Food and drink choices before, during and after training and competition have a direct impact on health, body mass and composition, nutrient availability and recovery time. An optimal diet can significantly improve exercise performance.

Nutrition for Sport and Exercise outlines the fundamental principles of nutrition in relation to sport and exercise and then applies these principles through practical tools such as food and nutrient lists, recipes and menu options.

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• Concise and accessible, combining theory and practice

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ABOUT THE AUTHOR

Hayley Daries, MSc (Med), is a registered dietitian with 18 years of professional experience in the field of nutrition and sport. She has worked in South Africa and the United Kingdom, where she has held positions such as consultant dietitian in London’s Harley Street, senior lecturer at a leading university in Wales, and chief dietitian in the NHS. Currently freelancing, Hayley divides her time between university lecturing, writing, radio interviews, course development, dietary consultation with patients and athletes, and outreach work in resource-poor schools and sport clubs.

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A Practical Guide

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Professor Timothy D Noakes

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Preface

I am a teacher at heart, and for this purpose I have been absorbing knowledge from a very young age. My first inspiration came from my father, Winston Warren Daries (Pops), who taught me in primary school. He had a gift for teaching and inspired his students with his enthusiasm for Geography. Later life brought me other great teachers in the field of nutrition and sport, like Professor Edelweiss Wentzel-Viljoen (dietetics) and Professor Timothy Noakes (sport and exercise medicine), and my previous colleague and author, the late Mary Barasi (nutrition) who are all great examples of Excellence in their respective fields.

Hence, the idea of this book first came about while lecturing Sport and Exercise Nutrition at the University of Wales Institute, Cardiff (now Cardiff Metropolitan University) and Cardiff University. There Mary Barasi recognized my dedication to sport and teaching and recommended me to Blackwell’s Nigel Balmforth. I will never forget my nerves and excitement on the day of our first meeting, and I am so grateful for the opportunity to impart what I know and have experienced in this field.

This book is for the many students, athletes and teachers who share my passion for sport and exercise nutrition. While it has a sound scientific underpinning, it presents the fundamental principles in an easy-to-read format. The subject is rapidly expanding and athletes and students want to know about the latest scientific research, the dietary habits of other athletes, and the spec on the most fashionable supplement. A book that can combine the science of sport and exercise nutrition with application of knowledge (as student exercises) and real food choices (as recipes) seems to achieve more than one objective. The students want to know ‘why?’ and the athletes want to know ‘who to?’ It is the ‘hands on’ part that will make it all stick in the end; this I have learnt through my work with students and athletes in the field.

Hayley Daries
2012
I would like to thank the team at Wiley-Blackwell, including Nigel Balmforth, Katrina Hulme-Cross and Rupert Cousens. It is also with a grateful heart that I thank Sara Crowley-Vigneau for her support, encouragement and profound professionalism in the final leg of the manuscript. I have had the privilege of expert guidance and advice from Rebecca Huxley, and also thank Amit Malik for his contribution.

I have been very lucky to find Rene Petersen who helped with the recipes and did an excellent job, and Cheryl Wolfe whose optimistic assistance I could rely on day and night and who has exceptional organizational and technical skills.

I thank my husband Rupert, *triathlete par excellence*, with whom I share my love for exercise, and who has always been there with little and big rewards along the way. I am blessed with a wonderful family, also my cheerleading squad who always believed in me and saw me through all the seasons of my manuscript.

Natalie, Vanessa, Michelle, your families and Mom, Thank You So Much.

Last but not least, I thank all the athletes and students who have always been at the forefront of inspiration for me to complete this incredible journey.
Foreword

It is a special privilege to write the foreword for the book by a former student. For it is in the writing of a book that one acquires the wisdom that no teacher can ever impart. Teachers can provide the tools and perhaps the spark, but never the desire nor the commitment to expend the thousands of hours that are required to produce a work of substance as is this book.

I know Hayley Daries as an inquisitive, independent, self-directed but impatient thinker who is dissatisfied with the way things are. She is driven to understand what is beyond the horizon of our knowledge. The research for her Masters degree sought to answer the question: How much do athletes really need to drink during exercise? At a time when the global standard was ‘drink as much as tolerable’, she was one of the first courageous enough to question whether drinking according to the dictates of thirst might be better. Her findings were amongst the first to question the value of drinking at high rates during exercise.

Hayley’s gentle nature belies a steely strength and firm resolve to make a difference in all that she undertakes – as a teacher, clinician, researcher, writer, wife and mother. She does not need nor does she seek external affirmation; she alone is the best judge of the quality of the work she undertakes in all the different components of her life. Her standard is perfection. She told me about this book only after most of it had been written and then only to seek my advice about a specific section. She knows that she knows better than others on exactly what it is she needs to write. And this knowledge has been earned at the coalface – advising athletes what they need to eat and then putting that practical information together in lectures and articles, an ongoing process that will continue for as long as she practices her calling.

