International Journal of Sport Nutrition and Exercise Metabolism, 2009, 19, 504-518
© 2009 Human Kinetics, Inc.

Development and Validation of a Food Pyramid for Swiss Athletes

Samuel Mettler, Christof Mannhart, and Paolo C. Colombani

Food-guide pyramids help translate nutrient goals into a visual representation of suggested food intake on a population level. No such guidance system has ever been specifically designed for athletes. Therefore, the authors developed a Food Pyramid for Swiss Athletes that illustrates the number of servings per food group needed in relation to the training volume of an athlete. As a first step, an average energy expenditure of 0.1 kcal · kg^{-1} · min^{-1} for exercise was defined, which then was translated into servings of different food groups per hour of exercise per day. Variable serving sizes were defined for athletes' different body-mass categories. The pyramid was validated by designing 168 daily meal plans according to the recommendations of the pyramid for male and female athletes of different body-mass categories and training volumes of up to 4 hr/d. The energy intake of the meal plans met the calculated reference energy requirement by 97% ± 9%. The carbohydrate and protein intakes were linearly graded from 4.6 ± 0.6–8.5 ± 0.8 g · kg^{-1} · d^{-1} and 1.6 ± 0.2–1.9 ± 0.2 g · kg^{-1} · d^{-1}, respectively, for training volumes of 1–4 hr of exercise per day. The average micronutrient intake depended particularly on the dietary energy intake level but was well above the dietary reference intake values for most micronutrients. No tolerable upper intake level was exceeded for any micronutrient. Therefore, this Food Pyramid for Swiss Athletes may be used as a new tool in sports nutrition education (e.g., teaching and counseling).

Keywords: nutrition, exercise, sports nutrition, communication

Food-guide pyramids are a form of food-based dietary guideline that help translate nutrient goals into a visual representation of suggested food intake on a population level. Generally, the World Health Organization describes food-based dietary guidelines as "the expression of the principles of nutrition education mostly as foods; intended for use by individual members of the general public; and written in language that avoids, as far as possible, the technical terms of nutritional science" (1998).

Although some food-based dietary guidance systems allow for the higher energy needs of physically active individuals (e.g., the U.S. MyPyramid covering energy needs up to 3,000 kcal/day with a food pattern designed for more than 60

Mettler and Colombani are with ETH Zurich, Dept. of Agricultural and Food Sciences, Zurich, Switzerland. Mannhart is with the Swiss Olympic Association, Swiss Federal Institute of Sport Magglingen, CH-2532 Magglingen, Switzerland.

min of daily physical activity; U.S. Department of Agriculture, 2008), no guidance system has ever been specifically designed for athletes.

Scientific guidelines for macronutrient intake in sports are usually formulated as the amount of nutrients per kilogram of body mass that athletes should eat (Maughan, Burke, & Coyle, 2004). However, because such guidelines cannot be easily translated into food by most athletes, we developed a Food Pyramid for Swiss Athletes (FPSA), which not only provides guidelines for food and fluid choices on a daily basis but does so using a helpful visual aid that should facilitate decision making relative to the amount of food and fluid to be consumed on a given training day.

Development of the Pyramid

The Basic Pyramid

As with the recommendation for any other population group, the recommendations for athletes should primarily focus on the long-term maintenance of health. This implies that an athlete's diet should be well balanced and follow the same general rules recommended for nonathletes. Therefore, we built the FPSA as an extension of an existing food-guide pyramid for nonathletes—the food pyramid for healthy Swiss adults of the Swiss Society for Nutrition (Walter, Infanger, & Mühlemann, 2007). The particular layout of this food pyramid for healthy Swiss adults (called the basic pyramid from now on) furthermore made it easy to extend for the purpose of meeting the energy and nutrient needs of athletes. The authors of this article were also involved in the development of the basic pyramid, and one of the authors was the head of the expert group for the further development of the basic pyramid.

Additional Energy

The first step in the extension of the basic pyramid was to determine the additional energy needed for athletic training and competition, which primarily depends on the intensity and duration of exercise and the body mass of the athlete. This additional energy need was derived with the aid of comprehensive summary tables of energy expenditures for different types of exercises at different intensities (Ainsworth et al., 1993; Ainsworth et al., 2000; McArdle, Katch, & Katch, 1996; Montoye, 2000). A general problem was that although it is impossible to derive a mean energy expenditure covering all exercise types at all intensities, such an average energy expenditure is needed to build the pyramid. Therefore, the additional energy was derived by identifying minimal and maximal energy needs in sports to set the range of exercise energy expenditures, followed by selecting an intermediate energy expenditure that matched a possibly large range of exercise situations. To calculate the additional energy need of exercise, the energy need of an average sitting activity (0.025 kcal $\cdot$ kg^{-1} $\cdot$ min^{-1}) was always subtracted, because exercise replaces a sedentary lifestyle rather than being added to it.

Maximally sustainable aerobic-energy expenditure rates were found to be around 0.3 kcal $\cdot$ kg^{-1} $\cdot$ min^{-1}, representing about 17–20 km/hr (10.5–12.5 miles/hr) running speed, which only world-class long-distance runners can sustain over a significant time span. Significantly higher anaerobic intensities are possible, but they cannot be sustained over very long time periods and are, therefore, not relevant when calculating an additional energy need of an hour or longer. Maximal values for intermittent activities such as those occurring during an intensive soccer game at the elite level were found to be around 0.2 kcal $\cdot$ kg^{-1} $\cdot$ min^{-1} (Ainsworth et al., 2000; Bangsbo, 1994). Moderate exercise intensities often corresponded to energy expenditure rates between 0.08 and 0.12 kcal $\cdot$ kg^{-1} $\cdot$ min^{-1} (with 0.1 kcal $\cdot$ kg^{-1} $\cdot$ min^{-1} representing an average value for moderate intensities), although lower additional energy demands can be found for low-intensity activities such as gymnastics.

