

STUDY GUIDE

PUBLIC HEALTH AND NUTRITION NUTRITION FOR FITNESS

**Course Code: EDHN-6016
PGD Public Health and Nutrition**



**Department of Nutritional Sciences & Environmental Design,
Faculty of Sciences**

ALLAMA IQBAL OPEN UNIVERSITY, ISLAMABAD

STUDY GUIDE

POST GRADUATE DIPLOMA IN PUBLIC HEALTH AND NUTRITION NUTRITION FOR FITNESS

COURSE CODE: EDHNS-6016

Unit: 1-9



**Faculty of Sciences Department of Nutritional
Sciences and Environmental Design
Allama Iqbal Open university, Islamabad.**

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FOREWORD

It is with great pleasure that the Department of Nutritional Sciences and Environmental Design, Faculty of Sciences, is offering PGD Public Health and Nutrition (PHN). The curriculum integrates the foundational principles of public health with cutting-edge insights into nutrition science, equipping students with the knowledge and skills necessary to address both global and local health issues.

Public Health focuses on disease prevention and health on a broader scale, providing a comprehensive understanding of the social, economic, and environmental factors that shape health and well-being. Nutrition focuses on the science of food and its impact on health, particularly as diet-related illnesses rise in developing countries and food systems face increasing strain due to uncontrolled population growth. Understanding this field is essential for promoting healthier lives and communities.

Allama Iqbal Open University is dedicated to promoting an educational environment where creativity and responsibility go hand in hand. We believe that the next generation of professionals will play a fundamental role in shaping a sustainable future.

This study guide on the course “Nutrition for Fitness” is structured to facilitate critical thinking, evidence-based analysis, and effective problem-solving, which are essential competencies for today’s health professionals.

I encourage you to approach this guide not only as a source of academic knowledge but also as a tool for fostering your passion for public service. Your work in public health and nutrition has the potential to make a significant impact on individual lives, communities, and entire populations.

I wish you success in your studies and hope that this guide will be a valuable companion on your educational journey, preparing you to meet the demands of a rapidly evolving field and contribute meaningfully to improving global health outcomes.

Best Wishes

Prof. Dr. Nasir Mahmood
Vice-Chancellor

PREFACE

The Postgraduate Diploma in Public Health and Nutrition has been carefully designed to address the growing demand for skilled professionals who can tackle complex health and nutrition challenges in our society. As the world evolves, the importance of public health and nutrition in promoting well-being, preventing diseases, and ensuring sustainable health outcomes has become more critical than ever.

In an era of unprecedented global health challenges, including pandemics, malnutrition, and the rising burden of non-communicable diseases, this diploma equips students with the tools, knowledge, and skills necessary to lead positive health transformations in diverse settings. The curriculum integrates the latest scientific research, practical applications, and evidence-based strategies, ensuring that students are well-prepared to contribute meaningfully to the health sector, both locally and globally.

This study guide is designed to support you through each step of your journey. It outlines the key concepts, learning objectives, recommended readings, and assessment strategies for each unit. Whether your goal is to advance in your current role or to embark on a new career path in public health or nutrition, this guide will serve as a valuable resource throughout your academic experience.

I encourage you to approach this course with curiosity, critical thinking, and a commitment to applying your knowledge to real-world challenges. The faculty and I are dedicated to providing you with a supportive and enriching learning environment. Together, we will explore the vital intersections of health, nutrition, and public policy to build healthier communities.

I wish you success in your studies and look forward to seeing the impact you will make in the field of public health and nutrition.

Yours sincerely,

Prof Dr. Sher Muhammad
Dean, Faculty of Sciences

MESSAGE FROM CHAIRMAN

Dear Students,

Welcome to the Department of Nutritional Sciences and Environmental Design's Diploma program in Public Health and Nutrition. I am pleased to announce the development of a comprehensive study guide focused on a basic understanding of nutrition for fitness.

This guide aims to equip all students with the necessary knowledge of Nutrition for Fitness i.e. carbohydrates, proteins, lipids and water. You will understand their digestion, absorption, and metabolism in detail with a clear understanding of their requirements for the human body. Understanding these macronutrients is essential not only for your health but also for the health of your family and the broader community.

I encourage all students to actively engage with the study guide and utilize its resources to enhance their understanding of macronutrients. Together, we can create an awareness about healthy eating choices and healthful behavior for better nutrition throughout the life cycle.

Thank you for your attention to this important matter. If you have any questions or suggestions, please don't hesitate to reach out to the program coordinator.

Stay Safe, Stay Vigilant!

Best Wishes

**Dr. Zaheer Ahmad
Chairman**

ACKNOWLEDGMENT

All praises to **Allah**, who gave me the strength to complete this project. The development of this comprehensive study guide on "Nutrition for Fitness" has been a collaborative effort, drawing upon the expertise and support of numerous individuals. It gives me immense pleasure to express my profound gratitude and reverence to the Vice Chancellor of Allama Iqbal Open University, **Prof. Dr. Nasir Mehmood**, for guiding, facilitating, and supporting the preparation of the course. We extend our heartfelt gratitude to all those who have contributed to the creation of this resource.

I would like to express my sincere appreciation to **Prof. Dr. Sher Muhammad**, Dean, Faculty of Sciences, for her support and encouragement. Thanks to **Dr. Zaheer Ahmed**, Chairman, Department of Nutritional Sciences and Environmental Design, for his sustenance and trust. All the faculty members, especially **Dr. Mahpara Safdar**, Assistant Professor, Department of Nutritional Sciences and Environmental Design, and **Ms. Khadija Amjad**, an expert in Community Health and Nutrition, provided valuable insights and guidance throughout this study guide's planning and development stages. Your expertise and dedication have been instrumental in ensuring the content's quality and relevance.

I also acknowledge the contributions of the design and editorial team, production, and printing team who worked diligently to ensure the clarity, coherence, and accessibility of the content presented in this study guide. Your dedication and attention to detail have been essential in bringing this resource to fruition.

Lastly, we extend our deepest appreciation to the post-graduate students who will use this study guide as a tool for learning and professional development. It is our sincere hope that it will serve as a valuable resource in your studies and practice of public health and nutrition in your daily life.

Thank you to everyone who has contributed to the creation of this study guide. Your collaboration and support have been invaluable in making this project a reality.

Dr. Asma Afreen
Course Coordinator

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INTRODUCTION TO THE COURSE

The course Nutrition for Fitness is designed to prepare students for careers in various fitness and alternative health-related fields for personal and professional applications. This fitness nutrition course program integrates the philosophy of exercise science with biological medicine and promotes organic whole foods in conjunction with dietary supplements. Nutrition is the study of foods and their effects upon health, development, and performance. Over the years, nutrition research has made a significant contribution to our knowledge of essential nutrient needs. During the first part of the twentieth century, most nutrition research focused on the identification of essential nutrients and amounts needed to prevent nutrient-deficiency diseases, such as scurvy from inadequate vitamin C. In the twenty-first century, our love affair with fitness and sports continues to grow. Worldwide, although physical inactivity is still very prevalent in developed nations, more of us are joining fitness facilities or initiating fitness programs, such as bicycling, running, swimming, walking, and weight training. Improvement in health and fitness is one of the major reasons that more and more people initiate an exercise program, but many may also become more interested in sports competition, such as age-group road racing; running and walking race competitions have become increasingly popular, and every weekend, numerous road races can be found within a short drive. Research has shown that adults who become physically active may also become more interested in other aspects of their lifestyles, particularly nutrition, that may affect their health in a positive way. Indeed, according to all major health organizations, proper exercise and a healthful diet are two of the most important lifestyle behaviors to help prevent chronic disease. In this book, Unit 1 introduces the general effects of exercise and nutrition on health-related and sports-related fitness, including the importance of well-controlled scientific research. Unit 2 provides a broad overview of sound guidelines relative to nutrition for optimal health and physical performance. Units 3 through 6 deal with the six basic nutrients— carbohydrate, fat, protein, vitamins, minerals, and water—with emphasis on the health and performance implications for the physically active individual. Units 7 through 9 review concepts of body composition and weight control, with suggestions on how to gain or lose body weight through diet and exercise, as well as the implications of such changes for health and athletic performance.

LEARNING OUTCOMES

After reading this study guide, the students will be able to:

1. Enhance student comprehension of sports nutrition, fitness and alternative health care for personal and professional application.
2. Integrate the philosophy of biological medicine with exercise science.

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Unit -1

INTRODUCTION

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Reviewed by:

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INTRODUCTION

Maintaining a healthy, balanced diet is essential for overall well-being, whether you're a professional athlete or someone who exercises regularly to stay fit. Proper nutrition enhances training effectiveness, helping individuals achieve their fitness goals through informed dietary choices. A balanced diet should supply sufficient energy by incorporating a diverse range of readily available foods, meeting the body's needs for carbohydrates, proteins, and fats essential for both health and physical activity. Healthful nutrition is important throughout the life span of the physically active individual because suboptimal health status may impair training and competitive performance. In general, the diet that is optimal for health is also optimal for exercise and sports performance. The World Health Organization (WHO) indicates that chronic diseases are now the major cause of death and disability worldwide. A major risk factor is being overweight or obese, a condition that affects almost two-thirds of the population and is increasing worldwide. The combination of an unhealthy diet and physical inactivity, which may contribute to being overweight or obese, was ranked as the leading cause, followed by tobacco use and alcohol abuse.

LEARNING OBJECTIVES:

After studying this unit, the students will be able to:

1. Explain the role of both genetics and environment, particularly nutrition and exercise, in the determination of optimal health and successful sport performance.
2. List each of the components of health-related fitness and then identify the potential health benefits of an exercise program designed to enhance both aerobic and musculoskeletal fitness.
3. Understand the importance of proper nutrition, including the role of dietary supplements as ergogenic aids, in sports performance.

Our food intake provides the necessary nutrients for bodily functions. However, no single food or food group contains all the essential nutrients required. Therefore, athletes and fitness enthusiasts should consume a variety of foods to ensure they obtain all the vital nutrients needed for preparation, participation, and recovery in sports and exercise. The body's energy comes from nutrients in our diet, which vary in amount across different foods and are metabolized to release energy, typically measured in kilocalories (kcal) per gram (g). The primary energy-yielding nutrients and their energy contributions are:

- Carbohydrates: 4 kcal/g
- Proteins: 4 kcal/g
- Fats: 9 kcal/g
- Alcohol: 7 kcal/g

1.1 ROLE OF NUTRITION IN HEALTH PROMOTION

In most developed nations, healthcare has advanced significantly during the last century. Once-fatal illnesses are no longer a major hazard because of modern medical procedures. The focus now is on preventing and treating chronic diseases like obesity and diabetes, which are the focus of much research and health recommendations. In the US in 2015, the approximate proportion of fatalities attributable to each cause. Nearly one in four deaths is caused by heart disease, which continues to be the leading cause of death for both men and women. Dietary and physical activity habits are closely associated with a number of these major causes of death, such as heart disease, cancer, stroke, Alzheimer's disease, diabetes, and renal disease. According to the U.S. Department of Health and Human Services (HHS), two of the main causes of death in the country are poor diet and inactivity.

Genetics is a significant component in the likelihood of developing chronic diseases, in addition to lifestyle variables. There is a genetic component to every disease, according to Simopoulos' studies. Genetic linkages to many chronic illnesses, including breast and prostate cancer, have been discovered by the Human Genome Project, which mapped the DNA sequence of our 80,000 to 100,000 genes. Women whose mothers had breast cancer, for instance, are more likely to have the disease, and males whose fathers had prostate cancer are more likely to get prostate cancer. In the long run, genetic therapy may provide therapeutic cures or effective treatments for people with genetic predispositions to chronic diseases like cancer.

A healthy diet, consistent exercise, and knowledge of personal risk factors can help prevent many chronic diseases. For instance, smoking is closely associated with lung cancer, and being overweight and leading a sedentary lifestyle are major risk factors for heart disease and some types of diabetes. A comprehensive list of health goals is released every ten years by the U.S. Office of Disease Prevention and Health Promotion (ODPHP) to encourage improved health among Americans. Enhancing diet and physical exercise was a major component of the Healthy People 2025 initiative's goals.

1.2 SPORTS, FITNESS, AND NUTRITION

At the top levels, athletes need to have the ideal mix of physiological, psychological, and biomechanical traits. Researchers have investigated the genetic foundation of top running, strength, and sprinting performance. Although genetics is important, intense coaching and training are also necessary to achieve peak performance. Improving biomechanics and preparing the mind for specialized training regimens help athletes reach their full genetic potential.

1.3 NUTRITION'S IMPACT ON ATHLETIC PERFORMANCE

Proper nutrition and customized exercise are still crucial for athletes who want to reach their maximum potential. Deficits in essential nutrients can seriously hamper

performance, but the correct supplements can increase stamina, postpone weariness, and enhance overall performance.

1.4 NUTRITION, EXERCISE, HEALTH, AND SPORTS-RELATED FITNESS

1.4.1 Physical Fitness

The ability of a person to engage in particular forms of physical activity is referred to as physical fitness. Professional health groups like the Society of Health and Physical Educators (SHAPE), divide fitness into two primary categories. Sports-related fitness and health-related fitness.

1.4.2 Sports-Related Fitness versus Health-Related Fitness

A healthy diet and regular exercise are two lifestyle choices that have a big impact on general health and fitness. Along with enhancing cardiovascular-respiratory fitness, muscular strength, muscular endurance, and flexibility, health-related fitness places a strong emphasis on maintaining a healthy body weight and composition. Other markers, including blood pressure, bone strength, balance, postural control, and markers of lipid and carbohydrate metabolism, are also seen as markers as people age. Athletes' strength, power, speed, endurance, and neuromuscular motor skills are all part of their sports-related fitness, which is unique to that sport. To reach their maximum potential, athletes must undergo intense mental and physical training that optimizes their genetic makeup.

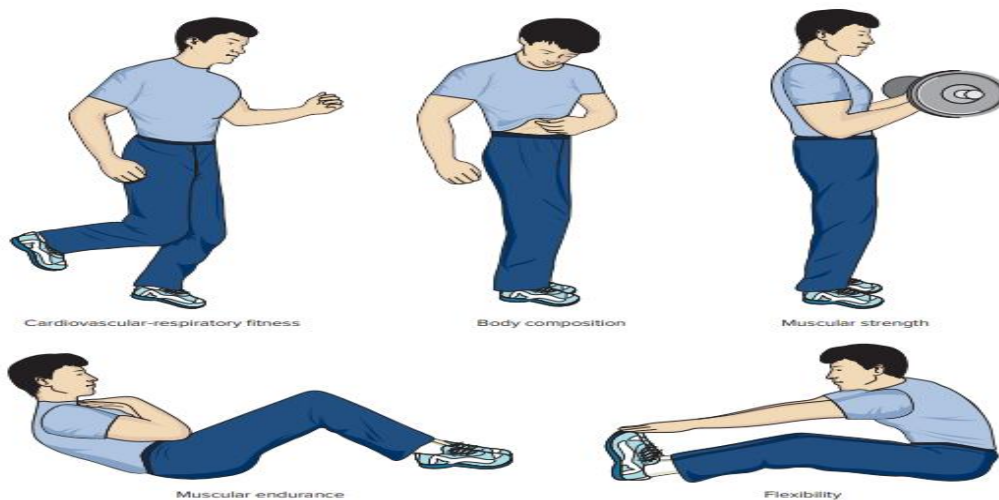


Figure 1: Health-related fitness components. The most important physical fitness components related to personal health include cardiovascular-respiratory fitness, body composition, muscular strength, muscular endurance, and flexibility.

1.5 FUNDAMENTALS OF PHYSICAL TRAINING

The American College of Sports Medicine (ACSM) and the American Heart Association (AHA) are two health organizations that stress the value of physical activity in improving health. Any physical movement resulting from muscle contractions that requires energy expenditure is considered physical exercise. Two categories are typically used to classify physical activity for research and health purposes:

- Activities including walking, climbing stairs, cycling, gardening, dancing, and other non-exercise-related motions are sometimes referred to as leisure-time hobbies. These activities are crucial for keeping a healthy body weight and general well-being, even though they are not intended as exercise.
- Planned Exercise is organized physical activity programs created especially to increase fitness. These activities, which are referred to as exercise, involve moderate to intense physical activity, such as brisk walking.

1.5.1 Principle of Overload

The overload principle is fundamental to exercise training. It involves adjusting the intensity, duration, and frequency of exercise to challenge the body. For example, a running program aimed at improving cardiovascular-respiratory fitness might involve running at 70% of the maximal heart rate for 30 minutes, five times a week. The body adapts primarily based on the specific overload imposed during training.

1.5.2 Principle of Progression

The progression principle is an extension of the overload principle. Once the body adapts to an initial overload, it's necessary to increase the intensity, duration, or frequency of exercise for continued improvements. For example, you may begin with lifting 20 pounds and gradually increase the weight to 25 pounds as your strength improves. Overloads are progressively increased until the desired health or performance goals are achieved or physical limits are reached.

1.5.3 Principle of Specificity

The specificity principle emphasizes that the body adapts specifically to the type of exercise and overload performed. For example, running and weightlifting stress different energy systems in the muscles, leading to distinct adaptations. Each type of exercise provides unique health benefits, and training programs can be tailored to target either health-related fitness or sports-specific performance improvements.

1.5.4 Principle of Recuperation

The recuperation principle, also known as the recovery principle, stresses the importance of rest after exercise. This allows the body to recover and adapt. Recuperation can refer to rest periods within a workout, such as taking breaks

between multiple sets of weightlifting, or to rest days between intense exercise sessions, like allowing a day of recovery between long cardiovascular workouts.

1.5.5 Principle of Individuality

The individuality principle highlights that the effects of exercise training vary from person to person, depending on genetic factors. The health benefits derived from a specific exercise program may differ greatly between individuals. For example, while most people with high blood pressure might see a reduction through cardiovascular-respiratory fitness training, some may not experience the same benefit.

1.5.6 Principle of Reversibility

The reversibility principle, often referred to as disuse or the "use it or lose it" concept, states that without regular exercise, the body will gradually lose the adaptations it gained through training. A brief break in an exercise routine, such as a week off, may lead to only minor losses in fitness.

However, a complete return to a sedentary lifestyle can undo all health-related fitness improvements.

1.5.7 Principle of Overuse

The overuse principle refers to excessive exercise that can lead to negative health effects rather than benefits. This is particularly common at the beginning of a fitness program, where individuals may overdo it out of enthusiasm, such as running too much or too far, leading to injuries like shin splints.

Overuse can also be seen in elite athletes who experience overtraining, which may cause harm rather than improve performance.

1.5.8 Physical Activity and Promoting Health

Physical inactivity is a major contributor to chronic diseases, termed as Sedentary Death Syndrome (SeDS). Weight gain and metabolic decline are the short-term costs of inactivity; an elevated risk of diseases like type 2 diabetes is the intermediate cost; and early death is the long-term cost.

Because exercise alters gene expression, which impacts cell structure and function, it probably helps avoid chronic diseases. The body produces good cytokines (adipokines in fat, myokines in muscles) when you exercise, and these cytokines have a positive effect on genes.

Frequent exercise can minimize the risk of conditions including diabetes, cancer, and heart disease while also improving insulin sensitivity and reducing inflammation.

By decreasing extra body fat, increasing bone density, and boosting cognitive function, exercise also fights aging-related problems like sarcopenia (muscle loss). Insulin sensitivity, blood lipid profile, and inflammation can all be improved with only one exercise session; however, these effects must be sustained over time.



Figure 2: Exercise is medicine. Here are some of the benefits of regular moderate physical activity and exercise.

1.6 Dietary Supplements and Sports Performance

The most effective way to enhance your natural sports ability and achieve your fitness goals is through efficient training combined with optimal nutrition. Many athletes consider supplements essential for sports success.

1.6.1 What are Dietary Supplements?

'Dietary supplements', 'functional foods', 'nutraceuticals', 'ergogenic aids', and 'sports supplements' are just some of the terms used interchangeably. According to the US Food and Drug Administration (FDA): 'a dietary supplement is a product (other than tobacco) that is intended to supplement the diet and bears or contains one or more of the following dietary ingredients: a vitamin, a mineral, a herb or other botanical, an amino acid, a dietary substance for use by humans to supplement

the diet by increasing its total daily intake, or a concentrate, metabolite, constituent, extract, or combination of these ingredients'. This differs slightly from the definition provided by the European Food Safety Authority (EFSA), which uses the term 'food supplement': 'A Food Supplement is a concentrated source of nutrients or other substances with a nutritional or physiological effect whose purpose is to supplement the normal diet.

They are marketed in a dose form as pills, tablets, capsules, or liquids in measured doses. Furthermore, EFSA states that: 'Supplements may be used to correct nutritional deficiencies or maintain an adequate intake of certain nutrients. However, in some cases, excessive intake of vitamins and minerals may be harmful or cause unwanted side effects; therefore, maximum levels are necessary to ensure their safe use in food supplements. Nutrients other than vitamins and minerals, or other substances with a nutritional or physiological effect, are being considered for regulation at a later stage when adequate and appropriate scientific data about them becomes available. The regulatory environment is under constant progressive change, but legislation differs across countries.

Studies suggest that most athletes use some form of performance-enhancing agent. Research on Canadian varsity athletes found that 99% consumed supplements, while a U.S. study revealed that 65% of athletes regularly used some type of supplement. The most commonly used supplements in these studies were vitamins, minerals, carbohydrate supplements, creatine, and protein powders. Advertising claims often sound convincing, but manufacturers may exaggerate or selectively use scientific research to promote their products. Endorsements from well-known athletes further add to the marketing hype. However, it's important to be cautious with ergogenic aids, as some may contain prohibited substances not listed on the label. Certain supplements, such as ephedrine, are available online but are banned in competitive sports and could lead to a positive doping test.

1.6.2 Commonly Used Supplements:

Athletes worldwide utilize a variety of dietary supplements (DS) to enhance performance, support recovery, and maintain overall health. The prevalence and types of supplements used can vary based on factors such as sport, gender, and regional practices.

- **Multivitamins and Vitamin C:** These are among the most frequently used supplements. In the UK, approximately 73% of athletes reported using multivitamins, and 71% used vitamin C.
- **Creatine and Whey Protein:** Creatine is popular for its role in enhancing muscle mass and strength, with usage rates around 36% among UK athletes.

Whey protein is used by about 32% of athletes for muscle recovery and growth.

- **Iron and Magnesium:** Iron supplementation is common, especially among female athletes, due to its importance in oxygen transport. Magnesium is widely used in countries like Germany, Portugal, and Poland, with usage rates up to 80%, but it is less popular in the UK and Norway.
- **Caffeine:** Used by about 24% of UK athletes, caffeine can enhance alertness and performance, but may have side effects like increased anxiety.

1.6.3 Are sports supplements safe?

Sports supplements are not regulated as strictly as medicines, meaning their safety and effectiveness can vary. While vitamin and mineral supplements in the EU are subject to stricter rules under the Food Supplements Directive, sports supplements do not have the same rigorous testing or labelling requirements. This means there's no guarantee that they always meet their claims or are free from harmful substances.

Some risks of unregulated sports supplements include:

- Contamination – Some may contain banned substances or undeclared ingredients.
- Mislabeling – Ingredients and dosages might not match the label.
- Health Risks – Overuse or mixing with other supplements can cause side effects.

