnesium and zinc was not complete the food consumption data were checked for missing values, and if necessary, values were borrowed from other food composition tables (2, 7, 15, 21, 26).

Results

In Table 1 the mean and s.d. of the Mg and Zn intake of the 25 groups of athletes is presented. Also the recommended daily allowances in the Netherlands for the age groups are given (23). The intake of Mg and Zn supplements were not included, because no detailed information about the intake with supplements was available.

Table 1. Magnesium and zinc intake (mg, mean ± sd) in elite endurance, strength and team sport athletes and the dutch recommended daily allowances (DRDA) in mg/day.

	Sex	*n*	Age	Magnesium		Zinc	
			(yr)	intake	DRDA	intake	DRDA
Endurance (E)							
1. Tour de France*	M	5	26	526 ± 109	300–350	25 ± 6	7-10
2. Tour de l'Avenir*	M	4	24	449 ± 154	300–350	31 ± 5	7-10
3. Triathlon	M	3	26	651 ± 59	300-350	18 ± 3	7-10
4. Cycling, amateur	M	14	20	565 ± 76	300-350	16 ± 2	7-10
5. Marathon skating*	M	5	33	528 ± 83	300-350	19 ± 3	7-10
6. Swimming*	M	20	20	474 ± 128	275-325	19 ± 8	8-11
7. Rowing*	M	18	22	470 ± 128	300-350	15 ± 4	7-10
8. Running*	M	56	30	418 ± 123	300-350	14 ± 3	7-10
9. Rowing	F	8	23	461 ± 60	250-300	15 ± 2	6-9
10. Cycling, amateur*	F	21	23	298 ± 60	250-300	10 ± 2	6-9
11. Running*	F	18	31	350 ± 125	250-300	11 ± 3	6-9
12. Swimming	F	50	12	240 ± 61	155-185	8 ± 3	5-7
Strength (S)							
1. Body building*	M	8	30	440 ± 73	300-350	17 ± 4	7-10
2. Judo*	M	4	23	378 ± 115	300-350	15 ± 4	7-10
3. Weight lifting*	M	7	27	356 ± 99	300-350	13 ± 4	7-10
4. Judo*	M	28	18	331 ± 101	275-325	12 ± 3	8-11
5. Top gymnastics	F	11	15	236 ± 50	210-250	9 ± 2	7-10
6. Subtop gymnastics*	F	41	13	209 ± 43	210-250	7 ± 2	7-10
7. Body Building*	F	4	25	240 ± 67	250-300	9 ± 3	6-9
Team sport (T)							
1. Waterpolo*	M	30	24	513 ± 155	300-350	22 ± 8	7-10
2. Soccer*	M	20	20	350 ± 98	300-350	15 ± 5	7-10
3. Hockey*	M	8	27	324 ± 52	300-350	14 ± 2	7-10
4. Volley*	F	9	23	277 ± 65	250-300	10 ± 3	6-9
5. Hockey*	F	9	24	254 ± 50	250-300	10 ± 2	6-9
6. Handball	F	8	22	235 ± 71	250-300	9 ± 3	6-9
Total		419					

*Including World, European, and Olympic medal winners (n = 64).

It appears that on a group level, Mg intake was for most groups in agreement with or higher than the Dutch RDAs. However it should be mentioned that in some female groups Mg intake is lower than recommended (handball and, body building). Zn intake was for all groups in agreement with or higher than the RDA.

Previous calculations for calcium and iron have revealed a significant relation between energy intake and nutrient intake (9). It was interesting to find out whether this phenomenon was also found for the relation between energy intake and both Mg and Zn intake. In Figures 1 and 2 the mean intake of these minerals in relation to mean energy intake is depicted.

From these figures it can be concluded that Mg intake as well as Zn intake correlates well on a group level. The higher energy intake is, the higher Mg and Zn intake will be. For Mg the Pearson correlation coefficient was 0.85 ($p < 0.001$) and for Zn 0.93 ($p < 0.001$).
Regression equations were $Y = 97.556 + 21.935 X$, (Y = Mg, mg; X = energy, MJ) for Mg and energy, and $Y = -0.28872 + 1,1202 X$ (Y = Zn, mg; X = energy, MJ) for Zn and energy.

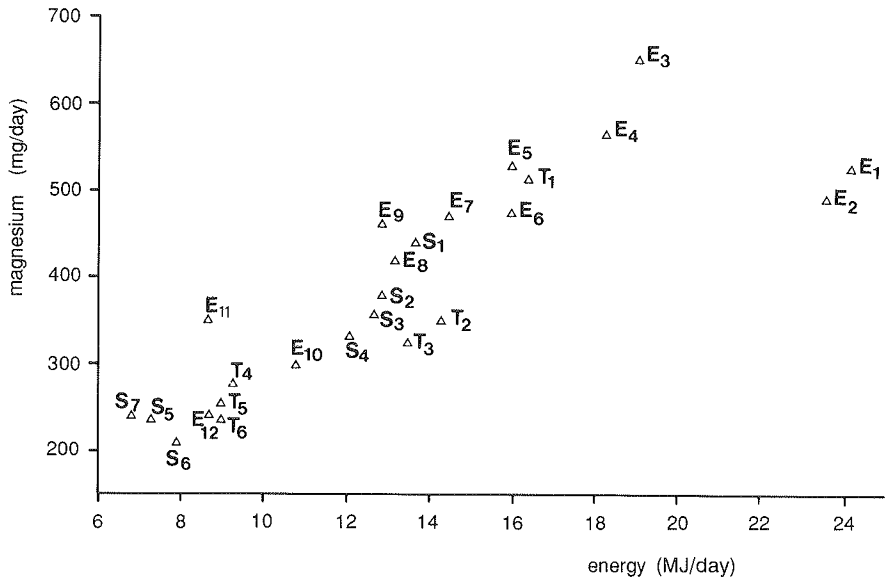

Fig. 1 Mean Magnesium intake (mg)in relation to total energy intake (MJ) in elite endurance (E), strength (S) and team sport (T) athletes (for corresponding numbers see Table 1).

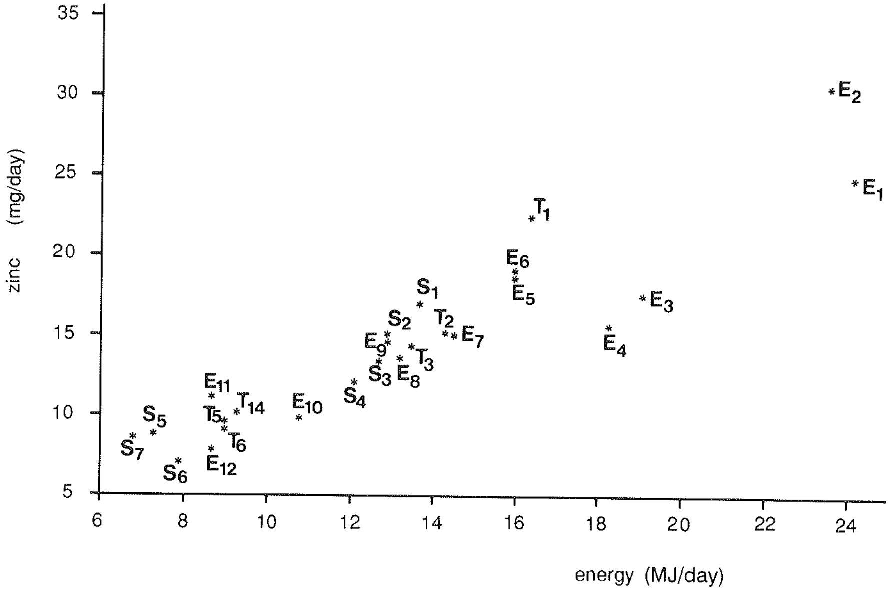

Fig. 2 Mean Zinc intake (mg) in relation to total energy intake (MJ) in elite endurance (E), strength (S) and team sport (T) athletes (for corresponding numbers see Table 1).

Discussion

The nutrient values in the Dutch Food Composition Table are mainly based on food analyses (60%). For completeness sake, calculations based on ingredients and values borrowed from other food composition tables were also used. It is clear that if a nutrient value is missing and the contribution of a given food item to that specific nutrient intake is likely, mean calculated intake will be lower than actual intake. For this reason all food data were checked for missing values; if a value was missing the best-fitting nutrient value was taken from other sources (2, 7, 15, 21, 26).

To get insight into the validity of the Dutch Food Composition Table the analysed data from a market basket study of 18-year-old Netherlands boys were compared with calculated nutrient values (10). For Zn as well as for Mg the difference between intake based on food analyses and calculations of food intake was 11%. For Mg, calculated intake was 386 mg per day, while the analyses showed an intake of 434 mg per day. For Zn, calculated intake was 12.0 mg, while the analyses revealed a Zn intake of 13.6 mg. Individual food groups contributed for less than 2% to the differences between the calculated and analysed nutrient values. It was than concluded that no improvement of the validity of the Food Composition Table was to expected if more analysed values would have been available. (Detailed information about the Market Basket Study is presented by van Dokkum et al (6)).

Because the analysed intake showed a higher value than the calculated intake it can be concluded that if the intake of Mg or Zn, based on calculations, is adequate an even higher actual intake is very likely. On the other hand, if calculated intake is low the results must be interpreted with caution.

The Mg intake was compared to the RDA adequate for all groups and marginal for the females of the body building, handball and sub-top gymnastic groups. In recent literature most results about magnesium intake relate to running athletes. On a group level all intakes were in agreement with or higher than the recommended allowances. Mean intakes varied among males from 366 to 424 mg per day (24, 30, 32). Singh et al (31) and Manore et al (20) found in female groups a mean magnesium intake of 376 and 323 mg per day respectively.

For all investigated groups zinc intake was in agreement with or higher than the RDAs. Also in other groups of athletes zinc intake has been reported to be adequate, varying from 10.2 to 16.8 mg per day (4, 18, 24, 30, 32). In the Netherlands only one group of non-exercising 18-year-old men were studied with respect to magnesium and zinc intake. It has been found that these men had a mean daily intake of 433 mg magnesium and 13.7 mg zinc respectively (6). It can be concluded that magnesium as well as zinc intake tend to be adequate.

A special RDA for athletes?

Regarding the evaluation of intake data, it may be questioned whether the present RDAs for the Dutch population are also applicable for athletes. The Dutch RDAs are based on balance studies. Factorial methods are also used, in which the losses via the faeces, urine, skin etc. are assessed which must be compensated by food intake. These figures are derived from studies in healthy but not excessively training subjects. In the literature, however, abnormal Mg and Zn plasma levels and the increase of urinary Mg and Zn levels in athletes are frequently reported. Both Consolazio (3) and Haralambie (13, 14) state that substantial losses of both Mg and Zn via the sweat may occur. They indicate that an increase of 10–25% of Zn and Mg in sweat are not unusual. So for this reason one could conclude that the Dutch RDA must be raised.

It is often not known whether these low serum values are the result of extra demands of the exercising body, or of an inadequate mineral intake or both. Recently some studies have been presented in which the actual serum levels of Mg and Zn were determined, while at the same time Mg and Zn intake was calculated on the basis of actual food intake. In this respect, we should mention the studies of Singh et al (30, 31), Deuster et al (4), Lugaski et al (18) and Saris et al (28). Singh found in female runners an intake of 369 mg magnesium per day, a level slightly higher than in our female runners. Their Mg serum levels were normal. In male US Navy trainees mean Mg intake was 424 mg per day, 121% of the RDA level. Mean plasma Mg was adequate on a group level. Actual Zn intake relative to Zn plasma levels has been studied as well and it was concluded that if Zn intake was in agreement with the RDA no problems regarding zinc were to be expected. However it should be mentioned that the RDAs for Zn in this study (18) were set at 15 mg per day. In the Netherlands a Zn intake of 7–9 mg per day is advised. On the other hand, Lugaski et al (18) found normal pre-exercise Zn levels in highly trained female athletes despite an intake of 10 mg Zn per day. Saris et al (28) reported Mg and Zn plasma values of the Tour de France before and after the race. Considering the intake values (Table 1: 526 mg Mg and 25 mg Zn) it was interesting to find, that the Zn plasma concentration in fact increased during the race. So, for Zn it can be concluded that if dietary intakes are in agreement with the recommendations the zinc status will be adequate as well.

It remains an interesting question to what extent the RDA for Mg should be elevated to maintain adequate body Mg levels. It is well known that Mg is lost via sweating, and after 30 minutes of recovery the decrease is even more pronounced (20). It should also be mentioned that the normal Mg levels found in athletes often coincide with a Mg intake higher than the recommendations.
The intake value for Mg in the Tour de France is 526 mg/day, while the plasma concentration remained constant over the race period (28).

These results stress the importance of increasing the Mg recommendations for intensively exercising athletes, but it is generally accepted that further studies are needed to determine to what level the RDA must be upgraded to guarantee balance of the Mg levels, especially during long-lasting exercise.

Relation of Mg and Zn intake with energy intake.

It is not difficult to imagine that if more energy is taken nutrient intake will increase concomitantly. From other studies it is well known, that to a certain extent a positive correlation exists between energy intake and nutrient intake is present. If we look at the Mg and Zn intake in the groups of elite athletes it is evident that Zn intake as well as Mg intake are significantly related to energy intake. It was surprising to observe that in contrast with Mg, where low energy intake means low Mg intake, mean Zn intake was adequate for all groups of different energy intake. Low iron intake has also been found to be related to low energy intake (9).

Low energy intake is mostly found in female groups and in athletes following a weight-reducing diet. Especially in the female groups of body builders and gymnasts a low energy intake is highly prevalent. The urge to keep body mass and body fat mass as low as possible is an important factor for the low energy intake usually found in these groups.

The relatively low Mg intake in the group of handball athletes is probably the result of improper food choice. Looking at Mg intake in female volley and hockey players it is obvious that a proper Mg intake is possible at an energy intake of 9 MJ per day, a level also found in the handball athletes. If energy intake is less than 8 MJ per day, Mg intake can become problematic.

Although detailed information on Mg and Zn supplementation in these groups is lacking it is well known that Mg as well as Zn supplements are used in other groups (25). However, the current general opinion is that if intake is adequate supplements have no advantage for athletic performance (17, 33). Another reason for being cautious is the fact that the functions of these minerals are complex. Although the importance of these minerals is not completely understood it has been found that Mg and calcium can be antagonistic in biological systems (12, 29). Pharmacological doses of Zn have been found to influence the availability of copper and that it can have adverse effects on the ratio between HDL and LDL cholesterol levels (11, 27). The precise mechanisms are not yet understood, but it is certain that supplementation should be advised only if normal balanced nutrition is not available. Based in the regression equation between energy intake and Mg or Zn intake and the RDAs a minimal energy intake level can be set on 9-10 MJ/day.
Supplementation for both Mg and Zn can be indicated if energy requirement is less than 8 MJ.

Conclusion

It can be concluded that for all groups the Zn intake was at the recommended level and sometimes even higher than the recommendations.

It is advisable to increase the Mg intake if substantial losses of body water by sweating are likely. To what level Mg intake should be increased is still uncertain. In some circumstances it is possible that groups are at risk for low Mg levels. In this respect attention should be given to female athletes in general and male athletes groups with a low energy intake because of weight-reducing practices.

No reasons, however, exists that supplementation is necessary for these groups of athletes. If higher recommendations are to be assessed for athletes, it should be mentioned that the intensity and duration of the training makes also a higher demand on energy intake. This study indicates that, if energy intake increases, Mg as well as Zn intake increases as well.

Thus Zn and Mg intake in Dutch elite athletes seems adequate; supplementation of both minerals is not indicated.

References

1. *Anonymous.* Advice concerning sport food supplements (dutch). Neth J Nutr 48: 73-97, 1987.
2. *Anonymous.* Levnedsmiddeltabeller 1989. Storkokkencentret Levnedsmiddelstyrelsen Soborg 1989.
3. Consolazio CF. Nutrition and Performance. *Progress in Food and Nutr Sci* 7: 1-187, 1983.
4. Deuster PA, BA Day, A Singh et al. Zinc status of highly trained women runners and untrained women. *Am J Clin Nutr* 49: 1295-1301, 1989.
5. Dixon WJ. *BMDP Statistical Procedures.* University of California Press. Berkeley 1983.
6. Dokkum W van, RH de Vos, Th Muys et al. Minerals and trace elements in total diets in The Netherlands. *Brit J Nutr* 61: 7-15, 1989.
7. Dokkum W van, RH de Vos, J Schrijver et al. *Total diet study 1988/89* (dutch). TNO Nutrition and Food Research, Zeist, 1990.
8. Erp-Baart AMJ van, WHM Saris, RA Binkhorst et al. Nationwide survey on nutritional habits in elite athletes. Part 1. Energy, carbohydrate, protein and fat intake. *Int J Sports Med* 10 suppl. 1: S3-S10, 1989.
9. Erp-Baart AMJ van, WHM Saris, RA Binkhorst et al. Nationwide survey on nutritional habits in elite athletes. Part 2. Mineral and vitamin intake. *Int J Sports Med* 10 suppl. 1: S11-S16, 1989.
10. Erp-Baart AMJ, W van Dokkum et al. *The validity of the Netherlands Food Composition Table NEVO.* Eurofoods Meeting, Uppsala, Sweden, 1989.
11. Fosmire GJ. Zinc toxicity. *Am J Clin Nutr* 51: 225-227, 1990.
12. Greger JL. Effect of dietary protein and minerals on calcium and zinc utilisation. *Crit Rev Food Sci Nutr* 3: 249-271, 1989.
13. Haralambie G, B van Dam. *Untersuchungen* über Vitamin-Electrolyt-Status bei *Spitzenfechterinnen.* Leistungssport 7: 214-219, 1977.
14. Haralambie G. Serum Zinc in athletes in training. *Int J Sports Med* 2: 135-138, 1981.
15. Holland B, ID Unwinn, DH Busch. *Cereals and cereal products.* Third supplement to McCance and Widdowson's The Composition of Foods. The Royal Society of Chemistry, 1988.
16. Kistemaker C, M Wedel. VEVES: *Food calculation program* (dutch), TNO Nutrition and Food Research, report V 88.303/680156. Zeist, 1988.
17. Kunz P, G Steiner, C Wenk. The importance of providing minerals to long distance runners during a 30 km course. *Internat J Vit Nutr Res* 59: 426, 1989.
18. Lugaski HC, BS Hoverson, DB Milne et al. Copper, zinc and iron status of female swimmers. *Nutr Res* 5: 493-502, 1989.
19. Lijnen P, P Hespel, R Fagard et al. Erythrocyte, plasma and urinary magnesium in men before and after a marathon. *Eur J Appl Physiol* 58: 252-256, 1988.
20. Manore MM, CL Wells, WR Lehman. Blood magnesium and red blood cell hemolysis following exercise in female runners consuming adequate dietary magnesium. *Nutr Rep Int* 39: 787-797, 1989.
21. Meer MA van der. *Intake and bioavailability of zinc from vegetables and fruit* (dutch). ATO Agrotechnology, Report nr. 2323, Wageningen 1986.
22. McDonald R, CL Keen. Iron, zinc and magnesium nutrition and athletic performance. *Sports Med* 5: 171-184, 1988.
23. Nutrition Council. Recommended daily allowances 1989 (dutch), The Hague, The Netherlands, 1989.
24. Nieman DC, JV Butler, LM Pollet et al. Nutrient intake of marathon runners. *J Am Diet Assoc* 89: 1273-1278, 1989.
25. Nieman DC, JV Butler, LM Pollet et al. Supplementation patterns in marathon runners. *J Am Diet Assoc* 89: 1615-1619, 1989.
26. Paul AA, Southgate DAT. McCance and Widdowson's. *The Composition of Foods.* Elsevier/North-Holland Biomedical Press, Oxford, Amsterdam, 1987.
27. Saris WHM, J Schrijver, MA v Erp-Baart, F Brouns. Adequacy of vitamin supply under maximal sustained workloads: The Tour de France. In: *Elevated dosages of vitamin benefits and hazards.* P Walter, G Brubacher, H. Stähelin (eds). H Hubers Publishers, 1989.