Because the aim of the pyramid is to provide recommendations to the average athlete, the additional energy required for a given exercise activity had to match the habitual exercise training situation of the average athlete as much as possible. This situation likely corresponds to the moderate exercise intensity discussed in the preceding paragraph, with an energy expenditure of about 0.1 kcal $\cdot$ kg^{-1} $\cdot$ min^{-1}. In addition, different mathematical and qualitative considerations (e.g., averaging energy expenditures of different sports at moderate intensities, designing training sessions for different sports with more and less intensive parts, considering different intensities of different training sessions over a week, or weighing different sports according to numbers of athletes in Switzerland) also led to values of around 0.1 kcal $\cdot$ kg^{-1} $\cdot$ min^{-1}. Therefore, a value of 0.1 kcal $\cdot$ kg^{-1} $\cdot$ min^{-1} was finally defined as the average moderate energy-expenditure rate. This rate represents running at 8 km/hr (5 miles/hr), cycling at 2 W/kg on a bicycle ergometer, or the stop-and-go intensity of many field sports of moderate intensity.

Additional Servings

Once the total additional energy requirement per time unit for the average exercise activity was defined, it was distributed as extra servings across the different food groups of the basic pyramid, taking into consideration the specific macronutrient recommendations for sport (Burke, Kiens & Ivy, 2004; Tipton & Wolfe, 2004) and considering whether the extra servings were practical in an athlete's real-life setting. The extra servings were linked to a defined exercise time unit, which for practical reasons was chosen to be 1 hr. Furthermore, sport-specific foods such as sport drinks, energy bars, or recovery products were included as choices for the extra servings next to the food items of the basic pyramid. The problem of different energy needs relative to body mass was solved by using variable serving sizes. Consequently, it is the duration of daily exercise training that determines the number of extra servings, whereas the athlete's body mass determines the serving size. Sports nutritionists and dietitians were involved in all steps of the FPSA development, and their feedback was integrated into its design.

Validation of the Pyramid

Qualitative evaluation of the FPSA included informal evaluation by a core group of Swiss sport dietitians (9 dietitians) and sports nutrition scientists and consisted primarily of applicability issues related to understanding the sports-related extension of the basic pyramid. Feedback on both the content and the layout was taken into account, and the FPSA was adapted accordingly.

The final version of the FPSA was validated quantitatively by six sport nutrition scientists. The validation consisted of designing 168 meal plans according to the recommendations of the FPSA for different hypothetical athletes assumed to have either the limit of the range of body mass described in the FPSA as a guideline for selecting the serving size (50 kg and 85 kg) or having an intermediary body mass of 67.5 kg. As a second variable, different daily training volumes were assumed from zero (to simulate resting days) up to 4 hr. This range of body mass and training volume was thought to cover most athletes. Half the athletes were assumed to be women and half to be men. Gender did not influence the design of the meal plans and was considered only for the calculation of the reference energy target.

The foods selected are all commercially available on the Swiss market. They were chosen exactly as recommended in the pyramid in relation to the number of servings (i.e., only the number of servings of the basic pyramid for a day with no exercise [a recovery day] or the number of servings of the basic pyramid plus the recommended number of servings for exercise in relation to the hours of exercise per days) and in relation to the selection of foods in a food group (e.g., one serving of meat, fish, egg, cheese, or tofu per day was used alternately on different days, or three servings of vegetables and two servings of fruits were included consistently every day according to the instruction for this food group). The only foods fortified with nutrients used in the validation were the sports foods and sports drinks, most of which are fortified with some micronutrients. The reason for this restriction was that the basic pyramid had already been shown to deliver micronutrient amounts well above the recommended values when devising daily menu plans without the use of fortified foods (calculated from 320 daily plans, unpublished report).

Meal plans were designed for 168 days (84 for each gender, 56 for each of the three body-mass categories, and 12, 36, 41, 39, and 40 for 0, 1, 2, 3, and 4 hr of exercise, respectively, per day). All meal plans were evaluated with the dietary assessment software EBISpro for Windows (version 5.01, University Hohenheim, Germany) based on the Swiss version of the German Food Composition Database (BLS v2.3, Karlsruhe, Germany). The reference values for energy were calculated using the formula for the estimated energy requirement (EER) of the dietary reference intake for adult men and women (Institute of Medicine, 2005). A physical activity level of 1.4 (corresponding to physical activity coefficient values of 1.11 and 1.12 for men and women, respectively, in the EER formula [Institute of Medicine, 2005]) was used for a sedentary lifestyle (zero hours of exercise), because the basic pyramid is designed for this physical activity level (Walter et al., 2007). The previously defined additional energy requirement for exercise of 0.1 kcal $\cdot$ $kg^{-1} \cdot min^{-1}$ was added to the sedentary-lifestyle energy requirement to get the reference energy intakes for 1, 2, 3, and 4 hr of exercise per day. An age range of 20–35 years was designated to the athletes for the reference energy calculation because this range was thought to cover most athletes. Age is a parameter in the EER formula, although the influence of this parameter is inferior to other parameters such as body mass.