1.6.3.1 Amino Acid Supplements

One of the most popular supplements includes branched-chain amino acids (BCAAs): valine, leucine, and isoleucine. These three essential amino acids make up about one-third of muscle proteins. The primary theory behind BCAA supplementation is that it helps prevent muscle breakdown during intense exercise. BCAAs are converted into two other amino acids, glutamine and alanine, which are released in large amounts during aerobic exercise. Additionally, they can be used directly as fuel by muscles, particularly when muscle glycogen levels are depleted. Research from the University of Guelph, Ontario, suggests that taking 4 g of BCAAs during and after exercise can reduce muscle breakdown. BCAAs may help preserve muscle in athletes following a low-carbohydrate diet. Research also found that BCAA intake before and during prolonged endurance exercise reduced muscle damage. However, similar benefits were observed with carbohydrate drinks, raising questions about whether BCAAs offer any unique advantages.

For muscle recovery, Doses of 6–15 g may help reduce muscle protein breakdown and post-exercise soreness, especially during intense training periods. BCAAs are generally safe, as they are naturally found in dietary protein. However, excessive intake may interfere with the absorption of other amino acids.

1.6.3.2 Antioxidant supplements:

Antioxidant supplements contain various nutrients and plant extracts that help protect the body from free radical damage. Common ingredients include Vitamins (Beta-carotene, Vitamin C, Vitamin E), Minerals (Zinc, Magnesium, Copper, Selenium), Plant-Based Antioxidants: Lycopene (found in tomatoes), Catechins (found in green tea), Anthocyanidins (pigments in purple or red fruits) and Other Compounds: Coenzyme Q10.

During intense exercise, oxygen consumption increases, leading to the production of free radicals. If left unchecked, these free radicals can damage cell membranes, disrupt DNA, destroy enzymes, increase the risk of atherosclerosis and cancer, and contribute to post-exercise muscle soreness. While regular exercise strengthens the body's natural antioxidant defenses, some researchers suggest that antioxidant supplements may offer additional protection.

Vitamin C supplementation (200 mg for 2 weeks) reduced muscle soreness and improved recovery after intense exercise. Vitamin C, Vitamin E, and Selenium supplements reduced muscle damage in women after weight training. Similarly, Antioxidant supplements (Vitamin C, Vitamin E, Beta-carotene) boosted immune cells in runners after a 2-hour run. Antioxidants may support overall health and recovery from exercise but eating a balanced diet rich in natural antioxidants may be just as effective. Aim for at least 5 servings of fruits and vegetables daily, especially deeply colored ones (e.g., berries, spinach, carrots). Include healthy fats from avocados, oily fish, and vegetable oils for Vitamin E.

Side Effects:

- Vitamin C (>2000 mg): May cause diarrhea and bloating.
- Carotenoids: High doses can temporarily turn skin orange (harmless).
- Zinc, Magnesium, Selenium, and Copper, in high doses, can be toxic, so stay within safe limits.

1.6.3.3 Caffeine:

Caffeine is a stimulant that affects the central nervous system and is classified as a drug rather than a nutrient. It is found naturally in coffee, tea, cola, chocolate, and herbs such as guarana. Caffeine has several effects on the body that may contribute to improved sports performance. It stimulates the central nervous system, enhancing concentration and mental clarity. It triggers the release of adrenaline, a hormone that helps boost physical and mental performance. When consumed in doses above 5 milligrams per kilogram of body weight, caffeine promotes the release of fatty acids from fat stores, allowing the body to use them as energy instead of glycogen. This effect helps conserve glycogen, which is beneficial for endurance activities. Caffeine increases calcium release from storage sites in muscle cells, improving the strength and efficiency of muscle contractions. This can be useful for both aerobic and anaerobic activities.

1.6.3.3.1 Side Effects of Caffeine

Although caffeine is widely used for its potential performance benefits, it also has certain side effects; some individuals may experience anxiety, trembling, or difficulty sleeping after consuming caffeine. Sensitivity to caffeine varies from person to person, and those who are more susceptible to its effects should consider avoiding it. Concerns about coffee raising cholesterol levels have been attributed to certain oils present in boiled coffee rather than caffeine itself. Filtered and instant coffee contains lower levels of these oils and does not appear to have the same impact on cholesterol.

1.6.3.3.2 Creatine

Creatine is a protein naturally produced in the body using three amino acids: arginine, glycine, and methionine. It is found in foods such as meat and fish and is also available as a dietary supplement. Many supplements, especially meal replacement drinks and performance-enhancing "stacks," contain creatine. Creatine combines with phosphorus in muscle cells to form phosphocreatine (PC), an energy-rich compound that fuels muscles during high-intensity activities like sprinting and weightlifting. Supplementing with creatine raises PC levels by around 2%, enabling longer sustained effort and faster recovery between sets.

It boosts short-duration, high-intensity performance and helps draw water into muscle cells, promoting muscle hypertrophy. It reduces muscle acidity by neutralizing hydrogen ions, delaying fatigue, and helping retain muscle mass after intense exercise, improving strength over time.

1.6.3.3.3 Recommended Dosage of Creatine

There are different ways to take creatine for optimal results:

Loading Phase (Traditional Method)

- 20–25 g per day (4 doses of 5–7 g each) for 5 days
- Increases muscle creatine rapidly, but may lead to water retention

Low-Dose, Gradual Loading

- 3–5 g per day for 30 days
- Achieves similar muscle saturation with less water retention

Efficient Absorption Method

- 6 doses of 0.5–1 g per day, sprinkled over food
- Slows absorption, reducing waste, and maximizing muscle uptake

1.6.3.3.4 Side effects:

The primary side effect of creatine is weight gain, mainly due to water retention and muscle mass increase. The long-term effects of high-dose creatine use remain unknown, so athletes should use it with caution and monitor their response.

1.6.3.4 Fat Burners (Ephedrine-Free)

Ephedrine-free fat burners are supplements that claim to boost metabolism, enhance fat loss, and mimic the effects of ephedrine without harmful side effects. The main ingredients in these supplements include:

Citrus Aurantium (Synephrine)

Synephrine is a mild stimulant, chemically similar to caffeine and ephedrine. It is believed to suppress appetite, increase metabolic rate, and promote fat burning. However, scientific evidence supporting these claims is weak, and their effectiveness remains uncertain.

Green Tea Extract

Green tea contains polyphenols called catechins, primarily epigallocatechin gallate (EGCG), which have strong antioxidant properties. Some studies suggest that green tea can enhance thermogenesis (calorie burning) and aid in fat loss when consumed in sufficient amounts.

Coleus Forskohlii

This herb contains forskolin, which is believed to activate enzymes involved in fat breakdown. The theory is that it increases cyclic adenosine monophosphate (cAMP) levels, stimulating fat metabolism. However, no strong clinical studies have proven its effectiveness for weight loss.

1.6.3.5 Protein Supplements

These supplements typically contain whey protein, casein, soy protein, or a combination of these sources. They provide a concentrated source of protein to support muscle repair and overall protein intake.

- Whey Protein – Derived from milk, rich in essential amino acids, and quickly absorbed by the body. It supports muscle recovery and may boost immune function.
- Casein Protein – Also from milk, but digests slowly, providing a sustained release of amino acids. It may help prevent muscle breakdown during long periods without food.
- Soy Protein – A plant-based option suitable for vegans. It can also help lower cholesterol when consumed as part of a diet low in saturated fat (25 g per day is recommended for cholesterol management).

There is no debate that resistance training increases protein needs. Some studies suggest that whey protein supplementation (1.2 g/kg body weight per day) can improve muscle gains during resistance training. Most people can get enough protein from whole foods such as meat, chicken, fish, dairy, eggs, beans, and lentils. Vegetarians can meet their protein needs by consuming a variety of plant-based proteins like tofu and nuts. The recommended protein intake is:

- 1.2–1.4 g per kg of body weight per day for endurance athletes.
- 1.4–1.8 g per kg of body weight per day for strength athletes.

1.6.3.5.1 Side Effects:

Consuming excess protein, whether from food or supplements, does not provide additional health or performance benefits. While excessive protein is not harmful, it is unnecessary if your dietary intake is already sufficient. Despite the widespread availability of sports supplements, there is no specific national or EU legislation governing their effectiveness, purity, and safety.

Self-Assessment questions:

Fill in the blanks:

1. The U.S. Department of Health and Human Services identifies _____ and _____ as two main contributors to chronic diseases.
2. The _____ principle involves increasing exercise intensity, duration, or frequency to challenge the body and improve fitness.
3. The _____ principle states that the body adapts specifically to the type of exercise performed.
4. The three branched-chain amino acids are _____, _____, and _____.
5. The recommended protein intake for strength athletes is _____ to _____ grams per kilogram of body weight per day.
6. Consuming more than 2000 mg of Vitamin C may cause _____ and _____.
- 7.

Short-Answer Questions

1. What is the role of nutrition in preventing chronic diseases?
2. What is the significance of the principle of recuperation?
3. What is the primary purpose of dietary supplements for athletes?
4. What are the potential benefits of caffeine consumption for endurance athletes?
5. What are some potential side effects of consuming high doses of antioxidant supplements?

Activity-Based Questions:

- Plan a balanced one-day meal for a teenage athlete, ensuring it includes appropriate amounts of carbohydrates, protein, and fat. Prefer to use local/Pakistani foods.
- Collect 2 supplement labels (e.g., whey protein, pre-workout). Compare its Ingredients, Claims, and Safety notices.

Recommended Books:

Antonio, J., Kalman, D., Stout, J. R., Greenwood, M., Willoughby, D. S., & Haff, G. G. (2008). *Essentials of sports nutrition and supplements*. Humana Press.

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Fink, H. H., Mikesky, A. E., & Burgoon, L. A. (2011). *Practical applications in sports nutrition* (3rd ed.). Jones & Bartlett Learning.

Lanham-New, S. A., Stear, S. J., Shirreffs, S. M., & Collins, A. L. (2011). *Sports and exercise nutrition*. Wiley-Blackwell.

Maughan, R. J. (Ed.). (2000). *Nutrition in sport: The encyclopedia of sports medicine*. Wiley-Blackwell.

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Williams, M. H., Anderson, D., & Rawson, E. (2012). *Nutrition for health, fitness, & sport* (10th ed.). McGraw-Hill Education.

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Unit -2

HEALTHFUL NUTRITION FOR FITNESS AND SPORTS

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INTRODUCTION

In past years, nutrition research focused on the determination of how specific nutrients in our diet, such as saturated fat, affect our health, primarily as related to the development of chronic diseases. Although such research continues to be important, in recent years, an increased focus has involved the health effects of the overall diet and whole foods within such diets, and such diets have been promoted by governmental health agencies and professional health organizations. As science evolved, human food consumption patterns gradually changed. For example, food scientists identified specific nutrients, foods rich in such nutrients, and the amounts of each necessary to life. Food hazards, such as bacteria, were also uncovered and methods to combat them were developed. Foods could be packaged, refrigerated, and shipped thousands of miles. Overall, modern developments in the food industry have improved food quality and safety. For example, the provision of a wide variety of foods has helped to eradicate most nutrient-deficiency diseases in industrialized nations. However, some current practices in the food industry are a cause for concern. For example, increased availability of a wide variety of high-fat, high-sugar, high-calorie, low-fiber foods appears to have increased the possibility of the development of various chronic diseases. The three keys to a healthful diet are balance, variety, and moderation. In general, a healthful diet is simply one that provides a balanced proportion of foods from different food groups, a variety of foods from within the different food groups, and moderation in the consumption of any food. Such a diet should provide us with the nutrients we need to sustain life and, as noted later, food scientists have determined the amounts of each we need.

LEARNING OBJECTIVES

After studying this unit, the students will be able to:

1. List the six major classes of nutrients that are essential for human nutrition and identify specific nutrients within each class.
2. Explain the development of the DRI and explain the meaning of its various components, including the RDA, AI, AMDR, UL, EAR, and EER.
3. Discuss the concept of the balanced diet as applied to the My Plate food guide.
4. Describe the various classes of vegetarians, what foods they may consume in their diets, and the potential health benefits.

2.1 ENERGY STORAGE IN THE HUMAN BODY

The immediate source of energy in the body is **adenosine triphosphate (ATP)**. ATP is a high-energy molecule that, when broken down by enzymes, rapidly releases energy for critical functions like muscle contraction. Although ATP is essential, it is stored in only small amounts within tissues, making it necessary for the body to constantly replenish it. Muscle contraction, for example, depends entirely on a continuous supply of ATP, and the body has developed sophisticated systems to regenerate it quickly.

In addition to ATP, another high-energy compound called phosphocreatine (PCr) exists in small quantities in tissues. ATP can be produced from the metabolism of carbohydrates, fats, or proteins. Each nutrient undergoes complex biochemical transformations to eventually form ATP. Notably, carbohydrates can also provide quick energy through anaerobic pathways, allowing energy production without oxygen for short periods. Because ATP and PCr reserves are limited and can be depleted in seconds during intense activity, the body relies on stored energy from carbohydrates, fats, and proteins to maintain a steady supply. Carbohydrate stores are found in blood glucose, liver glycogen, and muscle glycogen. However, the body's largest energy reserve is fat, stored predominantly as triglycerides in both muscle and adipose tissues. A small supply of free fatty acids circulates in the blood.

2.2 HUMAN ENERGY METABOLISM

2.2.1 What is Metabolism?

Metabolism is the sum of all physical and chemical changes that occur within the body. It includes processes such as converting food into energy, creating new compounds like hormones and enzymes, growing muscle and bone tissue, and breaking down body tissues.

Metabolism consists of two main processes:

- **Anabolism** is the building-up process, where the body synthesizes complex compounds from basic nutrients. For example, after strength training, muscle mass increases through anabolic processes. Anabolism requires energy.
- **Catabolism** is the breaking-down process, where complex body compounds are broken down into simpler ones. The breakdown of muscle glycogen into glucose, and eventually into carbon dioxide, water, and energy, is an example. The energy released during catabolism often supports anabolic activities.

The metabolic rate measures how quickly the body uses its energy, varying based on many factors. Total daily energy expenditure (TEE) is mainly composed of:

- Energy used for basal metabolism
- Energy used to process food intake
- Energy used for physical activity

Basal metabolism forms the largest part of TEE, while physical activity is the most variable. This section focuses on basal metabolism and the thermic effect of food (TEF); the effect of exercise is discussed later.

2.2.2 The Thermic Effect of Food (TEF)

TEF refers to the energy required to digest, absorb, and process the nutrients in food. Different nutrients have different effects:

- Protein: 20–30% of its energy is used during digestion.
- Carbohydrates: 5–10%.
- Fat: Minimal, about 0–5%.

High-protein meals significantly increase TEF compared to high-carbohydrate or high-fat meals. Although the extra calorie burn is relatively small (around 6 kcal per hour), over time it can have a meaningful effect on energy balance. Typically, TEF accounts for about 5–10% of your daily energy expenditure. For instance, a 500-kcal meal may expend about 50 kcal just in digestion. The role of TEF in obesity remains debated—overfeeding may raise TEF, while underfeeding reduces it. Some researchers suggest that fluctuating eating patterns could contribute to long-term weight gain.

Estimating Resting Energy Expenditure (REE)

The resting energy expenditure (REE) is the amount of energy your body uses at rest. Accurate measurement requires clinical testing (like a BMR test), but estimations can be useful.

REE represents the number of calories your body burns at rest. A simple formula is:

- Women: $\text{BMR} = \text{Body weight (kg)} \times 22$
- Men: $\text{BMR} = \text{Body weight (kg)} \times 24$

A normal 10% variation is expected.

- Male: Range of 1,575–1,925 kcal/day.
- Female: Range of 1,174–1,434 kcal/day.

2.2.3 Genetic Factors Affecting REE

Several genetic factors influence REE:

- **Amount of metabolically active tissue:** Organs like the heart, liver, and kidneys are highly active, while muscle is more active than fat.
- **Age:** REE is very high in infants and declines with age.
- **Sex:** Women generally have a 10–15% lower REE than men due to a higher body fat percentage.
- **Body size and composition:** Lean individuals with more muscle mass have higher REEs.

- **Surface area:** Leaner individuals lose more heat through radiation, leading to higher energy expenditure.

Research has identified around 2,400 genes related to REE, highlighting the strong genetic influence on metabolic rate.

2.2.4 Calculate Your Daily Calorie Needs

Multiply your REE by your PAL to estimate your total daily energy expenditure:

Daily Calorie Needs = BMR × PAL

Example:

A woman weighing 70 kg with a moderately active lifestyle (PAL = 1.4):

- BMR = $70 \times 22 = 1,540$ kcal
- Total calorie needs = $1,540 \times 1.4 = 2,156$ kcal/day

Activity Level	Description	PAL Value
Sedentary	Mostly sitting, little movement	1.2
Fairly Active	Walks/exercises 1-2 times a week	1.3
Moderately Active	Exercises 2-3 times per week	1.4
Active	Hard exercise 3+ times per week	1.5
Very Active	Intense daily workouts	1.7

This approach provides a simple yet effective way to manage energy intake for athletic performance and overall health.

2.3 ESSENTIAL NUTRIENTS AND RECOMMENDED NUTRIENT INTAKES

Proper nutrition plays a fundamental role in athletic performance, ensuring optimal energy levels, muscle recovery, endurance, and overall health. The following guide summarizes key nutritional components based on scientific consensus from the International Olympic Committee (IOC) and the International Association of Athletic Federations (IAAF).

2.3.1 Carbohydrates – The Primary Fuel Source

Carbohydrates serve as the main energy source for physical activity. They are stored in the body as glycogen in the liver and muscles:

- Liver glycogen (100g ≈ 400 kcal) helps regulate blood sugar levels.
- Muscle glycogen (up to 400g ≈ 1600 kcal) provides fuel for movement and exercise.

The amount of carbohydrates an individual needs depends on their training intensity and duration:

Training Type	Carbohydrate Intake (g/kg BW/day)
Low-intensity/moderate-duration training	5–7 g/kg BW
Moderate to heavy endurance training	7–10 g/kg BW
Intensive training (4+ hours/day)	10+ g/kg BW

2.3.1.1 Carbohydrates for Recovery

After exercise, replenishing glycogen stores is essential. The IOC recommends consuming 1 g per kg BW per hour during the first four hours post-exercise to optimize muscle recovery.

- If another workout is scheduled within 8 hours, refueling immediately with moderate/high GI carbs (e.g., fruit, sports drinks, rice, potatoes) is crucial.
- If recovery time exceeds 24 hours, the timing of carbohydrate intake is less critical, but nutrient-dense sources should be prioritized.

For workouts lasting over 60 minutes, consuming 20–60 g of carbohydrates per hour can maintain blood glucose levels, delay fatigue, and improve endurance.

2.3.2 Protein – Essential for Muscle Repair and Growth

Proteins provide the amino acids necessary for tissue repair, muscle building, and Enzyme and hormone production. Although protein contributes minimally to energy production, athletes have higher protein needs than sedentary individuals due to increased muscle breakdown during training.

Recommended Protein Intake

Group	Protein Requirement (g/kg BW/day)
Sedentary individuals	0.75 g/kg BW
Athletes	1.2–1.7 g/kg BW

Consuming extra protein does not directly increase muscle mass. Excess protein is converted to urea and energy or stored as fat if calorie intake exceeds expenditure. Studies suggest that consuming protein with carbohydrates post-exercise enhances muscle recovery and growth.

2.3.3 Dietary Fat – An Important Energy Source

Fat plays a crucial role in Cell membrane integrity, Brain and nerve function, Hormone production, and Vitamin absorption (A, D, E, K). The American College of Sports Medicine (ACSM) and the American Dietetic Association (ADA) recommend that 20–25% of an athlete's total calorie intake should come from fat.

Fat Type	Sources	Recommendation
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Unsaturated Fats (Healthy)	Fish, nuts, seeds, olive oil, avocados	Preferred source
Saturated Fats (Limit)	Butter, red meat, full-fat dairy	Less than 10% of total calories
Trans Fats (Avoid)	Processed foods, fast food, and margarine	Minimize completely

Omega-3 fatty acids (found in fish, flaxseeds, and walnuts) may improve oxygen delivery to muscles, reduce inflammation & joint stiffness and Aid recovery & endurance.

2.3.4 Hydration – Optimizing Performance

Dehydration can lead to reduce fatigue & risk of heat-related illnesses. Hydration Guidelines include:

- Fluid loss should not exceed 2% of body weight (e.g., a 75 kg athlete should lose no more than 1.5 kg).
- Overhydration can dilute sodium levels, which can be dangerous in long-duration events (4+ hours).
- Water is sufficient for light workouts and Sports drinks are better for intense exercise lasting over 60 minutes, as they provide electrolytes (sodium, potassium) to maintain fluid balance.

2.3.5 Vitamins & Minerals – Supporting Health & Performance

Athletes require higher levels of certain vitamins and minerals, but a well-balanced diet typically meets these needs. Iron & calcium deficiencies are more common in female athletes and may affect performance. There is limited evidence supporting vitamin/mineral supplementation for athletic performance. The IOC warns against excessive supplement use, as some may be contaminated with banned substances.

2.4 HEALTHFUL DIETARY GUIDELINES

Your diet before a competition will greatly impact your performance and could provide you with that winning edge. In addition, what you eat and drink on the day of the event can affect your ability to recover between heats and your performance in subsequent heats. Understanding the adequacy of dietary intake necessitates an appreciation of individual nutritional requirements. These requirements vary significantly, especially among individuals engaged in regular sports or exercise, whose needs for energy and nutrients are typically elevated.

2.4.1 Qualitative Dietary Guidelines

Qualitative dietary guidelines serve as public health tools that categorize foods into distinct groups and recommend appropriate proportions for a balanced diet. These guidelines vary across countries to reflect cultural dietary patterns and are usually presented visually for ease of understanding.

- In the UK, the Food Standards Agency presents healthy eating advice through the My Plate model. This model divides the diet into five main food groups shown as segments of a plate. Previously known as the 'Balance of Good Health,' this model aligns with traditional eating habits (e.g., "meat and two veg").

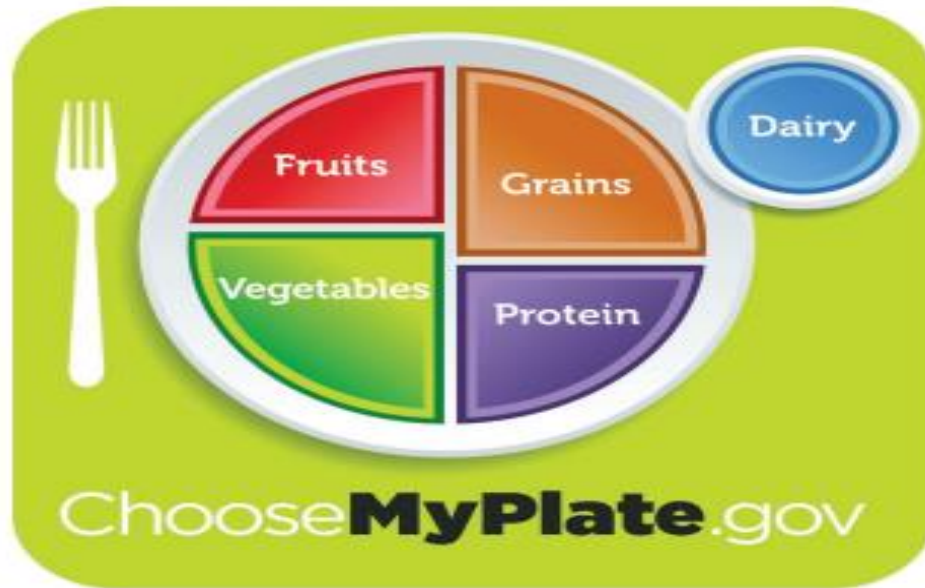


Figure 3: The food guide for the 2015 Dietary Guidelines for Americans is My Plate. The guide consists of five food groups, plus oils and empty Calories, and offers tips on how to balance Calories, which foods to increase in the diet, and which foods to reduce. Physical activity is an important part of the My Plate program.