28. Sandstead HH, Evans GW Zinc. In: Nutrition Reviews. *Present Knowledge in Nutrition*. The Nutrition Foundation, Inc. Washington, D.C. 1984.
29. Shils ME. Magnesium. In: Nutrition Reviews. *Present Knowledge in Nutrition*. The Nutrition Foundation, Inc. Washington, D.C. 1984.
30. Singh A, BA Day, JE DeBolt et al. Magnesium, zinc, and copper status of US Navy SEAL trainees. *Am J Clin Nutr* 49: 695-700, 1989.
31. Singh A, PA Deuster, BA Day et al. Dietary intakes and biochemical markers of selected minerals: comparison of highly trained runners and untrained women. *J Am Coll Nutr* 9: 65-75, 1990.
32. Weight LM, TD Noakes, D Labadarios et al. Vitamin and mineral status of trained athletes including the effects of supplementation. *Am J Clin Nutr* 47: 186-191, 1988.
33. Weight LM, KH Myburgh, TD Noakes. Vitamin and mineral supplementation: effect on the running performance of trained athletes. *Am J Clin Nutr* 47: 192-195, 1988.

Comparison of habitual dietary fat intake with plasma lipids in active sportsmen

A.M.J. van Erp-Baart, W.H.M. Saris, J.A. Vos, J.W.H. Elvers and R.A. Binkhorst
(submitted for publication)

Abstract

As part of an experimental study on dietary intervention during strength training food intake and plasma lipid levels in different groups of active sportsmen was evaluated. The total population existed of one group of elite endurance athletes, one group of elite strength athletes and a control group of active police- and firemen.

Blood lipids were determined according WHO criteria. Fat and cholesterol intake was assessed with a 4-day food diary.

Although fat and cholesterol intake differed significantly between group A (32 En% fat and 389 mg cholesterol), and B (39 En% fat and 814 mg cholesterol), blood lipid levels were the same (TC 4.6 mmol/l, HDLC 1.22 and 1.23 mmol/l).

It was concluded that the results of this observational study suggests that physical exercise has a beneficial effect on HDL-cholesterol levels independent of fat intake, either absolute or as a percentage of energy intake.

Introduction

It is well established that physical exercise enhances the HDL/total cholesterol plasma ratio which has to be considered as favourable for reduced risk of coronary artery disease (CAD). From epidemiological and intervention studies in the general population positive relations are found between physical exercise and HDL cholesterol levels (8, 9, 15, 20, 23, 29). On the other hand, reduction of total fat intake and modification of the ratio between saturated to poly-unsaturated fatty acids (P/S ratio) change plasma lipid levels as well (12, 28). However little is known about the interaction between diet and physical exercise in changing plasma lipid levels. Some authors (17, 31, 32) have studied the relation between diet and exercise. They concluded that both aspects induce a favourable change towards a higher HDL and a lower LDL cholesterol level. However this change was more pronounced in exercise than in dieting.

Another important factor is that a change towards a higher carbohydrate intake seems to have an inverse effect on HDL levels. Because endurance-trained athletes tend to increase their dietary carbohydrate intake in their diet, because of the positive effect on exercise performance, the positive effects of exercise may be inversely affected. The underlying mechanisms of the above mentioned effects are still unknown, but it has been hypothesized that the lipoprotein lipase activity in adipose tissue and muscle might be an explanation (36).

Most investigations have dealt with people who trained at lower levels of exercise intensity (a recreational level) and the type of training is mostly of an endurance type like walking and running. A limited number of studies (14, 16, 20) dealt with a strength type of training and there are some indications that strength training can induce the favourable effect as well.

As part of an experimental study on dietary intervention during strength training, we were able to evaluate food intake and plasma lipid levels in different groups of active sportsmen. The total population existed of one group of elite endurance athletes, one group of elite strength athletes and one group of controls. In this way we were able to evaluate the impact of type of training and food intake on plasma lipid levels.

Subjects and methods

Fourteen well trained endurance athletes (group A), aged 22–36, training 10–16 h per week, 14 well trained strength athletes (group B), aged 22–28, training 8–12 h per week, and a control group of 23 fit police- and firemen (group C), aged 24–36, training 2–6 h per week, participated in this study. The endurance athletes were middle- and long-distance runners. The strength athlete group consisted of body builders. The athletes had been active in their sports for at least 5 years. The control group had their regular supervised training hours as part of their job. No nutritional supplements or medication were used at the time of the study. Especially in the body builders group the use of anabolic steroids was orally checked before entering the study.

Body fat percentage was predicted from the sum of four skinfolds (10,11). Strength was measured with the use of a strain gauges equipment (37).

Haemoglobin (Hb), haematocrit (Ht), total protein, creatinine-phosphate kinase (CPK) and total serum iron (Fe) were determined with the automatic SMA-12 system.

Venous blood samples were taken in a non fasting state. Total serum cholesterol was measured with Lieberman-Burchardt reagent using serum calibrators, calibrated according to Abell et al. (1). HDL cholesterol was determined after manganese heparin precipitation of apo-β containing lipoproteins (7). Plasma lipids were determined according to the WHO criteria at Wageningen Agricultural University where accuracy was checked by analysis of serum pools of known values provided by the Center for Disease Control (Atlanta, GA) (27).

For the assessment of food intake a four-day food consumption diary (2 week and 2 weekend days) was completed by each subject (26). The food diaries were kept by the subjects themselves. Personal instructions were given at the training centers by a trained dietitian. The methods have been described elsewhere (13). Nutrient analysis was based on the UCV food tables (18).

Student's t-test was used to test statistical differences between the groups. If the variance was statistically different Student's t-test for separate estimates was used.

Results

In Table 1 the anthropometric characteristics and strength measurements of the subjects are presented. The three groups were matched for age. As expected, differences in body mass and body composition were found. The trained athletes had a lower percentage of fat mass (11.4% and 11.5%) than the control group (18.2%). The higher body mass in the police- and firemen is the result of a higher amount of fat mass.

The absolute values of the strength measurements are presented as well. As expected, the strength athletes showed higher values than the other two groups, while the endurance athletes had the lowest values.

Table 1. Anthropometric characteristics (mean ± sd) and strength measurements (mean ± sd) of endurance (A) and strength (B) athletes and a control group of police- and firemen (C).

	group A	group B	group C	Student's t test		
				AvsB	AvsC	BvsC
Age (yr)	28.7 ± 5.2	26.8 ± 4.8	29.5 ± 3.9			
Height (cm)	180.0 ± 6.4	180.0 ± 8.1	182.2 ± 5.4			
Body mass (kg)	68.1 ± 4.7	77.4 ± 13.9	82.7 ± 7.5	***	***	
Body fat (%)	11.4 ± 2.5	11.5 ± 3.2	18.2 ± 4.1		***	***
Fat-free mass (kg)	60.4 ± 4.4	69.2 ± 10.1	67.6 ± 6.2	**	***	
Both legs extension (N)#	4659 ± 930	6211 ± 105	5786 ± 901	***	***	**
Back extension (N)	1335 ± 210	1545 ± 48	1431 ± 273	**	*	*
Arm flexion R (N)	291 ± 31	415 ± 63	343 ± 23	***	***	***
Vertical jump (cm)	42.7 ± 4.4	51.4 ± 6.3	50.0 ± 4.0	***	***	

#N,Newton; R,right; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

The blood analysis values (Table 2) revealed normal blood values for Hb, Ht, total protein and Fe (24). Hb and Ht values were lowest in the endurance group. CPK was elevated in all groups (normally < 130 U/l). It is a well known fact that physical training can increase CPK levels in men, but the increase in CPK after physical exercise is more pronounced in untrained than in trained people (24). This fact might be responsible for the higher CPK levels in the control group than in the runners and strength athletes.

The total cholesterol as well as the HDL cholesterol levels were similar for both groups of athletes, while the control group tended to have a higher cholesterol and a lower HDL cholesterol level, leading to a significant lower ratio of HDL/Total cholesterol.

Table 2. Biochemical analysis (mean ± sd) in endurance (A) and strength (B) athletes and a control gr of police- and firemen (C).

	group A	group B	group C	Student's t test AvsB	AvsC	Bv
Hb ($mmol.l^{-1}$)	8.7 ± 0.6	9.6 ± 0.2	9.1 ± 0.4	**	*	
Ht	43 ± 0.015	47 ± 0.014	45 ± 0.014	***		
Total protein ($g.l^{-1}$)	71 ± 5.1	73 ± 2.5	70 ± 3.6			
CPK ($U.l^{-1}$)	165 ± 80	160 ± 105	200 ± 139			
Fe ($mmol.l^{-1}$)	13.9 ± 5.5	15.5 ± 5.7	19.7 ± 4.8		***	
TC ($mmol.l^{-1}$)	4.6 ± 0.9	4.6 ± 0.5	5.3 ± 0.7			
HDLC($mmol.l^{-1}$)	1.22 ± 0.2	1.23 ± 0.3	1.20 ± 0.3			
HDLC/TC ratio	0.27 ± 0.07	0.27 ± 0.05	0.23 ± 0.09		*	*

TC, total cholesterol; HDLC, HDL cholesterol * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

The subjects' habitual nutritional intake is presented in Table 3. There was a significant difference between habitual food intake of the endurance and the strength athletes. Although no supplements were used, protein intake was significantly higher in the strength athletes than in the runners. Also, total fat and cholesterol intake was highest in the strength athletes. Energy intake was highest in the runners group.

The control group had the highest fat intake. For all nutrients except alcohol, values for the controls were intermediate between the values for runners and strength athletes.

Table 3. Habitual daily nutritional intake (mean ± sd) of a group of endurance (A) and strength (B) athletes and a control group of police- and firemen (C).

	group A	group B	group C	Student-t test AvsB	AvsC	BvsC
Energy intake						
in MJ	15.1 ± 2.0	14.3 ± 2.3	13.3 ± 2.2			
in kcal	3604 ± 354	3420 ± 560	3161 ± 535			
Protein animal (g)	78 ± 39	137 ± 63	80 ± 21		***	***
vegetable (g)	48 ± 28	29 ± 14	30 ± 10	***	***	***
total (en%)	14 ± 2	20 ± 5	14 ± 2	***		***
Fat						
saturated (g)	57 ± 10.2	68 ± 13.5	60 ± 12.0	*		
polyunsat. (g)	21 ± 8.2	19 ± 6.5	19 ± 7.5			
total (g)	128 ± 29.0	148 ± 33.2	131 ± 30.5	*		
total (en%)	32 ± 5	39 ± 8	37 ± 9	**	*	
Cholesterol (mg)	389 ± 212	814 ± 463	460 ± 225	***		**
Carbohydrates						
modis (g)	236 ± 78	188 ± 59	165 ± 70	*	**	
total (g)	467 ± 114	338 ± 102	321 ± 101	**	**	
total (en%)	52 ± 6	39 ± 5	41 ± 5	**	**	
Alcohol (g)	10 ± 8	11 ± 14	40 ± 37		***	***
(en%)	2 ± 2	2 ± 3	8 ± 8		**	**

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

Discussion

The mean energy intake found in the runners group was higher than in a comparable group of elite athletes studied previously (12.3 MJ) (13). Also in view of the number of training hours, the group of athletes can be considered as elite athletes. In the group of strength athletes the same level of energy intake was found as in the comparable group of body builders in the National Survey on food habits (13). Expressed per kg body mass, endurance athletes showed the highest energy intake (218 kJ) and the controls the lowest intake (159 kJ). The strength athletes had a mean energy intake of 184 kJ per kg body mass.

Information about the energy intake of comparable groups of athletes is scanty. Short (30) found the same energy intake as in our groups. Bazarre (4) found a lower energy intake (8 MJ) in the group of strength athletes who prepared themselves for contests. Weight-reducing diets are often used then. A higher energy intake (20 MJ) was found during a so-called building-up period. These athletes used at the time of measurement anabolic steroids in combination with high energy and protein intake. Mean energy intake was lowest in the control group. Compared to the energy intake levels of a representative sample of Dutch men of comparable age (12.6 MJ) the intake level found in the control group is higher, suggesting that these police- and firemen are more active (2).

The most interesting question that can be addressed is the intake of carbohydrates. From epidemiolical as well as intervention studies it is known that a change towards high carbohydrate intake can lead to a decrease in HDL levels (21). Endurance-trained athletes tend to increase their carbohydrate intake. In this runners group the carbohydrate intake differed significantly from that in the other two groups. Nevertheless the HDL levels in the group of endurance-trained athletes were comparable.

The Netherlands Nutrition Council has drawn guidelines for a healthier diet (28). These guidelines are, in general, the same as those set by the American Food and Drug Administration and are based on epidemiological as well as intervention studies. The Council recommends for all people a total fat intake of 30–35% of total energy intake, a P/S ratio of 0.5–1.0 and a cholesterol intake of 33 mg/MJ at the most.

If the results of cholesterol intake, total fat intake and the P/S ratio of the different groups are compared with the recommendations it is obvious that the food choice of the endurance athletes was the most prudent one. The P/S ratio (endurance 0.37, strength 0.27, controls 0.31) is far from ideal. Cholesterol intake was highest in the strength group, expressed as total as well as per MJ. One explanation for this phenomenon is the high consumption of eggs in this group. Some athletes used to eat 10 eggs for breakfast. Also the consumption level for meat and milk products was high, leading to a low P/S ratio.

The control group had a lower fat intake than the strength group and a more favourable food pattern than the general population, 37% of energy intake as fat, versus 40% or more in the general population (28).

The macronutrient intake in the strength group differed widely from the runners group. Strength athletes take an abundance of proteins, because they believe that it is necessary for the development of muscle mass (13, 14, 30). Endurance-trained athletes have a higher carbohydrate intake: in endurance types of training exercise intensity and duration are positively related with performance when carbohydrate intake is high(7).

Recently a positive relation between the amount of dietary fat consumed and HDL cholesterol is reconfirmed (27). Therefore, increased HDL cholesterol levels induced by higher physical activity could be attributed to a consequently higher fat intake. To our knowledge no results are available as to whether total fat intake or fat intake as a percentage of energy intake determines HDL levels.

In general high intake of fat, a low P/S ratio and high cholesterol intake might lead to increased levels for some coronary heart risk indicators such as high total cholesterol level and a low HDL fraction of it. Especially the strength athletes were expected to have a high level of total cholesterol as well as a low HDL levels compared with the endurance athletes. However the results of this study indicate that this is not necessarily the matter. Some facts might explain for this phenomenon. Hurley (20) hypothesized that strength training with more repetitions, moderate resistance and longer intervals than in strength training with less repetitions, high resistance and short intervals have the same effect on lipid and glucose metabolism as endurance types of training.

Also the fact that active training is a useful means to regulate the balance between energy intake and energy expenditure may be another explanation for the favourable blood lipid profiles found in this group. Berns (5) found that blood lipid levels are correlated with body fat mass and Williams (35) found that not only the diet but also the lower fat mass of runners is responsible for the favourable blood lipid levels. Nevertheless, no clear evidence has been found yet and further studies are needed to clarify the underlying physiological mechanisms.

The control group had (non significantly) higher total cholesterol levels and lower HDL/total cholesterol ratio than the trained athletes. The absolute HDL level, however, was similar. Comparison with total cholesterol levels in the general population (21) reveals a normal but relatively high level in this group. Considering the fact that weight training (16, 20) was performed and the food intake was slightly more favourable than usually found in the general population (28), one should have expected lower total cholesterol levels than those found in the general population, especially, with regard to the findings of Hurley, who found also a lowering effect on total cholesterol in resistive training at lower levels (20).

As expected the body composition of the control group was different from that of the athlete groups. Body fat mass was higher than the fat mass in both athlete groups and fat-free mass was higher in the strength athletes. The fact that this control groups was fairly active explains the relatively high fat-free mass found in this group. Their physical training is part of their daily professional activities, but is of a shorter duration and a lower intensity than in the trained athletes.

With respect to body composition it was interesting to find that both athlete groups are low and comparable in percentage of fat mass. Related to the absolute kg of fat-free mass the strength and control group of police- and firemen are comparable. Thus related to serum lipids percentage of fat mass seems to be of importance.

Looking at the results for strength measurements it is obvious that the strength group was strongest. The relatively great strength, found in the control group of police- and fireman can be explained by the fact that they had been involved in strength training on a regular basis in the past.

The relatively high HDL cholesterol levels found in the strength group clearly indicates that this group did not use anabolic steroids. From other studies (3, 4, 19, 25) it is known that the use of anabolic steroids can lead to a dramatic decrease of the HDL cholesterol level.

In conclusion, the results of this study indicate that a less prudent diet does not necessarily lead to a less favourable HDL/total cholesterol ratio, when intensive exercise is performed and body fat mass is low, which is indicative of a good energy balance. A negative effect on HDL levels can be expected if endurance training coincides with increased carbohydrate intake. The results of this observational study suggests that physical exercise has a beneficial effect on HDL levels independent of fat intake, either absolute or as a percentage of energy intake.

References

1. Abel LL, BB Levy, BB Brody et al. A simplified method for the estimation of total cholesterol in serum and demonstration of its specificity. *J Biol Chem* 195: 357-366, 1952.
2. Baecke JAH, WA van Staveren, J Burema. Food consumption, habitual physical activity, and body fatness in young Dutch adults. *Am J Clin Nutr* 37: 278-286, 1983.
3. Baldo-Enzi G, F Giada, G Zuliani et al. Lipid and apoprotein modifications in body builders during and after self-administration of anabolic steroids. *Metabolism* 39, 2: 203-208, 1990.
4. Bazarre TL, SM Kleiner, MD Litchford. Nutrient intake, body fat, and lipid profiles of competitive male and female bodybuilders. *J Am Coll Nutr* 9: 136-142, 1990.
5. Berns MA, JHM de Vries, MB Katan. Increase in body fatmass as a major determinant of changes in serum total cholesterol and high density lipoprotein cholesterol in young men over a 10-year period. *Am J Epidemiol* 130: 1109-1122, 1989.
6. Burnstein M, J Samaille. Sur un dosage rapide du cholesterol lié aux α- et aux β-lipoprotéines du serum. *Clin Chim Acta* 5: 609, 1960.
7. Costill DL. Carbohydrates for exercise: dietary demands for optimal performance. *Int J Sports Med* 9: 1-18, 1988.
8. Dannenberg AL, JB Keller, PWF Wilson et al. Leisure time physical activity in the Framingham Offspring study. *Am J Epidemiol* 129: 76-88, 1989.
9. Dufaux B, G Assmann, W Hollmann. Plasma lipoproteins and physical activity: a review. *Int J Sports Med* 3: 123-136, 1982.
10. Durnin JVGA, MM Ramahan, The assessment of the amount of fat in the human body from measurements of skinfold thickness. *Brit J Nutr*, 21, 681, 1967.
11. Durnin JVGA, Womersley J. Body fat assessed from total body density and its estimation from skinfold thickness: measurements on 481 men and women aged 16 to 72 years. *Brit J Nutr* 32: 77-79, 1974.
12. Erkelens DW. Cholesterol consensus in the Netherlands. *Eur J Clin Nutr* 43: 89-96, 1989.
13. Erp-Baart AMJ van, WHM Saris, RA Binkhorst et al. Nationwide survey on nutritional habits in elite athletes. Part 1. Energy, carbohydrate, protein and fat intake. *Int J Sports Med* 10: S3-S10, 1989.
14. Faber M, AJ Spinnler-Benade, A Daubitzer. Dietary intake, anthropometric measurements and plasma lipid levels in throwing field athletes. *Int J Sports Med* 11: 140-145, 1990
15. Frey I, A Berg, MW Baumstark et al. Effects of age and physical performance capacity, on distribution and composition of high-density lipoprotein subfractions in men. *Eur J Appl Physiol* 60: 441-444, 1990.
16. Goldberg L, DL Elliot, RW Schutz, FE Kloster. Changes in lipid and lipoprotein levels after weight training. *JAMA* 252, 4: 504-506, 1984.
17. Griffin BA, R Skinner, RJ Maugham. The acute effect of prolonged walking and dietary changes on plasma lipoprotein concentrations and high-density lipoprotein subfractions. *Metabolism* 37: 535-541, 1983.
18. Hautvast JGAJ The development of a computerized system for calculation of food consumption data (dutch). *Neth J Nutr* 36: 356-361, 1975.
19. Hurley BF, DR Seals, JM Hagberg et al. High-density-lipoprotein cholesterol in Body builders versus Powerlifters. Negative effects of androgen use. *JAMA* 252, 4: 507-513, 1984.