Generally accepted reference values for athletes were selected as target intakes for carbohydrate and protein (Tipton & Wolfe, 2004; Burke et al., 2004). In contrast to the macronutrients, there are no specific recommendations for micronutrient intakes for athletes. Therefore, the recommended dietary allowance (RDA), or the adequate intake (AI), for men was used (Institute of Medicine, 1997, 2000a, 2000b, 2001, 2004). In the case of iron, the only micronutrient for which women have greater needs than men, the higher RDA for women was considered. For the validation of the micronutrient intake, the average micronutrient intake of the 20 meal plans with the lowest daily energy content (1,890–2,320 kcal/day), the 20 meal plans around the median energy content (3,060–3,300 kcal/day), and the 20 meal plans with the highest energy content (4,490–5,270 kcal/day) were considered. The number of meal plans for each of these three energy levels was chosen arbitrarily. However, it needed to be large enough to not be influenced by an outlier but also not too large, to keep the selected energy level as homogeneous as possible.

Results

The final FPSA is shown in Figure 1. The energy intake of the meal plans met the calculated energy requirement by 97% ± 9% (Figure 2). The energy content of the meal plans ranged from 1,890 kcal for resting days and a body mass of 50 kg to 5,270 kcal per day for a body mass of 85 kg and 4 hr of exercise. The carbohydrate and protein intakes were 4.6 ± 0.6–$8.5 \pm 0.8\ g \cdot kg^{-1} \cdot day^{-1}$ and 1.6 ± 0.2–$1.9 \pm 0.2\ g \cdot kg^{-1} \cdot day^{-1}$, respectively, for training volumes of 1–4 hr of exercise per day (Figure 3). The micronutrient intake was above the RDA/AI for most micronutrients at the low and median energy levels (Figure 4) and even higher for the highest energy level considered (data not shown). The RDA/AI was not met at all energy levels for potassium and vitamin D. Iron was considered critical for women with a low energy intake. No tolerable upper intake level (Institute of Medicine, 1997, 2000a, 2000b, 2001) was exceeded at any considered energy level.

Discussion

Dietary guidance systems aim to translate the nutrient recommendations developed by nutritionists and dietitians into more easily understandable food-based recommendations. Because no such system was available for the specific population group of athletes, we developed and validated the first food pyramid for an athletic population, reflecting the fundamental needs of an athlete's diet in comparison with the dietary needs of a sedentary population. The FPSA was built on the Swiss food pyramid for healthy adults (Walter et al., 2007), which considers the internationally accepted recommendations for public health nutrition. Although the foods visualized in the Swiss food pyramid were chosen according to the Swiss eating culture, the amount of nutrients resulting from the pyramid's recommendation is consistent with internationally accepted dietary reference intakes.