MyPlate food group	Serving size
Dairy	1 cup milk or yogurt 1 1/2 ounces natural cheese 2 ounces processed cheese
Protein	1 ounce cooked lean meat, poultry, or fish 1/4 cup cooked dry beans 1 egg 1 tablespoon peanut butter
Grains	1 slice of bread 1 ounce ready-to-eat cereal 1/2 cup cooked cereal, rice, or pasta
Vegetable 	1 cup raw, leafy vegetables 1/2 cup other vegetables, cooked or chopped raw 1 cup vegetable juice
Fruit 	1 medium apple, banana, or orange 1 cup chopped, cooked, or canned fruit 1 cup fruit juice 1/2 cup dried fruit
Oils and empty Calories (not an official food group)	1 teaspoon

Figure 4: Serving sizes for the My Plate food guide

- The United States Department of Agriculture (USDA) promotes the 'My Pyramid' system, a modernized version of the traditional food pyramid. It comprises six food groups and is designed to reflect American dietary customs.

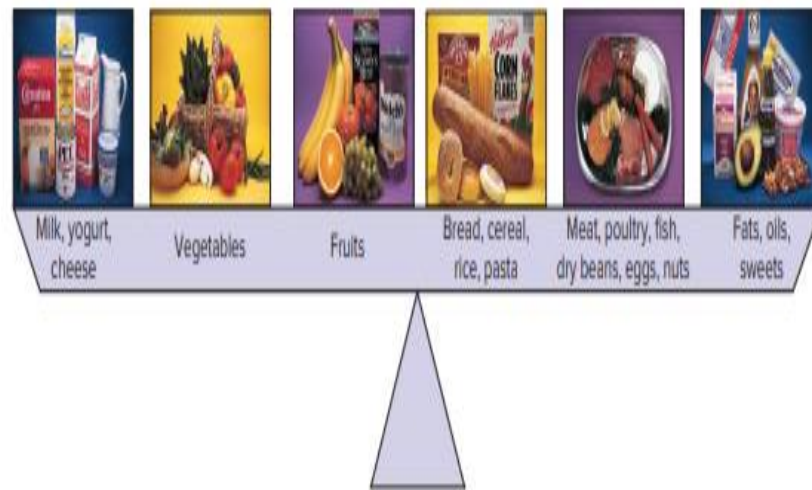


Figure 5: The key to sound nutrition is a balanced diet that is high in nutrients and adequate in Calories. For balance, select a wide variety of foods from among and within the food groups in the My Plate food guide or the Exchange Lists.

- Additionally, the Food and Agriculture Organization (FAO) and World Health Organization (WHO) have developed regional food-based dietary guidelines tailored to cultural and regional differences. These include specific recommendations for Latin America, the Western Pacific, and various Asian countries like Pakistan.

Following culturally appropriate dietary guidelines post dietary assessment helps individuals identify any food group deficiencies or excesses. When total energy intake is adequate, adherence to these guidelines can ensure sufficient intake of macronutrients and micronutrients.

2.4.2 Quantitative Reference Intakes

Quantitative reference intakes offer numerical values for daily nutrient intake for a healthy population and serve as benchmarks for assessing an individual's nutritional adequacy. A nutrient requirement is defined as the lowest ongoing intake level that maintains health in a specific population group. These requirements vary by life stage, such as pregnancy, lactation, adolescence, and older adulthood. The UK used Recommended Daily Amounts (RDAs) and the US used Recommended Daily Allowances—both abbreviated as RDA, despite differences in definitions and values. Since 1991, the UK has transitioned to Dietary Reference Values (DRVs),

while the US adopted Dietary Reference Intakes (DRIs), expanding upon RDAs and incorporating Canadian standards.

In both systems, reference values are based on intake distributions among healthy individuals. Key terms include:

- **Estimated Average Requirement (EAR):** Mean intake value meeting the needs of 50% of a healthy population.
- **Reference Nutrient Intake (RNI) / Recommended Dietary Allowance (RDA):** Intake levels two standard deviations above the EAR, covering 97-98% of the population.
- **Adequate Intake (AI):** Used when an RDA cannot be determined, based on observed intakes in healthy populations.
- **Tolerable Upper Intake Level (UL):** The maximum daily intake unlikely to cause adverse health effects.

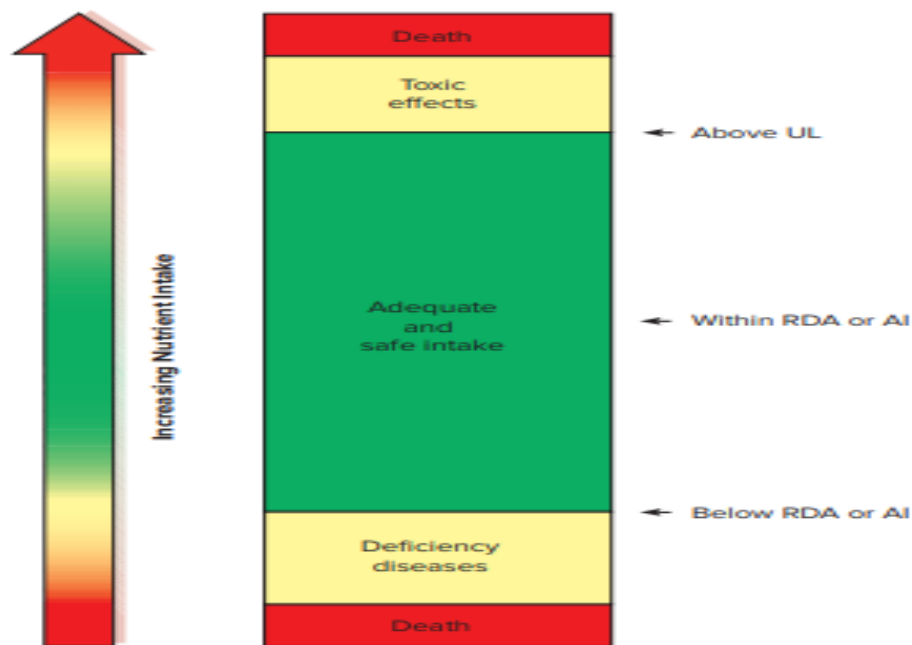


Figure 6: One model of the possible relationship between nutrient intake and health status. An inadequate intake may lead to nutrient-deficiency diseases, while excessive amounts may cause various toxic reactions. Both deficiencies and excesses may be fatal if carried to extremes. Nutrient intakes within the Recommended Dietary Allowance (RDA) or Adequate Intake (AI) levels are normally adequate and safe, while those below these levels may lead to deficiency diseases. Nutrient intakes above the Tolerable Upper Intake Level (UL) may lead to toxic reactions.

More recently, the UK's Scientific Advisory Committee on Nutrition suggested increasing the EAR for energy, recommending:

- **Women (19+ years):** 2104–2176 kcal/day
- **Men (19+ years):** 2630–2726 kcal/day

These values are based on a median physical activity level of 1.63.

Athletes or individuals with above-average physical activity levels will typically require higher energy and nutrient intakes. Accurate use of reference intakes depends on robust, quantitative dietary assessments, which can be challenging due to methodological limitations and reporting inaccuracies.

2.5 Vegetarianism

A vegetarian diet does not include fish, shellfish, game, meat, poultry, or animal fats or gelatin, which are byproducts of slaughter. As an alternative, it contains grains, legumes, nuts, seeds, fruits, vegetables, and the choice to include dairy and eggs.

Different kinds of vegetarian diets exist, including:

- Lacto-ovo-vegetarian: The most popular vegetarian diet includes dairy and eggs.
- Eggs are not included in the lacto-vegetarian diet, but dairy products are.
- Vegans abstain from all animal products, such as dairy and eggs.

2.5.1 The Health Advantages of a Plant-Based Diet

The British Dietetic Association (BDA, 2005) states that all vital nutritional requirements at every stage of life can be satisfied by a well-balanced vegetarian diet. A diverse vegetarian diet supports general health by adhering to dietary guidelines for a low-fat, high-fiber intake. According to a study, vegetarians are less likely to acquire heart disease, cancer, type 2 diabetes, obesity, and high blood pressure because their diets tend to be lower in saturated fats and higher in fiber, vitamins, and antioxidants. A balanced vegetarian diet can help people stay healthy and lower their chances of developing chronic illnesses.

2.5.2 Sports Performance and the Vegetarian Diet

For moral reasons, many athletes decide to consume less red meat or adopt a vegetarian diet. According to extensive dietary surveys, vegetarians tend to consume lower amounts of saturated fat and cholesterol and more fruits, vegetables, fiber, antioxidants, and phytonutrients than meat eaters. According to the National Diet and Nutrition Survey, 2001, one in three people in the UK infrequently eat meat, and one in twenty people are vegetarians (National Diet and Nutrition Survey, 2001).

2.5.3 Is a Vegetarian Diet Adequate for Athletes?

A prevalent misunderstanding is that meat is necessary for gaining muscle mass, strength, and endurance, and that a plant-based diet cannot give athletes the nourishment they need. Nevertheless, there is no scientific proof to back up these

assertions. According to the American Dietetic Association (ADA) and Dietitians of Canada (1997), competitive athletes can achieve their nutritional goals with a well-planned vegetarian diet. In a joint statement released in 2000, the American College of Sports Medicine and the American Dietetic Association confirmed this stance, concluding that animal products are not required to achieve peak sports performance. Vegetarian diets with the right combination can help athletes of all skill levels by promoting muscle growth, endurance, and general physical fitness.



Figure 7: It is important for the vegetarian to eat protein foods that complement each other (e.g., nuts and bread, rice and beans) so that all the essential amino acids are obtained in the diet

2.6 CONSUMER NUTRITION-FOOD QUALITY AND SAFETY

As science advanced, human food consumption patterns evolved significantly, particularly in the areas of food quality and safety. Food scientists identified essential nutrients and the foods rich in them, while also uncovering food hazards like harmful bacteria. In response, they developed methods such as pasteurization, refrigeration, and improved packaging to enhance food safety and extend shelf life. These innovations allowed foods to be safely transported over long distances without spoilage.

Modern developments in the food industry have greatly improved the overall quality and safety of food, helping to eliminate many foodborne illnesses and nutrient-deficiency diseases, especially in industrialized countries. However, despite these advancements, the increased availability of highly processed foods high in solid fats, added sugars, and low in fiber has introduced new health challenges, such as obesity and chronic disease. Today, maintaining food quality and safety remains critical, and a healthful diet should emphasize safe handling,

proper storage, balanced nutrition, and moderation to support overall health and prevent food-related illnesses.

Self-Assessment questions:

Mark the statement true or false

1. Carbohydrates are the primary fuel source for physical activity and are stored in the body as glycogen in the liver and muscles.(true/false)
2. Consuming protein with carbohydrates post-exercise enhances muscle recovery and growth.(true/false)
3. Fat intake should constitute more than 35% of an athlete's total calorie intake.(true/false)
4. Overhydration can dilute sodium levels, posing dangers during long-duration events.(true/false)
5. The Estimated Average Requirement (EAR) meets the needs of 97-98% of the population.(true/false)

Short-Answer Questions

1. Name two sources of unsaturated fats recommended for athletes.
2. Why is it important to avoid excessive supplement use in athletes?
3. What is the purpose of qualitative dietary guidelines?
4. What does the term 'Tolerable Upper Intake Level (UL)' refer to?

Activity-Based Questions:

- Create a balanced one-day meal plan for an endurance athlete and a strength athlete.
Including Carbs, Protein, Healthy fats, and Hydration strategy
- Compare the two and discuss why their needs differ.
- Convert a traditional athlete's diet plan into a vegetarian meal plan. Replace meat-based items with vegetarian sources while maintaining protein and energy levels.

Recommended Books:

Antonio, J., Kalman, D., Stout, J. R., Greenwood, M., Willoughby, D. S., & Haff, G. G. (2008). *Essentials of sports nutrition and supplements*. Humana Press.

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Unit -3

CARBOHYDRATES: THE MAIN ENERGY FOOD

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INTRODUCTION

One of the most important nutrients in your diet, from the standpoint of both health and athletic performance, is dietary carbohydrate. The major role of carbohydrates in human nutrition is to provide energy, and scientists have long known that carbohydrates are one of the prime sources of energy during exercise. Of all the nutrients we consume, carbohydrates have received the most research attention in regard to a potential influence upon athletic performance, particularly in exercise tasks characterized by endurance, such as long-distance running and cycling. Such research is important to athletes who are concerned about optimal carbohydrate nutrition during training and competition. In this Unit we explore the nature of dietary carbohydrates, their metabolic fates and interactions in the human body, their possible influence upon health status, and their potential application to physical performance, including the following: the adverse effects of low-carbohydrate diets; the value of carbohydrate intake before, during, and after exercise; the efficacy of different types of carbohydrates; the role of carbohydrate loading; and carbohydrate foods or compounds with alleged ergogenic properties.

LEARNING OBJECTIVES

After studying this unit, the students will be able to:

1. List the different types of dietary carbohydrates and identify foods typically rich in the different types.
2. Explain the role of carbohydrate in human energy systems during exercise.
3. Understanding the mechanisms of various dietary strategies involving carbohydrate intake (amount, type, and timing) before, during, and after exercise may help to optimize training for and competition in sport.
4. Identify athletes for whom carbohydrate loading may be appropriate and describe the full carbohydrate loading protocol, highlighting dietary intake and exercise training considerations.
5. Evaluate the efficacy of metabolic by-products of carbohydrate metabolism as ergogenic aids.

3.1 HUMAN ENERGY

When exercising, your body needs to produce energy at a much faster rate compared to when it is at rest. This increase in energy demand is driven by more intense muscle contractions, faster heart rate to deliver oxygen and nutrients to working muscles, and increased lung activity to supply oxygen for energy production. To sustain physical activity, your body must efficiently generate and utilize energy. Understanding where this energy comes from and how to optimize its production can enhance your endurance and performance.

3.1.1 What is Energy?

Although energy itself is invisible, its effects are noticeable through heat production and physical work. Energy in the human body is primarily derived from the breakdown of a molecule called adenosine triphosphate (ATP), which serves as the body's "energy currency."

ATP is a small molecule composed of:

- An adenosine backbone
- Three phosphate groups

Energy is released when one of the phosphate groups is removed, converting ATP into adenosine diphosphate (ADP). This energy fuels essential functions such as muscle contractions. However, only about 25% of the released energy is used for work, while the rest is lost as heat, explaining why body temperature rises during exercise.

3.1.1.1 ATP and Energy Supply during Exercise

The body has only a small reserve of ATP, just enough to maintain essential functions at rest. During exercise, ATP is rapidly depleted within seconds, necessitating the breakdown of additional fuel sources to regenerate ATP and sustain activity.

3.1.1.2 Sources of Energy for Exercise

The body derives energy from four key macronutrients. Carbohydrates and alcohol serve as immediate energy sources, Fats act as a long-term energy reserve, and Proteins are generally preserved for muscle repair and other bodily functions, only contributing to energy production when carbohydrate stores are depleted. After consumption, these nutrients are broken down:

- Carbohydrates → Glucose, Fructose, Galactose
- Fats → Fatty Acids
- Proteins → Amino Acids
- Alcohol → directly absorbed into the bloodstream

3.1.1.3 Energy Efficiency during Exercise

Despite energy being generated from food, the body's energy conversion process is not highly efficient. For example, during cycling, only about 20% of the produced energy is converted into actual power, with the remaining 80% dissipated as heat.

Energy is quantified in Calories (kcal) and Joules (J).

1 kcal = 4.2 kJ

The energy yield of food depends on its macronutrient composition:

Nutrient	Energy per Gram
Carbohydrate	4 kcal (17 kJ)
Protein	4 kcal (17 kJ)
Fat	9 kcal (38 kJ)
Alcohol	7 kcal (29 kJ)

Fat is the most concentrated energy source, providing over twice as much energy per gram as carbohydrates or proteins. However, for exercise, carbohydrates are generally considered the most efficient fuel source because they are readily accessible and metabolized more rapidly than fats.

3.1.1.4 Fuels that are Most Important for Exercise

Carbohydrates, fats, and proteins all serve as energy sources for exercise, as they can be transported to and broken down within muscle cells. However, alcohol does not contribute to energy production during physical activity. Unlike other macronutrients, alcohol can only be metabolized in the liver, which processes it at a fixed rate. Proteins play a minimal role in energy production under normal circumstances. They become a more significant fuel source only during prolonged or extremely intense exercise, when the body's carbohydrate and fat stores are insufficient. For most types of physical activity, the primary source of ATP (the body's energy currency) is the breakdown of carbohydrates and fats. These two macronutrients provide the bulk of energy needed to sustain movement and performance.

3.1.2 What is fatigue?

Fatigue is an inability to sustain a given power output or speed. It is a mismatch between the demand for energy by the exercising muscles and the supply of energy in the form of ATP.

3.1.2.1 Why does fatigue develop during exercise?

During explosive activities involving maximal power output, fatigue develops due to ATP depletion. During activities lasting between 30 seconds and 30 minutes, fatigue is caused by a different mechanism. During high-intensity exercise lasting up to half an hour, there is a gradual increase in muscle acidity, which reduces the ability of the muscles to maintain intense contractions. It is not possible to continue high-intensity exercise indefinitely because the acute acid environment in your muscles would inhibit further contractions and cause cell death.

Fatigue during moderate and high-intensity aerobic exercise lasting longer than 1 hour occurs when muscle glycogen stores are depleted. Muscle glycogen is in short supply compared with the body's fat stores. During low to moderate-intensity exercise lasting more than three hours, fatigue is caused by additional factors. Once glycogen stores have been exhausted, the body switches to the aerobic lipolytic system, where fat can supply most (not all) of the fuel for low-intensity exercise. However, despite having relatively large fat reserves, you will not be able to continue exercising as fat cannot be converted to energy fast enough to keep up with the demand by exercising muscles. These include a rise in the concentration of the brain chemical serotonin, which results in an overall feeling of tiredness, acute muscle damage, and fatigue due to lack of sleep.

3.2 DIETARY CARBOHYDRATES

Carbohydrates serve as the primary fuel source for almost every type of physical activity. The amount of glycogen stored in your muscles and liver directly impacts your ability to perform. When muscle glycogen levels are high, you can train at your optimal intensity and maximize performance. However, low glycogen levels can lead to early fatigue, reduced training intensity, and suboptimal results.

3.2.1 Simple vs. Complex Carbohydrates

Carbohydrates are traditionally categorized based on their chemical structure, but this classification can sometimes be misleading. The most basic division is into simple carbohydrates (sugars) and complex carbohydrates (starches and fibers), which differ based on the number of sugar units in their molecular structure.

Simple Carbohydrates (Sugars)

These are small molecules containing one or two sugar units, making them easily digestible. They include:

- **Monosaccharides (1-sugar unit):**

Glucose (dextrose) – the body's primary energy source.

Fructose (fruit sugar) – found in fruits and honey.

Galactose – found in dairy products.

- **Disaccharides (2-sugar units):**

Sucrose (table sugar) – made of glucose + fructose.

Lactose (milk sugar) – made of glucose + galactose.

- **Complex Carbohydrates (Starches & Fiber)**

These are larger molecules made up of 10 to thousands of sugar units, mostly glucose. They include:

- Starches (Amylose & Amylopectin) are found in grains, potatoes, rice, and legumes.
- Non-Starch Polysaccharides (Dietary Fiber): Cellulose, Pectin, and Hemicellulose are found in fruits, vegetables, and whole grains, aiding digestion and satiety.

Intermediate Carbohydrates include Glucose Polymers & Maltodextrin. These contain 3 to 10 sugar units and are derived from corn starch. They are commonly used in processed foods (e.g., sauces, puddings, baby food) and Sports drinks & meal replacements due to their low sweetness and high energy density.

3.2.2 Glycemic Index (GI) and Its Role in Nutrition

The Glycemic Index (GI) is a scientifically developed system that ranks foods based on their impact on blood sugar levels. Originally designed to help diabetics manage blood glucose, it is now widely used in sports nutrition and general health planning. The GI measures how quickly a food raises blood sugar levels compared to a reference food, usually pure glucose (GI = 100).

- **High GI (71–100):** Foods that cause a rapid spike in blood sugar.
- **Medium GI (56–70):** Foods with a moderate effect on blood sugar.
- **Low GI (0–55):** Foods that release glucose slowly into the bloodstream.

Importance of GI in Sports & Nutrition

- **High GI foods:** Best for post-exercise recovery to rapidly replenish glycogen.
- **Low GI foods:** Provide sustained energy for endurance and weight management.

Examples of High vs. Low GI Foods

High GI (71–100)	Medium GI (56–70)	Low GI (0–55)
White rice (87)	Basmati rice (58)	Lentils (32)
Baked potatoes (85)	Whole wheat bread (69)	Chickpeas (28)
White bread (75)	Sweet corn (59)	Oatmeal (49)
Soft drinks (75+)	Pineapple (66)	Apples (36)

Glycemic Load (GL) and Its Importance

While the Glycemic Index (GI) measures how fast a food raises blood sugar, the Glycemic Load (GL) considers both the quality (GI) and the quantity of carbohydrates per serving. The formula for Glycemic Load is:

$$GL = GI \times \text{Carbohydrate per serving (g)} / 100$$

Example: Watermelon

- GI = 72 and Carbohydrates per serving (150g) = 6g

$$GL = (72 \times 6) \div 100 = 4.3GL$$

Even though watermelon has a high GI, its GL is low because it has very little carbohydrate per serving.

GL Categories

GL Value	Impact on Blood Sugar	Examples
Low (0–10)	Minimal rise in blood sugar	Lentils, Apples, Chickpeas
Medium(11–19)	Moderate rise in blood sugar	Whole wheat bread, Brown rice
High (20+)	Large spike in blood sugar	White bread, Potatoes, Soft drinks

3.3 CARBOHYDRATES FOR EXERCISE

Sports nutrition experts consistently recommend a high-carbohydrate, low-fat diet for regular exercisers, as this enhances endurance and performance, particularly for activities lasting over an hour (ACSM/ADA/DC, 2000; American Dietetic Association). Since carbohydrate is the primary fuel for endurance exercise, maintaining adequate muscle and liver glycogen levels is essential.

3.3.1 Carbohydrate Requirements Based on Body Weight

Earlier recommendations suggested that 60–70% of total daily energy should come from carbohydrates. However, this approach is not ideal, as it assumes a fixed calorie intake and does not account for individual differences in energy needs. Experts now recommend calculating carbohydrate intake based on body weight and training volume to provide a more accurate and flexible approach. This method ensures adequate fuel for muscles without relying on calorie intake alone.