Hayley describes that her passion is to write a book that provides a practical resource for athletes, based on a sound analysis of the science of sports nutrition. Students, she says, want to know ‘why’ and the athletes want to know ‘how to’. In fact, both really want to understand both the practical ‘how’ and the scientific ‘why’. Hayley has succeeded admirably in describing both the art and the science of sports nutrition in a friendly and easily accessible format. She has succeeded in her goal of producing the practical information that she believes is often missing from the purely scientific
texts. It is this information that she thinks will in the end ‘make it all stick’. And so her book will find a special place in the discipline because it resonates with the goodness, the honesty, the practicality and the intellectual integrity of its author.

Hayley knows that the abiding principle she learnt from me is that, at its core, science is about disproving that which we hold the most dear. She is aware of the maxim that 50% of what we teach is wrong but the problem is that we do not know which 50% that is. The core belief in sports nutrition mirrors that of the nutritional sciences both of which are founded on the belief that carbohydrate is the crucial macronutrient for both health and for competitive sport. Fat on the other hand is branded as unhealthy and a poor choice for those who are active. But the nature of our knowledge is that it is, and must always be, in flux.

Prior to the 1960s the worldview of nutrition was altogether different. Then it was believed that fat and protein are the healthy choices for athletes whereas carbohydrates are fattening. Athletes were also advised not to drink during exercise. The advice on fluid replacement was clearly wrong. But are we absolutely certain that our understanding of the ideal macronutrient composition of both the healthy and the athletic diet is beyond question?

I pose this question to remind us all that our eternal search is for the truth. And truth as one scientist wrote is like a mirage; the closer we approach it, the more likely it is to disappear.

Until we have that final truth, there is much in the nutritional sciences, especially as they apply to sport and health, which remains an art.

We must never forget that.

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CHAPTER 1
Introduction

Key terms

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The importance of an adequate diet for athletes

It has been clearly demonstrated that the nutritional composition and adequacy of an athlete’s diet has an impact on performance and overall well-being. The consumption of food and fluid as fuel and hydration, before, during and after training and competition, can affect the athlete’s nutritional and immune status, health, body mass and composition, energy stores and nutrient availability, exercise performance and recovery.

Participation in all types of exercise, ranging from recreational exercise to competitive sport increases the physical demands on the body. Their increased energy expenditure requires athletes to consume higher energy intakes and specific amounts of nutrients from food and fluids, in the pursuit of meeting the demands of sport and exercise. Therefore, an important goal of an adequate diet for athletes is achieving and maintaining energy balance, which aims to restore energy reserves and leads to greater fulfilment of health and performance goals. While positive energy balance (when energy intake is higher than energy expenditure) encourages weight gain,
negative energy balance (when energy intake is lower than energy expenditure) can result in weight loss. However, there are consequences to both positive and negative energy balance that need to be considered in the long term. Positive energy balance may lead to over-fatness and chronic illness, and negative energy balance may result in an increased risk of muscle tissue loss, fatigue, injury and illness.

An adequate diet involves more than just energy balance, as key nutrients and fluid replacement have a role in preparation, support and enhancement of the athlete’s exercise and sports performance. An adequate sports diet also prevents some negative effects associated with prolonged exercise, such as nutrient fatigue. The nutrients, namely, carbohydrates, proteins and fats provide energy for exercising muscles. The proportion of these nutrients required are dependent on factors such as the athlete’s body weight, age, gender, intensity and duration of exercise and timing of meals (i.e. eating before, during and after training or competition). While many athletes believe they are eating a high-carbohydrate, low-fat eating plan, on closer inspection or analysis of the diet it is often revealed that the diet is in fact a high-fat, low-carbohydrate plan, and not much different to the average western diet. Participation in exercise may also increase the need for certain vitamins and minerals, those that have specific functions in exercise metabolism and the immune system.

All athletes start out with recreational exercise. Some may continue this level of exercise participation indefinitely. However, for many athletes, participation in sport can become highly competitive and this environment requires that athletes train and compete at their maximum capacity. The need for an adequate sports diet can help athletes sustain strenuous activities that may be of varying intensity, duration, frequency and skill.

To help an athlete achieve an adequate sports diet, the goals set out in the following text can be applied to all athletes participating at any level of sport. These goals form the foundation of the athlete’s everyday diet, which can then be tailored to suit the individual needs of an athlete as their demand for food and fluid change through various stages of training, competition and recovery.