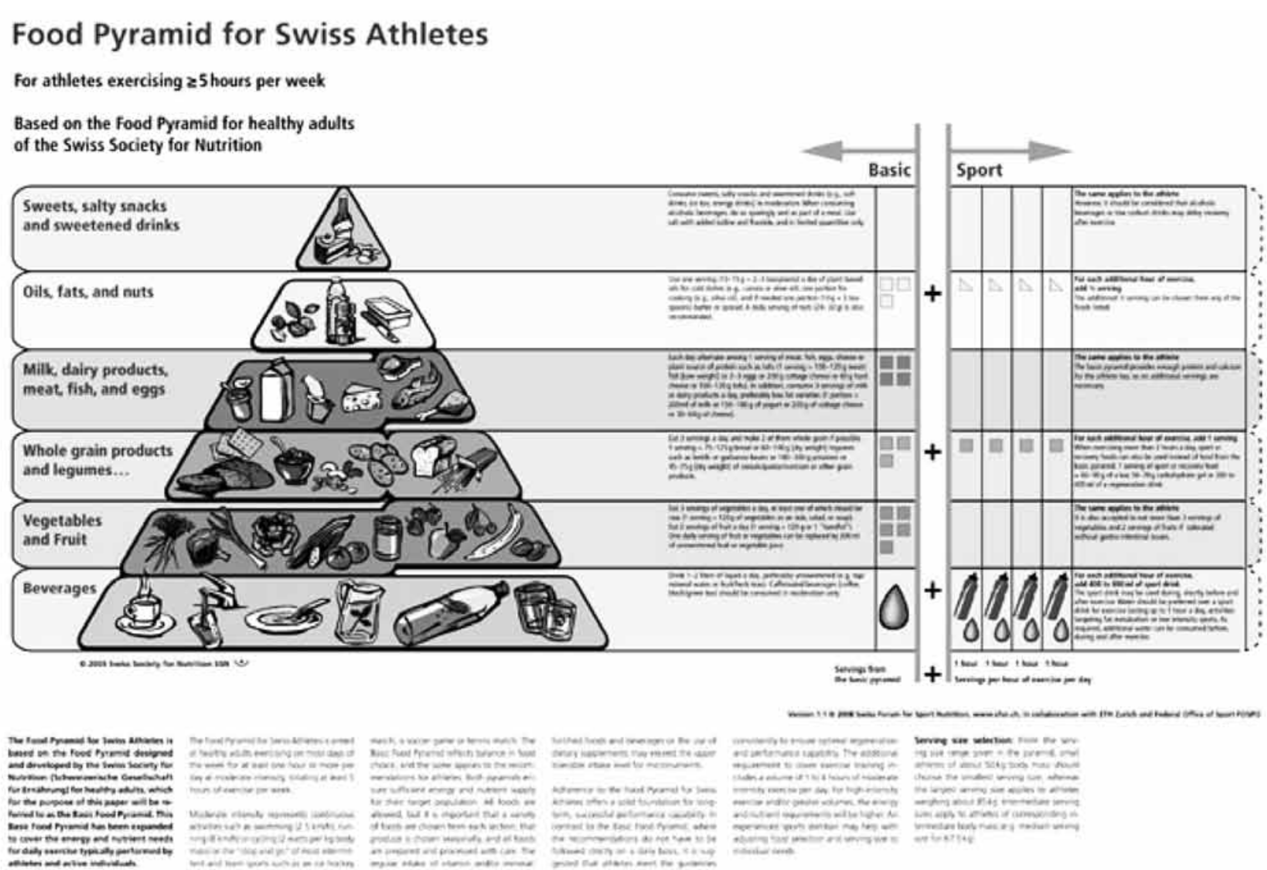

Figure 1 — The Food Pyramid for Swiss Athletes (FPSA) is intended to always be used with the explanatory text, so pyramid and text are considered a single graphical unit. The FPSA was designed to be printed on A3 landscape paper. A clearer version of the FPSA can be downloaded from the Web site of the Swiss Forum for Sport Nutrition: www.sfsn.ch/index_EN

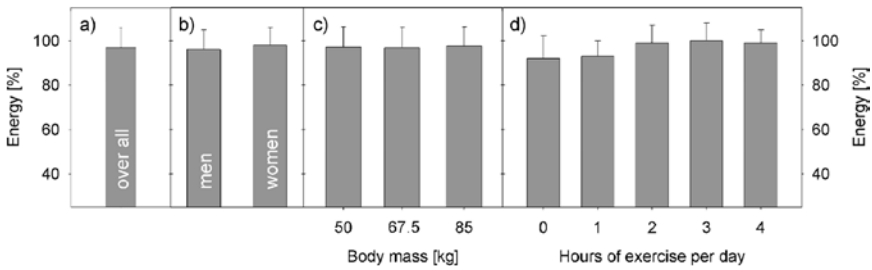

Figure 2 — Average energy intake of the 168 meal plans relative to the estimated energy requirement (a) overall, (b) by gender, (c) by body mass, and (d) by training volume, *M* ± *SD*.

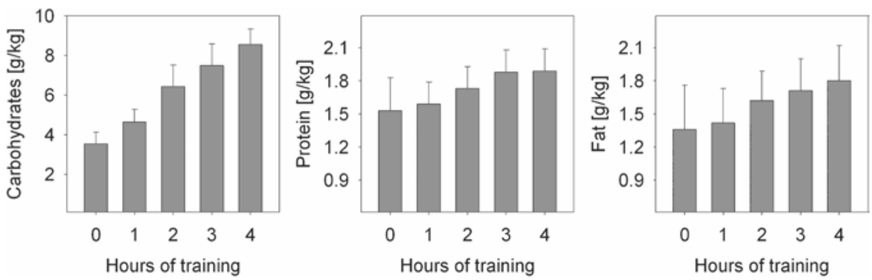

Figure 3 — Average daily macronutrient intake of the 168 meal plans by training volume, *M* ± *SD*.

Energy

The quantitative validation revealed that the energy requirement was met by 97% ± 9%. Although it might be argued that an average energy intake of slightly less than 100% of the predicted energy need may result in an inappropriate energy delivery over the long or short term, with consequent negative energy balance and impaired physical performance, there are several lines of argument suggesting that this need not be a matter of concern. Most important, there is no calculation of the energy requirement based on formulas that can exactly predict the real energy needs of an individual. It should also be considered that there is significant individual variation in energy requirements, and the EER formula for total energy expenditure used to estimate the energy need of athletes is a regression on the population level (Institute of Medicine, 2005). Furthermore, predicted energy expenditure using formulas such as the Harris Benedict equation, the FAO/WHO/UNU equation, or the EER formula may over- or underestimate the basal metabolic rate for specific population groups (Muller et al., 2004; Wahrlich, Anjos, Going, & Lohman, 2007; Elizabeth Weekes, 2007). Regardless, the newly developed FPSA represents, as any other guidance system, a general recommendation that needs to be fine-tuned on an individual basis (e.g., by intrinsic factors such as hunger and satiety signals or with the help of experienced sport dietitians).

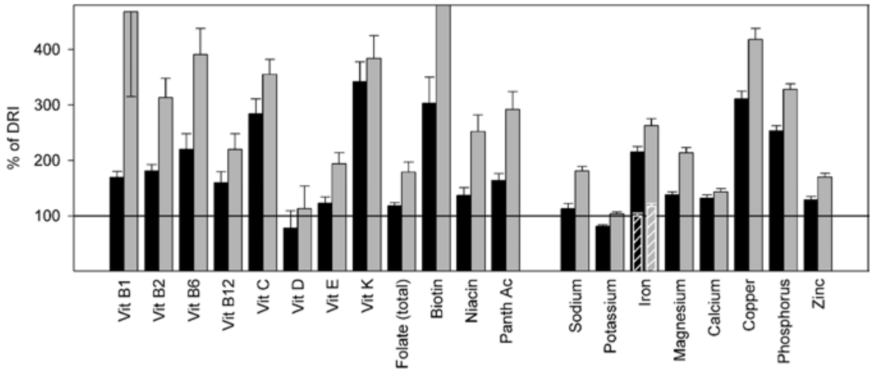

Figure 4 — Micronutrient intake relative to the corresponding dietary reference intake (DRI; Institute of Medicine, 1997, 2000a, 2000b, 2001). The thin horizontal black line represents 100% of the DRI for men. In case of iron, the inserted white hatched bars indicate the situation if the increased DRI for women had been used. For each micronutrient, the intake relative to the DRI is given for the low energy level (1,890–2,320 kcal/day, n = 20, black bars), as well as for the median energy level (3,060–3,300 kcal/day, n = 20, gray bars). The biotin intake at the median energy level was 825% ± 163% ($M \pm SEM$). Vitamin D and potassium, for which not all energy levels fulfilled the DRI as well as iron, are further discussed in the text.