3.3.2 Carbohydrate Needs by Training Volume

Training Level	Carbohydrate Intake (g/kg body weight/day)
Light exercise (low intensity, skill-based)	3–5 g/kg BW

Moderate training (1 hour/day)	5–7 g/kg BW
Endurance training (1–2 hours/day)	6–7 g/kg BW
Heavy training (2+ hours/day)	7–10 g/kg BW
Extreme training (ultra-endurance events)	10–12 g/kg BW

Example Calculation for a 70 kg Athlete Training 1–2 Hours per Day

Carbohydrate requirement = 6–7 g/kg BW

- $70 \times 6 = 420$ g/day
- $70 \times 7 = 490$ g/day

Daily carbohydrate intake: 420–490 g

3.4 CARBOHYDRATE STORAGE IN THE BODY

Carbohydrate is stored as glycogen in the muscles and liver, along with about three times its water weight. Altogether, there is about three times more glycogen stored in the muscles than in the liver. Glycogen is a large molecule, similar to starch, comprising many glucose units joined together. The total store of glycogen in the average body amounts to about 500 g, with approximately 400 g in the muscles and 100 g in the liver. This store is equivalent to 1600–2000 kcal, enough to last one day if you were to eat nothing. This is why a low-carbohydrate diet tends to make people lose quite a lot of weight in the first few days. The weight loss is almost entirely due to the loss of glycogen and water. Endurance athletes have higher muscle glycogen concentrations compared with sedentary people. Increasing your muscle mass will also increase your storage capacity for glycogen. The purpose of liver glycogen is to maintain blood glucose levels at rest and during prolonged exercise. Small amounts of glucose are present in the blood (approximately 15 g, which is equivalent to 60 kcal) and in the brain (about 2 g or 8 kcal) and their concentrations are kept within a very narrow range, both at rest and during exercise. This allows normal body functions to continue.

3.5 DAILY CARBOHYDRATE REQUIREMENTS FOR EXERCISE AND PERFORMANCE

Sports nutritionists and exercise physiologists strongly recommend that individuals who exercise regularly consume a diet high in carbohydrates and relatively low in fat. This recommendation is based on extensive research showing that carbohydrate intake significantly enhances endurance and improves performance, particularly for activities lasting longer than one hour. Carbohydrates serve as the body's primary source of fuel, stored in two key locations:

- **Liver Glycogen:** Helps regulate blood sugar levels, ensuring a steady energy supply.
- **Muscle Glycogen:** Provides direct energy for physical activity.

Since carbohydrate stores are limited, failing to replenish them adequately can lead to fatigue and reduced athletic performance. Depleted glycogen stores may result in early exhaustion, preventing athletes from training effectively or performing at their best. Research studies confirm that ensuring high pre-exercise glycogen stores can improve endurance, delay exhaustion, and allow for prolonged and more intense exercise.

3.5.1 Pre-Exercise Nutrition Guide: What, When & How Much to Eat

Your pre-workout meal plays a key role in performance, endurance, and fat burning. Here's a breakdown of what you should eat before exercise based on your fitness goals.

3.5.2 When to Eat Before Exercise?

Ideally, you should eat between 2 and 4 hours before training, leaving enough time for your stomach to settle so that you feel comfortable, not too full, and not too hungry. This helps increase liver and muscle glycogen levels and enhances your subsequent performance. The exact timing of your pre-exercise meal will depend on your daily schedule and the time of day you plan to train. If you leave too long an interval between eating and training, you will be at risk of hypoglycemia, and this will certainly compromise your performance. You will fatigue earlier and, if you feel light-headed, risk injury too.

3.5.3 How much carbohydrate before exercise?

Most studies suggest 2.5 g carbohydrate/kg of body weight about 3 hours before exercise. Researchers at Loughborough University found that this pre-exercise meal improved endurance running capacity by 9% compared with a normal trial. So, for example, if you weigh 70 kg, that translates to 175 g of carbohydrate. You may need to experiment to find the exact quantity of food or drink and the timing that works best for you.

3.5.4 What are the best foods to eat before exercise?

Whether to eat high GI or low GI foods pre-exercise has long been a controversial area. Many experts recommend a low GI meal based on the idea that such a meal would supply sustained energy during exercise. In studies, the researchers took blood samples at regular intervals from cyclists and found that low GI meals produce higher blood sugar and fatty acid levels during the latter stages of exercise,

which is advantageous for endurance sports. In other words, the low GI meals produce a sustained source of carbohydrate throughout exercise and recovery.

3.5.5 During Exercise

For moderate-to-high-intensity exercise lasting over 60 minutes, carbohydrate consumption during exercise can help maintain blood sugar levels and prevent fatigue. Recommended carbohydrate intake during exercise is 30-60 grams per hour.

3.6 CARBOHYDRATE SOURCES

- Liquid forms (sports drinks) are convenient and also provide hydration.
- Solid options like energy bars, gels, bananas, and raisins can be used with water.

It's advised to start consuming carbs within the first 30 minutes of exercise to avoid fatigue, and consuming protein along with carbs may further enhance endurance and recovery. A common ratio for a carbohydrate-protein drink is 4:1 (carbohydrate: protein).

3.7 CARBOHYDRATE DURING EXERCISE

An intake of between 30–60 g carbohydrate/hour is recommended by leading researchers; this matches the maximum amount of carbohydrates that can be taken up by the muscles from your bloodstream during aerobic exercise. Consuming more carbohydrates will not improve your energy output nor reduce fatigue. It is important to begin consuming carbohydrates before fatigue sets in. It is said that it takes at least 30 minutes for the carbohydrate to be absorbed into the bloodstream. The best strategy is to begin consuming carbohydrates soon after the start of your workout, certainly within the first 30 minutes. While consuming carbohydrates during exercise can delay fatigue, perhaps by up to 45 minutes, it will not allow you to keep exercising hard indefinitely.

3.7.1 Which foods or drinks should you consume during exercise?

It makes sense that the carbohydrates you consume during exercise should be easily digested and absorbed. You need it to raise your blood sugar level and reach your exercising muscles rapidly. Thus, high or moderate GI carbohydrates are generally the best choices. Carbohydrate-containing drinks have a dual benefit because they provide fluid and fuel, reducing dehydration and fatigue. Whether you choose liquid or solid carbohydrates, aim to consume at least 1 liter of fluid per hour. Recent studies have suggested that consuming a drink containing protein as well as carbohydrates during exercise improves endurance to a greater extent than carbohydrates alone. It may also minimize protein breakdown following exercise

and improve recovery. Several studies suggest that consuming protein plus carbohydrates during exercise improves recovery from exercise and results in less muscle damage. The exact amount of each ingredient is not clear, but most of the trials used drinks containing a carbohydrate: protein ratio of approximately 4:1 (e.g., 80g carbohydrate: 20g whey protein).

3.8 AFTER EXERCISE

The length of time that it takes to refuel depends on how depleted your glycogen stores are after exercise, the extent of muscle damage, the amount and the timing of carbohydrates you eat, and your training experience and fitness level.

The more depleted your glycogen stores, the longer it will take you to refuel. This, in turn, depends on the intensity and duration of your workout. The higher the intensity, the more glycogen you use. The minimum time it would take to refill muscle glycogen stores is 20 hours. After prolonged and exhaustive exercise (e.g. marathon), it may take up to 7 days. The duration of your workout also has a bearing on the amount of glycogen you use. For example, if you complete 10 sets of shoulder exercises in the gym, you will use more glycogen from your shoulder muscles than if you had completed only 5 sets using the same weight. Therefore, you need to allow more time to refuel after high-intensity or long workouts. Certain activities that involve eccentric exercise (e.g., heavy weight training, plyometric training, or hard running) can cause muscle fiber damage. Muscle damage, in turn, delays glycogen storage, and complete glycogen replenishment could take as long as 7–10 days.

How soon should we eat after exercise?

The best time to start refueling is as soon as possible after exercise, as glycogen storage is faster during this post-exercise ‘window’ than at any other time. Research has shown that glycogen storage following exercise takes place in three distinct stages. During the first 2 hours, replenishment is most rapid, at approximately 150% (or one-and-a-half times) the normal rate. During the subsequent 4 hours, the rate slows but remains higher than normal; after this period, glycogen manufacture returns to the normal rate. Therefore, eating carbohydrates during this time speeds up glycogen recovery.

There are two reasons why glycogen replenishment is faster during the post-exercise period. Firstly, eating carbohydrates stimulates insulin release, which, in turn, increases the amount of glucose taken up by your muscle cells from the bloodstream and stimulates the action of the glycogen-manufacturing enzymes. Secondly, post-exercise, the muscle cell membranes are more permeable to glucose, so they can take up more glucose than normal.

How much carbohydrate?

Most researchers recommend consuming 1 g/kg body weight during the 2-hour post-exercise period. So, if you weigh 70 kg, you need to consume 70 g of carbohydrate within 2 hours of exercise. Even if you finish training late in the evening, you still need to start the refueling process, so do not go to bed on an empty stomach. For efficient glycogen refueling, you should continue to eat at least 50 g of carbohydrate every 2 hours until your next main meal. If you leave long gaps without eating, glycogen storage and recovery will be slower.

3.9 CARBOHYDRATE LOADING

Carbohydrate loading is a technique developed in the 1960s to increase muscle glycogen stores beyond normal levels. Higher glycogen availability can delay fatigue and enhance endurance performance, making it beneficial for activities lasting over 90 minutes, such as long-distance running, cycling, or multi-event competitions like tennis tournaments or swimming galas. However, it is unlikely to provide a significant advantage for events shorter than 90 minutes, where glycogen depletion is not a limiting factor. Research shows that carbohydrate loading can increase endurance by approximately 20% and improve performance by 2–3%.

A recommended method		Original, classic method	
1st day:	tapering exercise	1st day:	depletion exercise
2nd day:	mixed diet, moderate carbohydrate; tapering exercise	2nd day:	high-protein/fat diet; low carbohydrate; tapering exercise
3rd day:	mixed diet, moderate carbohydrate; tapering exercise	3rd day:	high-protein/fat diet; low carbohydrate; tapering exercise
4th day:	mixed diet, moderate carbohydrate; tapering exercise	4th day:	high-protein/fat diet; low carbohydrate; tapering exercise
5th day:	high-carbohydrate diet; tapering exercise	5th day:	high-carbohydrate diet; tapering exercise
6th day:	high-carbohydrate diet; tapering exercise or rest	6th day:	high-carbohydrate diet; tapering exercise or rest
7th day:	high-carbohydrate diet; tapering exercise or rest	7th day:	high-carbohydrate diet; tapering exercise or rest
8th day:	competition	8th day:	competition
High-carbohydrate diet: 400–800 g per day depending on body weight; about 70–80 percent of dietary Calories should be carbohydrate.			

Figure 8: Different methods of carbohydrate loading

Traditional Carbohydrate Loading

The original 6-day regimen involved:

- Days 1–3: Intense training with a low-carbohydrate diet to deplete glycogen stores.
- Days 4–6: Reduced training with a high-carbohydrate diet to supercompensate glycogen levels.
- Day 7: Competition day with maximized glycogen stores.

While effective, this approach had several drawbacks. The low-carb phase often left athletes feeling weak, fatigued, and irritable, and some struggled to achieve optimal glycogen replenishment.

Modern Carbohydrate Loading Strategies

Researchers developed improved protocols to achieve similar glycogen increases with fewer side effects:

The 6-Day Tapering Method:

- Days 1–3: Gradual reduction in training while maintaining a normal diet.
- Days 4–6: Continue tapering exercise and switch to a high-carbohydrate diet.
- Day 7: Competition with optimized glycogen stores.

Rapid Carbohydrate Loading:

- A single-day protocol requiring 10 g of carbohydrate per kg of body weight following a short, high-intensity workout (~3 minutes).
- This method significantly boosts glycogen storage in just 24 hours, reducing the need for prolonged dietary changes.

Practical Carbohydrate Loading Plan

- Day 1: Perform endurance training (~1 hour) to lower glycogen stores.
- Days 2–4: Reduce training volume and consume a moderate-carbohydrate diet (5–7 g carbs/kg body weight).
- Days 5–7: Further taper or rest while increasing carbohydrate intake (8–10 g carbs/kg body weight).

Since glycogen storage is linked to water retention (~3 g of water per 1 g of glycogen), weight gain of 1–2 kg may occur. This might affect performance

depending on the sport. If you plan to use carbohydrate loading, test it during training to find what works best for you. Avoid trying it for the first time before an important competition, as adjustments in food choices and intake amounts may be needed.

Key Concepts



- ▶ Carbohydrate loading is not a technique for all types of athletes, but it may benefit athletes involved in long-distance competition such as marathoning.
- ▶ Various carbohydrate loading techniques may effectively increase muscle glycogen stores, but tapering exercise or rest and a high-carbohydrate diet are the essential points.

Carbohydrate Intake for Exercise Performance

Phase	Before Exercise (2–4 hours prior)	During Exercise (lasting > 60 min)	After Exercise (within 2 hours)	Between Workouts (daily intake)
Carbohydrate Amount	2.5 g/kg body weight	30–60 g per hour	1 g/kg body weight, or 60% of energy intake	5–10 g/kg body weight
Timing	2–4 hours before exercise	Start after 30 min, then at regular intervals	Within 2 hours; then every 2 hours	Spread across 4–6 meals/snacks
Glycemic Index (GI)	Low	High	High or Low	Low
Examples	Rice with chicken and vegetables	500–1000 ml isotonic drink or diluted fruit juice (6 g/100 ml)	Meal replacement shake	Pasta or rice with beans/chicken/fish
	Pasta with tomato-based sauce and salad	Energy bar with water/1–2 bananas	Fresh fruit with milk or yogurt	Noodles with tofu/poultry/seafood
	Porridge	1–2 handfuls of raisins (40–80 g)	Sports bar	Beans on toast

Table 1: Daily food plan for carbohydrate loading

Dietary sources of fats, proteins, and carbohydrates	Amount and calories	Grams of carbohydrate, protein, and fat
Meat, fish, poultry, eggs, cheese, select low-fat items	6–8 oz Calories: 330–440	0 grams carbohydrate* 42–56 grams protein 18–24 grams fat
Breads, cereals, and grain products	10–20 servings Calories: 800–1,600	150–300 grams carbohydrate 24–60 grams protein
Vegetables, high Calorie (such as corn)	4 servings Calories: 280	60 grams carbohydrate 8 grams protein
Fruits	4 servings Calories: 240	60 grams carbohydrate
Fats and oils	2–4 teaspoons Calories: 90–180	10–20 grams fat
Milk, skim	2 servings Calories: 180	24 grams carbohydrate 16 grams protein
Desserts, such as pie	2 servings Calories: 700	102 grams carbohydrate 6 grams protein 30 grams fat
Beverages, naturally sweetened	8–24 ounces Calories: 80–240	20–60 grams carbohydrate
Water	8 or more servings Calories: 0	
TOTAL KCAL	2,700–3,860	
TOTAL GRAMS AND APPROXIMATE % OF DIETARY CALORIES		
Carbohydrate	416–606	65%
Protein	96–146	15%
Fat	58–74	20%



Multiple Choice Questions (MCQs)

- What is the primary immediate source of energy for muscle contractions?
A) Glucose
B) Glycogen
C) Adenosine Triphosphate (ATP)
D) Fatty acids
- During high-intensity exercise lasting up to 30 minutes, fatigue is primarily caused by:
A) Dehydration
B) Depletion of muscle glycogen
C) Accumulation of lactic acid leading to increased muscle acidity
D) Lack of oxygen supply
- What is the Glycemic Index (GI) value range for low-GI foods?
A) 0–55
B) 56–70
C) 71–100
D) Above 10
- What is the approximate total glycogen storage in an average human body?
A) 100 grams
B) 200 grams
C) 500 grams
D) 800 grams
- What is the primary role of liver glycogen during exercise?
A) Fueling muscle contractions
B) Maintaining blood glucose levels
C) Synthesizing proteins
D) Storing fat

1. What is ATP, and why is it important during exercise?
2. Why is carbohydrate intake important for endurance athletes?
3. How does the Glycemic Load (GL) differ from the Glycemic Index (GI)?
4. Why carbohydrate loading is generally not beneficial for events shorter than 90 minutes.

- Design a pre-workout or post-workout snack using 3–4 ingredients that provide energy, recovery, and hydration.
- A cyclist weighs 65 kg and trains 90 minutes daily. Calculate their recommended daily carbohydrate intake.

- A triathlete weighs 70 kg and is preparing for a 3-day carb-loading phase before a competition. Calculate the daily carbohydrate requirement during the high-carb loading days (8–10 g/kg).

Recommended Books:

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Unit -4

FATS AND PROTEINS AS ENERGY SOURCES

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INTRODUCTION

From a health standpoint, dietary fat is the nutrient of greatest concern to the American Heart Association because excessive consumption of certain types of fat has been associated with the development of coronary heart disease. Excessive consumption of dietary fat may also contribute to the development of obesity, a risk factor for several other chronic diseases, such as diabetes. Thus, one of the major recommendations advocated in Healthy People 2020 for a healthier diet is to reduce the amount of dietary fat intake to a reasonable level.

We need some fat in our diet. Despite its potential health hazards when consumed in excess, dietary fat contains several essential nutrients that serve a variety of important functions in human nutrition.

The National Academy of Sciences has set an Acceptable Macronutrient Distribution Range (AMDR) for total fat of 20–35 percent of daily energy intake and there is no health or performance benefit to consuming a diet containing less than 20 percent energy from fat. For the endurance athlete, one of the most important functions of fat is to provide energy during exercise, and researchers have explored a variety of techniques in attempts to improve endurance performance by increasing the ability of the muscle to use fat as a fuel.

Protein is one of our most essential nutrients for optimal health. Additionally, it has a wide variety of physiological functions that are essential to optimal physical performance. For example, protein forms the structural basis of muscle tissue, is the major component of most enzymes in the muscle, and can serve as a source of energy during exercise. Because protein is so important to the development and function of muscle tissue, and because most feats of human physical performance involve strenuous muscular activity in one form or another, it is no wonder that protein has persisted throughout the years as the food of the athlete.

It is recommended that the protein be derived from natural food sources and the amount of protein recommended is well within the Acceptable Macronutrient Dietary Range (AMDR).

LEARNING OBJECTIVES

After studying this unit, the students will be able to:

1. List the different types of dietary fatty acids and identify general types of foods in which they are found.
2. Explain the role of fat in human energy systems during exercise and how endurance exercise training affects exercise fat metabolism.

3. List the various dietary fat strategies and dietary supplements that have been investigated as a means of enhancing exercise performance, and highlight the major findings.
4. Distinguish between complete and incomplete proteins and identify foods that may be one or the other.
5. Explain the role of protein in human energy systems during exercise.
6. Describe the dietary strategies involving protein intake (amount, type, and timing) before and/or after exercise that may help provide the substrate and hormonal milieu conducive to muscle tissue anabolism during recovery.

As athletes in almost every sport strive to get leaner and competitive standards get higher, the relationship between body fat, health, and performance becomes increasingly important. However, the optimal body composition for fitness or sports performance is not necessarily a desirable one from a health point of view. It highlights the dangers of attaining very low body fat levels, as well as the risks associated with a very low-fat diet. It gives realistic guidance on recommended body fat ranges and fat intakes and explains the difference between the various types of fats found in the diet.

4.1 DIETARY FATS

Fats are a diverse group of molecules that play crucial roles in energy storage, cellular structure, and overall health. They are primarily composed of fatty acids—chains of carbon and hydrogen atoms with a carboxylic acid group at one end—bonded to a backbone structure, often glycerol. The characteristics and functions of fats are largely determined by the types of fatty acids they contain.

Saturated Fats: Saturated fats, primarily present in fats originating from animals, are solid at room temperature and significantly contribute to cholesterol levels. Primary dietary sources comprise conventional cheese, full-fat milk, ice cream, processed meats, and specific processed meals. These fats elevate levels of LDL cholesterol and are linked to an increased risk of cardiovascular disease.

Monounsaturated Fats: Monounsaturated fats, derived mostly from plant oils such as olive, avocado, and almonds, maintain a liquid state at room temperature and have health advantages, such as enhancing blood lipid profiles. Typical dietary sources include French fries, salad dressings, almonds, and specific meat meals.

Polyunsaturated Fats: Polyunsaturated fats, which are obtained from plant oils such as soybean, corn, and sunflower oils, play a vital role in preserving cell structure and function. These fatty acids, omega-6 and omega-3, are essential for maintaining good health. Salad dressings, mayonnaise, and processed foods are dietary sources of omega-6 polyunsaturated fats, whereas fatty fish such as salmon, mackerel, and trout are rich in omega-3 polyunsaturated fats.

4.2 ENERGY CONTENT AND METABOLIC ROLE

Fats are the most energy-dense macronutrient, providing approximately 9 kcal/g. This high energy yield makes fats an efficient energy source, especially during prolonged, low to moderate-intensity exercise. In endurance individuals, the body becomes more adept at oxidizing fats for energy, sparing glycogen stores and enhancing performance. However, fat oxidation is a slower process and requires more oxygen than carbohydrate metabolism, making it less efficient during high-intensity activities.

4.3 DIETARY RECOMMENDATIONS

- **Saturated Fats:** High intake of SFAs is associated with increased LDL cholesterol levels. It's advisable to limit saturated fat to less than 10% of total daily calories.
- **Unsaturated Fats:** Incorporate sources of MUFAs and PUFAs, such as olive oil, nuts, seeds, and fatty fish, to support heart health.

- **Omega-3 to Omega-6 Balance:** Aim for a dietary ratio that favors omega-3 intake to mitigate inflammation and support cardiovascular health.

4.4 FATS AND EXERCISE

Lipids provide approximately 37.5 kJ/g, compared to 16.9 kJ/g for carbohydrates, making them a more energy-rich fuel source. Adipose tissue stores can supply energy sufficient for extended periods of exercise, potentially sustaining skeletal muscle contraction for about 120 hours at marathon running pace. The complete oxidation of fatty acids yields more ATP per molecule than glucose (e.g., 147 ATP from stearic acid vs. 38 ATP from glucose).

4.4.1 Factors Influencing Fat Oxidation

- **Exercise Intensity:** At lower intensities (e.g., 25% VO_2 max), fat contributes up to 85% of energy expenditure. As intensity increases, the reliance shifts toward carbohydrates.
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- **Training Status:** Endurance training enhances the body's ability to oxidize fats by increasing mitochondrial density and the activity of enzymes involved in fat metabolism.
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- **Dietary Intake:** High-fat diets can increase the availability of fatty acids, potentially sparing glycogen stores during prolonged exercise.

4.4.2 Limitations of Lipid Utilization

- **Oxygen Requirement:** Fat oxidation requires more oxygen than carbohydrate oxidation, which can limit its use during high-intensity exercise when oxygen availability is reduced.
-
- **Slower Energy Release:** The process of mobilizing and oxidizing fats is slower than that of carbohydrates, making fats less suitable for immediate energy needs during sudden, intense efforts.

- Increased blood flow and capillarization to the muscle, delivering more plasma FFA
- Increased muscle triglyceride content, possibly associated with increased insulin sensitivity. Insulin regulates movement of FFA into muscle cells; exercise training may also increase the activity of lipoprotein lipase or fatty acid transporters at the muscle cell membrane
- Increased sensitivity of both adipose and muscle cells to epinephrine, resulting in increased FFA release to the plasma and within the muscle from triglycerides
- Increased number of fatty acid transporters in the muscle cell membrane to move fatty acids from the plasma into the muscle cell
- Improved ability to use ketones as an energy source
- Increased number and size of mitochondria, and associated oxidative enzymes for processing of activated FFA
- Increased activation of FFA and transport across the mitochondrial membrane
- Increased activity of oxidative enzymes

Table 2: Possible mechanisms associated with the increased use of fat as an energy source during aerobic endurance exercise following exercise training

4.5 FAT STORAGE IN THE BODY

Fat is stored as adipose (fat) tissue in almost every region of the body. A small amount of fat, about 300–400g, is stored in muscles, called intramuscular fat, but the majority is stored around the organs and beneath the skin. The amount stored in different parts of the body depends on genetic makeup and individual hormone balance. The average 70 kg person stores 10–15 kg of fat. Interestingly, people who store fat mostly around their abdomen (the classic pot-belly shape) have a higher risk of heart disease than those who store fat mostly around their hips and thighs (the classic pear shape). Males usually take after their father, and females after their mother. Female hormones tend to favor fat storage around the hips and thighs, while male hormones encourage fat storage around the middle. This is why, in general, women are ‘pear-shaped’ and men are ‘apple-shaped’.