20. Hurley BF, JM Hagberg, AP Goldberg et al. Resistive training can reduce coronary risk factors without altering VO2max or percent body fat. *Med Sci Sports Exerc* 20, 2: 150-154, 1988.
21. Katan MB. Diet and HDL. In: NE Miller, GJ Miller (eds). *Clinical and metabolic aspects of high-density lipoproteins*. Elsevier Science Publishers,1984.
22. Knuiman JT, MB Katan. Serum cholesterol levels in the Netherlands as compared with those in the United States (dutch). *Neth J Med* 52: 2500-2505, 1985.
23. Kokkinos PF, BF Hurley. Strength training and lipoprotein-lipid profiles. A critical analysis and recommendations for further study. *Sports Med* 9, 5: 266-272, 1990.
24. Kreuzer HH, JA Raymakers (eds). *Interpretation of data of laboratory research in medicine* (dutch). Uitgeverij Bohn, Scheltema & Holkema, Utrecht/Antwerpen 1982.
25. Lenders JWM, PNM Demacker, JA Vos et al. Deleterious effects of anabolic steroids on serum lipoproteins, blood pressure, and liver function in amateur body builders. *Int J Sports Med* 9: 19-23, 1988.
26. Marr JW. Individual dietary surveys: purposes and methods. *World Rev Nutr* 13: 105-164, 1971.
27. Mensink RP, Katan MB. Effects of monounsaturated fatty acids versus complex carbohydrates on high-density lipoproteins in healthy men and women. *The Lancet* 1: 122-124, 1987.
28. Netherlands Nutrition Council. Guidelines for a healthy diet. *Neth J Nutr* 47: 159-182, 1986.
29. Paffenbarger RS. Contributions of epidemiology to exercise science and cardiovascular health. *Med Sci Sports Exerc* 20, 5: 425-438, 1988.
30. Short SH, WR Short. Four-year study of university athletes' dietary intake. *J Am Diet Assoc* 82: 632-645, 1983.
31. Thompson PD, B Lazarus, EM Cullinane e.a. Exercise, diet, or physical characteristics as determinants of HDL-levels in endurance athletes. *Atherosclerosis* 46: 333-339, 1983.
32. Thompson PD, EM Cullinane, R Eshleman et al. The effects of high-carbohydrate and high-fat diets on the serum lipid and lipoprotein concentrations of endurance athletes. *Metabolism* 33: 1003-1010, 1984.
33. Weltman A, S Matter, BA Stamford. Caloric restriction and/or mild exercise: effects on serum lipids and body composition. *Am J Clin Nutr* 33: 1002-1009, 1980.
34. Williams PT, PD Wood, RM Krauss e.a. Does weight loss cause the exercise-induced increase in plasma high density lipoproteins? *Atherosclerosis* 47: 173-185, 1983.
35. Williams PT. Weight set-point theory and the high-density lipoprotein concentrations of long-distance runners. *Metabolism* 39: 460-467, 1990.
36. Wood PD, WL Haskell. The effect of exercise on plasma high density lipoproteins. *Lipids* 14: 417-427, 1979.
37. Vos JA. *Static and dynamic strength measurements* (dutch). Thesis State University, Gent. Belgium, 1976.

CHAPTER 6

Energy intake and energy expenditure in top female gymnasts

A.M.J. van Erp-Baart, L.W.H.M. Fredrix, R.A. Binkhorst, T.C.L. Lavaleye, P.C.J. Vergouwen and W.H.M. Saris

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Summary

A study on daily energy intake (EI) and energy expenditure (EE) of 11 female top gymnasts has been carried out.
To assess daily EE net-EE values of daily activities and training were added to the individual's 24-h resting metabolic rate (RMR). EE during training was estimated using two methods: 1) a time-and-motion study (T&M) and 2) a heart rate (HR) method. EE of daily activities was obtained by a questionnaire. RMR was measured with a closed spirometer system. Mean EI was 7277 kJ/day, mean EE was 8502 and 9125 kJ/day for respectively the T&M and HR method. It is suggested that part of this difference can be accounted for by methodological problems. The actual difference in EI and EE indicates that a number of these gymnasts have a real energy disbalance

Introduction

It is well know that gymnasts need a low body weight to perform well and that their food intake generally is low. Because they train daily for hours, a larger energy intake (EI) might be expected. Therefore, it was decided to study EI as well as energy expenditure (EE) of a group of female gymnasts in the Netherlands to obtain information about their energy balance.

Methods

A group of 11 top female gymnasts belonging to the national selection group participated in this study. They trained 3 hr/day, 5 days/week in a national sports center. During the week they lived with foster parents and during weekends they returned home. Anthropometric data for the subjects are given in Table 1. The percentage of body fat was assessed from skinfold measurements according to the method used by Durnin and Ramahan (3). This body fat value in comparison with their peers was low (25%) (7).

Data on EI were collected using a 7-day record which was analyzed by means of a computerized program (5).

Daily EE minus EE during the training hours was obtained by measuring each individual's 24-h resting metabolic rate (RMR). To this measured RMR the net EE of daily activities obtained from a questionnaire (Q) was added. RMR was determined with a closed spirometer system using an energy equivalent for O_2 of 20.3 kJ (4.825 kcal).

The Q was divided into two parts: that is, weekend and weekday. Mean values for net EE of activities are given in Table 2.

Table 1. Anthropometric data of 11 subjects, mean ± SD.

Age (years)	Height (cm)	Weight (kg)	Body fat (%)	Lean body mass (kg)
15.4 ± 1.4	158 ± 8	48 ± 8	16.4 ± 2.7	40.0 ± 5.4

Table 2. Net energy expenditure for daily activities from literature (see text for further explanation).

Activity	$kJ.min^{-1}$	Activity	$kJ.min^{-1}$
Running	36	Walking	10
Swimming	25	Shopping	10
Football	25	General moderate	8
Sport at school	25	Domestic	7
Tennis	21	Playing organ	2
Chopping wood	19	General light	2
Dancing	17	Sleeping = RMR	
Bicycling	11		

Mean data of Durnin & Passmore (2), Van der Sluys & Dirken (12), Reiff (9), and Kemper (7).

EE during the training hours was estimated using two methods. First, a time-and-motion study was performed. During each training session 1 subject was observed and the activities and the time spent in each were recorded. The activities were divided into three categories: heavy, moderate, and light. For heavy activities, net EE was obtained from data in the literature (see Table 3). Because EE were lacking data on acrobatics, floor and ballet, a net EE of 192, 96, and 50 $kJ.min^{-1}$, respectively, was estimated based on the observations in the present study and data in Table 3. For moderate (e.g., warming-up, preparing the apparatus) and light (e.g., sitting, standing, walking slowly) net EE was fixed, respectively, at 17 and 6 $kJ.min^{-1}$ (see Table 2).

Second, EE during training was estimated using the heart rate (HR) method, in which EE was calculated from the recorded HR and the individual's relationship of HR and EE as obtained at different working levels on a treadmill (11).
HR was recorded on a heart rate memory (HRM) system (10). To predict EE from HR below 100 $beats.min^{-1}$ the individual's RMR plus 0.029 $kJ.kg\ BW^{-1}$ (12) was taken, as was suggested by Saris (11). From the mean HR above 100 $beats.min^{-1}$ and the HR-EE relationship on the treadmill, the remainder of the EE during training was calculated. In summary, the 24-hour EE was the sum of the individual's 24-hr RMR plus net EE of daily activities (from the questionnaire) plus net EE during training (from the time-and-motion study or from the HR method).
For statistical analysis, Student's t-test for paired data was used.

Table 3. Net energy expenditure for gymnastics from literature (see text for further explanation).

Activity	$kJ.min^{-1}$	Literature
Vaulting-horse	380	H&H
Parallel bars	68	H&H
Trampoline	54	H&H
Press up	38	D&P
Balancing beam	15	H&H

H&H = Hollmann & Hettinger (6)
D&P = Durnin & Passmore (2)

Results

Energy intake

Table 4, first column, shows the EI of the group per 24 hr in total, per kg BW, and per kg FFM. No significant differences were found in EI between the weekdays and the weekends: 7.211 ± 1.576 kJ and 7.440 ± 2.136 kJ, respectively. From the standard deviation (SD) it can been seen that large interindividual differences existed. One girl indicated she was on a weight-reducing diet. Table 4, second column shows the recommended daily allowances of the Dutch Food and Nutrition Board (4).

Table 4. Mean ± SD of energy intake (EI and DF&NB) and energy expenditure (EE) of top female gymnastics.

Units	EI	DF&NB*	EE (T&M)	EE (HR)
$kJ.hr^{-1}$	7277 ± 1530	9614	8502 ± 861	9125 ± 865
$kJ.BW^{-1}$	158 ± 43	185	180 ± 28	193 ± 28
$kJ.FFM^{-1}$	184 ± 47	247	215 ± 30	230 ± 30

*Recommended by the Dutch Food and Nutrition Board for girls of this age with normal physical activity.
EE (T&M): EE determination including time-and-motion study. EE (HR): EE determination including heart rate method (see method for further explanation).

Energy expenditure

Mean RMR for this group was 5.317 $kJ.24\ hr^{-1}$. This was not significantly different from standard data applicable for this age group: e.g. 5.697 kJ (13) and 5.447 kJ (14).

Time-and-motion study during training showed that the mean time spent on a training session was 3 hr and 15 min. The intensity of the training was on the average 15% heavy, 8% moderate, and 77% light. The mean total EE/min of all girls was calculated to be 15 $kJ.min^{-1}$ for the training.
The mean total EE/min during the training predicted from HR measurements was 19 $kJ.min^{-1}$. The 24-hr EE's are presented in Table 4. The third column shows the results using the HR–method. The values are the weighted means of week and weekend days. There were significant differences between these periods ($p < .001$): for the values obtained with the time-and-motion study, it was 8.937 ± 869 $kJ.24\ hr^{-1}$ for weekdays and 7.394 ± 890 $kJ.24\ hr^{-1}$ for weekend days, while the values from the HR-method were 9.769 ± 857 $kJ.24\ hr^{-1}$ and 7.394 ± 890 $kJ.24\ hr^{-1}$, respectively.

Discussion

The data in Table 4 show that EE was estimated to be higher than EI. Values differed significantly (EI vs. EE (T&M): $p < 0.01$ and EI vs. EE (HR): $p < 0.001$). It was assumed that the differences were due mainly to the difficulty in assessing EE during training correctly, because there were no significant differences between EI and EE during the weekends (EI = 7.440 kJ.24 hr^{-1} and EE 7.394 kJ.24^{-1}) during which practically no training was performed. A systematic difference of about 623 kJ between EE employing the time-and-motion method and EE utilizing the HR method was found.

The difference between EI and EE might be attributed to the fact that the HR method usually overestimates EE (11). Another possibility is that some girls reduced their EI in order to meet the social acceptability within this group that needed to be lean for their best performances. Finally, it is generally assumed that EE yields about 418 to 1.672 kJ higher values than EI (15).

Compared with the scarce data in the literature, the results show that EI of the present group (see Table 4) was not greatly different from other groups. In Japan, Matsuoka and Kitagawa (8) found an intake of 165 kJ.kg BW^{-1} or 198 kJ.kg FFM^{-1}. This group trained 6 days/week, 4 hr/day. Caldarone et al. (1) in Italy found that a group of young female artistic gymnasts had a mean intake of 8.999 kJ.day^{-1}. They trained 3 times/week, 1 to 3 hr/day. However, in Russia Zabourkin et al. (16) advised that the intake should be 251 kJ/kg BW per day. However, no information was given about intensity and frequency of training.

Related to the recommended daily allowances of the Dutch Food and Nutrition Board (see Table 4), EE values in kJ per kg BW were comparable to these standards. EI, however, was about 25 to 30 kJ.kg BW^{-1} lower than that recommended.

It is tentatively concluded that a part of the differences between EI and EE can be accounted for by methodological problems. However, the actual difference between the mean EI and EE indicates that a number of these gymnasts has a real energy imbalance. In our opinion, this aspect is an important nutritional problem in these types of sport.

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References

1. Caldarone G, Amicis AD, Berlutti G et al. Nutrition of athletes: The role of confectionery in the diet of young girls in training. *J Sports Med* 22: 120-124, 1982.
2. Durnin JVGA, Passmore R. *Energy, work and leisure.* London: Heinemann Books, 1967.

3. Durnin JVGA, Ramahan J. The assessment of the amount of fat in the human body from measurements od skinfolds thickness. *Brit J Nutr* 21: 681, 1967
4. Dutch Food and Nutrition Board. *Dutch Food Table* (dutch) The Netherlands Bureau for Food and Nutrition Information) (Ed.), 's-Gravenhage, 1981.
5. Elvers JWH. *GVOP Food Coding Software Packet* GVO reports (Health Education Project) University of Nijmegen, 1980.
6. Hollmann W, Hettinger Th. *Sportmedizin, arbeits- und training grundlagen (Sport-medicine, work and training principles).* Stuttgart: Schattauer Verlag (Schattauer Editor), 1976.
7. Kemper HCG, Dekker H, Ootjers G et al. *Growth and health of teenagers*, Amsterdam: University of Amsterdam, 1983.
8. Matsuoka H, Kitagawa K. Investigation of a certain diet program and its effects on the various body functions of female college gymnasts (english title). *Res J Phys Ed Chukyo Univ* 24: 27-37, 1983.
9. Reiff GG, Montoye HJ, Remington RD et al. Assessment of physical activity by questionnaire and interview. In: MJ Karvonen, AS Barry (Eds.). *Physical activity and the heart* (Chapter 31). Springfield: Thomas, 1967.
10. Saris WHM, Snel P, Baecke J et al. A portable miniature solid-state heart rate recorder for monitoring daily physical activity. *Biotelemetry* 4: 131-140, 1977.
11. Saris WHM. *Aerobic power and daily physical activity in children.* Thesis, University of Nijmegen, 1982.
12. Sluys H van der, Dirken JM. *Daily energy expenditure of the Dutch industrial worker)* (dutch). Groningen: Wolters-Noordhoff, 1970.
13. Talbot FB. Basal metabolism standards for children. *Am J Dis Childr* 55: 455-159, 1938.
14. Wijn JF de. Energy expenditure at rest and for work. In: *International Course in Food Science and Nutrition.* Gent (unpublished), 1974).
15. Workshop. *Reappraised of methods of estimating energy expenditure and body composition.* The 4th European Nutrition Conference in Amsterdam, May, 1983.
16. Zabourkin EM, Volkov AG, Psjendin AI. Pitánieje gimnástov (Nutrition of gymnasts). *Gimnastika* II: 40-43, 1972.

CHAPTER 7

Reproducibility of urinary 3-methylhistidine excretion in human subjects consuming freely selected diets

H.P. Peters, A.M.J. van Erp-Baart, J.M.F. Trijbels and J.W.H. Elvers
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Summary

Eight males and six females consumed their normal diet for 9 weeks, except for weeks 3 and 9 when they followed a self-selected diet free of 3-methylhistidine (3MH) for five subsequent weekdays (day 1-5). Timed 24-h urine collections were obtained on days 3,4 and 5 of these 3MH-free dietary periods and on one day during weeks 1 and 7.

At the group level, no differences in 3MH excretion ($p > 0.05$) between days 3,4 and 5 in weeks 3 and 9 and between these weeks were observed. Reproducibility at the individual level was indicated by the within-subject coefficient of variation (CVw).

CVw within weeks 3 and 9 was 2.5 and 5.1% for men and 4.8 and 8.0% for women. CVw between these weeks was highest when more than one measurement per week was performed. Relating 3MH to creatinine decreased the CVw between weeks. If muscle protein breakdown is to be measured at the individual level, a reasonably large biologic variation is to be taken into account and repeated measurements should be done to decrease the CVw.

Introduction

The rate of excretion of the amino acid 3-methylhistidine (3MH) in urine has been proposed as an indicator of muscle protein breakdown (1). If the appearance of an amino acid in urine is to provide a valid index of muscle protein degradation rate, an amino acid must be selected that is neither reutilized for muscle protein synthesis nor metabolized by the skeletal muscle, not formed to an important extent in other tissues, quantitatively excreted via the urine and present in known amounts in muscle protein. 3MH has been recognized as an amino acid that seems to meet these criteria (1).

Another source of urinary 3MH is dietary, i.e. exogenous, 3MH, as present in meat, meat products and fish (2, 3). Therefore the use of 3MH as an accurate index depends on either accurate monitoring dietary input or the imposition of a 3MH-free diet (4). The measurement of endogenous urinary 3MH excretion, i.e. 3MH only originating from body sources, has been used to study the effects of dietary manipulation, growth, fever, trauma and various diseases (5-10). But only a few efforts have been undertaken to determine the daily variability of endogenous 3MH excretion under constant, normal conditions (11, 12) and to our knowledge no data on the reproducibility of endogenous 3MH excretion over a period longer than five days are available.

The main purpose of the present study was to determine daily variation over three subsequent days and reproducibility for a period of 5 weeks of endogenous 3MH excretion in urine at both group and individual level under constant conditions. An intervening period of 5 weeks was chosen, because the results of this pilot study will be used in a subsequent study in which the effect of energy restriction on muscle protein catabolism in athletes for a period of 5 weeks is tested.

Furthermore, the dietary contribution of 3MH to the total 3MH output in urine and the time necessary to eliminate exogenous 3MH from the body after cessation of dietary input have been assessed.

Materials and methods

General protocol

The experimental design of this study is summarized in Fig. 1. The participants of this study consumed their normal diet for a period of nine weeks, except for five weekdays (days 1-5) during the third and ninth week. During these days each subject consumed a self-selected diet free of any 3MH, to eliminate 3MH from the diet.

Timed 24-hr collections of urine were obtained on day 3,4 and 5 of these 3MH-free dietary periods and also on day 3 or 4 in weeks 1 and 7. In this way the contribution of dietary, exogenous 3MH to the urinary 3MH output and the time required to clear exogenous 3MH from the body after cessation of dietary input was assessed.

In weeks 1,3,7 and 9 body weight (BW), height and skinfold thicknesses were measured at day 1 and three-day dietary and activity records were kept on days 2 to 4 (Fig. 1).