**Goals of an adequate sports diet**

- To follow the basic healthy eating guidelines
- To meet energy and nutrient requirements
- To maintain health and well-being in both short term and long term
- To reach and maintain a healthy body mass, appropriate body composition levels, including body fat and body muscle tissue, and body water, as well as other health indices (i.e. waist circumference).
- To plan and implement training and competition nutrition strategies
Introduction

To ensure optimal hydration before, during and after exercise
To treat suboptimal nutrient levels and any known nutritional deficiencies
To treat and manage any ailments or diseases (i.e. diabetes) while eating for sport
To determine if or when nutritional supplements may be of benefit to the diet and exercise performance

Barriers to achieving an adequate sports diet and best food practice

Although athletes are constantly seeking ways to improve exercise performance, there may be a number of reasons that may prevent athletes from choosing or adhering to an adequate sports diet or adjusting their dietary behaviour to achieve optimum performance. The following will be discussed in the subsequent text:

- Athletes’ source of information (i.e. the media) and misconceptions about optimal sports nutrition practices
- Poor nutrition knowledge
- Dietary extremism
- Poor practical food skills
- Frequent travel

Athletes’ primary source of information and misconceptions

There is a plethora of information available through the media, and surveys on athletes have found that many athletes rely on the media as the primary source of nutrition information (Jacobson and Aldana, 1992). Thus at the time, TV, commercials, magazines, advertisements, books, popular magazines and newspapers appeared to be a source of nutritional information for athletes. Another media forum, the Internet, has become accessible and affordable to athletes. Various social networking websites allow users to exchange information by chat-room forums, email and instant messaging, some allowing content to be distributed in ‘real-time’ as it is uploaded. Facebook, Bebo and Twitter are among the popular online social networks.

However, not all forms of information are credible or substantiated by scientific evidence (also referred to as evidence-based information), and may lead to confusion for many athletes. This confusion may be one reason why athletes lack understanding in this specialised science of sport and exercise nutrition. It is advisable that athletes educate themselves about sources of valid and reliable information, try to access nutritional support programmes that are available to them or seek the advice or counselling of
a qualified sports dietitian or sports and exercise nutritionist if they require specialist dietary advice.

**Poor nutrition knowledge**

Since knowledge, attitudes and beliefs may act to encourage or discourage behaviour change (Thompson and Byers, 1994; Main and Wise, 2002), lack of knowledge about sports nutrition may be a barrier for athletes who wish to follow an adequate sports diet and make favourable dietary choices. It seems that while some athletes may perceive themselves to have an understanding of nutrition for athletes, their perception may not match their performance in a knowledge survey. With the rise in over-drinking during exercise, a recent survey examined how ‘beliefs about hydration and physiology drive drinking behaviours in runners’. Winger et al (2011) found that most runners relied on personal experience of ‘trial and error’ as a factor influencing their drinking behaviour. However, the survey revealed this group of athletes’ inadequate understanding of physiological principles underlying hydration practices, putting them at risk overhydration and its consequences.

Some athletes may have a general nutrition knowledge base, but fair poorly when asked questions specifically about the diet for athletes. Most athletes in recent surveys have been unable to identify the role of sport-specific nutrients such as carbohydrates and its role in exercise (Dunn et al, 2007), and/or proteins as a fuel for exercise. The latter misconception, that protein is a primary source of energy for muscle contraction, is a common finding among athletes surveyed (Zawila et al, 2003; Condon et al, 2007; Rash et al, 2008). It is, therefore, not surprising when athletes regard protein supplementation as necessary for exercise performance (Rosenbloom et al, 2002; Rash et al, 2008).

Not all athletes have poor nutrition knowledge, as certain groups of athletes appear to have a higher level of knowledge in nutrition. Apart from having a few misconceptions, elite athletes competing at national level, scored higher on nutrition-related multiple-choice, general knowledge and sport-specific questions than their age-matched non-athletes (Cupisti et al, 2002). Similarly, Raymond-Barker et al (2007) found that competitive endurance athletes’ level of knowledge of general nutrition was significantly higher than non-athletes of the same age group and gender.

**What knowledge would benefit athletes?**

Athletes need to understand the concepts in energy and fluid balance. In general these include, but are not exclusively:
- energy and its terms, i.e. kilocalorie, kilojoule;
- their individual energy expenditure and energy intake, and the relationship between dietary intake and physical performance;
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• proportion of nutrients in the diet, i.e. percentage of carbohydrate, protein and fat. That is, do athletes know what a 60% carbohydrate-rich diet means?
• the nutrient carbohydrate, and glycaemic index and sport;
• the nutrient protein, amino acids and the required amount and effects of excessive intake;
• the nutrient fat and requirements for sport, fat adaptation diets and their effects;
• the nutrient water and the fine balance between dehydration and overhydration in sport and the consequences thereof;
• the nutrient alcohol and its impact on sports performance and recovery;
• vitamins, minerals, dietary allowances and their role in health and exercise; and
• antioxidants, muscle soreness and requirements for athletes of various sports.