4.6 CAN HIGH-FAT DIETS IMPROVE ENDURANCE?

Some studies have examined whether high-fat diets could train muscles to use fat more efficiently for energy, conserving glycogen for prolonged endurance performance. Research indicates that:

- Increasing fat intake enhances fat metabolism in the muscles.
- The muscles become more efficient at taking up fat from the bloodstream and using it as fuel.
- These effects are primarily observed in elite endurance athletes and only when exercising at low intensities.

However, high-fat diets offer no performance advantage for non-elite athletes or individuals exercising at moderate to high intensities (>65% VO₂ max).

4.7 DIETARY PROTEIN

Protein makes up part of the structure of every cell and tissue in your body, including your muscle tissue, internal organs, tendons, skin, hair, and nails. On average, it comprises about 20 % of your total body weight. Protein is needed for the growth and formation of new tissue, for tissue repair, and for regulating many metabolic pathways, and can also be used as a fuel for energy production. It is also needed to make almost all of the body's enzymes, as well as various hormones (such as adrenaline and insulin) and neurotransmitters. Protein has a role in maintaining optimal fluid balance in tissues, transporting nutrients in and out of cells, carrying oxygen and regulating blood clotting.

4.7.1 Amino acids

The 20 amino acids are the building blocks of proteins. They can be combined in various ways to form hundreds of different proteins in the body. When you eat protein, it is broken down in your digestive tract into smaller molecular units – single amino acids and dipeptides (two amino acids linked together). Twelve of the amino acids can be made in the body from other amino acids, carbohydrates, and nitrogen. These are called dispensable, or nonessential, amino acids (NEAAs). The other eight are termed indispensable, or essential, amino acids (EAAs), meaning they must be supplied in the diet. Branched-chain amino acids (BCAAs) include the three EAAs with a branched molecular configuration: valine, leucine, and isoleucine. They make up one-third of muscle protein and are a vital substrate for two other amino acids, glutamine and alanine, which are released in large quantities during intense aerobic exercise. Also, they can be used directly as fuel by the muscles, particularly when muscle glycogen is depleted. Strictly speaking, the body's requirement is for amino acids rather than protein.

Essential amino acids	Nonessential amino acids
Histidine	Alanine
Isoleucine*	Arginine**
Leucine*	Asparagine
Lysine	Aspartic acid
Methionine	Cysteine**
Phenylalanine	Glutamic acid
Threonine	Glutamine**
Tryptophan	Glycine**
Valine*	Proline**
	Serine
	Tyrosine**

Figure 9: The dietary amino acids

4.8 PROTEINS AND EXERCISE

Protein is not stored in the same way as carbohydrates and fat. It forms muscle and organ tissue, so it is mainly used as a building material rather than an energy store. However, proteins can be broken down to release energy if needed, so muscles and organs represent a large source of potential energy.

4.9 HOW DOES EXERCISE AFFECT PROTEIN REQUIREMENTS?

Numerous studies on both endurance and strength exercise indicate that the standard recommended protein intake of 0.75 g/kg body weight/day is insufficient for individuals who engage in regular exercise or sports. Increased protein is essential to compensate for heightened protein breakdown during and after exercise, as well as to support muscle repair and growth.

Exercise activates an enzyme that oxidizes key amino acids in the muscles, utilizing them as a fuel source. The intensity and duration of exercise directly influence the extent of protein breakdown. The longer and more intense the workout, the greater the protein breakdown.

4.9.1 Optimal Protein Timing

Timing protein intake is crucial for maximizing recovery and muscle growth. Research suggests consuming protein within the first hour post-exercise, ideally combined with carbohydrates in a 1:4 ratio. This enhances muscle repair and glycogen replenishment. Rather than increasing total food intake, athletes should distribute their protein and carbohydrate consumption strategically to optimize recovery and performance.

4.9.2 How to Meet Protein Needs?

In general, protein intake is closely linked to total calorie intake. If you are consuming enough calories from a variety of foods, you are likely meeting your protein needs. Studies show that most athletes already consume more than the recommended protein levels without the need for supplements. However, if you are following a calorie-restricted diet or eliminating entire food groups, such as in a vegan diet or due to a dairy allergy, you may find it challenging to meet your protein needs. Ensuring adequate calorie intake is crucial for maintaining protein balance and promoting muscle retention.

4.10 PROTEIN AND WEIGHT LOSS

A protein-rich diet enhances the fat-loss benefits of exercise. Women who consumed a high-protein diet while following a workout routine (five 30-minute walking sessions and two 30-minute weight training sessions per week) lost significantly more body fat than those on a high-carbohydrate diet with the same calorie intake. Additionally, nearly all the weight loss in the high-protein group was fat, especially from the abdominal area. In contrast, up to a third of the weight loss in the high-carbohydrate group was muscle. Researchers attribute these findings to leucine, an amino acid that aids fat-burning while preserving muscle mass.

When following a fat-loss program, increasing protein intake can help preserve muscle mass. Most researchers recommend adding an extra 0.2g/kg of body weight to standard protein requirements.

- Endurance athletes on a fat-loss plan: Up to 1.6g/kg body weight/day
- Strength athletes on a fat-loss plan: Up to 1.9g/kg body weight/day

4.11 GOOD SOURCES OF PROTEIN

Protein is found in a variety of foods, including meat, fish, dairy products, eggs, nuts, seeds, legumes, and plant-based alternatives like tofu and soy products. Here are some examples of protein-rich foods:

4.12 PROTEIN-RICH FOODS AND THEIR NUTRITIONAL VALUES

Meat and Fish

Food	Portion Size	Protein (g)	Calories (Kcal)
Beef, fillet steak (grilled, lean)	2 slices (105 g)	31 g	197 kcal
Chicken breast (grilled, meat only)	1 breast (130 g)	39 g	191 kcal
Cod (poached)	1 fillet (120 g)	25 g	113 kcal
Tuna (canned in brine)	1 small tin (100g)	24 g	99 kcal

Dairy Products and Eggs

Food	Portion Size	Protein (g)	Calories (Kcal)
Cheddar cheese	1 thick slice (40 g)	10 g	165 kcal
Cottage cheese	1 small carton (112 g)	15 g	110 kcal
Skimmed milk	1 glass (200 ml)	7 g	66 kcal
Low-fat yogurt (plain)	1 carton (150 g)	8 g	84 kcal
Low-fat yogurt (fruit)	1 carton (150 g)	6 g	135 kcal
Eggs (size 2)	1 egg	8 g	90 kcal

Nuts and Seeds

Food	Portion Size	Protein (g)	Calories (Kcal)
Peanuts (roasted & salted)	1 handful (50 g)	12 g	301 kcal
Peanut butter on bread	1 slice (20 g)	5 g	125 kcal
Cashew nuts (roasted & salted)	1 handful (50 g)	10 g	306 kcal
Walnuts	1 handful (50 g)	7 g	344 kcal
Sunflower seeds	2 tbsp (32 g)	6 g	186 kcal
Sesame seeds	2 tbsp (24 g)	4 g	144 kcal

Pulses

Food	Portion Size	Protein (g)	Calories (Kcal)
Baked beans	1 small tin (205 g)	10 g	166 kcal
Red lentils (boiled)	3 tbsp (120 g)	9 g	120 kcal

Red kidney beans (boiled)	3 tbsp (120 g)	10 g	124 kcal
Chickpeas (boiled)	3 tbsp (140 g)	12 g	169 kcal

4.13 PROTEIN REQUIREMENT

Your protein requirements depend on your activity level:

- **Endurance athletes:** 1.2–1.4g per kg of body weight per day
- **Strength athletes:** 1.4–1.7g per kg of body weight per day

For example, a 70kg endurance athlete needs 84–98g of protein daily, while a 70kg strength athlete requires 98–119g per day. Some strength athletes consume 2–3g/kg body weight/day, but research shows that increasing protein intake beyond 1.4–1.7g/kg does not lead to additional muscle mass or strength gain. Similarly, research at Kent State University showed that 1.4–1.5g/kg/day was sufficient for strength athletes. Beyond this level, extra protein does not enhance muscle size, strength, or mass.

4.14 PROTEIN BIOAVAILABILITY

Protein quality is measured by biological value (BV), which indicates how efficiently the body can use the protein for growth and repair. Foods with a BV of 70–100 are considered high-quality protein sources.

- **High BV (70–100):** Eggs (BV 100), dairy, meat, fish, poultry, and soy.
- **Lower BV (<70):** Nuts, seeds, legumes, and grains

4.15 PROTEIN: ERGOGENIC ASPECTS

4.15.1 Protein Requirements for Different Types of Training

i. Endurance Training

Prolonged and intense endurance exercise raises protein requirements due to:

- **Increased protein breakdown:** When muscle glycogen stores deplete, typically after 60–90 minutes of endurance activity, certain amino acids, particularly glutamate and branched-chain amino acids (BCAAs), serve as alternative energy sources. Leucine, one of the BCAAs, converts into alanine, which is then processed by the liver into glucose, providing additional energy.
- **Muscle repair and recovery:** Intense endurance training necessitates additional protein to support muscle tissue recovery.

Protein may contribute up to 15% of total energy production when glycogen stores are low, compared to less than 5% when glycogen stores are sufficient.

ii. Strength and Power Training

Strength and power athletes require more protein than endurance athletes due to:

- **Increased protein turnover:** After resistance training, protein breakdown initially surpasses synthesis. Over time, adequate dietary protein enhances muscle growth and recovery.
- **Positive nitrogen balance:** To build muscle effectively, the body must retain more dietary protein than it excretes or uses as fuel. Insufficient protein intake leads to slower muscle growth or potential muscle loss despite training efforts.

While the body can adapt to variations in protein intake, a high-protein diet alone does not guarantee muscle growth.

Minimizing Protein Breakdown during Exercise

Protein breakdown increases significantly when muscle glycogen stores are low. To reduce reliance on protein as an energy source:

- Begin training sessions with high glycogen levels by consuming adequate carbohydrates.
- If on a weight-loss program, avoid drastic reductions in carbohydrate intake, as insufficient carbs force the body to use protein for energy, limiting muscle repair and growth.
- Maintain at least 60% of total caloric intake from carbohydrates, adjusting proportionally based on calorie reductions.

4.16 RECOMMENDED PROTEIN INTAKE FOR ATHLETES

Athlete Type	Daily Protein Requirement (g/kg body weight)
Endurance athlete (moderate to heavy training)	1.2–1.4
Strength and power athlete	1.4–1.8
Athlete on a fat-loss program	1.6–2.0
Athlete on a weight-gain program	1.8–2.0

Self-Assessment Questions:

Fill in the blanks:

1. Saturated fats are primarily found in animal products and are _____ at room temperature.
2. During low-intensity exercise (e.g., 25% VO_2 max), fat can contribute up to _____ % of energy expenditure.
3. The body stores fat as _____ tissue, with a small amount stored in muscles as _____ fat.
4. Protein comprises about _____ % of total body weight and is essential for tissue growth and repair.

5. Endurance athletes may require up to _____ g/kg body weight/day of protein, while strength athletes may need up to _____ g/kg.

Short Question Answers:

1. Why is fat oxidation less efficient during high-intensity exercise?
2. How does endurance training affect fat metabolism?
3. What are essential amino acids, and why are they important?
4. Can consuming too much protein be harmful?
5. What is biological value (BV) in terms of protein, and which foods have high BV?

Activity-Based Questions:

- Why might a high-fat diet be ineffective for most athletes competing at moderate to high intensities? Explain the metabolic limitations involved.
- Fatima is a 24-year-old female endurance athlete weighing 60 kg. She is on a fat-loss program and wants to preserve muscle mass while training for a marathon. a). Calculate her daily protein requirement. b) List 3 protein-rich meals/snacks she could consume throughout the day to meet her requirement.

Recommended Books:

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Unit -5

THE ORGANIC AND INORGANIC REGULATORS

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INTRODUCTION

Vitamins are a diverse class of 13 known specific nutrients that are involved in almost every metabolic process in the human body. We need only minute amounts of vitamins in our daily diet, so they are classified as micronutrients. Nevertheless, they are one of our most critical nutrients. Noticeable symptoms of a deficiency may appear in 2 to 4 weeks for several of the vitamins, and major debilitating diseases may occur with prolonged deficiencies. Vitamin deficiencies appear to be widespread in many developing countries, and according to Bouis, they affect a greater number of people in the world than does protein-energy malnutrition. Plant breeding of commonly eaten food crops, such as wheat, rice, and corn, to fortify them with vitamins and minerals may help alleviate this major health problem.

Much research attention is currently being devoted to the role of mineral nutrition in health and disease, including both epidemiological and laboratory research. For example, using the RDA as a basis for comparison, national surveys among the general population have revealed that either an inadequate dietary intake of some minerals or an excessive dietary intake of others in certain small segments of the population may be contributing to several health problems. Laboratory studies using either animals or humans as subjects have explored the roles of both deficiencies and excesses of various minerals, including both essential and nonessential elements, on human health and disease processes. An increasing number of research studies have been conducted with athletes to evaluate the effect of mineral nutrition on physical performance and the converse—the effect of exercise on mineral metabolism. Because some minerals function similarly to vitamins, a deficiency state could adversely affect performance. Moreover, exercise in itself may be a contributing factor to mineral deficiencies or impaired mineral metabolism in some types of athletes. Additionally, several mineral supplements have been marketed specifically for physically active individuals.

LEARNING OBJECTIVES

After studying this unit, the students will be able to:

1. Explain the potential effects on health and sports performance associated with a deficiency of each essential vitamin.
2. Describe the various means whereby minerals may carry out their functions in the human body.
3. Name the essential minerals, state the RDA or AI for each, and identify several foods rich in each mineral.
4. Explain the theory as to how phosphate salt supplementation may enhance sports performance.
5. Explain the potential effects on health and sports performance associated with a deficiency of each trace mineral.

5.1 VITAMINS AND MINERALS: ESSENTIAL BUT NOT ENERGY PROVIDERS

Vitamins and minerals are often associated with vitality, energy, and strength. Many believe consuming them in abundance is the key to a long and healthy life. However, while essential for overall well-being, they do not directly provide energy. Having more does not guarantee better health, increased stamina, or improved athletic performance. Instead, maintaining the right balance of vitamins and minerals is crucial for good health and optimal physical function. It is a common misconception, especially among athletes, that taking extra vitamins will enhance performance. While small amounts are beneficial, more is not necessarily better.

Vitamins are essential micronutrients required in small amounts to support growth, health, and overall well-being. Many functions as key components of enzyme systems that regulate energy production and exercise performance. Others play critical roles in immune function, hormone regulation, and nervous system health. Since our bodies cannot produce vitamins, they must be obtained through diet. Minerals are inorganic elements that serve various structural and regulatory functions. Some, like calcium and phosphorus, are essential for strong bones and teeth. Others help regulate fluid balance, muscle contractions, nerve signaling, enzyme activity, and red blood cell formation. Like vitamins, minerals must also come from food sources, as the body cannot synthesize them.

5.1.1 Fat- & Water-Soluble Vitamins

Fat-soluble vitamins:

The four fat-soluble vitamins are A, D, E, and K. Because they are soluble in fat, but not in water, dietary sources often include foods that have some fat content. The body may contain appreciable stores of each fat-soluble vitamin, and several of them may be manufactured by the body, making deficiencies less common than for most of the water-soluble vitamins. On the other hand, excessive intake may be toxic

5.1.2 Vitamin A:

Vitamin A is a fat-soluble, physiologically active form of vitamin A known as retinol. The human body is capable of forming retinol from a provitamin known as carotenoids, primarily beta-carotene. Both preformed vitamin A, or retinol, and carotenoids are found in the foods we eat.

The RDA may be expressed in several ways, including as retinol equivalents (RE), retinol activity equivalents (RAE) as a combination of retinol and carotenoids, or as international units. In brief, 1 RAE equals 1 mcg of retinol, or 12 mcg of beta-carotene, or about 3.3 IU. The RDA is 900 mcg RAE, or 3,000 IU, for adult males and 700 mcg RAE, or 2,300 IU, for adult females. The UL for adults is 3 mg RAE/day from retinol, or 10,000 IU. No UL has been established for carotenoids.

Preformed vitamin A is found in substantial amounts in some animal foods such as liver, butter, cheese, egg yolks, fish liver oils, and fortified cow's milk. Provitamin A, as beta-carotene, is found in dark green leafy and yellow-orange vegetables, as well as in some fruits such as oranges, limes, pineapples, prunes, and cantaloupes.

- Vitamin A is essential for the maintenance of the epithelial cells, those cells covering the outside of the body and lining the body cavities. It is also essential for proper visual function, such as night vision and peripheral vision.
- Vitamin A has a variety of other physiological roles in the body that are not well understood, although it is considered essential in proper bone development and for maintaining optimal function of the immune system.
- Beta-carotene functions as an antioxidant and, in this role, may be beneficial in the prevention and treatment of chronic disease.
- Inadequate intake of vitamin A could have serious health implications if prolonged. The gradual loss of night vision is one of the first symptoms of vitamin A deficiency. Other symptoms of mild deficiencies include increased susceptibility to infection and skin lesions.
- Excessive amounts of vitamin A, generally caused by self-medication with mega doses, can cause a condition known as hypervitaminosis A. Symptoms may include weakness, headache, loss of appetite, nausea, pain in the joints, and peeling of skin.

5.1.3 Vitamin D (cholecalciferol)

Vitamin D, a term representing several compounds, has been classified as both a fat-soluble vitamin and a hormone. Vitamin D is naturally found in foods, but can also be made when the skin cells are exposed to the sun's UV radiation. In brief, the ultraviolet rays from sunshine initiate a process that eventually converts a provitamin found in the skin (7-dehydrocholesterol) into cholecalciferol (vitamin D₃), a prohormone, which is released into the blood and is eventually converted by the liver and kidneys into the active hormone, calcitriol (1,25-dihydroxycholecalciferol).

The RDA for vitamin D is given in mcg of cholecalciferol or as IU; 1 mcg of cholecalciferol is the equivalent of 40 IU. Even though sunlight is a major source of vitamin D for some people, the RDA is based on minimal exposure to sunlight. For infants 0–12 months old, the AI is 10 mcg (400 IU); for ages 1 to 70 years, the RDA is 15 mcg (600 IU); and for 70 years and older, the RDA is 20 mcg (800 IU). The UL for those over age 9 is 100 mcg (4,000 IU).

Fatty fish, such as salmon, mackerel, sardines, and catfish, are good sources of vitamin D and may contain about 200–500 IU in 3 ounces. One glass of fortified cow's milk will provide approximately 100 IU of vitamin D, which is about 15 percent of the RDA for children and adults up to age 70. Some ready-to-eat cereals and orange juice may also be fortified with vitamin D.

- Vitamin D plays a central role in bone metabolism through its effect on calcium and phosphorus, whose roles in bone metabolism are discussed in the next chapter. It works in conjunction with several other hormones, particularly parathyroid hormone (PTH) secreted by the parathyroid gland.
- Vitamin D aids in the absorption of calcium from the intestinal tract and the kidneys, helping to maintain normal serum calcium levels and proper bone metabolism. Vitamin D also helps regulate phosphorus metabolism, another mineral essential in bone formation.
- Vitamin D status has been associated with chronic, non-skeletal diseases, including cardiovascular disease, hypertension, multiple sclerosis, arthritis, infection, autism, and certain cancers.
- Health and Physical Performance According to the 2020–2025 Dietary Guidelines for Americans, vitamin D is a “nutrient of public health concern.” Indeed, research suggests that nearly half of American adults have low blood levels of vitamin D. These low levels of vitamin D have been related to poor intake of the vitamin as well as insufficient exposure to UV light.
- A deficiency of vitamin D is known as rickets in children and osteomalacia in adults. Both rickets and osteomalacia contribute to the softening and weakening of the bones. Bones can start to bend and break more easily. As well, those with osteomalacia experience muscle weakness. This muscle weakness has been theoretically linked with impaired calcium metabolism in the muscle, possibly due to inadequate activation of vitamin D receptors in the muscle.
- Low levels of vitamin D in the blood have also been associated with insulin resistance and increased risk of diabetes. Additionally, vitamin D deficiency may lead to an increased production of renin by the kidneys, which could lead to increased blood pressure. Low levels of vitamin D may also affect mental health.
- The Academy of Nutrition and Dietetics (AND), Dietitians of Canada, and the American College of Sports Medicine (ACSM) suggest that vitamin D is a “micronutrient of key interest” for athletic performance. According to the position paper, vitamin D status has been related to injury prevention, rehabilitation, improved neuromuscular function, increased type II muscle fiber size, reduced inflammation, decreased risk of stress fracture, and reduced risk of acute respiratory illness.
- Weight training increases the serum concentration of vitamin D, which is theorized to be related to the increased bone mass developed through exercise. Those athletes living and training at higher latitudes and/or who are indoors are at the greatest risk for a vitamin D deficiency. For those considering supplementation with vitamin D, experts recommend having blood levels of vitamin D assessed before supplementation.

5.1.4 Vitamin E (alpha-tocopherol)

In its natural form, vitamin E is a complex family of eight compounds including

tocopherols and tocotrienols, each with alpha, beta, gamma, and delta forms. Alpha-tocopherol alone is the basis for the RDA, and it is the most common form in the bloodstream and dietary supplements. The RDA for vitamin E for adults is 15 mg of alpha-tocopherol. One mg of alpha-tocopherol is equivalent to about 1.5 IU. The UL for adults is 1,000 mg/day, which is equal to 1,500 IU.

The most common dietary sources of vitamin E are polyunsaturated vegetable oils, such as corn, soybean, and safflower oils; 1 tablespoon of vegetable oil contains about 5 mg of vitamin E. Sunflower seeds, almonds, peanuts, wheat germ, and several vegetables are also good sources of vitamin E. One-quarter cup of sunflower seeds provides about 8 mg of vitamin E, while 1/2 cup of cooked spinach provides about 2 mg of vitamin E.

- The key role of vitamin E is to serve as an antioxidant in the cell membrane. Vitamin E works in concert with other antioxidants, such as vitamin C, to prevent the oxidation of unsaturated fatty acids in cell membrane phospholipids, thereby protecting the cell from damage. It may also help prevent the oxidation of vitamin A.
- Vitamin E may also play a key role in the synthesis of hemoglobin or serve a pro-oxidant effect by activating enzymes in the mitochondria to improve cellular oxygen utilization; however, these claims are not well documented in humans. Some of the vitamin E antioxidant effects are theorized to help prevent the development of several chronic diseases or muscle tissue damage during exercise.
- Because vitamin E is rather widely distributed in foods, and because it is also stored in the body, a true vitamin E deficiency in humans is rare. However, certain individuals with genetic diseases, such as the inability to absorb fat, do experience a deficiency. Since vitamin E plays a role in preventing damage from free radical oxidation, a deficiency has been theorized to contribute to the development of heart disease and cancer in humans.
- Vitamin E supplementation has also been studied as a means to enhance VO₂ max and aerobic endurance capacity by maintaining red blood cell membrane integrity and polyunsaturated fatty acid content.