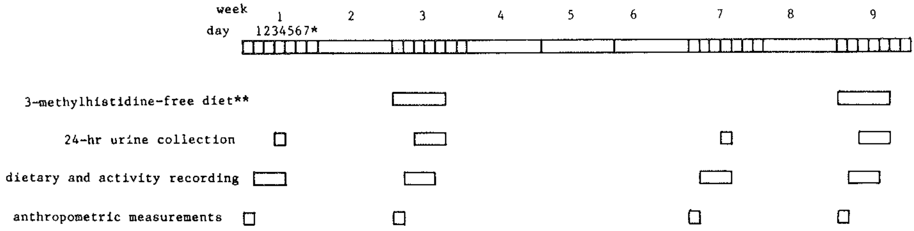

Figure 1. Time table of the experiment
* day 1 to 7 is similar with Monday to Sunday
** the other days and weeks the subjects consumed their normal diet

Subjects

Fourteen adults, eight males and six females, volunteered to participate in this pilot study. Each subject was examined for assessment of general health status and determination of fatness to participate in the study. Most subjects did perform physical activity regularly, and they were asked to maintain their usual daily activity for the duration of the study. The subjects were familiarized with the procedures and purpose of the study and gave their informed consent.

Anthropometric measurements

BW and height were measured with the subjects only wearing shorts. Skinfold thicknesses were measured at four sites (biceps, triceps, subscapula and suprailiaca) using a Harpenden skinfold caliper. The equations of Durnin and Womersley (13) were used to calculate percentage body fat (%BF) from the skinfold data. Fat free body weight (FFW) was calculated from %BF and total BW.

Diet and energy expenditure

Individual energy and protein intakes and the contribution of 3MH-containing products, i.e. meat, meatproducts and fish, to these intakes were calculated from three-day dietary records, kept on weekdays in week 1 and 7. The dietary data were analyzed using a computer program based on accepted Dutch food tables (14). During the two 3MH-free dietary periods in weeks 3 and 9, the subjects were advised of the types and quantities of foods that could be eaten to maintain their previous levels of energy and protein intake. Adherence to this 3MH-free diet was tested by another 3-day dietary record in these weeks 3 and 9. The subjects were asked to maintain their usual energy (EI) and protein intake (PI) and their usual daily activity throughout the experiment, as verified by the four three-day dietary records during weeks 1, 3, 7 and 9 and by three-day activity records, also kept in these weeks. All three-day dietary and activity records were kept on days 2 to 4 (Fig. 1).

The Harris-Benedict equation (15) was used for estimating basal energy expenditure (EE). Additional energy cost was calculated from the 3-day activity records using the method of Van der Sluis and Dirken (16) for normal daily activities and additional data of Seliger (17) and Van Baak (18) for selected physical exercises.

Urine collections

Urine collections started and ended at about 08.00 hr after voiding in the morning. Urine was collected in plastic bottles, containing three drops of toluol as a preservative. Urine volume was measured daily and a 10-ml aliquot was stored at -20°C until it was analyzed for 3MH. The subjects were asked to store their urine bottles in the refrigerator as much as possible during each 24-hr collection period. Completeness of urine collection was assessed on the basis of creatinine excretion measurements.

The determination of urinary 3MH concentration was performed by ion exchange chromatography using an automated amino acid analyzer (Biotronik LC6000). Urinary CR excretion was determined using the Jaffe reaction. The coefficients of variation for the 3MH and CR methods were 3.3 and 3.0% respectively.

Statistics

Analysis of variance was performed to test for a change in BW, FFW, EE, EI, PI and PI as expressed per kg of BW during the 9 week period (19).

Reproducibility at the group level between weeks 3 and 9 for 3MH excretion was tested by comparing 3MH excretion per se and as related to CR excretion (3MH/CR) in weeks 3 and 9 using the paired t-test.

Reproducibility of the 3MH and 3MH/CR excretion data at the individual level both within as between weeks 3 and 9 was expressed by the within-subject coefficient of variation (CVw), as calculated by ANOVA.

CVw between weeks 3 and 9 were calculated when one, two, or three subsequent measurements per week were performed and averaged (CVw1, CVw2 and CVw3 respectively). This was done to reduce the contribution of CVw within weeks 3 and 9 to the CVw between these weeks.

For calculation of the contribution of dietary 3MH input to the total urinary 3MH output the difference in 3MH output between weeks 1 and 3 and between weeks 7 and 9 was calculated:

$$\% \text{ dietary 3MH output in urine} = \frac{\text{mean 3MH output in wk 1 - wk 3}}{\text{3MH output in wk 1}}$$

To test if differences between weeks were significantly different from zero the paired t-test was used.
All values are presented as means ± SD. Significance was accepted at the $P < 0.05$ level (20, 21).

Results

Physical characteristics

Data of the eight men and six women in weeks 3 and 9 are presented in Table 1. Data obtained in week 1 and 7 are not significantly different from week 3 and 9 respectively and are therefore not presented. ANOVA revealed no significant changes in BW, %BF and FFW for both groups over the 9 week period.

Protein intake, food energy intake and energy expenditure

Table 1 gives mean values for total PI, for PI when expressed per kg of BW, EI and EE in week 3 and 9. No significant changes during the 9 week period were noted.

Despite the change from their normal diet to a 3MH-free diet in weeks 3 and 9 the subjects maintained a relatively constant EI as well as constant EE, although mean EE was significantly higher than mean EI in both weeks and for both groups. Also, PI and PI when expressed per kg of BW did not change significantly throughout the experiment. PI per kg of BW is above the recommended dietary allowance (22).

The three-day activity records revealed only small changes in the subjects' daily activities.

3MH excretion

Since the vegetarians did not differ significantly in 3MH excretion from the non-vegetarians, vegetarians and non-vegetarians were included in one group. This group was divided on the basis of sex, i.e. one male and one female group. Mean and individual 3MH excretion data in weeks 1, 3, 7 and 9 are presented in Table 2.

Table 1. Physical characteristics, energy expenditure, energy intake and protein intake of 8 male (M) and 6 female (F) subjects in weeks 3 and 9.

		Week 3		Week 9	
	sex	mean ± SD	range	mean ± SD	range
Age, yr	M	26 ± 4	22-32	26 ± 4	22-32
	F	22 ± 3	20-27	22 ± 3	20-27
Height, cm	M	177.9 ± 6.1	168.0-188.0	177.9 ± 6.1	168.0-188.0
	F	173.6 ± 5.9	169.5-183.5	173.6 ± 5.9	169.5-183.5
Body weight, kg	M	66.4 ± 6.3	55.6-76.2	66.6 ± 5.9	56.4-74.9
	F	60.9 ± 5.2	55.1-66.5	60.3 ± 5.2	54.6-66.2
Body fat percentage, %	M	11.0 ± 2.5	8.5-16.8	10.3 ± 2.5	8.3-16.1
	F	21.7 ± 3.9	18.4-27.8	20.9 ± 4.2	17.0-27.4
Fat-free body weight, kg	M	59.0 ± 5.2	50.9-67.7	59.6 ± 5.0	51.7-67.7
	F	47.8 ± 5.3	41.8-54.3	47.8 ± 5.3	41.5-55.0
Energy expenditure, kcal/day($\times 10^3$)	M	3.0 ± 0.3	2.7-3.6	3.0 ± 0.3	2.6-3.4
	F	2.8 ± 0.5	2.4-3.6	2.7 ± 0.6	2.2-3.8
Energy intake, kcal/day($\times 10^3$)	M	2.7 ± 0.3	2.4-3.5	2.7 ± 0.5	2.3-3.7
	F	2.5 ± 0.8	1.9-3.7	2.5 ± 0.8	1.8-4.0
Protein intake, g/day	M	84 ± 12	71-108	80 ± 25	59-125
	F	71 ± 15	48-88	80 ± 21	50-110
Protein intake per kg body weight, g/day/kg	M	1.3 ± 0.2	1.1-1.6	1.2 ± 0.4	0.9-1.8
	F	1.2 ± 0.3	0.9-1.5	1.3 ± 0.3	0.9-1.7

Mean excretion was greatest during the subjects' normal diet in weeks 1 and 7. After cessation of meat- and fish consumption 3MH excretion was significantly lower on day 3. At this time excretion was apparently stabilized, since no significant differences between 3MH excretions on days 3 through 5 were found for both groups and for both weeks. This difference in 3MH excretion between the meat-free and meat-containing period was not seen in the female group when 3MH outputs for weeks 9 and 7 were compared. When subjects consumed their normal diet about 21% and 22% of the total 3MH excretion for men and 12% and 5% for women in weeks 1 and 7 respectively, was of dietary origin. This component varied from 0 to 37% of the total depending on the dietary habits of the subjects.

3MH excretion over days 3,4 and 5 in weeks 3 and 9 averaged 288 ± 51 and 298 ± 39 µmol 3MH/d for men respectively, and 219 ± 55 and 213 ± 36 µmol/d for women. No significant differences were noted in 3MH excretion between weeks 3 and 9 for both groups independent of the day or the number of days excretions are measured. Also no significant differences were found within these weeks.

Reproducibility at the individual level both within as between weeks 3 and 9 is indicated by the CVw. CVw within weeks 3 and 9 was 2.5 and 5.1% for men and 4.8 and 8.0% for women, respectively. CVw between these weeks had the lowest value for men when performing two subsequent measurements: CVw2 was 4.4%. CVw for the female group was lowest when three subsequent measurements were performed: CVw3 was 12.1%. This represents a within-subject standard deviation of 13 μmol 3MH for men and 27 for women.

Table 2. Individual and mean 3-methylhistidine (3MH) excretion data (μmol/day) in weeks 1,3,7 and 9 in male (subject 1 to 8) and 6 female (subject 9 to 14) subjects.

week	1		3		7		9	
day	3/4	3	4	5	3/4	3	4	5
subject								
1	460	304	300	-*	359	316	319	282
2	431	299	296	299	371	321	323	314
3	378	250	254	272	342	300	286	322
4	376	314	314	327	475	315	311	309
5	228	216	221	205	251	220	224	229
6	323	254	249	254	434	272	270	283
7	528	370	374	378	552	341	391	350
8 **	286	300	288	287	297	271	297	285
mean ***	376^{a}	288^{b}	287^{b}	289^{b}	386^{a}	295^{b}	303^{b}	297^{b}
SD	97	47	47	55	98	39	48	36
9	203	167	176	189	179	175	163	169
10**	156	156	162	186	157	176	172	171
11	365	314	312	330	345	277	230	214
12	275	242	235	226	255	257	240	278
13**	239	192	205	196	185	212	233	208
14	263	199	213	236	226	230	219	216
mean***	250^{c}	212^{d}	217^{d}	227^{d}	225^{cd}	221^{d}	210^{d}	209^{d}
SD	71	58	53	54	69	42	33	40

* no data on 3MH excretion due to meat-ingestion on day 5

** vegetarians

*** values within a column or row bearing the same letter are not significantly different from each other (P >0.05)

Mean and individual 3 MH/CR molar ratios are presented in Table 3. Relating 3MH to CR excretion yielded a mean ratio of 20.9 ± 1.7 and 21.9 ± 1.8 μmol 3MH/mmol CR for men and 19.8 ± 1.9 and 19.6 ± 1.9 μmol/mmol for women in weeks 3 and 9 respectively. Whereas for the female group the ratio was reproducible at the group level between the two weeks, for the male group the ratio in week 3 was significantly lower than that in week 9 ($P < 0.05$).
Both for men as for women CVw between weeks decreased with an increasing number of subsequent measurements: CVw3 was 3.1% for men and 6.6% for women.
The 3MH/CR ratio did not differ significantly between days and CVw within weeks 3 and 9 was smaller in week 3 than in week 9.

Table 3. Individual and mean 3-methylhistidine/creatinine (3MH/CR) molar ratio's (μmol/mmol x 10^3) in weeks 1,3,7 and 9.

week	1		3		7		9	
day	0	3	4	5	0	3	4	5
subject								
1	20.6	21.3	21.0	-*	22.1	23.2	20.1	21.8
2	29.3	21.4	21.8	21.4	22.0	22.9	20.8	22.3
3	25.9	20.4	20.3	21.6	24.5	21.9	23.8	23.8
4	22.8	20.8	20.2	20.5	29.7	20.4	20.3	20.1
5	18.0	18.0	18.5	17.4	19.8	18.9	18.7	19.2
6	25.1	21.3	22.9	23.5	33.0	21.4	21.5	22.9
7	30.8	23.5	22.4	23.5	34.0	25.7	25.7	23.0
8	21.1	22.6	21.2	23.0	23.6	20.6	22.9	24.0
mean**	24.2^a	21.1^b	20.6^b	21.1^b	26.7^a	21.9^c	21.7^c	22.1^c
SD	4.4	1.6	1.3	2.0	5.1	2.1	2.3	1.7
9	25.6	20.7	21.3	20.8	19.9	21.2	19.9	20.1
10	20.2	19.2	19.5	21.2	18.2	20.4	18.4	17.8
11	28.0	21.0	21.6	20.8	25.2	19.3	17.9	16.5
12	22.8	20.5	19.2	20.2	21.7	22.1	21.4	20.8
13	19.0	15.8	16.3	16.0	15.0	17.1	18.4	16.8
14	26.4	20.5	20.7	21.0	20.2	22.3	21.6	21.5
mean**	23.7^a	19.6^d	19.8^d	20.0^d	20.2^d	20.4^d	19.6^d	18.9^d
SD	3.6	2.0	1.9	2.9	3.4	2.0	1.6	2.2

* no data on 3MH/CR ratio due to meat-ingestion on day 5: ** values within a column or row bearing the same letter are not significantly different from each other ($P > 0.05$)

Discussion

Exogenous 3MH excretion

In this study 14 subjects consumed their normal diet for 9 weeks, except for weeks 3 and 9 when they followed a selfselected diet free of 3MH for five consecutive days. In weeks 1,3,7 and 9 several 24-hr urine collections were made. In this way the dietary contribution of 3MH to the total 3MH output in urine was tested. Table 2 shows the importance of the diet as a source of urinary 3MH, although this depends on the quantity of 3MH consumed: in the female group the dietary 3MH contribution to the total urinary 3MH excretion was only 5% in week 7 as a result of a low meat- and fish consumption. It should be emphasized that omission of the two female vegetarians will increase this percentage considerably. This makes it necessary to either monitor and adjust for exogenous 3MH intake or to eliminate 3MH from the diet. This last method seems the most satisfactory one, since the 3MH content of only a limited number of foodstuffs is established (2, 3, 23).

Several investigators identified a 3MH-free diet with a meat-free diet (4,11). Elia et al (3), however, found considerable amounts of 3MH in fish. Also in subject 13, who normally ate meat-free, a higher 3MH excretion in week 1 than in week 3 was noted. This could be attributed to her fish consumption in week 1. Both literature and our findings thus suggest the importance of both a meat-and fish-free diet in order to measure endogenous 3MH excretion.

In addition, it is important to determine when the influence of dietary 3MH sources becomes negligible. Recently, Tomas et al. (4) and Lukaski et al. (11) reported that 3MH excretion was constant after consumption of a meat-free diet for three days. The present study confirms this finding: 3MH excretion did not differ between days 3 through 5 and it was concluded that the 3MH excretion was of endogenous origin at day 3.

Endogenous 3MH excretion

Average absolute excretion values of healthy persons as stated in literature are ranging from 154–286 μmol 3MH per day for men and from 75-210 for women (24–27). Mean values as found in this study are somewhat higher than the upper range found in literature. Since 3MH excretion reflects muscle protein breakdown absolute values are depending on total muscle weight. In this regard, a correlation coefficient was reported for muscle weight and endogenous 3MH excretion ($r = 0.91$, $P < 0.001$;(11)). Most subjects in this study were physically active and had a low %BF and a high FFW and thus may have a larger muscle weight than the subjects used in the studies mentioned above. Another explanation for the high 3MH excretions is that well-trained subjects have a preponderance of slow twitch muscle fibers which may have a faster muscle protein turnover rate (28).

Daily variability of 3MH excretion within weeks 3 and 9.

While several studies focus on the effect of varying conditions on 3MH excretion, almost no information on the daily variability of endogenous 3MH excretion under normal, constant conditions exists.

At the group level 3MH excretion did not differ significantly between days for both the male and female group and for both weeks. Daily variability of 3MH excretion of the individual level can be expressed by the CVw. Based on five consecutive daily measurements, Lukaski et al. (11) found a mean CV of 4.5%, ranging from 2.2 to 7.0%. The study group included 14 men. Fitch et al. (12), however, found a mean CVw of 20.9% in a group of four women. We found a CVw of 2.5 and 5.1% for men and of 4.8 and 8.0% for women in week 3 and 9, respectively.

The smaller CVw in week 3 compared with that in week 9 might be explained by a greater variation in daily activities in week 9, probably as a result of seasonal influences (29): while week 3 was in spring time, week 9 was in summer. Short-term effects of exercise on 3MH excretion are observed in several studies, but the results are controversial (28, 30, 31). Some variability can also be attributed to measurement errors: the accuracy of the used method is 3.3%.

Also, diet may influence daily variability in 3MH excretion. Marliss et al. (32) observed a short-term effect of PI on 3MH excretion, but this relationship could be totally attributed to the muscle protein content of the diet.

Finally, daily fluctuations in BW, FFW, sweat losses and errors in urine collection may have influenced daily 3MH excretion. Completeness of urine collection, however, was assessed on the basis of creatinine excretion measurements. Urinary Cr excretion did not differ from week to week.

Reproducibility of 3MH excretion between weeks 3 and 9

As far as we know no data regarding the reproducibility of endogenous 3MH excretion when the intervening period was longer than five days are available. In the present study the intervening period was more than five weeks. Still, 3MH excretion was found reproducible at the group level, both for the male as for the female group. At the individual level larger differences between weeks were noted. When performing two or three subsequent measurements per week CVw was lower. In the male group after two subsequent measurements CVw2 was 4.4%. In the female group CVw was lowest when performing three subsequent measurements per week: CVw3 was 12.1%.

The total variance includes the variance due to errors in measurements and the residual error, which includes errors due to biological variability and behaviour. Only statements about the measurement error of the 3MH and CR excretion are possible. It was calculated that given the CVw between weeks 3 and 9 for the male subjects of 4.4% and CV for 3MH of 3.0%, the CV residue will be 3.2% ($4.4^2 = 3.0^2 + \text{residue}^2$). Therefore the contribution of the measurement error to total variance will be 48%. In the female group the measurement error between weeks 3 and 9 is 20%. It is clear that the larger CVw total, the smaller the contribution of the measurement error to total CVw will be.

Also, other sources of variation may determine variability in 3MH excretion, such as BW, body composition, intensity, duration and type of physical activity, and diet. In our study BW showed only small intra-individual changes. Daily variations in BW up to 1 kg are considered to be normal (33).
%BF showed some individual changes too between weeks 3 and 9, but this may be due more to errors in skinfold measurements than true changes in %BF.

Table 1 shows a constant EE at the group level during the 9 week period. Individual changes, however, are noted, partly explained by measurement errors (29). Theoretically an increase or decrease in EE should be compensated for by a concomitant increase or decrease in EI. We observed, however, mean EE to be systematically higher than EI and still no significant weight loss was observed. This discrepancy may be due to measurement errors, since both EE as EI were recorded on three weekdays and not during the weekend: a high EE and a low EI during weekdays may be compensated for by a low EE and a high EI, respectively, in the weekend. It is also generally accepted that EE yields about 418 to 1,672 kJ/day higher values than EI (34).

Not only the total EE may have changed, but also the intensity, duration and type of physical activity. The findings of several studies show that exercise can have a variety of long-term effects on 3MH excretions for humans, depending on type, intensity and duration of exercise (35, 36).