Athletes may not be able to practically apply their nutrition knowledge to make favourable food choices, due to the following reasons:

• Some may have a misunderstanding of food groups, or pictorial food guides like the Eatwell Plate (UK), MyPlate (USA) or the food pyramid guides, and its basic dietary guidelines. For example, the athletes surveyed by Dunn et al (2007) had problems translating nutrition knowledge into food choices as only half the questions about food choices were correctly answered. Furthermore, with a mean score of 36 points (out of 67) for the section on food groups, merely a third of athletes knew how many servings of fruits and vegetables are recommended daily. It is like having a few pieces of the puzzle but not being able to see the whole picture.

• Other studies have also shown that while athletes may have the knowledge, or know what advisable eating behaviour is, favourable dietary practices may not be applied (Nichols et al, 2005; Robins and Hetherington, 2005).

• An inability to understand the profile of foods within food groups, i.e. those foods within one food group have a similar, not identical nutrient make-up. For example, pasta, potatoes and bread are all starch that contain carbohydrates and have a similar nutrient profile when it comes to macronutrients (carbohydrate, protein and fat content). However, when it comes to micronutrients, a potato is rich in Vitamin C, potassium and copper, while pasta is a good source of Vitamin B2 (riboflavin) and manganese and copper. Brown and wholemeal bread contains Vitamin B1 (thiamin) and B2 (niacin), and minerals iron, magnesium, copper and others. Therefore, while each serving of pasta, potato and bread yields similar amounts of carbohydrate, protein, fat and likely copper, the rest of the micronutrient contribution is quite different. That is why it makes
sense to have a variety of foods within a food group. If a person just eats pasta and avoids potatoes and bread, they miss out on these foods that are rich in iron, magnesium, manganese and fibre. If the pattern persists over weeks or months, they can be at risk of suboptimal nutrient levels that can eventually lead to nutrient deficiencies.

- An inability to read food labels and choose the most appropriate packaged food or supplement as part of an adequate sports diet. In urban areas where there is no lack of access to processed and packaged food, athletes are bombarded with branding, nutritional claims, symbols of endorsement, ingredient lists and nutritional information. If they are not guided by what to look for to meet their individual health and exercise performance goals, they may fall prey to clever marketing and advertising of food companies, retailers and anecdotes of other athletes.

- Not knowing how to interpret and use dietary reference values (DRV), like recommended nutrient intakes (RNI), or guideline daily amounts (GDA) in their individual diets. Athletes may not be able to convert scientific sports nutrition principles into achievable dietary practices because they do not know:
  - about their body weight loss (through sweat) or gain (through over-drinking) during exercise and its impact on their health and performance;
  - about ergogenic aids (performance-enhancing aids) and its uses;
  - about pre-, during and post-competition nutrition strategies;
  - about sport-specific nutritional needs, i.e. fluid strategies to use in endurance sports.

**Dietary extremism**

Athletes who have misconceptions about nutrition and sports performance may be trapped by dietary extremism, which can limit the variety of foods they consume in their diet. Dietary extremism includes the following:

- Obsessive behaviour around food
- Disordered eating, i.e. food restriction, binge eating
- Excessive use of supplements, either nutritional or ergogenic aids
- Consuming very low (calorie) energy diets leading to underweight and low body fat levels
- Very low-fat diets
- Vegan diets, or extreme fibre intake
- Exclusion of one or more food groups
- Regularly skipping meals
- Fad diets
- Detoxification, ‘cleansing’ diets or excessive, inappropriate use of laxatives for weight loss
While vegetarianism is not an extreme dietary regimen, athletes need to pay special attention to their diet and ensure suitable plant proteins are consumed if eggs, dairy and/or fish are not consumed in their diet.