5.1.5 Vitamin K (menadione)

Vitamin K is often called the blood coagulation vitamin or antihemorrhagic vitamin. Vitamin K includes phyloquinone (in plant foods), menaquinone (in animal foods and the form synthesized by bacteria in the colon), and menadione (synthetic form). The AI for vitamin K is 120 and 90 mcg/day for adult males and females, respectively.

Vitamin K is found in a variety of plant and animal foods. Good plant sources include vegetable oils (soybean, olive) and green and leafy vegetables such as kale, turnip greens, broccoli, and spinach. Meats and cow's milk contain much lower

amounts. Phylloquinone is the major dietary source of vitamin K; 3 ounces of spinach contain 380 mcg, whereas 3 ounces of meat contain less than 1 mcg.

- Vitamin K is needed for the formation of four compounds that are essential in the blood-clotting process. If vitamin K is not available, blood-clotting factors are inactive and blood clotting is impaired.
- In addition, vitamin K appears to enhance the function of osteocalcin, a protein that plays an important role in strengthening bones. A deficiency of vitamin K is uncommon in healthy adults, but may occur with very low-vitamin K diets and in some individuals when antibiotic medications destroy the intestinal bacteria that produce the vitamin.
- Deficiencies may impair blood clotting and lead to hemorrhage. Low vitamin K intake has also been associated with an increased risk of osteoporotic bone fractures.

5.2 WATER-SOLUBLE VITAMINS

There are nine water-soluble vitamins, including eight in the vitamin B complex and vitamin C (ascorbic acid). The B complex vitamins include thiamin, riboflavin, niacin, B6, B12, folate, biotin, and pantothenic acid. There are also vitamin-like substances, including choline, that have similar general characteristics to the water-soluble vitamins. Being water soluble, they are not, with a few exceptions, stored to any significant extent in the body. For some of these vitamins, the effects of a deficiency may be noted in as little as 2–4 weeks, often reducing physical performance capacity. Excesses of these vitamins are usually excreted in the urine and are generally considered to be relatively harmless.

5.2.1 Thiamin (vitamin B1)

Thiamin, also known as vitamin B1, was the first vitamin to be discovered. The RDA for adult males is 1.2 mg/day and for adult females is 1.1 mg/day. Because very little thiamin is stored in the human body, deficiency symptoms can develop within a few days of insufficient thiamin intake. Thiamin is widely distributed in both plant and animal tissues. Excellent sources include whole-grain cereals, beans, and pork. One lean pork chop contains more than 50 percent of the daily recommendation for thiamin. Several fortified, ready-to-eat cereals contain 100 percent of the RDA for thiamin, as well as most of the other B vitamins.

Thiamin has a central role in the metabolism of carbohydrates. It is part of a coenzyme known as thiamin pyrophosphate (TPP), which is needed to convert pyruvate into acetyl-CoA for entry into the Krebs cycle. Thiamin is essential for the normal functioning of the nervous system and energy derivation from glycogen in the muscles.

5.2.2 Riboflavin (vitamin B2)

Riboflavin is also known as vitamin B2. Like thiamin, riboflavin is a component of the B complex. The RDA for riboflavin is 1.3 mg for the adult male and 1.1 mg for

the adult female.

Riboflavin is distributed widely in foods. Major food sources include cow's milk and other dairy products. Additional good sources include liver, eggs, dark-green leafy vegetables, wheat germ, yeast, whole-grain products, and enriched breads and cereals.

Riboflavin is a component of two coenzymes necessary for energy metabolism, flavin mononucleotide (FMN) and flavin adenine dinucleotide (FAD). FMN and FAD are also important for fatty acid and folate metabolism. Ariboflavinosis, a riboflavin deficiency, is very rare but has been seen in alcoholics and those adhering to various fad diets. Early signs of deficiency include glossitis (an inflammation of the tongue), cracks at the corners of the mouth, and dry, scaly skin at the corners of the nose. Confusion and headaches have also been reported in those experiencing ariboflavinosis. Although the effect of a riboflavin deficiency on physical performance has not been studied directly, research suggests that physically untrained individuals who initiate an aerobic training program may need a higher intake of riboflavin to synthesize more flavoproteins in the muscles.

5.2.3 Niacin:

Niacin, sometimes identified as vitamin B3, is also known as nicotinic acid, nicotinamide, or the anti-pellagra vitamin. Niacin is found naturally in many foods, but it may also be formed in the body from excess amounts of dietary tryptophan, an essential amino acid. Therefore, the RDA is expressed in niacin equivalents, or NE. One NE equals 1 mg of niacin or 60 mg of tryptophan—1 mg of niacin can be produced from that amount of tryptophan. The RDA for niacin is 16 NE for adult males and 14 NE for adult females. The adult UL for niacin is 35 mg/day.

Niacin is typically found in foods that have a high protein content. For example, niacin is most abundant in lean meats, organ meats, fish, poultry, whole-grain cereal products, legumes, and enriched foods. One-half of a chicken breast contains more than 60 percent of the RDA of niacin.

Niacin serves as a component of two coenzymes concerned with energy processes within the cell. Nicotinamide adenine dinucleotide (NAD) is important in the process of glycolysis and the Krebs cycle, which is how muscle glycogen produces energy both aerobically and anaerobically. NAD is also involved in fatty acid and amino acid metabolism. Nicotinamide adenine dinucleotide phosphate (NADP) is involved in fat metabolism by promoting fat synthesis in the body, which may block the release of free fatty acids from adipose cells.

5.2.4 Vitamin B6 (pyridoxine)

Vitamin B6 is a collective term for three naturally occurring substances that are all metabolically and functionally related: pyridoxine, pyridoxal, and pyridoxamine. Pyridoxine is most often used as a synonym. The adult RDA for vitamin B6 is 1.3 mg/day for ages 19–50, and then increases to 1.7 mg for males and 1.5 mg for

females above age 51. Recommendations for vitamin B6 are based on protein intake, so requirements may increase with high-protein diets. As excess B6 intake may cause some health problems, an UL of 100 mg/day has been set for adults.

Vitamin B6 is widely distributed in foods. The most reliable sources are protein foods such as meats, poultry, fish, wheat germ, whole-grain products, brown rice, and eggs. One-half of a chicken breast contains more than 25 percent of the RDA.

In its coenzyme form (primarily pyridoxal phosphate, PLP), vitamin B6 is critically involved in the metabolism of protein, but it is also involved in carbohydrate and fat metabolism. PLP functions with more than 60 enzymes in such processes as the synthesis of dispensable amino acids, the conversion of tryptophan to niacin, the formation of neurotransmitters in the nervous system, and the incorporation of amino acids into body proteins such as hemoglobin, myoglobin, and oxidative enzymes. Vitamin B6 is also involved in the breakdown of muscle glycogen, as well as gluconeogenesis in the liver.

5.2.5 Vitamin B₁₂ (cobalamin)

Vitamin B₁₂ (cobalamin) is a part of the B complex and is the most recent vitamin to be discovered. The adult RDA for vitamin B₁₂ is 2.4 mcg/day. The average mixed American diet provides about 5–15 mcg. Vitamin B₁₂ is found in good supply only in animal foods such as meat, fish, poultry, cheese, eggs, and cow's milk. One glass of cow's milk contains nearly 50 percent of the RDA. Vitamin B₁₂ is not found in natural plant foods such as fruits, vegetables, beans, and grains, but vitamin-fortified cereals may be an excellent source. As well, the vitamin is present in microorganisms such as bacteria and yeast, which may be found in some plant foods; however, the bioavailability of B₁₂ from these sources is uncertain. When consumed from natural food sources, vitamin B₁₂ is most often bound to animal protein, which prevents its digestion and absorption. To release the vitamin B₁₂ from the protein, HCl in the stomach is essential. Then, in the small intestine, vitamin B₁₂ binds to intrinsic factor, a substance made and secreted from the cells of the stomach. In the ileum, the intrinsic factor–vitamin B₁₂ complex separates, and the vitamin is absorbed.

Vitamin B₁₂ is a part of coenzymes present in all body cells and is essential in the synthesis of DNA. Vitamin B₁₂ works closely with folic acid, and both have important roles in the development of red blood cells. It is also essential for the formation of the protective sheath. Both folate and vitamin B₁₂ are necessary for normal RBC production. When intake of either vitamin B₁₂ or folate is insufficient, the precursor RBCs lose their nuclei before the “mature” RBCs enter the bloodstream.

5.2.6 Folate (folic acid):

Folate, or folic acid, is also a part of the B complex. Folate is found naturally in some foods, but folic acid is a synthetic form found in fortified foods and dietary

supplements. The RDA for folate is given as mcg of dietary folate equivalents (DFE). Absorption of folic acid from fortified foods or dietary supplements is about 1.7 times that of natural food folate. The RDA for folate is 400 mcg of DFE/day. During pregnancy, the RDA is increased to 600 mcg of DFE per day, and it is 500 mcg DFE during the early stages of lactation. Folate derives its name from foliage because it is found in green leafy vegetables such as spinach. Other good sources include seafood, poultry, nuts, legumes, whole-grain products, and some fruits. One papaya provides nearly 700 mcg, approximately twice the RDA for the average healthy adult. As well, all cereal and grain products in the United States are fortified with folic acid to reduce the occurrence of neural tube defects.

Folate serves as part of tetrahydrofolic acid (THFA), a coenzyme that plays a critical role in the metabolism of methionine, an essential amino acid. As well, folic acid is critical to the formation of DNA, the genetic material that regulates cell division. It is essential for maintaining normal production of RBCs, one of the most rapidly dividing cells in the body. Folate is also critical during the very early stages of pregnancy when cells in the fetus divide rapidly. Researchers indicate that during periods of rapid cell division, large amounts of folate are needed to make DNA.

Folate is also involved in the metabolism of homocysteine, an amino acid derived in a conversion from methionine and considered by some experts to be a possible risk factor for cardiovascular disease. With vitamin B12, folate is necessary for the reformation of methionine from homocysteine.

5.2.7 Pantothenic Acid:

Pantothenic acid is a water-soluble B vitamin found in a wide variety of foods. The Greek word pantothen means “everywhere,” referring to the presence of pantothenic acid in many different types of foods. The adult AI for pantothenic acid is 5 mg. Pantothenic acid is distributed widely in foods. It is found in all-natural animal and plant products, but the best sources include organ meats, eggs, legumes, yeasts, and whole grains. Grains, including cereal, have often been fortified with pantothenic acid. One cup of mushrooms provides about 3.5 mg of pantothenic acid. It is an essential component of coenzyme A (CoA), which plays a central role in energy metabolism.

Pantothenic acid is also involved in gluconeogenesis, the synthesis and breakdown of fatty acids, the modification of proteins, and the synthesis of acetylcholine, a chemical released by the motor neuron to initiate muscle contraction.

5.2.8 Biotin:

Biotin is the final vitamin in the water-soluble B-vitamin complex. The adult AI for biotin is 30 mcg. Good dietary sources of biotin include organ meats, such as liver, egg yolk, legumes, and dark-green leafy vegetables. Bacteria in the colon can also synthesize biotin.

As a coenzyme, biotin participates in chemical reactions involving the transfer of carbon dioxide. It is also important in the synthesis of glucose and fatty acids. Because biotin is an important coenzyme for gluconeogenesis, it may have some implications relative to endurance performance.

5.2.9 Vitamin C (ascorbic acid):

Vitamin C, or ascorbic acid, is a water-soluble vitamin widely known for its deficiency disease, scurvy, which was common for centuries in sailors who had little access to fresh fruits and vegetables. The adult RDA of vitamin C for males is 90 mg/day, and for females it is 75 mg/day. For adults, the UL has been set at 2,000 mg/day. The best food sources of vitamin C are fruits and vegetables, primarily citrus fruits and the leafy parts of green vegetables. Excellent sources include oranges, grapefruit, broccoli, and salad greens. Other good sources are green peppers, potatoes, strawberries, and tomatoes. Cow's milk, meats, and grain products are typically poor sources of vitamin C.

- Although vitamin C does not directly participate in enzyme-catalyzed conversions of substrate to product, the vitamin modifies mineral ions in the enzymes to make them active. Vitamin C has many different functions in the body, some of which have important implications for the physically active individual.
- It is a powerful antioxidant that protects cells from free radical damage, necessary for the formation and maintenance of cartilage, tendons, and bone.
- It is involved in the formation of certain hormones and neurotransmitters, including epinephrine (adrenaline), during exercise.
- It helps in the healing of wounds through the development of scar tissue, regulates the metabolism of folic acid, cholesterol, and amino acids.

5.3 VITAMIN SUPPLEMENTS:

Health Aspects

Like the general population, the majority of athletes receive recommended amounts of most vitamins as part of a mixed daily diet. While some studies report that certain groups of athletes receive less than the RDA/AI for some vitamins, or even have indicators of a biochemical deficiency. Most of the research on antioxidant supplements for athletes has focused on the prevention of muscle tissue damage and soreness. The most common supplements used were vitamins E and C and beta-carotene, but coenzyme Q10, selenium, and other substances have also been used. Most experts recommend that physically active individuals obtain antioxidant vitamins naturally from food sources. Increasing consumption of fruits and vegetables will enable athletes to obtain the proposed beneficial amounts of beta-carotene (10–30 mg) and vitamin C (250 –1,000 mg). There seems to be no valid reason to recommend antioxidant supplements to most athletes, except in those known to be consuming a low-antioxidant diet for prolonged periods.

Maintaining a balanced diet can be challenging, especially if you have a busy schedule, travel frequently, work long hours, train at irregular times, or rely on quick meals. Under these circumstances, planning a well-balanced diet requires extra effort, increasing the risk of nutrient deficiencies. Deficient intake is also likely if you consume fewer than 1,500 calories daily or exclude entire food groups from your diet.

Several studies indicate that many athletes do not consume adequate vitamins and minerals through their diet. Female athletes are particularly prone to deficiencies. A study of 60 female athletes found that their calcium, iron, and zinc intake was below 100% of the Recommended Daily Allowance (RDA).

5.4 WHO MAY BENEFIT FROM SUPPLEMENTS?

Research indicates that one in three people takes some form of vitamin supplement, with multivitamins being the most popular. However, supplements should not replace a healthy diet. If you suspect a deficiency, focus on incorporating more nutrient-rich foods into your meals. As a temporary measure, supplements may be beneficial if you:

- Have irregular eating habits
- Consume fewer than 1,500 kcal per day
- Are pregnant (folic acid)
- Eat out frequently or rely on fast food
- Follow a vegan diet (vitamin B12 and other nutrients)
- Have anemia (iron)
- Have a major food allergy or intolerance (e.g., dairy)
- Are you a heavy smoker or drinker
- Are you recovering from an illness

5.5 How Does Exercise Affect Vitamin and Mineral Requirements?

Regular, intense exercise increases the need for vitamins and minerals involved in energy metabolism, tissue repair, red blood cell production, and free radical defense.

- **Vitamin E:** Acts as a powerful antioxidant, protecting cell membranes from damage. A study on elite cyclists found that vitamin E supplementation reduced free radical damage after prolonged intense cycling.
- **Vitamin C:** Plays a crucial role in forming connective tissue, hormones, and red blood cells. It also enhances iron absorption and provides

antioxidant protection. Research suggests that vitamin C supplementation may reduce upper respiratory infections in ultra-marathon runners and minimize post-exercise muscle soreness.

- **B Vitamins (B1, B2, B3):** Essential for energy metabolism. Athletes require more B vitamins due to increased carbohydrate and calorie consumption. Whole grains, cereals, and brown rice are good sources, but those using carbohydrate supplements or consuming refined carbohydrates may need additional supplementation.
- **Vitamin B6:** Supports protein metabolism, red blood cell formation, and muscle recovery.
- **Pantothenic Acid (B5):** Crucial for glucose and fatty acid metabolism, steroid hormone production, and brain function.
- **Folic Acid & Vitamin B12:** Aid in red blood cell production and DNA synthesis. Athletes, especially vegans, should ensure adequate intake through fortified foods or supplements.
- **Beta-Carotene:** Functions as an antioxidant and enhances vitamin E activity. It is best consumed through a diet rich in colorful fruits and vegetables.
- **Calcium:** Essential for bone health, muscle function, and nerve transmission. Female athletes with low estrogen levels may require extra calcium to support bone density.
- **Iron:** Plays a vital role in oxygen transport and energy metabolism. Athletes, particularly those engaging in high-impact activities, are at risk of iron deficiency. Women recovering from pregnancy and individuals consuming fewer than 2,000 kcal per day should monitor their iron levels. Those who avoid red meat should seek alternative iron sources or supplements.

5.6 MINERALS AND THEIR IMPORTANCE TO HUMANS

Numerous studies have examined the effects of supplements on athletic performance, with most showing no significant improvement in healthy individuals. Any observed benefits, such as increased endurance, tend to occur in athletes with pre-existing nutrient deficiencies. Supplements help restore normal nutrient levels, but taking them in excess does not necessarily enhance performance. More is not always better. If you suspect a nutrient deficiency, consult a registered nutritionist or sports dietitian for a dietary analysis and personalized advice.



Figure 10: Minerals contribute to many functions in the body. Mineral deficiencies, therefore, lead to a variety of health problems and may impair physical performance

5.6.1 Macro Minerals & Trace Minerals

A mineral is an inorganic element found in nature. Minerals are found in the soil and are eventually incorporated into growing plants. Most animals get their mineral nutrition from the plants they eat, whereas humans obtain their supply from both plant and animal food. Drinking water may also be a good source of several minerals, including fluoride. As minerals are excreted daily from the body in sweat, urine, or feces, they must be regularly replaced.

- Many minerals are used as the building blocks for body tissues, such as bones, teeth, muscles, and other organic structures. In particular, calcium and phosphorus are important to bone health.
- Iron is also an important component of hemoglobin, which is needed for optimal oxygen transport during aerobic endurance exercise.
- Some minerals are involved in the regulation of metabolic processes. Many are components of enzymes known as metalloenzymes, such as the cytochrome enzymes in the mitochondria that facilitate ATP production.
- Specific to athletic performance, minerals are involved in muscle contraction, normal heart rhythm, nerve impulse conduction, oxygen transport, oxidative phosphorylation, enzyme activation, immune function, antioxidant activity, bone health, acid-base balance of the blood, and maintenance of body water supplies.
- Although minerals may play a significant role in generating energy via their metabolic functions, they do not provide energy (kcal) themselves. Inadequate mineral nutrition has been associated with impairment of normal physiological functions, as well as with a variety of human diseases, including anemia, high blood pressure, obesity, diabetes, cancer, tooth decay, and osteoporosis. However, excessive intake of minerals may also contribute to significant health risks. Thus, proper dietary intake of essential minerals is necessary for optimal health and physical performance.

5.6.2 Major Minerals

The seven major minerals are calcium, phosphorus, magnesium, potassium, sodium, chloride, and sulfur. In general, the human body maintains a proper balance of these minerals through precise hormonal control mechanisms, but deficiencies or excesses may occur and disturb normal physiological functions, thus impairing health or physical performance. Sulfur, an integral component of several amino acids and vitamins, is not discussed here as its functions are associated with those nutrients. Because potassium, sodium, and chloride are the major electrolytes in sweat, and in some sports drinks, they are covered in the following chapter dealing with water and temperature regulation.

i. Calcium (Ca):

Calcium, a silver-white metallic element, is the most abundant mineral in the body, representing almost 2 percent of the body weight. According to the 2020–2025 Dietary Guidelines for Americans, calcium is considered a “nutrient of public health concern.”

The RDA for calcium is 1,000 mg/day for adults aged 19–50. For females age 51 and older and males over age 70, the RDA increases to 1,200 mg/day. Comparatively, for children aged 9–18, the RDA is actually slightly higher at 1,300 mg/day to account for increased bone mass as a result of growth and development. The UL for adults is 2,000–2,500 mg/day.

Calcium content is highest in dairy products. One 8-ounce glass of cow's milk, which contains about 300 mg of calcium, supplies about one-third of the RDA for adults aged 19–50. Other equivalent dairy foods are 1/2 ounce of cheese and 1 cup of yogurt. In the United States, dairy products supply approximately 75 percent of the daily calcium intake for 283 adults. Other quality sources are fish with small bones, such as sardines and canned salmon, dark-green leafy vegetables (particularly broccoli, kale, and turnip greens), tofu, legumes, and nuts. For individuals with lactose intolerance, the use of yogurt, lactase enzymes, or smaller portions of cow's milk may be helpful. For the average adult, only about one-third of the calcium consumed in the diet is absorbed.

- The physiological functions of calcium, such as nerve cell transmission, take precedence over the formation of bone tissue. If the diet is low in calcium for a short time, the body can mobilize some from the skeleton through the action of hormones, such as parathyroid hormone and calcitriol (the hormonal form of vitamin D), to maintain an adequate amount in ionic form.
- The vast majority of body calcium, about 98 percent, is found in the skeleton, where it gives strength by the formation of salts such as calcium phosphate. One percent is used for tooth formation; the remainder, which exists in an ionic state or in combination with certain proteins, exerts considerable influence over human metabolism.
- Calcium activates many enzymes; in this capacity, it plays a central role in both the synthesis and breakdown of muscle glycogen and liver glycogen.
- Those individuals at the greatest risk for inadequate calcium intake include middle-aged and older females (50 years and older).
- Other groups of people who may be at risk for calcium inadequacy include Individuals with lactose intolerance or an allergy to cow's milk. Individuals with an eating disorder, including anorexia nervosa, may interfere with calcium metabolism. Some individuals follow a predominantly plant-based diet and consume no dairy products, particularly vegans, are at greatest risk. Athletes also exhibit signs of relative energy deficiency in sport (RED-S).

ii. Phosphorus (P):

Phosphorus is the second most abundant mineral in the body after calcium. Like calcium, a significant amount of the phosphorus in the human body, about 85 percent, is found as part of teeth and bones. The adult RDA is 700 mg/day for both males and females. Higher amounts are needed during periods of rapid skeletal growth, particularly between the ages of 9 and 18 years.

Phosphorus is distributed widely in foods. Indeed, all natural foods contain phosphorus as inorganic phosphate salts or organic molecules. Excellent sources include dairy foods such as cow's milk and cheese, seafood, meat, eggs, nuts, seeds, grain products, and a wide variety of vegetables. In some foods, phosphorus is also a part of phytate, which may diminish the absorption of minerals like calcium, iron,

zinc, and copper by forming insoluble phosphate salts in the intestine. A calcium:phosphorus ratio of up to 1:2 may be compatible with bone health; however, ratios of 1:4 may be associated with osteoporosis. Similar to too much phosphorus impacting the bioavailability of calcium, too much calcium can also impair phosphorus absorption and eventually lead to phosphorus insufficiency and osteoporosis.

- Phosphorus is a critically important element in every cell in the body. About 80–90 percent of the phosphorus in the body combines to form calcium phosphate, which is used for the development of bones and teeth. As with calcium, the bones represent a sizable store of phosphate salts.
- Other phosphate salts, such as sodium phosphate, are involved in acid-base balance. The remainder of the body phosphates are found in a variety of organic forms, including the phospholipids, which help form cell membranes, and DNA.

iii. **Magnesium (Mg):**

Magnesium is the sixth most abundant mineral found in the body. The mineral plays an important role in energy metabolism, muscle activity, and heart health. The adult RDA for magnesium is 400–420 mg/day for males and 310–320 mg/day for females. Magnesium is widely distributed in foods, particularly nuts, seafood, green leafy vegetables, other fruits and vegetables, black beans, and whole-grain products. One cup of cooked spinach provides approximately 160 mg of magnesium, which is about half of the adult female RDA for the mineral.