Despite the fact that our subjects were restricted to maintain a constant daily food intake and guidance in food choice was provided, they still showed some individual variation in daily PI and in PI expressed per kg BW between week 3 and 9. Data of Hickson and Hinkelman (36) suggested a possible relationship between PI level and 3MH excretion. The differences in PI level that occurred during our experimental period were much smaller; thus no effects of PI level on 3MH excretion can be expected.

The menstrual cycle may influence 3MH excretion. This may explain the greater CVw between weeks 3 and 9 in the female group compared to the male group. In four of the five subjects who showed a normal menstrual cycle a tendency towards a decreased 3MH excretion in the days preceding or during menstrual flow was observed. Only Dirren et al. (37) studied the relationship of menstrual cycle with 3MH excretion, but they found no such relationship. In this study, however, various factors, such as diet and physical activity, variables which may effect the excretion of urinary 3MH (31, 32, 35) were not included.

3MH excretion related to CR excretion

Expression of 3MH excretion data by CR excretion is a mean of correcting for differences among subjects within groups in total muscle mass (36,38), when CR excretion is used as an index of MM: the excretion of 1 g of CR per day would represent a certain amount of MM. But such a CR equivalence ranged experimentally from 17 to 22 kg of MM and is not definitively established (39).

Values for 3MH/CR ratios obtained from literature are ranging from 10.5 µmol/mmol (23) to 20.2 µmol/mmol (40). We found a ratio in our subjects of 20.9 and 21.9 µmol 3MH/mmol CR for the male group and of 19.8 and 19.6 µmol/mmol for the female group in weeks 3 and 9 respectively, which is rather high as compared to literature. This is only partly explained by their high 3MH excretions.

As mentioned before, part of the CVw of 3MH excretion between weeks 3 and 9 is explained by changes in FFW and thus possibly in muscle mass. Relating 3MH excretion to CR excretion should reduce the CVw of 3MH excretion between weeks, which indeed is true. Especially in the female group this resulted in a twofold reduction of CVw.

However, data expression by CR has some disadvantages: use of CR excretion has been criticized because of its large day-to-day variability (41), it assumes constancy of excretion among subjects per unit of BW (42, 43), CR excretion may change independently of skeletal muscle weight (39) and there is some evidence (44) that loss of FFW may cause a disproportionately greater fall in the excretion of CR than of 3MH. This may explain the lack of reproducibility of 3MH excretion when related to CR excretion. Some effects, such as exercise or diet, could be masked by 3MH/CR data expression (31, 36).

In conclusion, literature and our findings stress the importance of providing both meat- and fish-free diets for at least three days to determine accurately the endogenous excretion of 3MH.

This study showed that endogenous 3MH excretion was reproducible at the group level, independent of the day (day 3,4 or 5) or the number of days consecutive measurements were performed. This suggests that the measurement of 3 MH excretion in urine on the third day after cessation of meat and fish consumption may suffice to test changes in 3MH excretion at the group level, provided that BW, body composition, energy intake and physical activity have not changed significantly. However, at the individual level greater changes in 3MH excretion under the circumstances of this study are observed, although relating 3MH to CR decreased CVw. It is concluded that repeated measurements should be done on each subject when determining the effect of certain stimuli on 3MH excretion at the individual level.

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References

1. Young VR, Munro HN. N-Methylhistidine (3-methylhistidine) and muscle protein turnover: an overview. *Fed Proc* 37: 2291-2300, 1978.
2. Macy RL Jr, Naumann HD, Bailey ME. Water-soluble flavor and odor precursors of meat. Influence of heating on acid-extractable non- nucleotide chemical constituents of beef, lamb and pork. *J Food Sci* 35: 83-87, 1970.
3. Elia M, Carter A, Bacon S, et al. The effect of 3-methylhistidine in food on its urinary excretion in man. *Clin Sci* 59: 509-511, 1980.
4. Tomas FM, Ballard FJ, Pope LM. Age-dependent changes in the rate of myofibrillar protein degradation in humans as assessed by 3-methylhistidine and creatinine excretion. *Clin Sci* 56: 341-346, 1979.
5. Adlerberth A, Angerås U, Jagenburg R, et al. Urinary excretion of 3-Methylhistidine and creatinine and plasma concentrations of amino acids in hyperthyroid patients following preoperative treatment with antithyroid drug or ß-Blocking agent: results from a prospective, randomized study. *Metabolism* 36: 637-642, 1987.
6. Williamson DH, Farrell R, Kerr A, et al. Muscle protein catabolism after injury in man as measured by urinary excretion of 3-methylhistidine. *Clin Sci* 52: 527-533, 1979.
7. Robert JC, Serog P. Determination of 3-methylhistidine in human urine by ion exchange high performance liquid chromatography. Applications to patients in post-operative surgical care. *Clin Chim Acta* 142: 161-181, 1984.
8. Narasinga S, Rao BS, Nagabhusan VS. Urinary excretion of 3-methylhistidine in children suffering from protein-calorie malnutrition. *Life Sci* 12: 205-210, 1973.
9. Winterer J, Bistrian BR, Bilmazes C, et al. Whole-body protein turnover studies with 15N-glycine and muscle protein breakdown in mildly obese subjects during a protein-sparing diet and a brief total fast. *Metabolism* 29: 575-581, 1980.
10. Russell DMCR, Walker PM, Leiter LA, et al. Metabolic and structural changes in skeletal muscle during hypocaloric dieting. *Am J Clin Nutr* 39: 503-513, 1984.
11. Lukaski HC, Mendez J, Buskirk ER, et al. Relationship between endogenous 3-methylhistidine excretion and body composition. *Am J Physiol* 240: E302-307, 1981.
12. Fitch WL, Watson JE, King JC. Measurement of urinary 3-methylhistidine with cationic-exchange resin. *Anal Biochem* 154: 632-637, 1986.
13. Durnin JVGA, Womersley J. Body fat assessed from total body density and its estimation from skinfold thickness: measurements on 481 men and women aged 16 to 72 years. *Brit J Nutr* 32: 77-79, 1974.
14. Dutch Food and Nutrition Board (Ed.) *UCV food table.* 's Gravenhage 1984.
15. Harris JA, Benedict FG. *A biometric study of basal metabolism in man.* Publication No 279 of the Carnegie Institution of Washington, 1919.
16. Sluis H van der, Dirken JM. *Daily energy expenditure of the Dutch industrial worker* (dutch).Groningen. Wolters-Noordhoff: 8-17, 1980.
17. Seliger V. Energy metabolism in selected physical exercises. *Int Z Physiol Arbeitsphysiol* 25: 121-129, 1968.
18. Van Baak MA. *The physiological load during walking, cycling, running and swimming, and the Cooper exercise programs.* Thesis, Nijmegen, 1979.
19. *SAS/Statistics User's Guide.* SAS Institute Inc. Cary, N.C. 27511-8000, 1985.
20. Snedecor GW, Cochran WG. *Statistical Methods.* Iowa State University Press, Ames Iowa, 1971.

21. De Boer JO, Van Es AJH, Vogt JE, et al. *Reproducibility of 24 hour energy expenditure measurements using indirect calorimetry.* In: De Boer JO. Energy requirements of lean and overweight women, assessed by indirect calorimetry. Dissertation. Agricultural University Wageningen, The Netherlands, 1985.
22. Food and Nutrition Board. *Recommended Dietary Allowances,* 9th ed. Washington, DC: National Academy of Sciences, 1980.
23. Huszar G, Golenwsky G, Maiocco J, et al. Urinary 3-methyl-histidine excretion in man. The role of protein-bound and soluble 3-methylhistidine in meats. *Br J Nutr* 49: 287-294, 1983.
24. Young VR, Winterer JC, Munro HN, et al. *Muscle and whole body protein metabolism in aging with special reference to man.* In: Elias MF, Eleftherious BE, Elias PK (eds). Experimental Aging Research. Bar Harbor, ME, Ear: 217-252, 1976.
25. Long CL, Schiller WR, Blakemore WS, et al. Muscle protein catabolism in the septic patient as measured by 3-methylhistidine excretion. *Am J Clin Nutr* 30: 1349-1352, 1977.
26. Ward LC, Cooksley WG. The excretion of 3-methylhistidine by the normal healthy adult. *Clin Chim Acta* 91: 363-365, 1979.
27. Mendez J, Vollrath W, Druckemiller M. Body composition among college wrestlers and sedentary students with emphasis on 3-methylhistidine excretion and calculation of muscle mass. In: Biochemistry of exercise. Knuttgen HG, Vogel JA, Poortmans J. (eds). International series on sport sciences. Champaign, Il: *Hum Kin Publ, Inc.* 13: 373-377, 1983.
28. Rennie MJ, Edwards RHT, Kreywawych S, et al. Effect of exercise on protein turnover in man. *Clin Sci* 61: 627-639, 1981
29. Staveren WA van, Deurenberg P, Burema J, et al. *Seasonal variation in food intake, pattern of physical activity and change in body weight in a group of young adult dutch women consuming self-selected diets.* In: Staveren WA van. Food intake measurements: their validity and reproducibility. Dissertation. Agricultural University Wageningen, 1985, 73-93.
30. Dohm GL, Williams RI, Kasperek G, et al. Increased excretion of urea and 3-methylhistidine by rats and humans after a bout of exercises. *J Appl Physiol* 53: 27-33, 1982.
31. Calles-Escandon J, Cunningham JJ, Snyder P, et al. Influence of exercise on urea, creatinine, and 3-methylhistidine excretion in normal human subjects. *Am J Physiol* 246: E334-E338, 1984.
32. Marliss EB, Wei CN, Dietrich LL. The short-term effects of protein intake on 3-methylhistidine excretion. *Am J Clin Nutr* 32: 1617-1672, 1979.
33. Grande F, Keys A. *Body weight, body composition and calorie status.* In: Goodhart RS, Shils ME (eds.). Modern nutrition in health and disease, 5th edition. Philadelphia, PA: Lea and Febriger, 3-34, 1978.
34. Workshop: Reappraisal of methods estimating energy expenditure and body composition. Proceedings of the Fourth European Nutrition Conference in Amsterdam: Nutrition in Europe. The Hague: *Voorlichtingsbureau voor de Voeding*, 195-203, 1983.
35. Radha E, Bessman SP. Effect of exercise on protein degradation: 3-methylhistidine and creatinine excretion. *Biochem Med* 29: 96-100, 1983.
36. Hickson JF, Hinkelmann K. Exercise and protein intake effects on urinary 3-methylhistidine excretion. *Am J Clin Nutr* 41: 246-253, 1985.
37. Dirren H, Robinson AB, Pauling L. Sex-related patterns in the profiles of human urinary amino acids. *Clin Chem* 21: 1970-1975, 1975.
38. Keul J, Doll E, Keppler D. *Energy metabolism of human muscle.* Baltimore: University 247-8, 1972.
39. Heymsfield SB, Arteaga C, McManus C, et al. Measurement of muscle mass in humans: validity of the 24-hour urinary creatinine method. *Am J Clin Nutr* 37: 378-93, 1983.
40. Martin FC, Peters TJ. Assessment in vitro and in vivo of muscle degradation in chronic skeletal muscle myopathy of alcoholism. *Clin Sci* 68: 693-700, 1985.
41. Boileau RA, Horstman DH, Buskirk ER, et al. The usefulness of urinary creatinine excretion in estimating body composition. *Med Sci Sports* 4: 85-90, 1972.
42. Crim MC, Calloway DH, Margen S. Creatinine metabolism in men: creatine pool size and turnover in relation to creatine intake. *J Nutr* 106: 371-81, 1976.

43. Lykken GI, Jacob RA, Munoz JM, et al. A mathematical model of creatine metabolism in normal males-a comparison between theory and experiment. *Am J Clin Nutr* 33: 2674-85, 1980.
44. Rennie MJ, Millward DJ. 3-methylhistidine excretion and urinary 3-methylhistidine/creatinine ratio are poor indicators of skeletal muscle protein breakdown. *Clin Sci* 65: 217-25, 1983.

CHAPTER 8

Food intake and dietary adaptations in intensively exercising insulin-dependent diabetes mellitus patients

A.M.J. van Erp-Baart, J. van der Laan, M. van Soest, W.H.M. Saris, R.A. Binkhorst and J.W.H. Elvers
(submitted for publication)

Abstract

Food intake and dietary adaptations of a group of 16 intensively exercising insulin dependent diabetes mellitus athletes were studied. Data on food intake, dietary adaptation, blood glucose and blood lipid level and aerobic power were obtained from 16 endurance trained subjects (age 23 ± 5 yr). They trained on average 6 h per week. It was found that mean energy intake was 12.3 MJ/day. Despite the reported dietary adaptations carbohydrate intake was relatively low and contributed for 41 % to total energy intake. Mean blood glucose level was 12.7 mmol/l and HbA1 level was 10.2%.
It is suggested that with respect to diabetes control during regular exercise reduction of the insulin dose is to be preferred to an increase in carbohydrate intake.

Introduction

Already before the introduction of insulin exercise therapy was one of the major components in the treatment of diabetes mellitus (16). After decades of little interest on this aspect of the therapy, recently interest has revived due to the increasing body of literature pointing at strong beneficial effects of physical exercise in the treatment of diabetes mellitus. Although the precise mechanisms are not yet fully understood, several positive effects of exercise on blood glucose levels can be demonstrated. Exercise can increase the rate of glucose clearance in the blood and thus help to regulate high blood glucose levels. Furthermore, it has been found that endurance-trained subjects have an increased insulin sensitivity. So in the long term insulin-dependent diabetes mellitus (IDDM) athletes require lower concentrations of insulin to control blood glucose levels (10, 13, 15, 16, 17, 25, 26, 27, 35, 37).

Another positive effect can be expected from the fact that endurance-trained subjects tend to have increased levels of HDL cholesterol. It is generally accepted that high levels of HDL cholesterol can help prevent the development of atherosclerosis which is one of the major risks in IDDM. Exercise may help delay the progressive effects of atherosclerosis in patients with diabetes (29, 36, 37).

On the other hand, exercise may exert some negative effects on the control of IDDM. During exercise the absorption of insulin from subcutaneous depots can increase. This increase in insulin circulating in the blood, combined with the increased sensitivity of the cell to glucose, can result in hypoglycaemia during and after the exercise bout. On the other hand, if the insulin level is too low blood glucose cannot enter the cell, which entails the risk of hyperglycaemia. Performing exercise under such conditions will induce secretion of glugacon and adrenaline and thus promote hyperglycaemia and consequently ketosis. So, lack of circulating insulin as well as an overdosis of insulin during exercise may evoke adverse reactions (16, 17, 20).

It is clear that the exercising IDDM patient must be well aware of the physiological reactions induced by exercise and take certain precautions to prevent the onset of the adverse effects mentioned.

In what way the diet interferes with the exercise and with diabetes regulation is still a matter of debate.

It is from these points of view that we decided to carry out an inventory among intensively exercising IDDM athletes. The aim of our study was to obtain information on food intake, blood glucose levels, blood lipid levels and life-style.

Subjects and methods

Through an advertisement in a Dutch diabetics journal we recruited 50 IDDM patients who trained at least 7 hours a week. After their consent a form was sent with a number of questions about the onset of diabetes, the type of exercise and the duration and frequency of training. Furthermore, the subjects were asked to visit the exercise laboratory where anthropometric measurements were taken and aerobic power ($\dot{V}O_2$-max) was determined . Body mass was determined on a digital scale with an accuracy of 0.1 kg (SECA). Body height was determined with an accuracy of 0.5 cm. Body fat mass was assessed according to Durnin and Womersley (7), taking four skinfolds (supra-iliac, bicipital, tricipital and sub-scapular). To assess the $\dot{V}O_2$- max a submaximal exercise test according to Åstrand (1) was performed on an electromagnetically braked ergometer (LODE, Groningen, Netherlands). During six minutes the subjects had to exercise at a heart rate between 135 and 170. From the given workload and the mean heart rate over the last two minutes maximal $\dot{V}O_2$ can be estimated.

Blood sampling took place at the University's internal medicine clinic. Because the subjects came from all over the country blood sampling took place by day in a non-fasting state. Subjects were instructed to take their regular insulin injections and their regular meals. Determination of glucose, glycosylated haemoglobin (HbA1), total cholesterol (TC) and HDL cholesterol (HDLC) took place according to standard procedures (31, 32, 4, 5).

A semi-structured questionnaire was used to obtain information on the way the subjects had incorporated physical exercise in their daily life. First questions were asked about the onset of diabetes, the motivation for their sport activities and the type and dose of insulin injections. Information was obtained on the diet and the dietary precautions taken before, during and after the training. The subjects were asked whether they suffered from hypo- or hyperglycaemia before, during or after the training, and if so, what their reactions were to the blood glucose levels found. Those who were used to some form of glucose monitoring were asked about their reactions to the glucose levels observed.

Finally, instructions were given for a seven-day food diary. In this diary the types and amounts of foods and drinks were recorded by the subjects in household measures. Because diabetics are well aware of the types and amounts of food they eat this instruction was less comprehensive than for other groups of athletes. After return of the diary by post, if necessary, a telephone check was made to complete the information.

The foods were coded according to a computerized food composition table widely used in the Netherlands (33). Food intake was determined with a food calculation program, which enabled to calculate nutrient intake as well as the contributions of foods to nutrient intake (8).

The preliminary results for the nutritional aspects of the total group of IDDM athletes have been published elsewhere (19). For a better comparison, the results of a homogeneous group of 16 endurance-trained males aged 18 to 40 (IDDM group) are presented as well as the results of a reference group of non-diabetic long-distance runners (R group), who took part in a nationwide survey on food habits in elite athletes, where the same methods were used (9).
To test for differences between the two groups the Student's t-test was used.

Results

In Table 1 the characteristics of the IDDM group and the reference (R) group are presented. The IDDM athletes trained 1-2 hours daily and about 6 hours per week in endurance types of activities like running or cycling, sometimes in combination with team sport activities. All subjects recieved insulin injections daily. One subject changed during the study from insulin injections to tablets because of his intensive exercise. The R athletes were matched for body height and age. Training hours were of the same magnitude. They trained 1–2 hours per day with a mean total of 7 hours per week.

Table 1. Characteristics (mean ± sd) of 16 male insulin dependent diabetes mellitus (IDDM) and 16 male reference endurance athletes.

	IDDM athletes	Reference	Student's t-test
Age (yr)	23 ± 5	29 ± 7	n.s.
Height (cm)	181.6 ± 7.5	181.7 ± 6.8	n.s.
Body mass (kg)	72.0 ± 8.5	69.8 ± 7.1	n.s.
Body fat mass (%)	16.5 ± 4.5	11.8 ± 3.8	*
$\dot{V}O_2$-max ($ml.kg^{-1}.min^{-1}$)	46.2 ± 7.9	69.5 ± 9.3	*
Training (h per week)	6 ± 2	7 ± 3	n.s.
Insulin dose (IE)	54 ± 26		
Years of diabetes	6.5 ± 4.7		

* $p < 0.05$

Body fat mass was significantly higher and aerobic power was significantly lower in the IDDM group.

In Table 2 energy and macronutrient intake is presented. Total daily energy intake in the IDDM group differed significantly from the R group. This difference remained if energy intake was expressed per kg body mass.

Average intake of carbohydrates as percentage of total energy intake (En%) was significantly lower in the IDDM group. Furthermore, it was found that for the group of IDDM athletes 35% of total carbohydrate intake came from mono- and disaccharides, 60% from polysaccharides and 5% from sorbitol. In the reference group mono- and disaccharides as well as polysaccharides accounted for 50% of total carbohydrate intake. Sorbitol was not consumed by this group.