**Poor practical food skills**
The pattern of consumption and food selection may be influenced by athletes’ food preference (choosing one food over another) (Jonnalagadda et al, 2004). Athletes may lack the practical food skills or motivation in preparing appropriate meals. The following factors may have an effect on athletes’ food preference and affect whether they achieve an adequate sports diet and best food practice:
- Limited food and nutrition knowledge
- An inability to cook
- Lack of cooking facilities
- Limited access to food or healthy recipes
- Recipes with unknown ingredients or that seem long and complicated
- Poor food selection
- Overuse of highly processed foods (i.e. processed cheese, luncheon meats, sausage and/or bangers, which are high in fat, salt and have a high calorie, low nutrient value).
- Overuse of take-out foods
- Lack of motivation to prepare fresh food
- Inability to recognise nutrient quality of meals
- Inability to convert scientific nutrition principles into real food choices
- Limited time to prepare food to fuel and sustain their performance, such as in the case of athletes who have a heavy training load with little time between exercise sessions, or who have a busy lifestyle involving other responsibilities and commitments.

**Frequent travel**
The need for travel has increased in both recreational and competitive sport, attracting all levels of athletes to train and compete abroad (Waterhouse et al, 2004). Long distance travel can lead to travel fatigue, a temporary condition that can be overcome by appropriate preparation and precautions, before and during a flight. However, when travel involves a long distance flight across several time zones, athletes may experience jet lag for several days thereafter. Various methods have been proposed to counter the effects of jet lag, and to adjust the body clock as quickly as possible. Although there is insufficient evidence available for the ‘feeding hypothesis’, and the Argonne diet for athletes, Waterhouse et al (2004) suggests ways to minimise the effects of jet lag, including melatonin ingestion, bright-light-exposure-avoidance and management of sleep.
If local travel is involved, athletes travelling to a new venue may not be adequately prepared for training and competition due to the following reasons:

- Lack of preparation of foods and fluids
- Having an insufficient supply of foods and fluids for the duration of the event
- Feeling compelled to consume *all* the foods and fluids they have brought along
- Insufficient funds to purchase food or fluids
- Trying new foods or supplements for the first time during competition

Although this may seem trivial to athletes, athletes’ performance is often affected when they are not prepared or not able to get a particular food or drink at the new venue, one that they previously used during training. They then have to try a new food or drink, not known to them and with no idea of how it may affect their performance. If partaking in an endurance or team event, it may be that the event organisers have done well to provide beverages and race snacks for the athletes, although an athlete should never count on this. Rather be pleasantly surprised by the events’ food and fluid supply than disappointed or distraught by lack of supply. In the end it seems a clear choice to make, that is, to come to an event in the best possible shape by being prepared with foods and fluids suited to individual taste, considering the number of hours and numerous sacrifices athletes make on a daily basis for their sport. Since sport and exercise performance is multi-factorial, why spend all that time concentrating on the exercise component and then throwing it away by lack of preparation around nutrition.

Foreign travel poses another challenge for athletes, and depending on their level of performance, may be frequent (several times a year or season) or infrequent (once a year or less). Since there are restrictions with regards to what one may be able to take on board an aircraft, it limits the athletes’ nutrition preparation strategies. It is best then for them to familiarise themselves with the destination country, city and venue as much as possible by obtaining information prior to departure. This will depend heavily on their accommodation of choice, facilities that are available there and the surrounding area or sporting venue. At athletes’ villages they may be restricted and not allowed to bring in any food, fluid or supplementation.

They may be exposed to different foods than their home country, unknown brands of food, foreign language food labels and cultural staple foods. If venturing out and about, at worse, they may be exposed to unsafe foods or water. Athletes at a high level of performance, i.e. professional athletes or those representing their country may have a team of people to coordinate their trip and manage these challenges. Other athletes may not
be so lucky and the result is that their nutritional intake and performance will depend on their resourcefulness.

**Rationale for following sport and exercise nutrition principles**

While talent and ability contribute to overall sports performance, nutrition knowledge and good food practices can make a difference between winning and losing. The rationale for adhering to sport and exercise nutrition principles has been provided through years of scientific research and observation of athletes, both in laboratory settings, and in the field, i.e. in real life competitions. The literature reported in this book demonstrates that partaking in sport and exercise places energy and nutrient demands on the human body, in addition to those required for basic bodily functions, survival, prevention of disease and promotion of health. Thus, from a nutrition standpoint, understanding energy and nutrient requirements for sport and exercise participation, and applying these principles is of key importance to achieve and maintain a healthy body and achieve optimal sports performance.

The following factors influence energy and nutrient requirements:
- The athlete’s body composition (fat mass and lean body mass (muscle mass), weight (body mass) and height).
- Type of sport participation, i.e. intermittent-, power- or endurance-type exercise affecting intensity and duration of exercise, and subsequent fuel use during the activity.
- Environment, i.e. preceding diet, will affect fluid and nutrient requirements.

Other factors such as genetics, or natural ability, and training adaptations will affect, or change the athlete’s physiology that in turn affects the energy and nutrients they require, and how efficient their bodies are at using these resources.