Although other factors may play a role, the energy cost of exercise depends primarily on three variables: the intensity of exercise, the duration of exercise, and the body mass of the athlete. Therefore, the energy need of exercise is expressed as kcal · kg^{-1} · min^{-1}, and the energy requirement was fixed at 0.1 kcal · kg^{-1} · min^{-1}. The other two parameters, the body mass of the athlete and the duration of exercise, were left as variables and integrated into the FPSA by defining the serving size to account for a range of body mass for athletes and by defining the number of servings to account for the duration of exercise (number of servings per hour of exercise per day). A third variable such as exercise intensity or the timing of food and fluid intake would have made the message too complicated. The question is, therefore, whether the set average intensity was appropriate.

The maximal sustainable energy turnover for humans is about three times higher than the selected value of 0.1 kcal · kg^{-1} · min^{-1}, given at about 0.3 kcal · kg^{-1} · min^{-1} for a world-class running pace at a duration of over 1 hr (i.e., more than half a marathon race). However, only a very small number of athletes are able to perform at such high intensities, and the FPSA was designed for the average athlete. In addition, when considering stop-and-go or intermittent activities, as seen in many team sports, the maximal energy turnover at the elite level drops to about 0.2 kcal · kg^{-1} · min^{-1} (Ainsworth et al., 2000; Bangsbo, 1994). For average exercise intensities, values of 0.08–0.12 kcal · kg^{-1} · min^{-1} can be found for many sports (Ainsworth et al., 2000; McArdle et al., 1996; Montoye, 2000). Although some athletes will certainly have more intense training sessions from time to time, it is unlikely that the average intensity is that high for extended periods of time. An average exercise intensity corresponding to 0.2 kcal · kg^{-1} · min^{-1} is unlikely to be rational or tolerable for recreational or even elite endurance athletes.

It should also be considered that the selected 0.1 kcal · kg^{-1} · min^{-1} represents, for example, 28 hr of training per week (for athletes exercising 4 hr/day) and that this is equivalent to a running distance of 4 hr × 8 km/hr = 32 km/day. This is unlikely to significantly underestimate the average training intensity of even elite endurance athletes. In contrast, it is more likely that the FPSA overestimates the energy needs of some low-intensity sports. This may include sports primarily based on explosive force generation with long recovery times between activities, such as sprinting or jumping; aesthetic sports such as gymnastics; or sports activating only a few isolated muscles groups, such as machine-based resistance training. However, in this case the athlete can solve the problem easily (e.g., by eating for only 1 hr of exercise according to the FPSA while exercising for 2 hr/day). Another approach for endurance athletes is, as indicated, to calculate the energy need by the running distance covered daily or weekly, rather than by intensity and duration. Therewith, the intensity is not included in the guideline anymore for this particular sport.

Overall, the set intensity is likely to be acceptably close to the average energy expenditure of many sports. Finally, the FPSA—like other dietary guidance systems—does not claim to be able to precisely predict the required energy intake of every sport and for each individual in a sport at a given intensity and duration. Instead, the aims of the FPSA are to communicate a basic message about sports nutrition, to guide athletes with respect to the type of foods they may choose (qualitative message), and to give indications about the amount of foods needed (quantitative message). These messages need, of course, to be fine-tuned on an individual level.

The last general point is that the FPSA targets athletes exercising most days of the week, with a total training volume of at least 5 hr/week. Recreational athletes with two or three gym trainings or jogging sessions per week can cover their energy and nutrient needs by using the basic pyramid or any other food-guidance system for the general population. Such low training volumes should be seen as part of a healthy diet and lifestyle rather than as a training situation for which more energy and nutrients are needed. Therefore, this fundamental message is given in the first subtitle of the pyramid: "For athletes exercising ≥5 hours per week."

Macronutrients

The reference values for daily carbohydrate intake in sports range from 5 to 7 g · kg^{-1} · day^{-1} for low to moderate training volumes, 7 to 10 g · kg^{-1} · day^{-1} for higher training volumes of high intensity, and up to and more than 12 g · kg^{-1} · day^{-1} for extreme endurance events (Burke et al., 2004). The definitions were purposely not set more precisely, because there are not enough scientific data to rationally specify them more closely. One to two hours of exercise per day at moderate intensities, according to the FPSA, might be allocated to the lowest carbohydrate intake recommendation of 5–7 g · kg^{-1} · day^{-1}, and 3–4 hr of exercise per day may be defined as a high training volume, corresponding to the recommendation of a carbohydrate intake of 7–10 g · kg^{-1} · day^{-1}. The FPSA is not fixed at a maximum of 4 hr of exercise per day and can be extended by continuing to add further portions per additional hour of exercise. Estimated from about 6 hr of exercise a day, the highest carbohydrate recommendations of 12 $g \cdot kg^{-1} \cdot day^{-1}$ would be reached.