Total fat intake (En%) and cholesterol intake (mg) was significantly higher in the IDDM group than in the reference group. The contribution of different fatty acids to total fat intake was similar in both groups. The P/S ratio was 0.34 and 0.37 for the IDDM group and reference group respectively.

Total protein intake (En%) in the IDDM group was significantly higher than in the reference group. However absolute intake per kg body mass was comparable in both groups (1.4 and 1.5 g/kg body mass respectively).

Table 2. Energy and macronutrient intake (mean ± sd) of 16 athletes with IDDM and 16 reference athletes.

Nutrients	IDDM	Reference	Student's t-test
Energy,			
MJ	12.3 ± 2.4	14.2 ± 2.7	*
Kcal	2941 ± 564	3390 ± 566	*
$kJ.kg^{-1}$	172 ± 33	203 ± 44	*
Protein, En%	17 ± 3	12 ± 2	*
Fat, En%	39 ± 9	32 ± 6	*
Carbohydrate, En%	41 ± 10	50 ± 11	*
Alcohol, En%	2 ± 4	2 ± 2	n.s.
Cholesterol, mg	415 ± 83	378 ± 45	*

* $p < 0.05$

In Tables 3 and 4 the proportional contribution of different foods to energy and carbohydrate intake is presented. For the IDDM group the most important energy source appears to be cheese. Bread, fruits and potatoes are the most important sources of carbohydrates in both groups. Rice and pasta do not contribute substantially to carbohydrate intake in either group. Although sugar is not consumed in large amounts the contribution of mono- and dissaccharides to total carbohydrate intake is large (35%) in the IDDM group. They are mostly derived from fructose- and lactose-containing foods such as fruit and milk.

Table 3. Contribution (%) of food products* to total energy intake.

IDDM athletes (12.3 MJ)		Reference athletes (14.2 MJ)	
Cheese	10.6	Whole meal bread	7.9
Low fat milk	8.1	Margarine	5.5
Brown bread	7.8	Potatoes	4.3
White bread	5.4	Sugar	4.1
Whole meal bread	5.0	Brown bread	4.0
Potatoes	4.1	Cheese	4.0
Margarine	3.0	Beer	3.1
Low-fat margarine	2.3	Whole milk	2.9
Apples	2.2	Low-fat margarine	2.0

* Contributions of less than 2% are not shown.

Table 4. Contribution (%) of food products to total carbohydrate intake, calculated for main meals and snacks separately.

Food products	IDDM athletes		Reference athletes	
	main meals (183 g)	snacks (106 g)	main meals (247 g)	snacks (180 g)
Potatoes	14.0		14.0	
Wholemeal bread	9.9	8.4	15.4	5.2
Brown bread	14.0	15.8	10.9	
White bread rolls	10.1	9.0		
Currant bread	2.5			
Muesli			2.0	
Total bread	**36.5**	**33.2**	**28.3**	**5.2**
Apples	2.1	11.3		5.1
Oranges		2.5		2.0
Dried apples	2.2			
Orange/apple juice		4.2		3.7
Rose hip syrup			2.1	
Total fruit	**4.3**	**18.0**	**2.1**	**10.8**
Low-fat milk	7.6	6.8		
Whole milk			2.3	2.7
Total milk	**7.6**	**6.8**	**2.3**	**2.7**
Sugar			5.1	12.4
Honey			2.7	
Soft drinks				12.1
Beer				5.4
Biscuits				2.7
Ginger bread				2.4
Total miscellany	**0**	**0**	**7.8**	**35.2**

* Contributions of less than 2% are not shown

In Table 5 the results of blood analysis of the IDDM group are presented. The mean glucose level was 12.7 mmol/l which is relatively high for IDDM patients (acceptable level 9 mmol/l). The blood HbA1 level was 10.2 %, indicating a moderate control over a longer time.
The HDLC/total cholesterol ratio was 0.27.

Table 5. Blood analysis (mean ± sd) of 16 male IDDM endurance athletes.

Glucose ($mmol.l^{-1}$)	12.7 ± 5.5
HbA1 (%)	10.2 ± 2.0
Triglyceride ($mmol.l^{-1}$)	1.60 ± 0.98
Total cholesterol ($mmol.l^{-1}$)	4.88 ± 1.31
HDL cholesterol ($mmol.l^{-1}$)	1.34 ± 0.36

Some results of the questionnaire are presented in Table 6. Hobby and better diabetes control are the main motives for sport activities. Only one subject indicated that he used physical exercise as a means to reduce insulin medication. Nobody referred to the possible advantages for preventing or delaying the process of atherosclerosis.

All subjects had informed their consultant physician about their daily physical exercise. Ten subjects reported they had not been stimulated by the physician to perform exercise. Two subjects had chosen another doctor because they were not allowed to perform their regular exercises. Five subjects received medical advice, which consisted of general remarks like 'Eat an extra sandwich before starting the training!' One subject was advised to reduce the insulin dose before starting the exercise bout. Two subjects were advised about the type of exercise.
Ten athletes did not report adaptation of the diet to their regular exercise (Table 7). No dietitian was ever consulted in this matter.

Of the six athletes who reported to change their diet for the training, only one subject suffered from hypoglycaemia directly after the training. Of the ten athletes who did not take any dietary precautions, six athletes indicated that they suffered from hypoglycaemia during and after the training. Three athletes reported more hyperglycaemia before the training. No differences could be found in mono- and disaccharide intake and blood glucose levels between subjects who did not adapt their diet and were not used to regular glucose monitoring and those who said they did. The lowest HbA1 levels were found in the group who practised blood glucose monitoring. However the difference did not reach statistical significance.

Table 6. Life-style interview of the IDDM athletes.

Question	Answer no	yes	if yes, then....
1. Motivated for sports activities		16	hobby 9, improving diabetes control 5 always done 2
2. Medical advice	11	5	type of sport 2, food intake 3, insulin injections 1
3. Dietary adaptations	10	6	extra bread 13, fruits 8, sugared products 6
4. Adaptation of insulin dose	9	7	reduction of insulin
5. Hypoglycaemia	8	8	during and after training
6. Hyperglycaemia	12	3	before start of training
7. Glucose monitoring	5	11	in urine 2, in blood 4, in blood and urine 5

Table 7. Mono- and dissaccharide intake and blood glucose and HbA1 levels (mean ± sd) of the IDDM athletes who reported dietary adaptations and blood glucose monitoring and those who did not.

	n	Mono/disacch (%)	HbA1 (%)	Glucose (mmol/l)
Dietary adaptations				
yes	6	37.7 ± 9.7	10.3 ± 2.5	13.3 ± 4.1
no	10	36.7 ± 12.5	10.1 ± 1.8	12.4 ± 6.5
Blood glucose monitoring				
yes	9	36.6 ± 9.1	9.8 ± 2.3	12.4 ± 4.4
no	7	37.7 ± 14.2	10.7 ± 1.7	13.1 ± 7.2
Dietary adaptations and blood glucose monitoring				
yes	4	37.3 ± 10.3	10.4 ± 3.1	13.5 ± 5.0
no	5	37.4 ± 16.3	10.9 ± 1.9	13.2 ± 8.7

Discussion

Although the type of exercise and the duration and frequency of training are practically the same in both groups the aerobic power as assessed according to Åstrand was significantly lower in the IDDM group. Maximum oxygen consumption was for the IDDM group 46.2 $ml.min^{-1}.kg^{-1}$. Mean maximum oxygen consumption in the age-matched reference group of well trained runners was 69.5 $ml.min^{-1}.kg^{-1}$. Several studies report a difference in aerobic power between IDDM and non-diabetic groups (6, 15). One possible explanation for the reduced oxygen uptake is given by Poortmans et al., who state that aerobic power is inversely related to the state of metabolic control, measured as HbA1 (24). We did not find a relation between both variables. However due to the small number of subjects a relation cannot be excluded.

In diabetics neuropathy may develop with time and evoke malfunction of the cardiac system thus causing a lower oxygen uptake in the body (12, 18). However the latter effect is more pronounced in older than in younger diabetics. Because this group of IDDM athletes was relatively young and the onset of diabetes started 6.5 years ago on average it is not expected that neuropathy has developed to such a degree that the differences in aerobic power can be fully explained. With respect to diabetes control the HbA1 level was moderate.

Other explanations for a lower aerobic power of the IDDM group may be that these athletes train at the same duration and frequency, but at a lower intensity level. The fear for developing hypoglycaemia might be one important reason, but also the fact that the motives for performing exercise are hobby ($n = 9$) and the improvement of diabetic control ($n = 5$) may play a role. In this respect it should be emphasized that the reference group consisted of elite athletes, who compete regularly on national and international level (9).

With respect to body composition the fat mass was higher than in the age- and body height matched reference group. IDDM patients tend to have a lower body fat mass than non diabetics. Our group had a mean body fat percentage of 16%.

In general, endurance-trained athletes have a lower body fat percentage as is demonstrated by the reference group, who had a mean body fat mass percentage of 11.8%. The most likely explanation for the higher fat mass of the IDDM group can be found in the relatively high glucose concentrations which lead to a continuous metabolic drive to lipogenesis. Furthermore to avoid hypoglycaemia the IDDM athletes may have eaten extra carbohydrate-containing foods before and during training. In the questionnaire 14 subjects indicated that, if they eat more, they eat extra bread, 6 IDDM athletes reported eating sugared products, 8 subjects ate more fruit and only one subject did not adapt the amount of food to the exercise. To what extent this extra consumption may have disbalanced energy intake and energy expenditure is hard to answer because total energy expenditure was not assessed.

Energy intake in the IDDM group was lower than might be expected from the duration and frequency of their training. In endurance-trained athletes energy intake is usually at a higher level, as is demonstrated by the energy intake found in the reference group. If energy intake was expressed per kg body mass the differences remained. This difference in energy intake cannot be explained by a difference in endurance training time or frequency. Although duration and frequency of the training is similar for both groups the intensity of the training was probably much lower in the IDDM group. Nevertheless even if the IDDM athletes trained at the same percentage of their maximum aerobic power as the reference group did energy expenditure will be lower.

Another possible indication for the lower energy intake could be the bias in the estimation of the foods consumed by the subjects (3). It is a well known feature that obese people underestimate food consumption and hence energy intake. For this reason it is illustrative that the two persons with a relatively high fat mass had the lowest reported energy intake. Neither of them indicated that they followed a weight reducing diet.

It was interesting to find that the carbohydrate intake in the IDDM group, despite the reported dietary adaptations (Table 6), differed from the reference group. Compared with the carbohydrate intake in other endurance-trained athletes (9) total carbohydrate intake was low, 41 En% versus 50 En% or more.

Furthermore, it was found that the contribution of mono- and disaccharides and polysaccharides differed as well. Instead of the 50% polysaccharides and 50% mono- and disaccharides found in the reference group the IDDM subjects derived about 36-37% from mono- and lactose disaccharide sources. The mono- and disaccharides came mainly from fructose- and lactose-containing foods like fruit and milk (Table 4). The consumption of sugar and sugared products was minimal, despite the fact that six subjects reported to use these products regularly. This is in contrast to the non-diabetic reference group whose mono- and disaccharide intake originated predominantly from sugar and sugared foods such as soft drinks and sweets.

Because sugared foods give a quicker glucose response than bread and pasta and therefore are ideal to counteract the exercise-induced hypoglycaemia it should be expected that the mono- and disaccharide intake of the IDDM group would be more in agreement with that of the reference group. However, these results demonstrate that the dietary adaptations reported did not lead to a more liberal use of sugared foods.

The results of the life style interviews indicated that those who reported dietary adaptations suffered less from hypoglycaemia. However, this could not be confirmed by the blood glucose levels found on the day the subjects came to the laboratory. One of the explanations could be the limited knowledge on how to adapt the diet to these conditions. The blood glucose levels at the beginning of the training and the duration and intensity of the exercise bout are all factors to be considered when one decides when and how much carbohydrate is needed during training. The use of blood glucose monitoring is the only means to find out what is best. No general rules can be given because of the great individual differences in training circumstances and physiological responses to the exercise (30).

The occurrence of hypoglycaemia is so threatening that almost all IDDM subjects tried to avoid this by eating in advantage and during the training. The alternative of a reduction of insulin is not often chosen, because the physicians consulted mostly advised to take extra bread instead of advising to reduce the dose of insulin. Probably the main reasons for this are the therapeutic uncertainties and the need for an intensive control during such a change in training and insulin regime. The reduction of insulin, from the metabolic point of view, appears to be preferable to additional food, as long as no data are available on the health consequences of extra consumption before or during training. This is also confirmed by Meinders et al. (23) who investigated the physiological responses to intensive long-lasting exercise after deprivation of insulin 16 hours before the start of the exercise in IDDM subjects. They found no adverse effects during and after the exercise bout.

The high body fat mass also indicates that reduction of insulin should be preferred to extra food. Since the extra energy taken is partly stored as fat and consequently keeps the fat mass on level.

One disadvantage of diabetes control by reducing the insulin dose is that during days without training the blood glucose level remains high, thus causing hyperglycaemia. Some subjects experienced these problems and had bought a home-trainer to cycle at home with bad weather or when the planned exercises were not performed. In this way they kept blood glucose level under control.

For a better insight into the blood glucose control over the past, HbA1 was determined (11). The 10.2% found in this group indicates a moderate control of the blood glucose level (normally below 9% (14)). This was also indicated by the questionnaire, in which only three subjects indicated that they experienced hyperglycaemia. If so this was mostly noted before the exercise bout as a result of the extra foods eaten in advance.

Although a lower level of HbA1 was found in those subjects who reported to use some form of glucose monitoring, this was not confirmed in the group who reported blood glucose monitoring as well as dietary adaptations. Only one subject reported blood glucose monitoring as well as a decrease of the insulin dose. He had a mean HbA1 level of 8.7%.

Despite a less favourable fat intake (39 En%) in the IDDM group the blood lipid levels were similar to those in a reference group of runners, who had a more prudent intake of fat (32 En%) (28). In a group of less intensively exercising IDDM men studied previously (2) the total cholesterol level was 5.26 mmol/l and the HDL-cholesterol level was 1.32 mmol/l. The main difference with our IDDM group was the lower frequency and duration of training. Food intake was similar. Therefore it can be assumed that exercise is an important factor contributing to the favourable levels of TC and HDLC in the IDDM group. Whether this will delay the onset of

atherosclerosis cannot be answered, but the lower blood lipid levels will surely be of benefit.
The relatively high triglyceride level is most probably the result of the non-fasting state in which it was determined.

In conclusion the results indicate that in relation to diabetic control reduction of the insulin dose is to be preferred to an increase in carbohydrate intake when daily exercise is performed.
More study is needed to confirm the impression that the consumption of sugar and sugared foods during and after the training helps to prevent the development of hypoglycaemia.
Blood glucose monitoring before, during and after training is essential in this process.

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References

1. Åstrand PO, I Ryhming. A nomogram for calculation of aerobic capacity (physical fitness) from pulse rate during submaximal work. *J Appl Physiol* 7: 218, 1954.
2. Beek EJ van der, M Wedel, A van der Zedde et al. The relationship of diet, body composition, physical activity and the quality of metabolic control to blood lipid levels in Type-I-Diabetic men. *Int J Sports Med* 5: S59-S63, 1984.
3. Cameron ME, WA van Staveren. *Manual on methodology for food consumption studies.* Oxford University Press, 1988.
4. Demacker PNM, JBAH van Oppenraay, H Baadenhuijzen, AP Jansen. An improved semi-automated method for colorimetric determination of triglycerids in serum. *Clin Chim Acta* 64: 45-50, 1975.
5. Demacker PNM, AGM Hijmans, HE Vos-Janssen, et al. A study of the use of polyethylene glycol in estimating cholesterol in high-density lipoprotein. *Clin Chem* 26, 13: 1775-1779, 1980.
6. Dorchy H, J Poortmans. Sport and the diabetic child. *Sports Med* 7: 248-262, 1989.
7. Durnin JVGA, J Womersley. Body fat assessed from total density and its estimation from skinfold thickness: measurements of 481 men and women aged from 16 to 72 years. *Br J Nutr* 32: 77-97, 1974.
8. Elvers JWH. *GVOP Food Coding Software Packet.* GVO reports (Health Education Project) University of Nijmegen, 1980
9. Erp-Baart AMJ van, WHM Saris, JA Vos, et al. National survey of nutritional habits in elite athletes. Energy, carbohydrate, protein and fat intake. *Int J Sports Med* 1: S1-S15, 1989.
10. Franz MJ. Exercise and the management of diabetes mellitus. *J Am Diet Assoc* 87: 872-880, 1987.
11. Gonen B, AH Rubinstein. Haemoglobin A1 and diabetes mellitus. *Diabetologia* 15: 1-8, 1978.
12. Hilsted J, H Galbo, B Tronier et al. Hormonal and metabolic responses to exercise in insulin-dependent diabetics with and without autonomic neuropathy and in normal subjects. *Int J Sports Med* 2: 216-219, 1981.

13. Horton ES. Role and management of exercise in diabetes mellitus. *Diabetes Care* 11, 2: 201-211, 1988.
14. Holdrinet RSG, JHM Berden, JCM Hafkenscheid et al. *Functional research and laboratory diagnostics in internal medicine* (dutch). Dept. of Internal Diseases, University Clinic Nijmegen, 1988
15. Jacober B, RM Schmülling, M Eggstein. Carbohydrate and lipid metabolism in Type I Diabetes during exhaustive exercise. *Int J Sports Med* 4: 104-108, 1983
16. Kemmer FW, M Berger. Exercise and diabetes mellitus: Physical activity as a part of daily life and its role in the treatment of diabetic patients. *Int J Sport Med* 4: 77-88, 1983.
17. Kemmer FW, M Berger. Exercise in therapy and the life of diabetic patients. *Clin Sci* 67: 279-283, 1984.
18. Kremser CB, NS Levitt, KM Borow et al. Oxygen uptake kinetics during exercise in diabetic neuropathy. *J Appl Physiol* 6: 2665-2671, 1988.
19. Laan J van der, M van Soest. Study on nutrition and nutritional status of intensively exercising diabetics (dutch). *Ned T Diet* 39: 794-795, 1988
20. Macdonald MJ. Postexercise late-onset hypoglycaemia in insulin-dependent diabetic patients. *Diabetes Care* 10: 584- ,1987.
21. Maehlum S, EDR Pruett. Muscular exercise and metabolism in male juvenile diabetics. II Glucose tolerance after exercise. *Scand J Clin Lab Inv* 32: 149-153, 1973
22. Maehlum S, AT Hostmark, L Hermansen. Synthesis of muscle glycogen during recovery after prolonged severe exercise in diabetic and non-diabetic subjects. Effects of insulin deprivation. *Scand J Clin Lab Invest* 38, 35-39, 1978.
23. Meinders AE, FLA Willekens, LP Heere. Metabolic and hormonal changes in IDDM during long-distance running. *Diabetes Care* 11, 1: 1-7, 1988.
24. Poortmans JR, Ph Saerens, R Edelman et al. Influence of the degree of metabolic control on physical fitness in Type I diabetic adolescents. *Int J Sport Med* 7: 232-235, 1986.
25. Position Statement. Nutritional recommendations and principles for individuals with diabetes mellitus. *Diabetes Care* Suppl 1: 18-25, 1990.
26. Pruett EDR, S Maehlum. Muscular exercise and metabolism in male juvenile diabetics. Energy metabolism during exercise. *Scand J Clin Lab Inv* 32: 139-147, 1973.
27. Roch-Norlund AE. Muscle glycogen synthetase in patients with diabetes mellitus. Basal values, effect of glycogen depletion by exercise and effect of treatment. *Scand J Clin Lab Inv* 29: 1-6, 1972.
28. Saris WHM, AMJ van Erp-Baart, JA Vos, JWH Elvers. Effects of dietary fat om plasma lipids in active sportsmen. In: Van de Berg E.M.E., W. Bosman, B.C. Breedveld (eds). Nutrition in Europe. Proceedings of the 4th European Nutrition Conference. Voorlichtingsbureau voor de Voeding. The Hague, the Netherlands, 1984.
29. Stout RW. Diabetes, atherosclerosis, and aging. *Diabetes Care* 13, suppl 2: 20-23, 1990.
30. Trovati M, D Anfossi, S Vitali et al. Postprandial exercise in Type-I-diabetic patients on multiple daily insulin injection regimen. *Diabetes Care* 11, 2: 107-110, 1988.
31. Trinder P. Determination of blood glucose using glucose oxidase with an alternative oxygen acceptor. *Ann Clin Biochem* 6: 24027, 1969.
32. Trivelli LA, HM Ranney, HT Lai. Hemoglobin components in patients with diabetes mellitus. *New Engl J Med* 284: 353-357, 1971.
33. *UCV Food Table* (dutch). Voorlichtingsbureau voor de Voeding, Den Haag, 1984.
34. Voedingsraad. *Recommended daily allowances 1989* (dutch). Voorlichtingsbureau voor de Voeding, Den Haag, 1989.
35. Wallberg-Hendrikson H. Acute exercise: fuel homeostasis and glucose transport in insulin-dependent diabetes mellitus. *Med Sci Sports Exerc* 21, 4: 357-361, 1989.
36. Heine RJ, JA Schouten. The role of fat in the treatment of diabetes mellitus. In: Vergroesen A.J., M. Crawford (eds). *The role of fat in human nutrition.* Academic Press, London: 287-327, 1989.
37. WHO Technical Report Series 727. *Diabetes Mellitus,* Geneva 1985.