**Body composition affects dietary needs**

All athletes are individuals with different dietary needs and exercise demands that depend on type, duration and intensity of exercise, age, gender, weight and body composition and lifestyle. Body composition (body fatness and lean body mass) is estimated using physical body measurements (anthropometry) including weight (body mass), height, waist circumference, mid-arm muscle circumference, body frame size, body mass index (BMI) and skinfold thickness. These measurements, as well as age and gender are used for determining the estimated average requirements (EAR), which will be discussed in Chapter 2.
Factors affecting fuel use during exercise

At a competitive level of sport, high demands are placed on athletes’ energy and nutrient stores. Performance analysis techniques are a way to assess these demands so that the knowledge can be applied in training and competition performance, and used toward the dietary plan. It is used by researchers and in high-performance laboratories and provides useful information that tracks and measures athletes’ activities during sport participation, especially in sport that relies on a high number of activities and requires a high level of skill, such as squash or football. For example, football is a high-intensity intermittent type of exercise and players need to be agile and fast as well as being skilled. Although running rates as one of the most energy-demanding activities, other activities such as tackling, jumping, accelerating, turning and getting up from the ground place physical demands on players and test the athletes’ perpetual and motor skills performance. The analysis of football players’ activities shows the physical capacity differences in playing position. Studies indicate that male midfielder players have the highest aerobic power compared with attackers and defenders (Bangsbo et al, 1991; Bangsbo, 1994). Male footballers cover an average distance of 11 km (6.8 miles) during a 90-minute match. This corresponds to a mean speed of 7.2 km/h (4.5 miles/h). How far a player runs is just one measure of the physical demands of the game. One thousand metres (1100 yd) are covered in high-intensity running that comprises of 20 very short, fast sprints. Elite female players cover similar distances and high-intensity runs as male players. Players can change activities every 3.7 seconds of the game, yielding 1459 activity changes (Mohr et al, 2004).

Environmental factors

The preceding diet and amount of stored nutrient that is available affect energy and nutrient requirements of the athlete.

Nutrients derived from ingested food and fluid is converted to fuel during exercise. The body also stores nutrients in organs and tissues, which goes a long way to sustaining a given exercise intensity and duration. An optimal diet will provide the athlete with sufficient fuel stores, and with nutrients that are essential for energy metabolism and vital bodily functions. For example, nutritional factors such as antioxidants affect the strength of an athlete’s immune system and their ability to recover between sessions. These will be discussed in greater detail in Chapter 7.

Another factor that affects energy and nutrient requirements is training adaptations. Exercise training combined with the optimum diet has the ability to change and adapt the athletes’ physiology, causing an altered exercise metabolism that may favour sports performance. The greatest impact
Introduction

on exercise performance through enhanced physiological and biochemical adaptations may be in the application of specific nutritional principles to support athletes’ intensive training demands (Maughan, 2002). Spriet and Gibala (2004) emphasised existing and new developments in nutritional practices that may influence adaptations to training. These are:

1. caffeine ingestion and its ergogenic effect;
2. creatine ingestion and its ability to increase muscle fibre size;
3. using intramuscular triacylglycerol (IMTG) as a fuel during exercise, and its repletion; and
4. gene and protein expression in muscles and the role of nutrition.

The authors stress that research in these areas will alter nutritional recommendations given to athletes, which will improve the adaptive response to training. Chapter 9 will explore the performance-enhancing (ergogenic) effects of caffeine and creatine.

Endurance training increases fat oxidation that allows more fat to be used as a source of fuel during exercise. Increased oxidation of circulating fatty acids and triglycerides (or triacylglycerol) in the muscle (Kiens et al, 1993; Phillips et al, 1996) occurs as a result of training duration. There are ample stores of fat in the body. IMTG is the small amount of fat (a few hundred grams) in muscle found between muscle fibres and as fat droplets within muscle cells. Even in the leanest endurance runner there are several thousand grams of fat from adipose tissue (fat under the skin and in the abdomen between the organs). ‘Fat-loading’ diets have been used by trained and untrained endurance athletes to improve fat oxidation and spare carbohydrate during exercise. Jacobs et al (2004) observed that even previously untrained males who cycle trained for 10 days and consumed a high-fat diet, increased their rate at which fat was burned during 90 minutes of exercise, thus sparing carbohydrate. However, although carbohydrate was spared, performance did not improve after 90 minutes. Fat as a fuel for exercise will be explored further in Chapter 6.

Furthermore, trained athletes become adapted to higher oxidative stress by producing more antioxidant enzymes that enhances the enzymatic antioxidant system, and hence, endurance trained athletes have an enhanced endogenous antioxidant defence system (Kanter, 1998).