The body stores about 50–60 percent of its magnesium in the skeletal system, which may serve as a reserve during short periods of dietary deficiency.

- Magnesium influences bone metabolism and helps prevent bone fragility. Only about 1 percent is in the extracellular fluid, but the remainder is found in soft tissues such as muscle, where it is a component of numerous enzymes.
- Magnesium is involved in more than 300 essential metabolic reactions, many of which are important to the physically active individual, including neuromuscular, cardiovascular, and hormonal functions.
- Magnesium also helps block some of the actions of calcium in the body, such as contraction in both the skeletal and smooth muscles.

5.6.3 Trace Minerals

Trace minerals are those needed in quantities less than 100 mg per day. For several, the body needs only extremely minute amounts, such as a few micrograms per day. The trace minerals include chromium, fluoride, copper, iodine, iron, manganese, molybdenum, selenium, and zinc.

i. Iron (Fe):

Iron is a metallic element that exists in two general forms, ferrous (Fe^{2+}) and ferric (Fe^{3+}). According to the 2020–2025 Dietary Guidelines for Americans, iron is considered a “nutrient of public health concern” for certain populations, including young children, females capable of becoming pregnant, and females who are pregnant. Depending upon age and sex, the average individual needs to replace about 1.0–1.5 mg of iron that is lost from the body daily. The RDA for adult males is 8 mg/day, and for adult females aged 19–50 is 18 mg/day. For example, pregnant females need 27 mg/day, whereas postmenopausal females need only 8 mg/day.

Dietary iron comes in two forms. Heme iron is associated with hemoglobin and myoglobin and is found only in animal foods, such as meat, chicken, and fish. About 35–55 percent of the iron found in meat is heme iron, the percentage being somewhat higher in beef as compared to chicken and fish. Non-heme iron is found in both animal and plant foods. Heme iron has greater bioavailability than non-heme iron. Indeed, about 15–35 percent of heme iron is absorbed from the intestines compared to only 2–20 percent for nonheme iron.

- Iron in the body is the formation of compounds essential to the transportation and utilization of oxygen. The vast majority is used to form hemoglobin, a protein-iron compound in the RBC that transports oxygen from the lungs to the body tissues. Other iron compounds include myoglobin, the cytochromes, and several Krebs-cycle metalloenzymes, which help use oxygen at the cellular level.
- The iron in the blood, serum ferritin, is used as an index of the body's iron stores, as are some other markers such as transferrin, protoporphyrin, and hemoglobin. Approximately 30 percent of the body's iron is in storage form, while the remaining 70 percent is involved in oxygen metabolism.

ii. Copper (Cu):

Copper is a vital mineral that is a component of several enzymes. The RDA for copper is 900 mcg/day for adults aged 19–50, but amounts vary for other age groups. The UL for adults is 10,000 mcg/day. Food Sources Copper is widely distributed in foods and is found in high amounts in seafood, meats, nuts, beans, whole-grain products, and foods containing chocolate.

- Copper serves a prominent role as a cofactor for metalloenzymes, known as cuproenzymes, most of which are involved in oxidation processes.
- Copper also works closely with iron in oxygen metabolism. It is needed for the absorption of iron from the intestinal tract, helps in the formation of hemoglobin, and is involved in the activity of a specific cytochrome (cytochrome C oxidase), an oxidative enzyme in the mitochondria.

- Copper is also a component of ceruloplasmin, a glycoprotein in the plasma, and is in superoxide dismutase (SOD), an enzyme that functions as an antioxidant to quench free radicals.

iii. Zinc (Zn)

Zinc is a blue-white metal that is an essential nutrient for humans and is widespread in a variety of foods. The RDA for zinc is 11 mg/day for adult males and 8 mg/day for adult females. Good sources of zinc are meat, cow's milk, and seafood, particularly oysters. Three ounces of meat contain approximately 30–50 percent of the RDA, whereas only one oyster will provide more than 70 percent. Whole-grain products and legumes also contain significant amounts of zinc, but the phytate and fiber content will slightly decrease its bioavailability. Zinc is lost in the milling process of wheat, but some breakfast cereals are fortified to 25–100 percent of the RDA. In general, if you receive enough protein in your diet, you will obtain the RDA for zinc.

- Zinc is found in virtually all tissues in the body. Total body zinc is approximately 1.5 grams in females and 2.5 grams in males.
- Zinc has a large number of physiological functions, which may be related to its key role in the activity of more than 300 enzymes.
- It is involved in the Promotion of immune system functions, eye health, and wound healing.
- It helps in the Production of energy via the lactic acid energy system, the Synthesis of DNA, protein, and insulin and the Regulation of gene expression.

iv. Chromium (Cr):

Chromium is a very hard metal that exists in various oxidative states, with chromium III and chromium IV being the most important to human health. Chromium VI, hexavalent chromium, is an industrial waste product that, when inhaled or consumed, has been associated with an increased risk of cancer. The AI for chromium is 20–25 mcg/day for females and 30–35 mcg/day for males. Good sources of chromium include whole-grain products, organ meats, egg yolks, pork, oysters, nuts, and fruits and vegetables. Broccoli is a rich source of chromium, with one-half cup providing approximately 25 percent of the AI for chromium. Chromium is poorly absorbed from the intestinal tract; less than 1 percent is absorbed when intakes are within the AI range. At lower dietary intakes, absorption is somewhat increased.

- Chromium is particularly important in optimizing insulin activity, ultimately playing an important role in carbohydrate and lipid metabolism.

- Chromium is considered to be an essential component of the glucose-tolerance factor (GTF) associated with insulin in the proper metabolism of blood glucose. By enhancing the action of insulin, allowing glucose to enter cells, chromium, as a part of GTF, is important for carbohydrate, fat, and protein metabolism.
- Chromium helps maintain blood glucose levels, promotes glycogen formation in the muscles, and helps promote muscle tissue synthesis.

Self-Assessment Questions:

Multiple choice questions:

1. Which of the following is not considered a major mineral?
A. Phosphorus B. Iron
C. Sodium D. Sulfur
2. A deficiency of iron is most common in which of the following groups?
A. Older females B. older males
C. Young adult females D. Young adult males
3. Which of the following is the best source of heme iron?
A. Steak B. Whole-grain cereal
C. low-fat cow's milk D. Broccoli
4. The active form of vitamin A is:
A. Beta-carotene B. Retinol
C. Carotene D. Calcitriol
5. The RDA for vitamin E in adults is:
A. 5 mg B. 10 mg
C. 15 mg D. 20 mg

Short question answers

1. How is vitamin D synthesized in the body?
2. What is the main function of vitamin E in the body?
3. Which fat-soluble vitamin can also be classified as a hormone?
4. Explain which athletes are at the greatest risk for iron-deficiency anemia and contrast dietary sources of heme and nonheme iron.
5. What are the fat-soluble vitamins, and what is the physiologically active form of vitamin A?

Activity-Based Questions:

1. Design a day's meal plan for a vegetarian athlete to ensure adequate intake of Vitamins A, D, E, and K. Mention the key food sources.
2. A sprinter shared her daily food log:
 - Breakfast: Toast + jam + tea
 - Lunch: White rice + chicken curry
 - Dinner: Roti + dal
 - Snacks: Biscuits + cola

Identify two water-soluble vitamins likely to be low in this diet. Suggest 2 food swaps to improve vitamin intake.

3. Explain which athletes are at the greatest risk for iron-deficiency anemia and what recommendations you might make to these athletes to prevent and/or treat the anemia. Contrast dietary sources of heme and nonheme iron. What are the factors that increase the bioavailability of iron?

Recommended Books:

Antonio, J., Kalman, D., Stout, J. R., Greenwood, M., Willoughby, D. S., & Haff, G. G. (2008). *Essentials of sports nutrition and supplements*. Humana Press.

Driskell, J. A. (2007). *Sports nutrition: Fats and proteins*. CRC Press.

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Unit -6

WATER, ELECTROLYTES AND TEMPERATURE REGULATION

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INTRODUCTION

Water is the most important nutrient and, except for minerals, the simplest nutrient. The average individual can survive several weeks without food but only a week without water. Rapid losses of water and electrolytes through dehydration or diarrhea can be fatal in an even shorter period. Water is the solvent for the body's chemical processes and accounts for most of our body mass.

Our ability to derive energy from nutrients in food requires water for the chemical reaction known as hydrolysis. Electrolytes, part of the mineral class of nutrients discussed in the previous chapter, have a myriad of physiological roles, some of which are muscle contraction, neural action potentials, cofactors in energy metabolism, and activation of enzymes. Although electrolyte balance is normally tightly regulated by the body and adequate electrolyte intake is available in a healthy diet, a significant loss of electrolytes accompanies the loss of water by profuse sweating, vomiting, or diarrhea.

Deaths in children less than 5 years of age have dropped 47 percent since 1990 due in part to the standard WHO oral rehydration therapy (ORT) solution (sodium, potassium, chloride, and glucose) to rapidly replace lost fluid and electrolytes. However, diarrhea still accounts for 9 percent of all deaths in this age group and is the fourth leading cause of death of young children in certain regions of Africa and Southeast Asia. In addition to health, proper fluid replacement and electrolyte balance are important for performance in recreational/competitive sports and in the workplace.

Physically active individuals are aware that a hot and/or humid environment can impair performance. Environmental and metabolic heat results in loss of body water and electrolytes, which compromises the body's ability to dissipate heat and regulate core temperature. At best, loss of fluid and electrolytes will impair performance.

Inability to regulate core temperature can lead to heat illness, the most extreme form of which can be fatal. This chapter will discuss the roles of water and the key electrolytes sodium, chloride, and potassium in fluid regulation and performance; the effects of water and electrolyte loss on performance; strategies for proper hydration before exercise and proper rehydration during and after exercise; the recognition and prevention of heat illnesses; and the role of fluid/electrolyte balance, diet, and exercise in high blood pressure.

LEARNING OBJECTIVES

After studying this unit, the students will be able to:

1. Identify the principal water compartments in the body, describe the general function of each, and explain how your body maintains overall water balance.
2. Describe how exercise in the heat may impair endurance performance as compared to exercise in a cooler environment, and explain the physiological responses your body would make to promote heat loss.
3. Outline the key guidelines for consuming water, electrolytes, and carbohydrate before, during, and after exercise under warm or hot environmental conditions, and offer general recommendations to athletes participating in such events.

6.1 ROLE OF WATER & ELECTROLYTES IN THE BODY

Hydration and Exercise

Exercise leads to fluid loss through both sweat and water vapor in the breath. If not replenished, dehydration can occur, negatively impacting performance and health. This chapter explains the importance of hydration, the best times to drink, and how much fluid is needed before, during, and after exercise. It also explores sports drinks and their benefits compared to water, as well as the effects of alcohol on performance.

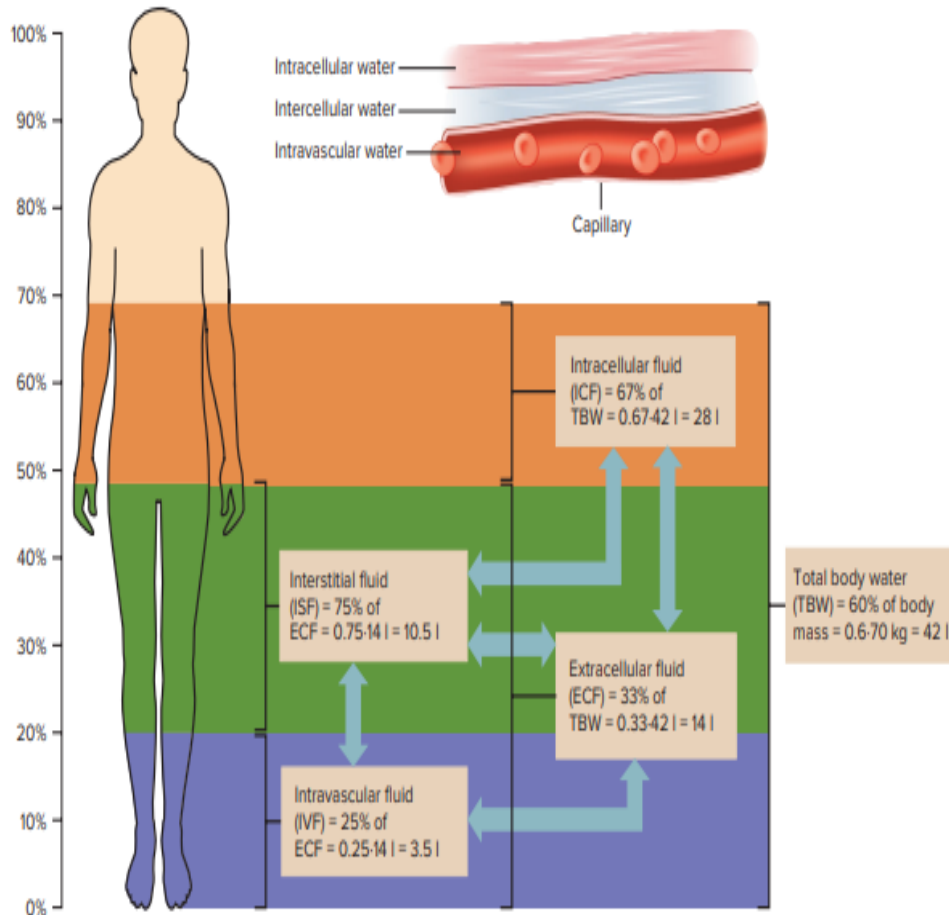


Figure 11: Body-water compartments in the 70-kg reference male. As illustrated by the blue arrows, there is a constant interchange among the different body-water compartments. The water inside the body cells, the intracellular water, is important for cell functions. The extracellular space includes intercellular, intravascular, and miscellaneous (e.g., cerebrospinal fluid). The intracellular water constitutes about 60–65 percent of the total body water, while the extracellular water constitutes the remaining 35–40 percent. In the blood, some of the water is intracellular in the blood cells, while the remainder is extracellular in the plasma. Decreases in blood volume (intravascular water) may adversely affect endurance capacity.

Why Do We Sweat?

When muscles work, they generate heat—about 75% of the energy used during exercise is converted into heat. To maintain a safe internal temperature (37–38°C), the body releases heat primarily through sweating. Water carried to the skin evaporates, cooling the body. For every liter of sweat evaporated, around 600 kcal of heat energy is lost.

Factors Affecting Fluid Loss

Sweat production, and thus fluid loss, depends on:

- Exercise intensity and duration
- Temperature and humidity
- Individual body chemistry

On average, a person loses about 1 liter of fluid per hour of exercise, with losses increasing in hot and humid conditions. Strenuous activities like marathon running can result in up to 2 liters of sweat loss per hour.

Individual Differences in Sweating

Sweat levels vary based on:

- **Body size:** Smaller individuals sweat less.
- **Fitness level:** Fitter people sweat more efficiently due to improved thermoregulation.
- **Gender:** Women generally sweat less than men due to smaller body size and better fluid retention.
- **Personal factors:** Some people naturally sweat more than others.

Measuring Fluid Loss

To estimate sweat loss, weigh yourself before and after exercise. A 1 kg weight loss equates to approximately 1 liter of fluid lost. This helps determine how much fluid you need to replenish for optimal hydration.

6.2 FLUID, CARBOHYDRATE, AND ELECTROLYTE REPLACEMENT The Risks of Dehydration

Excessive fluid loss negatively impacts both performance and health. As dehydration progresses, blood volume decreases, and body temperature rises, putting extra strain on the heart, lungs, and circulatory system. This makes exercise more difficult and reduces overall performance.

A fluid loss of just 2% of body weight can impair exercise capacity, reducing maximal aerobic performance by 10–20%. At 4% loss, nausea, vomiting, and diarrhea may occur. A 5% loss results in a 30% drop in aerobic capacity, while an 8% loss can cause dizziness, breathing difficulties, weakness, and confusion. Severe dehydration can lead to dangerous health consequences, including heat stroke.

Ironically, dehydration reduces sweating efficiency. Since blood volume drops due to fluid loss, the body prioritizes muscle circulation over skin cooling, causing an increase in body temperature. Without rehydration, a vicious cycle of rising body temperature and fatigue can result in heat stroke.

How to Reduce Fluid Loss

While fluid loss is a natural part of thermoregulation, dehydration can be minimized by:

- Staying well-hydrated before exercise
- Drinking sufficient fluids during and after workouts
- Replenishing fluids consistently throughout the day

Signs of Dehydration

Many athletes and non-athletes experience mild dehydration without realizing it. Since dehydration is cumulative, failing to rehydrate properly between training sessions can lead to progressive fluid loss over days.

Common symptoms of dehydration include:

- Sluggishness and fatigue
- Headaches
- Loss of appetite
- Feeling excessively hot
- Lightheadedness and nausea

A simple way to monitor hydration is by observing urine color. Pale yellow urine indicates proper hydration, while dark, concentrated urine suggests dehydration. Many trainers and coaches recommend using urine color as a hydration status indicator.

Why Do Sports Drinks Contain Sodium?

Sodium in sports drinks doesn't directly enhance performance but serves important functions:

- **Encourages Drinking** – Sodium increases thirst by stimulating the urge to drink, preventing dehydration. Drinking plain water can dilute sodium in the blood, reducing the urge to drink before full hydration is achieved.

- **Enhances Palatability** – A small amount of sodium (0.5–0.7 g/l) makes sports drinks taste better, making athletes more likely to drink enough fluids.
- **Does Not Improve Fluid Absorption** – Research found that sodium in sports drinks doesn't directly speed up water absorption. Instead, the body regulates sodium levels naturally in the intestines.

Why Do Sports Drinks Contain Carbohydrates?

Carbohydrates in sports drinks serve two key purposes:

- **Speeds up Fluid Absorption**—Studies show that dilute sugar solutions (hypotonic or isotonic drinks, 5–8 g carbohydrate per 100 ml) improve water absorption from the intestines into the bloodstream.
- **Provides Energy** – During prolonged or high-intensity exercise, consuming carbohydrates helps maintain blood glucose levels, preventing fatigue and enhancing endurance.
- **High-Carb Drinks Slow Absorption** – Drinks with >8% carbohydrates (hypertonic drinks) delay stomach emptying, slowing down hydration.

6.3 ERGOGENIC ASPECTS

6.3.1 When, What, and How Much Should You Drink?

1. Before Exercise

Ensuring proper hydration before exercise is crucial, as beginning a workout or competition in a dehydrated state can negatively impact performance. Studies show that even a 2% decrease in body weight due to dehydration can significantly reduce running speed. To stay hydrated before exercise:

- Monitor urine color and volume—pale yellow urine indicates good hydration.
- Drink 400–600 ml of fluids two hours before exercise to allow time for absorption and excretion of excess water.
- Avoid excessive fluid intake, as overhydration can lead to water intoxication.
- Water is ideal, but for workouts lasting over an hour at high intensity, a sports drink with carbohydrates may help maintain blood glucose levels.

Can You "Fluid Load" Before Exercise?

Hyperhydration may benefit endurance athletes, especially in hot and humid conditions or events with limited drinking opportunities. However, simply drinking excessive water leads to frequent urination, preventing effective fluid retention.

An alternative method involves consuming glycerol with fluids two hours before exercise. Glycerol increases total body fluid by drawing water into cells, potentially enhancing hydration, sweating efficiency, and temperature regulation. Studies have shown that athletes retained an extra 600 ml of fluid and improved performance by

2.4%. However, another study found no performance boost from hyperhydration with creatine and glycerol. Possible side effects include digestive discomfort and headaches.

2. During Exercise

Once exercise begins, fluid loss is inevitable. To prevent dehydration: Start drinking early and consistently throughout your workout

- Aim to limit dehydration to less than 2% of body weight. For example, this means 1 kg for a 50 kg person, 1.5 kg for a 75 kg person, and 2 kg for a 100 kg person.
- Replace at least 80% of sweat loss to maintain performance.
- Drink according to thirst—excess fluid intake can lead to hyponatremia (water intoxication).
- If exercising for over four hours in warm weather, limit intake to no more than 800 ml per hour and opt for a sports drink with sugar and electrolytes instead of plain water.

Best Drinks for Different Exercises

- Low/moderate-intensity exercise (<1 hour): Plain water is sufficient.
- High-intensity exercise (<1 hour): A sports drink with up to 8g sugar/100ml may enhance performance.
- High-intensity exercise (>1 hour): Rapid fluid and carbohydrate replenishment are necessary to prevent dehydration, glycogen depletion, and low blood sugar. Consume 20–60g carbohydrate/hour.

During hot and humid conditions, increase drink volume and opt for a diluted sports drink (20–40g carbohydrate/L) to aid absorption. Some athletes prefer glucose polymer-based drinks, which provide both fuel and fluid. However, many experience stomach discomfort, making sports drinks with 4–8g carbohydrate/100ml a more practical choice.

Choosing the Right Type of Drink

Exercise Conditions	Recommended Drink
Exercise lasting <30 minutes	No drink needed; water is optional
Low–moderate intensity exercise (<1 hour)	Water

High-intensity exercise (<1 hour)	Hypotonic or isotonic sports drink
High-intensity exercise (>1 hour)	Hypotonic or isotonic sports drink, or glucose polymer drink

1. After exercise:

To restore normal fluid balance after exercise, researchers recommend that you consume approximately 1.2–1.5 times the weight of fluid lost during exercise. The simplest way to work out how much you need to drink is to weigh yourself before and after training.

- Working on the basis that 1 litre of sweat is roughly equivalent to a 1 kg body weight loss, you need to drink 1.2–1.5 fluid for each kg of weight lost during exercise.
- You should not drink all this amount straight away, as a rapid increase in blood volume promotes urination and increases the risk of hyponatraemia.
- Consume as much as you feel comfortable with, then drink the remainder in divided doses until you are fully hydrated.
- Sports drinks may be better than water at speeding recovery after exercise, particularly when fluid losses are high or for those athletes who train or compete twice a day. The problem with drinking water is that it causes a drop in blood osmolality (i.e. it dilutes sodium in the blood), reducing your thirst and increasing urine output and so you may stop drinking before you are rehydrated.
- A low sodium concentration in the blood signals to the brain a low thirst sensation. Conversely, a high sodium concentration in the blood signals greater thirst and thus drives you to drink. Hence, the popular strategy of putting salted peanuts and crisps at the bar is to encourage customers to buy more drinks to quench their thirst.
- It is known that more concentrated drinks empty more slowly from the stomach and are absorbed more slowly from the intestines, which would explain the increased gastrointestinal discomfort. Many people find that diluting sports drinks helps alleviate these problems, but there's a balance to be struck between obtaining enough carbohydrate to fuel your exercise and avoiding GI discomfort. If the drink is too dilute, you may not consume enough carbohydrate to achieve peak performance.
- A study also suggests that consuming a drink containing carbohydrate with a small amount of protein improves fluid retention after exercise. Those athletes who consumed the carbohydrate-protein drink retained 15% more fluid than carbohydrate-only and 40% more than water alone.

6.3.2 Types of Sports Drinks

Sports drinks can be categorized into two main types:

Fluid Replacement Drinks

- Contain electrolytes and carbohydrates (sugars such as glucose, sucrose, fructose, and maltodextrins).
- Help replace fluids lost through sweat while maintaining blood sugar levels and preserving glycogen stores.
- Available in **hypotonic** or **isotonic** formulations.