Reference values for daily protein intake for athletes are often reported to be between 1.4 and 2.0 $g \cdot kg^{-1} \cdot day^{-1}$ (Campbell et al., 2007; Tipton & Wolfe, 2004), and values above 2–3 $g \cdot kg^{-1} \cdot day^{-1}$ are considered without scientific foundation (Tipton & Wolfe). The validation of the FPSA resulted in a protein intake ranging from 1.6 to 1.9 $g \cdot kg^{-1} \cdot day^{-1}$ for 1–4 hr of exercise, which is well within the recommendations for athletes. The resulting intakes of 1.6–1.9 $g \cdot kg^{-1} \cdot day^{-1}$ were obtained in spite of no additional servings of meat or dairy products at the pyramid level. This can be explained by the relatively high protein delivery of the basic pyramid (corresponding to a resting day for athletes), with which a mean intake of 1.5 $g \cdot kg^{-1} \cdot day^{-1}$ is achieved. Therefore, a relatively flat increase with higher exercise volume is possible in the protein supply, and this also ensures a good protein supply for sports with lower training volumes or lower energy needs (e.g., strength and sprint disciplines). It also avoids unnecessarily high protein intake for endurance athletes with high training volumes. The additional protein with increasing training volumes stems in particular from additional servings of grain products and sports food (e.g., recovery foods), which are all designated to the same food group in the FPSA. If other food-guidance systems would be used as a basis to be extended, it might be necessary to add extra servings of foods providing protein to match athletes' protein needs.

In contrast to carbohydrate and protein, there are no reference values thus far for fat intake in sports. There is no sound explanation for these missing reference values, because they can be derived once the requirements for total energy, carbohydrate, and protein are met. Because the energy, carbohydrate, and protein intakes are well within the recommendations, the resulting fat-intake values in the validation were considered safe. The resulting requirement for additional fat for exercise was met by adding half a serving from the fat, oil, and nuts food group.

Some elite endurance athletes such as cyclists or triathletes may have larger training volumes than the daily 4 hr displayed in the FPSA, resulting in very high energy requirements. These high energy needs (i.e., outside of the display of the FPSA at volumes of 5 hr of exercise per day or more) likely need to be covered by proportionally greater intake of fat at the expense of the grain food group, mainly because higher amounts of carbohydrate, particularly grains containing fiber, may be unmanageable at higher training volumes. However, this aspect has not been mentioned in the text accompanying the FPSA, because most athletes are not likely to exercise more than 28 hr/week.

Fluids

The basic pyramid recommends drinking 1–2 L of unsweetened fluids per day. For exercise, the FPSA recommends drinking 0.4–0.8 L of a sports drink or water during exercise as required (American College of Sports Medicine, 2007; Noakes & Speedy, 2007), as well as additional fluid after exercise for rehydration, without specifying the quantity. This is because fluid requirements highly depend on environmental and individual conditions (American College of Sports Medicine). Accordingly, the recommendations of the FPSA, in particular with respect to water and unsweetened drinks, are not fixed; they are adjustable according to specific needs (e.g., by the intrinsic thirst mechanism or with the help of an experienced sport dietitian).

Micronutrients

The general problem with assessing athletes' micronutrient intakes is that there are no specific recommendations for them. Although it cannot be ruled out that the micronutrient needs of heavily training athletes might be higher than those of the general population, the RDA/AI is basically seen as adequate for athletes (American College of Sports Medicine & Dietitians of Canada, 2000). Overall, the micronutrient intake resulting from the validation was much above the RDA/AI for all energy levels and for nearly all micronutrients considered. Therefore, the micronutrient intake should cover even the potentially higher needs of athletes. However, there were some micronutrients that should be addressed.

The resulting vitamin D intake did not meet the AI (5 μg/day; Institute of Medicine, 1997) for the low energy-intake level. However, it is common that vitamin D intake does not match the AI, and very few foods provide significant amounts of vitamin D (Institute of Medicine, 1997; Sioen, Matthys, De Backer, Van Camp, & Henauw, 2007). Vitamin D can be synthesized in the skin and, throughout the world, the major source of vitamin D for humans is exposure of the skin to sunlight (Institute of Medicine, 1997). In spite of this, sunlight exposure might not be a guarantee for a sufficient vitamin D status (Binkley et al., 2007), because skin pigmentation and sunscreen use significantly reduce vitamin D synthesis in the skin (Holick & Chen, 2008). At latitudes above 40° N or below 40° S, the photosynthesis of vitamin D can be limited in the winter months (Institute of Medicine, 1997). This issue may be even more relevant for athletes of indoor sports in general, for athletes exercising indoors during the winter months, and for athletes living in cold climates where skin exposure to the sun during outdoor activities is limited by wearing clothes covering most of the skin. For athletes at risk for insufficient vitamin D status, vitamin-D-fortified foods or vitamin D supplements may be considered, especially if fish (in particular, salmon, mackerel, or herring), as a major source of vitamin D, is not consumed at least as regularly as suggested by the FPSA.

The iron intake for men resulting from the FPSA validation was well above the RDA (8 mg/day; Institute of Medicine, 2001). Even when the RDA for women had been used as reference (iron is the only micronutrient for which women 19–50 years of age have a higher RDA [18 mg/day] than men), the resulting average intake would have been 100% of the RDA at the lowest and 120% of the RDA at the median energy intake.