CHAPTER 9

General discussion and conclusions

For adequate nutritional advice in the field of sports nutrition knowledge of the nutritional aspects of exercise as well as knowledge of the food habits and training pattern of the athlete is essential. The basic nutritional needs of the athlete are determined largely by his training regimen. Since this has a predominant influence on life style, it will affect food intake and meal patterns.

In general, three groups of sports can be distinguished, i.e. endurance, strength and team sport. The results presented in Chapter 2, 3 and 4 reveal that food intake varies among these groups. Specific recommendations for each group will be discussed and presented hereafter.

Endurance athletes

Special recommendations for food intake are required if one or more training sessions exceed 2 hours per day. The increase in energy expenditure is the major determinant of food intake, depending on duration, intensity level and frequency of training or contest.

If training is practiced daily, but less than 1 to 1.5 h per day, the increase in total energy intake is at most twice the resting metabolic rate (RMR) amounting to 10 MJ for females and 15 MJ per day for male endurance athletes (Chapter 2). It is concluded that these energy requirements can easily be met with usual foods.

If daily training exceeds two hours daily, total energy intake may increase to 3.5 times RMR. Especially in ultra endurance activities like road cycling and triathlon, energy requirements may exceed 20-25 MJ per day (Chapter 2). If energy intake exceeds the 20 MJ the amount of food to be consumed is large. Also the food pattern is significantly affected. Therefore, it is not surprising to see that almost 40% of total energy intake comes from eating "in between" (Chapter 2). Therefore attention must be paid to the quality of such snacks.

Carbohydrate intake is another important factor in endurance performance. In this study it is demonstrated that carbohydrate intake in endurance types of sports is in general higher than in sedentary age groups. However if endurance training or contests exceed 2 hours daily this increase is not enough to provide a minimum of 9-10 g of carbohydrate per kg body mass per day, which is needed to restore the glycogen in muscle and liver (5). To meet that criterion a further increase of carbohydrate intake to at least 60 % of total energy intake is required. For energy expenditures of up to 20 MJ per day this increase in carbohydrate intake can be met by increasing bread, potato, rice and pasta consumption. Nevertheless, few endurance athletes have an adequate carbohydrate intake, relatively as well as absolutely. One disadvantage of a change towards more carbohydrates and less fat is the increase in total volume of the foods. For instance if daily energy intake has to be about 16 MJ and the usual fat/carbohydrate ratio in the diet of 40:50 has to be changed to 30:60, one has to consume 14 slices of bread and 400 g potatoes instead of 7 slices of bread and 200 g potatoes. If energy intake exceeds 20 MJ per day the increase in carbohydrate intake in the form of bread and potatoes implies so large a volume, that other, more energy-dense foods like cakes and candy bars are chosen as alternatives.

As demonstrated by the case of the cyclists during the Tour de France and during the Tour de l'Avenir (Chapter 2), the increase in carbohydrate intake is also realized with carbohydrate-containing beverages. This is to prefer over eating all the carbohydrates required in solid foods, because fluid loss is substantial in this type of intensive exercise and fluid must be replaced as well. The study presented in Chapters 2, 3 and 4 did not deal specifically with fluid replacement during intensive exercise. Nevertheless, for the sake of completeness, some recommendations for fluid and energy replacement during exercise will be presented here. For more background information the reader is referred to the studies by Brouns (3) and Rehrer (15).

In general, it can be stated that during exercise the body looses fluid by sweating. If the exercise takes more than 60 minutes fluid replacement is needed. If the exercise is performed over a prolonged period of time (more than 1.5 hours) energy supply is important as well. It depends on the duration and intensity of the exercise bout and on ambient temperature and humidity which aspect is the most important. Current knowledge of sweating and dehydration leads to the recommendation to take low-carbohydrate drinks when one is exercising in the heat and fluid losses are substantial. More concentrated drinks may be consumed when sweat loss is depressed and carbohydrate supply becomes the most important factor in maintaining optimal performance. Where rehydration has priority the solution should contain 20-30 g carbohydrates per litre. Where substrate provision is more important, a more concentrated solution is needed, containing large amounts of glucose polymers in concentrations of 150-200 g/litre (14). When exercise is lasting less than 30 minutes there is no real need for fluid or carbohydrate replacement (4). Finally, it must be mentioned that whatever drink one chooses it should be tried out in advance under different training circumstances because of the great intra individual differences of gastric emptying and possible distress response.

Already since in 1842 von Liebig performed his studies on the role of proteins in nutrition, it was for a long time taken for granted that proteins play a negligible role in exercise. However, Lemon (12) has demonstrated that during intensive and prolonged endurance activities the excretion of urea in sweat is substantial. Although the contribution of protein to energy supply during long lasting intensive endurance activities is small (10–15%), it may become substantial in ultra endurance activities

(1). Lemon has set RDAs for protein intake for endurance types of sports, i.e. 1.2 to 1.4 g per kg body mass per day i.e. an 80–100% higher than the recommendations for the general population (12).

Our study demonstrated that increasing total energy intake automatically leads to an increase in protein intake of 1.8 to 3.0 g per kg body mass in triathletes and professional cyclists respectively. Thus the extra protein requirement can easily be met by consuming more of the usual foods, and protein supplements are not necessary.

In general, it can be concluded that vitamin and mineral intake of athletes is at the recommended level if energy intake lies between 10 and 20 MJ per day (Chapters 3, 4) and a normal varied diet is used. This has recently been reconfirmed by Fogelholm (8), who suggests that if energy requirements are below 20 MJ no problems are to be expected with respect to vitamin and mineral intake. However, there are two groups of endurance athletes who need extra attention: ultra-endurance athletes and female athletes.

Ultra-endurance athletes are frequently faced with a lack of time available for eating, as well as a lack of appetite due to heavy and prolonged training sessions and contests. At the same time they are forced to consume large amounts of foods within a short period of time. In these situations energy-dense foods like cakes, candy bars and carbohydrate-rich fluids are often the foods of choice. These foods have usually a low nutrient density. As was demonstrated in our study (Chapter 3), vitamin B-1 intake might become marginal, possibly leading to a decreased athletic performance. Supplementation might be indicated then at the recommended level of 1 mg per MJ.

The second group of athletes who need extra attention is the group of female endurance athletes. For endurance athletes oxygen transport is an important determinant for endurance performance and adequate body iron stores are necessary. Females have higher requirements (15 mg per day) than males because of the regular loss of iron through menstruation.

It was already demonstrated by Blix (2) that iron intake is in general closely related to energy intake. Also in our study with athletes a similar high correlation was found. Linear regression analysis revealed that the recommended level of 15 mg per day can only be met on the basis of customary food patterns if intake is at least 10 MJ per day. In our inventory mean energy intake in most female endurance groups never exceeded 10 MJ per day. Only the group of female rowers had an intake of 13 MJ per day and an iron intake at the recommended level (Chapter 3). If special attention is given to foods rich in iron such as fortified rose hip syrup and apple syrup, the recommended level can be met as demonstrated for the female cyclists (Chapter 3, Fig 1). Iron intake in this group was about 100% higher than what could be expected at that level of energy intake.

For female athletes a regular control of iron status is indicated and special attention for iron-rich foods is recommended.

Another possibility for increasing the quality of food in these special situations is the choice of specific sport food supplements enriched with vitamins and minerals to such an extent that RDAs are met based on the energy supply of the food supplements.

Strength athletes

In strength athletes nutrition is focused on building up muscle mass and strength. Therefore it is obvious that protein intake is one of the major concerns in their nutrition.
The traditional scientific view has been that athletes do not differ markedly in protein requirements from non-exercising adults. However, recent research has thrown some doubts on the adequacy of the generally recommended dietary allowances (Dutch RDA for adults 0.8 - 0.9 g per kg body mass per day).
It can be expected that protein metabolism accelerates in periods of heavy training in order to increase the amount of muscle mass. It is suggested that protein retention rates range from 7 to 28 g per day (5). Also Lemon (12) has calculated what protein intake should be to meet the needs for protein in strength training. He advises an intake of 1.2 to 1.7 grams per day per kg body mass.

Another aspect that might be of interest for strength athletes is the evidence of increased protein utilization when glycogen stores are depleted and exercise is continued at a high level. This situation is far from exeptional, taken into account the long intensive training sessions frequently seen in strength athlete groups. Also the fact that weight reduction is frequently observed in these groups of athletes may promote an increasing protein utilization of the body to provide the energy required.

Our study demonstrates that protein intake in strength types of sports is usually higher than generally recommended, ranging from 1.3 to 1.8 g per kg body mass, the use of protein supplements excluded. This is in agreement with the recommendations made by Lemon (12). It can be concluded that protein intake is adequate and supplementation can only be indicated if energy intake is low because of weight-reducing practices.

The observation that carbohydrate intake is low to marginal in these athletic groups leads to the conclusion that more attention must be paid to ensuring an adequate intake of carbohydrates (17) in order to avoid glycogen depletion and consequently protein breakdown. Although detailed information is lacking, it is suggested that a priority for carbohydrate at the expense of protein or fat will economize the protein needs.

There is no evidence that the high vitamin intake sometimes found in these groups of athletes is necessary for a better performance (Chapter 3). Related to the RDAs, the vitamin and mineral supply by food is more than adequate.

Team sport athletes

It was surprising to see that,in contrast with endurance and strength athletes, the team sport athletes have in general a food intake comparable with the food habits of the general non active population.
Considering the fact, that training and competition in elite athletes are daily practice, lasting several hours per day, it is remarkable that carbohydrate intake is not higher. Nevertheless, in periods of intensive competition the carbohydrate intake should be adequate. Proper advice is needed though to induce a change towards a higher carbohydrates intake. Intake values of carbohydrate were found in the order of 3-5 g per kg body mass per day (Chapter 2). For this type of athletic performance, a minimum of 5-8 g per kg body mass per day is advised (9); at least 55% of total energy intake should come from carbohydrates (Chapter 2). Therefore, it can be concluded that major changes in food habits are required.

The relative low vitamin and mineral intakes sometimes found in the female groups of team sport athletes are merely the result of improper food choices. Choosing more nutritious foods will improve the quality of the athlete's diet. There are no reasons to believe that, with the exception of iron, special food supplements are needed (Chapter 3, 4).

Young athletes

Increasing numbers of young athletes are involved in intensive training programmes. The question whether this is beneficial to the growing body remains unanswered. From the preventive point of view, the quality as well as the quantity o nutrition have to be considered (16). First of all, there is an increased requirement o energy and nutrients because from 10 to 18 years the body is growing. At the same time, the intensity and frequency if training increase. Our national survey included several groups of young athletes, i.e. a group of young male judokas, male and female swimmers, and female (sub)top gymnasts (7).

One surprising result was the sometimes low energy intakes found in these group growing athletes. Especially in the group of judokas and gymnasts. As pointed out earlier, a low level of energy intake can lead to marginal micronutrient intake. In this respect two nutrients, calcium and iron, can be considered as nutrients at risk. Both nutrients are extremely important for the growing body. Linear regression analysis o energy intake against both nutrients indicated that energy intake should be at least 1 MJ per day to meet the minimum requirements for these nutrients. The young female groups have energy intakes below this energy threshold (Chapter 2). Extra attention is therefore indicated for these young female groups.

Weight reduction

Although weight reduction was not the main objective of the inventory presented in Chapter 2, 3 and 4, this survey revealed, that weight reduction is common practice among elite athletes.
Weight reduction is practiced for many different purposes: to get rid of the extra weight built up during a resting period (female cyclists), to maintain body mass at the lowest level possible in order to be of advantage in endurance performance (female runners), to compete in the lowest weight class possible (body building, judo, rowing), for biomechanical reasons (turning and tumbling in gymnastics) and, last but not least, for aesthetic reasons (body building and gymnastics). The aim of weight reduction is to loose fat mass without loosing muscle mass and to keep the usual training schedules in order to maintain physical fitness.

However, practice shows that these athletes have no control with respect to these goals. Several times they seem to loose not just fat mass but muscle mass as well. Therefore a method should be developed to determine whether muscle mass is broken down during weight reduction. Second, a measure to quantify the amount of muscle mass lost during weight reduction is important. Our study on urinary 3-methylhistidine (3-MH) excretion, as a method to determine muscle loss, was meant as a first attempt to establish the effects of weight reduction in athletes on body composition and physical performance (Chapter 7).
It is concluded that the biological variation (expressed as within-subject coefficient of variation) of urinary 3-MH excretion in men is relatively small and can therefore be used to determine whether muscle mass is being broken down. For women the large biological variation makes it difficult to use this method. It is suggested that the menstrual cycle may influence the reproducibility of urinary 3 MH excretion. The intensity of training might be another interfering factor in this study. However, this aspect was not taken into account.
To quantify the loss of muscle mass during weight reduction further studies are needed (Chapter 7).

Besides scientific information about the extent of muscle protein breakdown, some practical indications can be given for guidance in weight reduction. First, before embarking on a weight-reduction programme it should be clearly established that the excess of body mass is caused by an excess of fat mass. This seems obvious, but in practice often only total body mass is measured and body composition is not taken into account. Second, attention should be given to the minimum energy requirement for athletes who wish to continue their daily training and to loose weight at the same time. Protein intake should be sufficient to maintain nitrogen balance. A minimum daily intake of 1.5-2.0 g per kg body mass is therefore indicated.

Carbohydrate intake should be at least 5 g per kg body mass per day to maintain and restore glycogen depots (13, 17) so that the risk for muscle mass breakdown can be limited. This leads to a minimum energy intake of 6 MJ for women and 8 MJ for men, depending on the training regimen.

Because of the relatively low energy intakes the nutritional quality of the diet mus be taken into account. Supplementation of minerals and vitamins might be indicated (Chapter 3, 4).

One should not forget that for some groups of athletes it is impossible to decreas energy intake if body weight has to be reduced. For instance, in female top gymnasts total energy intake is at such a low level (Chapter 6), that a further decrease will lead to an inadequate protein and carbohydrate intake. The suggestion of Wilmore (19) that one should be aware of inducing eating and weight disorders, such as anorexia nervosa, if weight reduction is based on body mass instead of excess of fat is enough reason to be careful in this group of young female athletes. An increase of energy expenditure by implementing endurance types of activities is to be preferred over a decrease of energy intake.

Finally, one can question the introduction of case studies, such as the one presented by Clark (6). She describes a way to guide weight reduction when one tries to achieve weight reduction, below a level where health risks will certainly be incurred. Not only health in general is at stake in such a case than, but one can also question whether it is ethical to help an athlete to attain a body weight that may be harmful to his or her health. Williams (18) poses that if the athlete cannot be convinced of the potential danger and would reduce weight on his/her own if assistance were not rendered, it may be advisable to provide guidance under medical supervision which may mitigate the harmful effects.

It is clear that more basic studies are needed for a better insight into the consequences of weight reduction in obviously lean and sometimes very young athletes.

Insulin-dependant diabetes mellitus (IDDM) athletes

The food intake and dietary adaptations of a group of intensively exercising IDDM athletes were studied (Chapter 8) as an example of a study in a group of athletes with a metabolic disorder.

IDDM athletes mostly focus on preventing hypoglycaemia from developing during or after the training. It is still difficult to give general guidelines for changes i food intake and insulin therapy. Our study demonstrates that IDDM athletes have a relatively low carbohydrate intake accounting for, on average, 41% of total energy intake. This is even lower than in the general population. Also the type of carbohydrates chosen is more according tradition (i.e. avoidance of sugar-containin foods).

It is demonstrated that for an adequate glucose response during exercise foods with a high glycaemic index and carbohydrate-enriched beverages are to be preferre (14). There is no reason to believe that IDDM athletes have gastric emptying rates and digestive reactions differing from non-diabetic athletes (15). Therefore, more studies are needed to answer the question what types of foods and what kinds of beverages are best for IDDM athletes. On the basis of the scarce evidence available, Horton advises to take 35-40 g of carbohydrates during training every 30 minutes (11).

Also important in relation to long-term health consequences was the observation of relatively high blood glucose levels before and at the start of exercise. This as a preventive measure against hypoglycaemia. However, if regular exercise is performed at relatively high intensities, a decrease of the daily insulin dose seems to be preferred over an increased carbohydrate intake. Because of the great individual differences in training and physiological responses to training it is clear that regular blood glucose monitoring is inevitable.

References

1. Applegate EA. Nutritional considerations for ultraendurance performance. *Int J Sports Nutr* 1,118-126, 1991
2. Blix G. A study on the relation between total calories and single nutrients in swedish foods. *Acta Soc Med Uppsal* 70: 117, 1965
3. Brouns F. *Food and fluid related aspects in highly trained athletes.* Sportwetenschappelijke onderzoekingen 15. De Vrieseborch. Haarlem, 1988.
4. Brouns F. Dehydration- rehydration: a praxis oriented approach. *J Sports Sc* 9, 143-152, 1991.
5. Burke LM, RS Read. Sports Nutrition. Approaching the Nineties. *Sports Med* 8, 80-100, 1989.
6. Clark N. Nutritional concerns of female athletes: a case study. *Int. J Sports Nutr* 1,257-264, 1991.
7. Erp-Baart AMJ van, RA Binkhorst, WHM Saris. Quantitative and qualitative aspects of nutrition in young talented athletes. In Oseid S, and K Carlsen (eds) *Children and Exercise XIII.* Human Kinetics Champaign Ill.pp 295-305, 1989.
8. Fogelholm GM, J Himberg, K Alopeus ea. Dietary and biochemical Indices of nutritional status in male athletes and controls. *J Am Coll Nutr* (in press) 1991.
9. Hargreaves M. Carbohydrates and exercise. *J Sports Sc* 9,17-28, 1991
10. Horswill CA, RC Hickner, JR Scott ea. Weight loss, dietary carbohydrate modifications, and high intensity, physical performance. Med Sci Sports Exerc 22, 470-476, 1990
11. Horton ES. Role and management of exercise in diabetes mellitus. *Diabetes Care* 11,2, 201-211, 1988.
12. Lemon PWR. Effect of exercise on protein requirements. *J Sports Sc* 9, 53-70, 1991.
13. McMurray RG, CR Proctor, WL Wilson. Effect of caloric deficit and dietary manipulation on aerobic and anaerobic exercise. *Int J Sports Med* 12: 167-172, 1991.
14. Maughan RJ. Fluid and electrolyte loss and replacement in exercise. *J Sports Sc* 9, 117-142, 1991
15. Rehrer NJ. *Limits to fluid availability during exercise.* Sportwetenschappelijke Onderzoekingen 19. De Vrieseborch. Haarlem 1990.
16. Saris WHM, Brouns F. Nutritional concerns for the young athlete. In J. Rutenfranz, R Mocellin, F Klimt (eds) *Children and Exercise XII* (pp 11-19)Champaign Ill. Human Kinetics 1986.
17. Simonsen JC, WM Sherman, DT Lamb e.a. Dietary carbohydrate, muscle glycogen and power output during rowing training. *J Appl Physiol* 70: 1500-1505, 1991.
18. Williams MH. Focus: Nutritional Ergogenic Aids. *Int J Sport Nutr* 1,213, 1991.
19. Wilmore JH. Eating and weight disorders in the female athlete. *Int J Sports Nutrition* 1,104-117, 1991.