Furthermore, when protein is metabolised, nitrogen is excreted by urine, faeces, sweat and other secretions such as skin, hair and nails. Training adaptations may improve protein retention to a greater extent than that of the average healthy person. Chapters 5 and 6 provide further information regarding training adaptations.

It is imperative that athletes formulate their own individual goals and identify the barriers that limit the fulfilment of these aspirations. They can equip themselves with evidence-based knowledge and practical food skills to make better (informed) choices. The factors influencing athletes’ energy
and nutrient requirements and how to address it will be discussed in detail in the subsequent chapters.

**Chapter summary**

- The nutritional composition of an athlete’s diet affects their nutritional status and health, body mass and composition, nutrient availability, exercise performance and recovery.

- The goals of an adequate sports diet can be used to establish a nutritional foundation for any athlete, participating in any sport at every level of exercise.

- The barriers that may prevent athletes from choosing an adequate sports diet, or adjusting their dietary behaviour to achieve optimum performance are, their own misconceptions about optimal sports nutrition practices, poor nutrition knowledge, dietary extremism, poor practical food skills and frequent travel.

- Of key importance is that athletes need to understand energy and nutrient requirements for sport and exercise participation, and apply these principles to achieve and maintain a healthy body and optimal sports performance.

- Athletes need to be aware of the physical demands of their sport so that they can use this knowledge to consume an energy- and nutrient-rich diet for sport that will support their training and competition.

- The preceding diet plays an important role in energy metabolism during exercise.

- Trained athletes develop adaptations that enhances their ability to perform, and recover between exercise sessions.
CHAPTER 2
The Athlete’s Energy Needs

Key terms

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Energy

All energy originates from the sun and various forms of energy exist to do work in the body including light, chemical, mechanical, osmotic, electrical and heat (thermal) energy. Plant and animal foods provide energy and nutrients such as carbohydrate, protein and fat.
Energy is measured in kilocalories (kcal) or kilojoules (kJ) where,

\[ 1 \text{ kcal} = 4.184 \text{ kJ} \]
\[ 1000 \text{ kcal} = 4.184 \text{ megajoules (MJ)} \]
\[ 1 \text{ kJ} = 0.239 \text{ kcal} \]
\[ 1 \text{ MJ (1000 kJ)} = 239 \text{ kcal} \]

(Thomas and Bishop, 2007)

**The nutrients providing energy**

*Dietary carbohydrate* (CHO) is the major energy source in the diet, and is a critical source of fuel for the contracting muscles during exercise, especially during high-intensity exercise. The simplest form of carbohydrate is glucose, and all carbohydrate-rich foods are converted to glucose. Carbohydrate is stored as glycogen in the liver and muscles. The liver supplies the blood with glucose, which maintains the brain’s essential glucose supply. Very low levels of blood glucose or hypoglycaemia (<3 mmol/L) can starve the brain of glucose, leading to a comatose state or brain damage.

\[ 1 \text{ g of CHO} = 4 \text{ kcal (16 kJ)} \]

The total carbohydrate stores in the body (liver and muscle glycogen and blood glucose) of a ∼70 kg man is ∼480 g with a caloric value of ∼1920 kcal and roughly enough to run for 100 minutes or ∼20 miles (Newsholme and Leech, 1983; Noakes, 2001; Maughan, 2002). Carbohydrate supplies fast energy during intense exercise (when compared with other nutrients protein and fat) and is the preferred energy source. Since exercise at a higher intensity or for a prolonged time rapidly depletes the body’s carbohydrate stores, it is essential to maintain carbohydrate intake through the day before, during and after training. Grains and cereals, fruits and vegetables, sugary and glucose-based food, snacks and drinks are carbohydrate rich. Excess carbohydrate in the diet can be converted to fat.

*Water* is an essential nutrient that has many life-giving functions. It is stored with glycogen, ∼3 g of water is stored with each gram of glycogen. During exercise water is lost when carbohydrate is used, and as sweat to dissipate heat that is built up through energy metabolism. The requirements for water increase during exercise.

*Protein* builds and maintains tissues and has a minimal role as a source of energy during exercise, providing 2–8% of energy supply for muscle contraction. Protein has a larger role after exercise and during recovery in the repair of damaged muscles fibres resulting from exercise, such as for ultra-endurance athletes who have the highest needs for post-exercise protein. The building blocks of protein are amino acids. Protein is stored in lean (muscle) tissue and during starvation, when not enough energy is
available protein has the potential to convert to glucose and free fatty acids (FFAs) as an alternative energy supply.