Iron deficiency is more prevalent in female than in male athletes (Sinclair & Hinton, 2005). In addition, iron supply to the body depends not only on iron intake but also on iron bioavailability (Venderley & Campbell, 2006). For example, vegetarian diets usually do not contain less iron than nonvegetarian diets, but iron bioavailability is worse, resulting in reduced iron status in vegetarian athletes (Venderley & Campbell). A sport dietitian can help athletes at risk for iron deficiency (e.g., women with a low energy intake) choose appropriate foods to improve iron intake and bioavailability.

The average potassium intake from our compilation of meal plans at the lowest energy-intake level was slightly below the AI (4.7 g/day; Institute of Medicine, 2004). However, the AI for potassium might also be considered rather high. Reference values from other countries are set substantially lower, with Germany, Austria, and Switzerland (DACH, 2000) using 2.0 g/day and other European countries using 3.1–3.5 g/day (EFSA, 2005). In addition, the median intake of potassium in the United States, Canada, and Holland is substantially lower than the AI, around 2.9–3.6 g/day (Geleijnse et al., 2007; Institute of Medicine, 2004). Therefore, a potassium intake slightly under the AI, but well above the European reference values, might not be considered an important problem for healthy athletes.

The use of micronutrient supplements or foods fortified with micronutrients is a popular and ongoing topic in sports nutrition. For the validation of the FPSA we did not use fortified foods, with the exception of sports foods and sports drinks, which are almost universally fortified. This decision was based on the results of an unpublished study showing that the basic pyramid already leads to micronutrient amounts way above the reference values for most micronutrients. Accordingly, the FPSA recommendations also resulted in estimated intakes that were much higher than the reference values for most micronutrients. Even if the sports foods and sports drinks were omitted from the validation without replacing them with other foods (to compensate for energy), micronutrient intakes would drop by about 10% and 20% for the low and median energy-intake levels, respectively, and they would still be well above 100% of the RDA/AI for all energy-intake levels (data not shown). On the other hand, low-dose multimineral and -vitamin supplements may also help athletes with low energy budgets ensure adequate micronutrient intake.

Limitations of the Pyramid

The FPSA is designed to give a general message about sports nutrition and to guide athletes of 50–85 kg weight, with weekly training volumes of 5–28 hr and age 20–35 years, in their daily food choices while highlighting their different energy and macronutrient needs compared with sedentary to normally active individuals exercising less than 5 hr/week. As with any other guidance system, it cannot predict the exact needs of athletes involved in specific sports, and, thus, fine-tuning of individual requirements is necessary. Further evaluation in the field is required to determine whether the pyramid is a practical and useful guide to athletes.

The quantitative validation of the FPSA indicated that it provides a reasonable amount of energy and macronutrients for a wide range of sports and for athletes of different body masses (50, 67.5, and 85 kg) and training volumes (1–4 hr of exercise per day) at moderate intensity. However, every user of the FPSA must be aware that the additional servings per hour of exercise are based on a moderate intensity. Otherwise, problems such as overfueling in low-intensity sports might arise.

An aspect that is only considered marginally in the FPSA but is of great relevance for sport performance, recovery, and training adaptation is the issue of the timing of food intake relative to training (information only given in the case of sports drinks). Nevertheless, this is a common feature of many dietary guidance systems, and integrating all necessary aspects related to the optimal timing of food intake in sports would have made the FPSA much more complex and perhaps significantly limited its usability or application.

Although the FPSA reflects the cultural food habits and choices in Switzerland, the variety of foods modeled in each food group was wide, and it would be possible to replicate these choices in many countries in the world, particularly Western countries where eating practices are similar to those of Switzerland. Furthermore, the amounts of nutrients resulting from the pyramid's recommendations are consistent with internationally accepted dietary reference intakes.

Conclusion

The FPSA was designed to translate energy and nutrient recommendations into food choices and to visually present them to athletes. Its validation revealed that the translation of scientific guidelines into understandable food recommendations resulted, at least in theory, in sufficient coverage of the current energy and nutrient recommendations used in sports nutrition. Therefore, the FPSA can be regarded as a new tool to help with communication in sports nutrition education (e.g., teaching or counseling).

Acknowledgments

We thank Andrea Hartmann for her support with designing the FPSA and Martina Pfeiffer and Jacques Décombaz for their help and input during its development and validation. There are no conflicts of interest or financial interests for any of the authors.

References

Ainsworth, B.E., Haskell, W.L., Leon, A.S., Jacobs, D.R., Jr., Montoye, H.J., Sallis, J.F., et al. (1993). Compendium of physical activities: Classification of energy costs of human physical activities. *Medicine and Science in Sports and Exercise, 25,* 71–80.

Ainsworth, B.E., Haskell, W.L., Whitt, M.C., Irwin, M.L., Swartz, A.M., Strath, S.J., et al. (2000). Compendium of physical activities: An update of activity codes and MET intensities. *Medicine and Science in Sports and Exercise, 32,* S498–S504.

American College of Sports Medicine. (2007). Exercise and fluid replacement. *Medicine and Science in Sports and Exercise, 39,* 377–390.

American College of Sports Medicine & Dietitians of Canada. (2000). Joint position statement: Nutrition and athletic performance. *Medicine and Science in Sports and Exercise, 32,* 2130–2145.

Bangsbo, J. (1994). Energy demands in competitive soccer. *Journal of Sports Sciences, 12*(Spec. No.), S5–S12.

Binkley, N., Novotny, R., Krueger, D., Kawahara, T., Daida, Y.G., Lensmeyer, G., et al. (2007). Low vitamin D status despite abundant sun exposure. *The Journal of Clinical Endocrinology and Metabolism, 92,* 2130–2135.