Summary

Optimal athletic performance is based on talent, training, proper equipment and, last but not least, adequate nutrition leading to a good nutritional status. From an abundance of physiological research the need for energy and specific nutrients is studied and it is demonstrated to what extent the diet should be adjusted to these needs. On the other hand, systematic analyses of the food consumed by intensively exercising athletes are scarce. However, for adequate nutritional advice information on habitual food intake of athletes performing on a top level is needed as well. Therefore it was decided to survey on a national scale the consumption habits of different groups of elite athletes. The aim of the study was to analyse the food and nutrient intake and the meal pattern. To make the picture as complete as possible groups of endurance, strength and team sport athletes were involved. Selection of athletes took place on the basis of training at least 1-2 h a day and competing mostly on an (inter)national level.

Because of these strict selection criteria it was possible that the groups to be investigated were relatively small. Therefore it was decided to use the 4-day and, if possible, the 7-day food diary to obtain information on food intake on a group level. If changes in food pattern were to be expected because of changes in training schedules this diary period was repeated once or twice. Energy intake as well as intake of nutrients was calculated with a computerized netherlands food composition table (UCV/NEVO).

Mean energy intake varied enormously among the groups. Energy intake ranged from 12.1 to 24.7 MJ per day in male groups and from 6.8 to 12.9 MJ per day in female groups. It was expected that endurance-trained athletes had an energy intake higher than their sedentary peers. This was true for the male athletes, but female groups had an energy intake comparable to or lower than that of their less active peers. In strength groups the energy intake was lower than in the other groups. Different explanations can be given for the discrepancy found between the calculated and the expected energy intake.

1. Reported consumption can be lower than the amount actually eaten. This is especially true for respondents with a relatively high fat mass or for those who can be described as restraint eaters. Therefore it was indicative that most of the female athlete groups had in general the lowest reported energy intakes.
2. In some athletic groups dieting is common practice. This was particularly demonstrated in the strength groups. Explanations for these practices are to be found in esthetic as well as performance reasons, and because the athletes have to compete in weight classes.
3. The energy actually expended might be overestimated. The usual way of assessing energy expenditure by adding up basal metabolic rate, energy cost of common daily

activities and training activities seems not always to be the best way. This was demonstrated in the group of female top gymnasts. It was found that on training days common daily activities were reduced to a minimum. It was also found that long-lasting intensive training does not necessarily mean intensive training from an energetic point of view. In the group of female gymnasts intensive activities attributed only for 15% to total training time.

Protein intake, supplements excluded, was sufficient, even in situations where higher intakes are recommended. This inventory clearly demonstrated that protein intake expressed in g/kg body mass is positively related to energy intake. Therefore if energy intake is adequate protein intake wil be adequate as well.

Only the group of body builders used protein supplements on a regular basis. It is still a matter of debate to what extent the recommendations for protein for the general population must be upgraded for the building-up and restoration of muscle mass. However it is clear that the protein intake found in protein-supplemented groups is far out of range.

Fat intake, expressed as percentage of total energy intake, in endurance-trained groups is in general lower than in the general population. Fat intake in the strength and team sport groups is more in line with that of the general less active population. Because in intensive training fat is not the most recommended energy source a reduction to a maximum of 35% of total energy intake (en%) is advised.

It is well established that physical exercise enhances the HDL/total cholesterol plasma ratio which has to be considered to reduce the risk for coronary artery disease (CAD). It is also known that in populations with a relatively low activity level a high fat and cholesterol consumption increases the risk for CAD. In this respect it was encouraging that a comparison among different athletic groups showed that a high fat intake does not necessarily lead to a high level of LDL cholesterol, a known risk factor for cardiovascular disease. It is suggested that keeping a good energy balance is one explanation for this phenomenon.

It is clear that special attention is needed for carbohydrate intake. Despite the physiological evidence that carbohydrate intake is positively related to duration and intensity of training, carbohydrate intake was relatively low (often less than 55% of total energy intake). At least 55% of total energy intake should be derived from carbohydrate sources. When training frequency and intensity is high (more than 2 hours per day and more than 70% of maximal aerobic power) carbohydrate intake should even be higher (60-70 en%).

It was also found that if energy intake exceeds 20 MJ/day the large volume of the food makes it extremely difficult to attain the required carbohydrate intake. In these situations it is adviced to prepare beverages rich in carbohydrates. More complex carbohydrates are then recommended in order to reduce the osmolarity of the drinks.

In most cases vitamin and mineral intake is at the recommended level. If energy intake is in agreement with energy expenditure supplementation of foods with vitamins and minerals is unneccessary. However there are two exeptions to this general rule. First, it has been demonstrated that iron intake is positively related to energy intake. For females an energy intake of at least 13 MJ is needed to have an iron intake at the recommended level (15 mg/day). As demonstrated in this study, such high energy intakes are only found in female rowers. All other female groups had lower energy intakes and are therefore at risk for iron-deficiency anaemia. Second, if energy intake exceeds the level of 20 MJ/day energy dense foods like cakes and candy bars are chosen. The intake of vitamin B-1 will become problematic and supplementation might then be indicated.

During the time the study was carried out it became clear that weight reduction was common practice among elite athletes. In general it is possible to reduce weight if overweight is caused by fat mass. However in athletes body fat mass is already low and further weight loss can only be achieved by losing muscle mass or through dehydration practices. Both phenomena lead to an unhealthy situation and should therefore not be encouraged. Because data on weight reduction under these specific circumstances are scanty we started a study to get more insight into this complex problem. In the first place we looked to the possibility of measuring muscle mass loss during weight reduction. The urinary 3-methylhistidine (3-MH) excretion method is often used to measure muscle mass loss. However the reproducibility was only known over days. Because weight reduction is often spread over weeks we looked at the reproducibility of urinary 3-MH excretion over weeks. It was found that the coefficient of variation was 4.4% for male athletes, and 12.1% for female athletes. We concluded that this method could be used in males, but not in females. Further studies are needed to learn how body mass can be reduced in athletes with a relatively low body fat mass who are training at a high level.

Finally, as an example of food habits in athletes with metabolic disorders, we studied the habitual food intake of intensively exercising insulin-dependent diabetes mellitus (IDDM) patients. It is well known that IDDM athletes mostly focus on the prevention of hypoglycaemia. Therefore, eating beforehand and/or during training is often practised. Because glucose can only be helpful in maintaining the blood glucose level if glucose leaves the stomach and enters the circulation it is important that proper foods are chosen. This inventory demonstrated that although taking extra food before and during training is often practised, it seems difficult to select the ideal foods. To meet the specific needs of the individual athlete they all have to learn by trial and error. In general there was a lack of expertice or interest to coach subjects when they decide to start training. Reduction of the insulin dose seems to be preferred to eating extra in case of daily intensive training. However this study made clear that exactly the opposite treatment is chosen leading to high glucose levels. Therefore monitoring the blood glucose level is inevitable to obtain insight in the individual's specific situation.

Samenvatting

Talent, training, goed materiaal en goede voeding vormen de basis voor een optimale sportprestatie. Op fysiologisch gebied is veel onderzoek gedaan naar de energiebehoefte en de relatie voeding en sport. Tegelijkertijd ontbreekt een systematische analyse van de voedingsgewoonten van intensief sportende atleten. Informatie over voedingsgewoonten van topatleten is een onontbeerlijke voorwaarde voor een adequate voedingsadvisering.
Om deze reden zijn we gestart met een nationaal onderzoek naar de voedingsgwoonten van verschillende groepen van topatleten. Het doel van het onderzoek was het verkrijgen van inzicht in voedsel- en voedingsstoffeninneming en in het maaltijdpatroon. Om een zo compleet mogelijk beeld te krijgen zijn groepen van duursporters, krachtsporters em teamsporters benaderd. Voorwaarde voor selectie was een dagelijkse training van 1 tot 2 uur en het deelnemen aan wedstrijden op (inter)nationaal niveau.
Informatie over voedingsgwoonten werd verzameld met behulp van een 4- of 7-daags voedingsdagboek. De voedingsstoffeninneming werd berekend met behulp van een voedingsberekeningsprogramma, gebaseerd op de nederlandse voedingsmiddelentabel (UCV/NEVO).

De gemiddelde energieinneming varieerde enorm van groep tot groep. Bij de mannelijke atleten verliep de energieinneming van 12,1 tot 24,7 MJ per dag en bij de vrouwelijke atleten varieerde deze van 6,8 tot 12,9 MJ per dag. Over het algemeen werd een hogere energieinneming verwacht. Dit kwam echter alleen voor bij de mannelijke duursporters. De vrouwelijke duursporters hadden een lagere energieinneming dan verwacht. Bij krachtsporters was de energieinneming over de gehele lijn lager.
Er zijn verschillende verklaringen te geven voor de discrepantie tussen de berekende en de verwachte energieinneming.
1. De gerapporteerde voedselconsumptie kan lager zijn dan de werkelijke consumptie. Algemeen bekend is dat met name mensen, die zichzelf te dik vinden de neiging hebben tot onderraportage. Het was daarom ook opmerkelijk dat over het algemeen bij vrouwelijke atleten de laagste energieinnemingen werden gevonden.
2. Bij sommige takken van sport is vermageren dagelijkse praktijk. Dit bleek vooral bij krachtsporters voor te komen. Verklaringen voor deze gewoonten liggen in het feit, dat zowel prestatie als esthetiek hierin een belangrijke rol spelen evenals het uitkomen in gewichtsklassen.
3. Er kan ook een overschatting van de benodige energie hebben plaatsgevonden. De gebruikelijke manier om het totale energieverbruik te schatten gebeurt door het

energieverbruik van de dagelijkse activiteiten en sportactiviteiten bij het basaal metabolisme op te tellen. Echter, zoals bij de topgymnastes is aangetoond kunnen bij intensieve training de dagelijkse activiteiten tot een minimum gereduceerd zijn. Ook is bij deze groep aangetoond, dat intensieve training niet automatisch intensief is vanuit energetisch oogpunt bezien. Bij deze groep is aangetoond dat slechts 15% van de totale tijd uit intensieve training bestond.

De eiwitinneming, met uitsluiting van supplementen was voldoende, ook daar waar een verhoogde inneming wordt aanbevolen. Deze studie heeft aangetoond, dat er een positieve relatie bestaat tussen energieinneming en eiwitinneming, weergegeven in g/kg lichaamsgewicht. Dus als de energieinneming adequaat is zal de eiwitvoorziening eveneens adequaat zijn.
Vooral de bodybuilders maakten regelmatig gebruik van eiwitsupplementen. Het staat nog steeds ter discussie tot welk niveau de aanbevelingen voor eiwitinneming moeten worden aangepast voor de opbouw en herstel van spiermassa bij intensieve krachttraining. Echter, het is overduidelijk dat de hoge eiwitinneming die bij bodybuilders gevonden is buitenproportioneel is.

De vetinneming, weergegeven als procentuele bijdrage aan de totale energieinneming is bij de onderzochte takken van duursport over het algemeen lager dan bij het niet-actieve deel van de bevolking. De vetinneming van de krachtsporters en de teamsporters komt meer overeen. Aangezien bij intensieve training vet niet de meest voor de hand liggende energiebron is is een vermindering tot tenminste 35% van de totale energieinneming aan te bevelen.
Het is overduidelijk aangetoond, dat fysieke inspanning de verhouding HDL/totaal cholesterol in gunstige zin verandert en derhalve het risico op atherosclerose verlaagt. Het is ook bekend dat een hoge vetconsumptie en een laag activiteitenpatroon het risico op atherosclerose doet toenemen. Het is daarom bemoedigend om te kunnen constateren dan bij krachtsporters een relatief hoge vet- en cholesterolconsumptie niet automatisch leidt tot een ongunstige verhouding HDL/totaal cholesterol in het bloed. De suggestie wordt gedaan, dat het lage lichaamsvetgehalte als indicator voor een goede energiebalans de verklarende factor zou kunnen zijn.

In dit inderzoek is duidelijk aangetoond dat de koolhydraatinneming aandacht behoeft. Ondanks het fysiologische gegeven dat de koolhydraatinneming bepalend is voor de uiteindelijke duur en intensiteit van training, blijkt de koolhydraatinneming betrekkelijk laag te zijn (over het algemeen lager dan 55% van de totale energieinneming). Bij een dagelijkse training van 1 tot 2 uur dient de bijdrage aan de energieinneming voor tenminste 55% uit koolhydraten te bestaan. Bij een dagelijkse training van meer dan 2 uur en een intensiteitsniveau van meer dan 70% van het maximaal prestatievermogen moet de koolhydraatinneming nog hoger zijn (60 tot 70% van de totale energieinneming).
Bij een hoge energieinneming (meer dan 20 MJ per dag) blijkt het moeilijk de benodigde koolhydraten naar binnen te krijgen. Dit vanwege het grote volume van de

voeding. Het verdient aanbeveling om in deze situatie dranken te bereiden met koolhydraten. Hierbij moet dan wel gelet worden op de osmolariteit van de dranken. Complexe koolhydraten verdienen dan de voorkeur.

De vitamine- en mineralenvoorziening was meestal in overeenstemming met hetgeen aanbevolen wordt. Indien de eneregieinneming adequaat is geldt ook hier, net als bij de eiwitinneming, dat supplementeren niet nodig is.
Op deze regel bestaan echter twee uitzonderingen. Op de eerste plaats is aangetoond dat de ijzerinneming positief gecorreleerd is aan de energieinneming. Voor vrouwen is een inneming van tenminste 13 MJ nodig om via de gebruikelijke voeding voldoende ijzer te consumeren (15 mg/dag). Een dergelijke energieinneming werd alleen bij de roeisters gevonden. Vrouwelijke atleten lopen dus de kans op een te lage ijzerinneming, en dientengevolge de kans op ijzergebreksanaemie.
Bij een energieinneming van meer dan 20 MJ per dag worden vaak energierijke produkten zoals koek, gebak en "candy bars" gekozen. Dit vanwege het gemak en hun energiedichtheid. De voorziening met vitamine B-1 kan daardoor in gevaar komen en supplementeren kan dan aangewezen zijn.

Tijdens de inventarisatie van de voedingsgewoonten is duidelijk geworden dan er regelmatig vemageringspogingen worden ondernomen. Over het algemeen is vermageren goed mogelijk indien het overgewicht veroorzaakt wordt door een teveel aan vet. Echter, bij topatleten is de lichaamsvetmassa relatief laag. Het gewichtsverlies wordt dan gerealiseerd door afbraak van spiermassa en door dehydratie. Beide methoden kunnen tot ongezonde praktijken leiden en dienen daarom vermeden te worden. Omdat systematisch onderzoek naar de grenzen van het mogelijke ontbreekt is een start gemaakt om deze problematiek aan te pakken. Op de eerste plaats is gekeken in hoeverre verlies aan spiermassa tijdens vermageren is te meten. Het meten van de uitscheiding van 3-methylhistidine via de urine is hiervoor de gebruikelijke methode. Echter alleen de reproduceerbaarheid over dagen is bekend. Aangezien gewichtsvermindering over het algemeen over weken wordt uitgespreid, is gekeken naar de reproduceerbaarheid over weken. Gebleken is dat de variatiecoëfficient voor mannen aanzienlijk lager was dan voor vrouwen (4,4% versus 12,1%). Naar aanleiding hiervan is geconcludeerd dat deze methode vooralsnog alleen voor mannen te gebruiken is en dat verdere studies nodig zijn om meer inzicht in deze problematiek te verkrijgen.

Als voorbeeld van voedingsgewoonten van atleten met metabole afwijkingen is onderzoek gedaan naar het voedingspatroon van intensief sportende insuline-afhankelijke diabeten. Het is algemeen bekend dat tijdens het sporten deze atleet ten alle tijden wil voorkomen dat er een hypoglycaemie ontstaat. Door van te voren en tijdens het trainen te eten probeert men dit te voorkomen. Omdat het nuttigen van glucose alleen zinvol is als glucose ook snel door het lichaam kan worden opgenomen is het belangrijk de juiste voeding te kiezen. Echter, deze eerste inventariatie heeft aangetoond dat het moeilijk is om de juiste voedselkeuze te doen. Om tegemoet te kunnen komen aan de specifieke behoeften moeten ze allen leren door "vallen en opstaan". Over het algemeen is er weinig deskundigheid en interesse om de atleten te begeleiden. Het lijkt erop dat vermindering van de insuline dosis te prefereren is boven het eten van allerlei voedingsmiddelen. Uit deze inventarisatie is gebleken, dat meestal het tegenovergestelde wordt gedaan. Dit leidde meestal tot hoge bloedglucosegehalten. Om beter inzicht in de individuele behoeften te krijgen is het regelmatig meten van het bloedglucosegehalte dan ook noodzakelijk.

Curriculum Vitae

Marie-Agnes van Erp-Baart werd op 3 januari 1945 geboren te Hulst. Aan het Jansenius Lyceum te Hulst werd na 4 jaar gymnasium en 2 jaar MMS in 1963 het MMS diploma behaald. Daaropvolgend is in Nijmegen de opleiding voor diëtist gevolgd, alwaar in 1967 het diploma werd verkregen. Vanaf 1967 tot 1968 is zij als diëtist werkzaam geweest in het Canisius Ziekenhuis te Nijmegen. Van 1972 tot 1978 heeft zij parttime meegewerkt aan het GVO Project bij de afdeling Preventieve Tandheelkunde van de Katholieke Universiteit te Nijmegen. In 1976 is zij begonnen als onderzoeksdiëtist bij de werkgroep Inspanningsfysiologie, eveneens van de Katholieke Universiteit. Het in dit proefschrift beschreven onderzoek is daar tot 1988 uitgevoerd. In 1984 is de eerste graads bevoegdheid voor Voeding en Diëtetiek aan de Rijksuniversiteit van Limburg behaald, en vanaf 1984 tot 1989 is zij werkzaam geweest als docent aan de Hogeschool Nijmegen, studierichting Voeding en Diëtetiek. In 1988 is zij bij TNO-Voeding te Zeist in dienst gekomen en heeft het beheer van het Nederlands Voedingstoffenbestand op zich genomen. In 1989 is zij tevens tot hoofd van de groep diëtiek benoemd. Momenteel is zij fulltime in dienst van TNO-Voeding.