1 g of protein = 4.1 kcal (17 kJ)

A 70 kg man with 12% body protein has 8.5 kg protein mass equal to 34,000 kcal of energy (Jeukendrup and Gleeson, 2004). Protein-rich foods include fish, poultry, meat and alternatives like eggs, beans, legumes and nuts.

Fat is the most concentrated source of energy and supplies some fuel for exercise, which increases depending on the duration and intensity of exercise. The basic units of fat are glycerol and FFAs and in this form they can be used by the muscle during exercise. The body stores fat as triglyceride in adipose tissue (around the organs and under the skin) as intramuscular fat known as triacylglycerol droplets in muscle, and a small amount in the plasma. Some endurance athletes have training adaptations that allow them to store more fat droplets in their muscles, for use during exercise.

1 g of fat = 9.4 kcal (37 kJ)

A 70 kg healthy adult male has roughly 10,000 g (10 kg) of fat equal to ~90,000 kcal enough to run for 4700 minutes (Newsholme and Leech, 1983; Noakes, 2001; Maughan, 2002; Jeukendrup and Gleeson, 2004). There is more than enough energy from fat to run slowly and continuously for more than 3 days, or for 1000 miles at 100 kcal per mile. Fats are found in a number of foods but the highest quantities of natural fats are found in vegetable oils, fish oils, butter, nuts and seeds.

Alcohol is not suitable before, during or after exercise as it can cause dehydration, leads to poor fuel sources, impaired skills and increase in heat losses. Alcohol causes vasodilation and impairs the recovery and repair phase that is essential after exercise. High alcoholic beverages increase urinary losses that may prevent athletes from achieving optimal rehydration after exercise. Refer to Chapter 3 for further information about alcohol and sensible consumption.

1 g of alcohol = 7 kcal (29 kJ)

Not all nutrients have an energy value, that is, vitamins, minerals and water do not contain energy but have vital roles in health and exercise.

**Energy and nutrients as fuel for exercise**

**ATP**

Every cell requires and consumes oxygen so that it can convert chemical energy (fuel) from the food we eat into mechanical energy. A
high-energy compound is produced called adenosine triphosphate (ATP) that is required for cellular work. During exercise, contracting muscle cells have high demands for ATP (the ‘energy currency’) that provides kinetic energy for skeletal muscle to do mechanical work. Heat is also produced in the process and is lost through the lungs through breathing and the skin in the form of sweat (loss).

Figure 2.1 provides a schematic drawing of ATP. High-energy bonds exist between the phosphate groups and are symbolised by \( \sim \). Each high-energy bond stores 8000 kcal of energy. When the third phosphate group is released from adenosine by the enzyme adenosine triphosphatase (ATPase), energy is released and adenosine diphosphate (ADP) is formed. Subsequently, the second phosphate group is released for energy and forms adenosine monophosphate (AMP). Figure 2.2 illustrates the release of energy for muscle contraction by the breakdown of ATP, first to ADP and then to AMP. Figure 2.3 shows how the potential energy from plant and animal food sources ensures that a constant supply of energy is available.

The body has the ability to select the most appropriate fuel for a specific exercise. There are various factors that influence which nutrient will be used as fuel during exercise including intensity and duration of exercise.
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Effect of intensity of exercise on fuel use

The intensity of exercise pays a role in the choice of fuel or nutrient that will be used during exercise. The balance of carbohydrate and fat oxidation, called substrate partitioning is for the most part influenced by exercise intensity (Brookes and Mercier, 1994).

Figure 2.4 demonstrates how increasing exercise intensity (measured by maximal oxygen uptake or VO2max) affects energy demand, and carbohydrate use (as muscle glycogen and blood glucose) during running. During low exercise intensity (<50% VO2max) blood carries sufficient oxygen (aerobic metabolism) to the muscles and fat is the predominant fuel, equal to more than half of the energy production during exercise. At this low intensity of exercise, carbohydrate supplies about one-third of energy. The ‘crossover’ concept by Brookes and Mercier (1994) suggests that the greater the intensity of exercise, the greater the reliance on carbohydrate as an energy source. As exercise intensity increases over 50% VO2max, carbohydrate becomes the major fuel for the contracting muscles as energy from fat cannot be released fast enough above 60–65% VO2max. During prolonged exercise at moderate intensity of 70–75% VO2max, carbohydrate provides about 50–60% of energy, and fat 40–50% of energy. Most of the energy will be derived from muscle glycogen. At very high exercise intensity over 75% VO2max (equal to running at a marathon speed of ~18 km/h in the aforementioned example), rapid energy is needed. At this point, carbohydrate mainly from muscle glycogen can be used to fuel the