Burke, L.M., Kiens, B., & Ivy, J.L. (2004). Carbohydrates and fat for training and recovery. *Journal of Sports Sciences, 22,* 15–30.

Campbell, B., Kreider, R.B., Ziegenfuss, T., La, B.P., Roberts, M., Burke, D., et al. (2007). International Society of Sports Nutrition position stand: Protein and exercise. *Journal of the International Society of Sports Nutrition, 4,* 8.

DACH. (2000). *Referenzwerte für die Nährstoffzufuhr*. Frankfurt, Germany: Umschau/Braus.

EFSA. (2005). Opinion of the Scientific Panel on Dietetic Products, Nutrition and Allergies on a request from the Commission related to the tolerable upper intake level of potassium. *EFSA Journal, 193,* 1–19.

Elizabeth Weekes, C. (2007). Controversies in the determination of energy requirements. *The Proceedings of the Nutrition Society, 66,* 367–377.

Geleijnse, J.M., Witteman, J.C., Stijnen, T., Kloos, M.W., Hofman, A., & Grobbee, D.E. (2007). Sodium and potassium intake and risk of cardiovascular events and all-cause mortality: The Rotterdam Study. *European Journal of Epidemiology, 22,* 763–770.

Holick, M.F., & Chen, T.C. (2008). Vitamin D deficiency: A worldwide problem with health consequences. *The American Journal of Clinical Nutrition, 87,* 1080S–1086S.

Institute of Medicine. (1997). *Dietary reference intakes for calcium, phosphorus, magnesium, vitamin D and fluoride*. Washington, DC: National Academy Press.

Institute of Medicine. (2000b). *Dietary reference intakes for thiamin, riboflavin, niacin, vitamin B6, folate, vitamin B12, pantothenic acid, biotin and choline*. Washington, DC: National Academy Press.

Institute of Medicine. (2000a). *Dietary reference intakes for vitamin C, vitamin E, selenium and carotenoids*. Washington, DC: National Academy Press.

Institute of Medicine. (2001). *Dietary reference intakes for vitamin A, vitamin K, arsenic, boron, chromium, copper, iodine, iron, manganese, molybdenum, nickel, silicon, vanadium and zinc*. Washington, DC: National Academy Press.

Institute of Medicine. (2004). *Dietary reference intakes for water, potassium, sodium, chloride, and sulfate*. Washington, DC: National Academies Press.

Institute of Medicine. (2005). *Dietary reference intakes for energy, carbohydrate, fiber, fat, fatty acids, cholesterol, protein and amino acids*. Washington, DC: National Academies Press.

Maughan, R.J., Burke, L.M., & Coyle, E.F. (2004). *Food, nutrition and sports performance II: The International Olympic Committee consensus on sports nutrition: The IOC Consensus Conference on Sports Nutrition* (2nd ed.). New York: Routledge.

McArdle, W.D., Katch, F.I., & Katch, V.L. (1996). *Exercise physiology* (4th ed.). Baltimore: Williams & Wilkins.

Montoye, H.J. (2000). Energy costs of exercise and sport. In R.J. Maughan (Ed.), *Nutrition in sport* (pp. 53–72). Oxford, UK: Blackwell Science.

Muller, M.J., Bosy-Westphal, A., Klaus, S., Kreymann, G., Luhrmann, P.M., Neuhauser-Berthold, M., et al. (2004). World Health Organization equations have shortcomings for predicting resting energy expenditure in persons from a modern, affluent population: Generation of a new reference standard from a retrospective analysis of a German database of resting energy expenditure. *The American Journal of Clinical Nutrition, 80,* 1379–1390.

Noakes, T.D., & Speedy, D.B. (2007). Time for the American College of Sports Medicine to acknowledge that humans, like all other earthly creatures, do not need to be told how much to drink during exercise. *British Journal of Sports Medicine, 41,* 109–111.

Sinclair, L.M., & Hinton, P.S. (2005). Prevalence of iron deficiency with and without anemia in recreationally active men and women. *Journal of the American Dietetic Association, 105,* 975–978.

Sioen, I., Matthys, C., De Backer, G., Van Camp, J., & Henauw, S.D. (2007). Importance of seafood as nutrient source in the diet of Belgian adolescents. *Journal of Human Nutrition and Dietetics, 20,* 580–589.

Tipton, K.D., & Wolfe, R.R. (2004). Protein and amino acids for athletes. *Journal of Sports Sciences, 22,* 65–79.
U.S. Department of Agriculture. (2008). *MyPyramid*. Retrieved from http://www.mypyramid.gov
Venderley, A.M., & Campbell, W.W. (2006). Vegetarian diets: Nutritional considerations for athletes. *Sports Medicine (Auckland, N.Z.), 36,* 293–305.
Wahrlich, V., Anjos, L.A., Going, S.B., & Lohman, T.G. (2007). Basal metabolic rate of Brazilians living in the southwestern United States. *European Journal of Clinical Nutrition, 61,* 289–293.
Walter, P., Infanger, E., & Mühlemann, P. (2007). Food pyramid of the Swiss Society for Nutrition. *Annals of Nutrition & Metabolism, 51*(Suppl. 2), 15–20.
World Health Organization. (1998). *Preparation and use of food-based dietary guidelines, report of a joint FAO/WHO consultation. FAO/WHO*. Retrieved from http://www.fao.org/DOCREP/x0243e/x0243e00.htm#TopOfPage