Carbohydrate (Energy) Drinks

- Contain a higher carbohydrate concentration than fluid replacement drinks, mainly in the form of glucose polymers (maltodextrins).
- Provide sustained energy while maintaining fluid balance.
- Typically, **isotonic** when ready-to-drink, but can be **hypotonic** or **isotonic** when mixed from powder.

6.3.3 Hypotonic, Isotonic, and Hypertonic Drinks

- **Hypotonic Drinks:**

It has a Lower concentration of carbohydrates and electrolytes than body fluids, and absorbs faster than plain water. It typically contains <4 g carbohydrate per 100 ml and is marketed as "sports water" for rapid hydration.

- **Isotonic Drinks**

It contains a similar concentration of carbohydrates and electrolytes as body fluids i.e. 04–8 g carbohydrate per 100 ml. It provides the best balance of hydration and energy replenishment.

- **Hypertonic Drinks**

It contains a **higher** concentration of carbohydrates than body fluids and is absorbed **more slowly** than water. It typically has **>8 g carbohydrate per 100 ml**. Examples: soft drinks, fruit juices, and energy drinks.

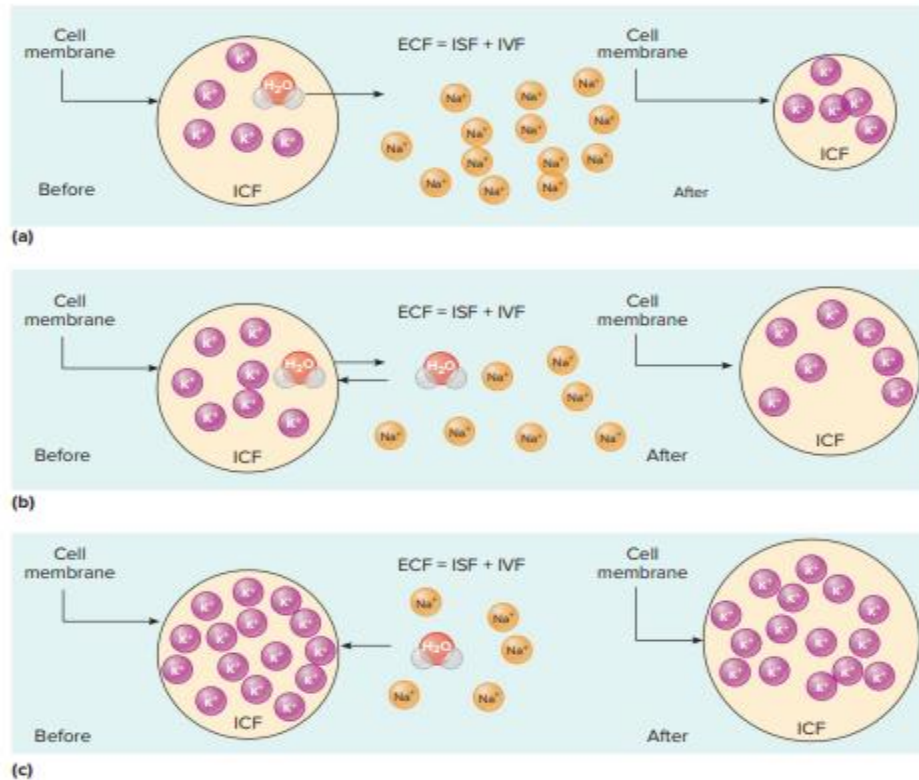


Figure 12: Osmosis and tonicity. (a) When the extracellular fluid (ECF) contains more electrolytes or other osmotic substances, it is hypertonic to the intracellular fluid (ICF) and water will flow from the ICF space to the ECF space (interstitial fluid [ISF] + intravascular fluid [IVF]) and the cell decreases in volume. In other words, water flows to the area of greater osmotic pressure. (b) When the solute concentration is the same in the cell and outside the cell, there is no net gain or loss of water from either space; therefore, there is no change in cell volume. (c) When the ICF contains more electrolytes or higher osmotic pressure than the ECF, water will flow into the ICF space from the ECF space, and the cell increases in volume.

6.4 HEALTH ASPECTS

Heat illness refers to a range of health issues caused by environmental heat stress. It poses a serious risk to athletes and physically active individuals, particularly during exercise in hot and humid conditions.

Hydration and Heat Stress

While staying hydrated is essential for performance, both dehydration and overhydration can be dangerous. Dehydration impairs performance and increases the risk of heat illness. On the other hand, drinking excessive amounts of water without proper electrolyte replacement may lead to exercise-associated hyponatraemia, a potentially life-threatening condition.

Exercising in the Heat

The American College of Sports Medicine (ACSM) provides clear guidelines on how to modify or cancel exercise in hot environments. These are based on the Wet-Bulb Globe Temperature (WBGT), a measure that accounts for temperature, humidity, wind, and solar radiation. If WBGT is not available, the heat index from weather forecasts can serve as a reasonable substitute, especially for shaded exercise. Higher heat index values indicate greater heat stress risk.

Risks of Heat Illness

Excessive heat stress can lead to multiple health issues. Studies show increased rates of conditions such as cardiovascular disease, diabetes, kidney failure, and intestinal infections during periods of high heat. From 2004 to 2018, the U.S. averaged over 700 heat-related deaths annually. Non-metropolitan areas often face higher risks, emphasizing the need for region-specific prevention strategies. Three main contributors to heat injuries include:

1. Elevated core temperature
2. Loss of body fluids
3. Loss of electrolytes

However, heat illness can occur even in cooler weather or during rest, particularly in susceptible individuals. The effects of heat on the body involve complex mechanisms, such as reduced blood flow to organs, inflammation, and potential multi-organ failure.

1. Heat Syncope

Also known as exercise-associated collapse, this involves fainting due to blood pooling in the legs and reduced return to the heart and brain. It's usually triggered by excessive vasodilation and reduced blood pressure. This can occur after stopping intense exercise, especially if the muscles stop contracting. Keeping the legs moving post-exercise helps reduce this risk.

2. Heat Cramps

These painful muscle spasms are more likely in hot, humid conditions. They are linked to salt and fluid loss, combined with muscle fatigue. Prevention and treatment include:

- Drinking a salt solution at the first sign of muscle twitching ($\frac{1}{2}$ tsp salt in 16 16-oz sports drink).
- Using electrolyte supplements.
- Increasing dietary salt intake for prone individuals.

3. Heat Exhaustion

A common form of heat illness, usually resulting from dehydration and prolonged heat exposure. Symptoms include Fatigue, dizziness, fainting, Rapid pulse, headache, Nausea, vomiting, chills, and muscle cramps. Rectal temperature is usually below 104°F (40°C). Cooling and fluid replacement typically resolve symptoms within hours.

4. Heat Stroke

This is the most severe and life-threatening heat illness. It can occur during exercise (exertional heat stroke) or at rest, especially in older adults. Risk factors include:

- High heat/humidity (WBGT > 28°C)
- Strenuous exercise
- Dehydration
- Lack of heat acclimatization or physical fitness
- Obesity
- Use of medications (e.g., stimulants, antihistamines, NSAIDs)
- Genetic factors (e.g., sickle cell trait)

Signs of exertional heat stroke include Rectal temperature above 104°F (40°C), Confusion, disorientation, agitation, irrational behavior, Collapse, seizures, or coma, Rapid pulse, vomiting, and hyperventilation. Heat stroke requires immediate medical attention and may lead to rhabdomyolysis (muscle breakdown), kidney damage, and even death if not treated promptly.

Self-Assessment Questions:

Short Question Answers:

1. How does dehydration affect exercise performance?
2. How can you estimate how much fluid you've lost during exercise?
3. What role does sodium play in sports drinks?
4. Why are carbohydrates added to sports drinks?

Fill in the Blanks:

1. _____ reduces blood volume and increases body temperature.

2. _____ in sports drinks encourages drinking and enhances palatability.
3. Drinks with more than **8%** carbohydrates are considered _____.
4. After exercise, drink fluids equal to _____ the amount of weight lost.
5. _____ can be consumed before exercise to increase total body water retention.

Activity-Based Questions:

1. Provide a diagram of a hydration pyramid (Before, During, and After Exercise)
 - Label the ideal drink type at each stage.
 - Indicate the recommended fluid intake amounts.
2. Describe at least five of the potential health benefits associated with resistance training.

Recommended Books:

Antonio, J., Kalman, D., Stout, J. R., Greenwood, M., Willoughby, D. S., & Haff, G. G. (2008). *Essentials of sports nutrition and supplements*. Humana Press.

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Unit -7

BODY WEIGHT AND COMPOSITION

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INTRODUCTION

Most individuals have a perception of an “ideal” body weight for standing height, age, and gender that is usually related to physical appearance. Most research efforts have attempted to find an ideal body weight for good health. Enhanced physical appearance may also improve one’s body image and self-esteem, factors important to psychological health. Although society may create a perception of an ideal body weight for appearance, this perceived ideal body weight may or may not be in accord with reality, optimal health, or physical performance. An enhanced physical appearance may also influence performance in certain sports that involve judging aesthetic movements, such as gymnastics and diving. Excess body weight may affect physical performance as well. For some athletes, simply being a little overweight may prove to be detrimental to physical performance because it costs energy to move the extra body mass. In contrast, increased body weight, provided it is of the right composition, may be advantageous to other athletes. At the other end of the body-weight continuum, weight losses leading to excessive thinness also may have an impact on health and physical performance. Although losing excess body fat may improve performance in some sports, excessive weight loss may harm both health and athletic performance.

LEARNING OBJECTIVES

After studying this unit, the students will be able to:

1. List the various components that constitute human body composition.
2. Describe the various techniques used to assess body composition and discuss the general uses and limitations of such techniques.
3. Identify body mass index and body fat values associated with underweight, overweight, and degrees of obesity.
4. Outline the health problems that are associated with obesity in both adults and youth.

7.1 BODY MASS INDEX

The BMI assumes that there is no single ideal weight for a person of a certain height, and that there is a healthy weight range for any given height. The BMI is calculated by dividing a person's weight (in kg) by the square of his or her height (in m). Researchers and doctors use BMI measurements to assess a person's risk of acquiring certain health-related conditions, such as heart disease. Studies have shown that people with a BMI of between 18.5 and 25 have the lowest risk of developing diseases that are linked to obesity, e.g., cardiovascular disease, gall bladder disease, hypertension (high blood pressure), and diabetes.

Disease Risk Relative to Normal Weight and Waist Circumference*			
		Normal Risk Visceral Fat Deposition*	High Risk Visceral Fat Deposition*
Category	BMI (kg/m ²)	Men ≤102 cm (40 inches); Female ≤88 cm (35 inches)	Men >102 cm (40 inches); Females >88 cm (35 inches)
Underweight	<18.5	–	–
Normal	18.5–24.9	–	–
Overweight	25.0–29.9	Increased	High
Obesity I	30.0–34.9	High	Very high
Obesity II	35.0–39.9	Very high	Very high
Obesity III	≥40	Extremely high	Extremely high

*Research suggests that waist sizes greater than 37 inches in men and 31.5 inches in women may increase health risks when accompanied by other conditions, such as high blood pressure.

Source: National Heart, Lung, and Blood Institute of the National Institutes of Health www.nhlbi.nih.gov/health/educational/lose_wt/BMI/bmi_dis.htm.

Figure 13: Classification of disease risk based on body mass index and waist circumference

Limitations of the BMI

BMI does not give information about body composition, i.e., how much weight is fat and how much lean tissue. It simply gives the desirable weight of average people. When you stand on the scales, you weigh everything – bone, muscle, water, and fat. Therefore, you do not know how fat you are.

- Individuals who are athletic and/or have a muscular build may be overweight. Bodybuilders would be classified as overweight or obese, as muscle weighs more than fat.
- Body fat can be underestimated in individuals who have little muscle or who have lost muscle mass. This often occurs with older people.
- Scientists believe that the distribution of your body fat is more important than the total amount of fat. This gives a more accurate assessment of your risk of metabolic disorders, such as heart disease, type 2 diabetes, high blood pressure, and gallbladder disease. Fat stored mostly around the

abdomen (visceral fat) gives rise to an ‘apple’ or ‘barrel’ shape, and this carries a much bigger health risk than fat stored mostly around the hips and thighs in a pear shape.

- For most people, visceral fat is the largest store and is one of the first places where excess fat is laid down. When the store gets too large, it pumps out inflammatory and clot-producing compounds. This means that a man with a ‘beer belly’ but slim limbs may be at greater risk of heart disease and diabetes than a pear-shaped person with the same BMI but less visceral fat.

7.2 BODY WEIGHT AND COMPOSITION

Body Composition

The human body is made up of many of the same elements found in the earth—about 25 of these elements are essential for healthy body function. Four key elements—carbon, hydrogen, oxygen, and nitrogen—make up about 96% of our body mass. These elements form the basis of important components like proteins, carbohydrates, fats, and water. The remaining 4% consists of minerals, primarily calcium and phosphorus in bones, and other key elements like sodium, chlorine, magnesium, sulfur, and micro minerals such as iron, zinc, iodine, and selenium.

Body Composition Levels

Scientists analyze body composition at different levels:

- Atomic
- Molecular
- Cellular
- Tissue-system
- Whole-body

For practical use, four main components are usually evaluated:

1. Fat Mass in the Body

- Essential fat is required for vital functions. In men, it accounts for ~3% of body weight. In women, it’s higher (12–15%) due to reproductive needs.
- Storage fat is excess energy stored in the body, and about 70–80% of it is subcutaneous fat (just under the skin). The rest, including visceral fat, surrounds organs and is linked to health risks like diabetes, heart disease, and metabolic syndrome. Cellulite is a type of subcutaneous fat often seen in women due to differences in connective tissue and hormones like estrogen.

2. Fat-Free Mass (FFM)

FFM includes **muscles, organs, water, minerals, and glycogen**, but no fat. Skeletal muscle is the largest component. Sometimes the term **lean body mass** is used, which includes **essential fat**.

For example, a person weighing 200 lbs with 30% fat would have:

- 60 lbs fat
- 140 lbs fat-free mass

3. Bone Mineral

Bones make up about 12–15% of total body weight. Roughly 3–4% of body weight comes from bone minerals like calcium and phosphorus.

4. Body Water

Water makes up around 60% of adult body weight. Fat-free mass is about 70% water and Fat tissue is less than 10% water. Water content is tightly regulated and varies by tissue type. For instance, blood has high water content, while fat tissue is relatively dry.

Body composition may affect skill and technique. In squash, having excessively high body fat levels may reduce agility and speed as well as heat tolerance, whilst having excessively low body fat levels may mean an athlete lacks endurance or is not consuming adequate nutrients for training and competition demands. In golf, there is no scientific evidence to show that overweight golfers will improve their game with weight loss; however, there are other benefits, such as improved heat tolerance, endurance, and fitness that may help prevent fatigue and affect skill and concentration.

Anthropometry (2)	Measures body segment girths to predict body fat
Bioelectrical impedance analysis (BIA) (2)	Measures resistance to electrical current to predict body-water content, lean body mass, and body fat
Body plethysmography (2)	Whole-body plethysmograph measures air displacement and calculates body density; comparable to water displacement protocol used in underwater weighing
Computed tomography (CT) (3)	X-ray scanning technique to image body tissues; useful in determining subcutaneous and deep fat to predict body-fat percentage; used to calculate bone mass
Dual energy X-ray absorptiometry (DEXA; DXA) (3)	X-ray technique at two energy levels to image body fat; used to calculate bone mass
Dual photon absorptiometry (DPA) (3)	Beam of photons passes through tissues, differentiating soft tissues and bone tissues; used to predict body fat and calculate bone mass
Infrared interactance (2)	Infrared light passes through tissues, and interaction with tissue components used to predict body fat
Magnetic resonance imaging (MRI) (3)	Magnetic-field and radio-frequency waves are used to image body tissues similar to CT scan; very useful for imaging deep abdominal fat
Neutron activation analysis (3)	Beam of neutrons passes through the tissues, permitting analysis of nitrogen and other mineral content in the body; used to predict lean body mass
Skinfold thicknesses (2)	Measures subcutaneous fat folds to predict body-fat content and lean body mass
Total body potassium (2)	Measures total body potassium, the main intracellular ion, to predict lean body mass and body fat
Total body water (hydrometry) (2)	Measures total body water by isotope dilution techniques to predict lean body mass and body fat
Ultrasound (2)	High-frequency ultrasound waves pass through tissues to image subcutaneous fat and predict body-fat content
Underwater weighing (hydrodensitometry) (2)	Underwater-weighing technique based on Archimedes' principle to predict body density, body fat, and lean body mass

Figure 14: Methods used to determine body composition using the two (2)- or three (3)-component model

7.3 WEIGHT GAIN, OBESITY, AND HEALTH

According to 2016 WHO data, 340 million children and adolescents aged 5–19 were classified as overweight or obese. Among adults, 39% were overweight and 13% were obese. Alarming, the global obesity rate has nearly tripled since 1975 and continues to rise across all WHO regions.

Health risks increase significantly with fat accumulation in the abdominal region. Adipose tissue, once thought to be merely fat storage, is now known to be metabolically active and plays a role in hormone regulation and immune responses. Dysfunctional fat, referred to as adiposopathy or "sick fat," can disrupt fat storage and increase insulin resistance, inflammation, dyslipidemia, and atherosclerosis. It also produces aromatase, an enzyme that converts androgens to estrogens, potentially contributing to visceral fat and metabolic disease. Adiposopathy is linked to metabolic syndrome, a group of risk factors including insulin resistance, high blood pressure, abnormal lipid profiles, and excessive abdominal fat.

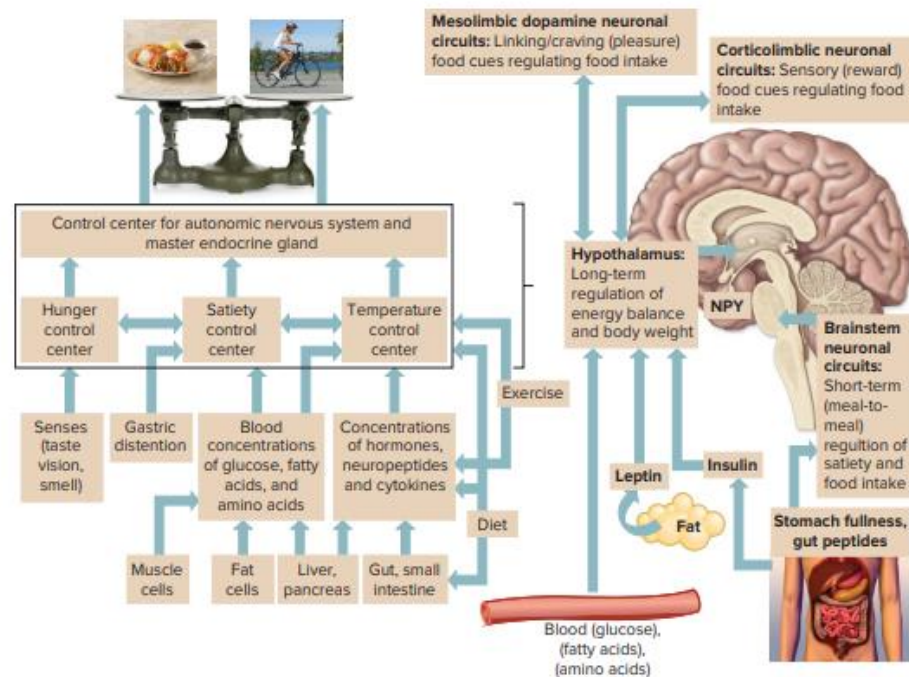


Figure 15: Simplified schematic for afferent and efferent control of energy balance and body weight. According to the setpoint theory, the hypothalamus regulates energy intake and body weight, comparable to its role as a thermostat in regulating body temperature. Increases in the normal body weight would lead to compensations, such as decreased appetite or increased basal metabolic rate, which would lead to weight loss and restoration of normal body weight. The opposite would occur with decreases in the normal body weight. The numerous control centers in the hypothalamus are influenced by feedback from the body, such

as the blood concentration of glucose and other nutrients. Such nutrients may also affect the pleasure/reward center in the brain, which may influence the hypothalamus. Exercise may influence the hypothalamus in a variety of ways, such as stimulating the secretion of several hormones by endocrine glands in the body, stimulating the temperature control center, and modifying blood levels of several nutrients, all of which may affect energy intake and output. Detailed coverage of the many brain structures, peptides, neurotransmitters, and stimuli directly or indirectly regulating energy balance is beyond the scope of this text.

Health Problems Linked to Overweight and Obesity

Obesity contributes to numerous health conditions. These include both the mechanical burden of excess weight and the metabolic effects of hormones and inflammatory markers produced by fat tissue. In 2016, obesity-related healthcare costs in the U.S. reached \$260 billion. Healthcare costs rise substantially with increasing obesity class.

Cardiovascular Disease

Obesity is a well-established risk factor for coronary heart disease (CHD). Some recent studies highlight the “obesity paradox,” where mild to moderate obesity appears to improve survival in heart failure patients, potentially due to protective adipokines and greater physiological reserves. However, obesity remains a key contributor to high blood pressure, high cholesterol, and type 2 diabetes—conditions that all elevate CHD risk.

Type 2 diabetes, in particular, has risen sharply alongside obesity. The term “diabesity” captures the tight link between the two. Resistin, an adipokine from fat tissue, promotes insulin resistance and connects obesity to diabetes. Obesity duration also matters—chronic obesity (10+ years) significantly raises the risk of developing diabetes. From 2001 to 2017, type 2 diabetes prevalence in youth (ages 10–19) increased by 95%, especially in racial and ethnic minorities.

Cancer

Obesity is linked to a higher risk for several cancers, including colorectal, liver, kidney, breast (postmenopausal), prostate, and uterine cancers. The mechanisms include elevated estrogen and inflammatory adipokines, along with reduced protective adiponectin. Obesity also raises insulin-like growth factor-1 (IGF-1) and other growth factors that promote cell proliferation and tumor development. For example, in females with a BMI >25, studies found higher leptin and TNF- α , and lower adiponectin levels—factors associated with increased cancer risk.

Cognitive Decline and Dementia

Obesity during midlife is associated with a higher risk of dementia and Alzheimer’s disease later in life. This is attributed to inflammation and hormonal imbalances caused by adipose tissue. Low adiponectin and high leptin levels may heighten the

risk. Interestingly, in older adults (65+), lower body weight may be linked to increased dementia risk, possibly due to changes in vascular health and adipokine levels.

Maternal and Infant Health

Excess weight before or during pregnancy is associated with increased risks of fetal death, stillbirth, and infant mortality. According to the Institute of Medicine, weight gain recommendations during pregnancy vary by pre-pregnancy BMI. Women with obesity (BMI ≥ 30) are advised to gain only 11–20 pounds during pregnancy to support healthy outcomes for both mother and child.

Mortality, Morbidity, and Quality of Life

Obesity is associated with premature death and numerous chronic conditions. A meta-analysis of 97 studies involving 2.88 million people found that compared to normal-weight individuals (BMI 18.5–24.9), those with grade 2 or 3 obesity (BMI ≥ 35) had a 29% higher risk of all-cause mortality. As of 2017, 8% of global deaths were attributed to obesity, almost double the percentage in 1990. Aside from shortened lifespan, obesity significantly affects quality of life. Maintaining a healthy body weight and composition greatly improves overall health and longevity.

7.4 EXCESSIVE WEIGHT LOSS AND HEALTH

Many fitness enthusiasts and sportsmen want to reduce their weight for competitive, health, or performance reasons. However, losing weight quickly might impair performance and pose major health hazards. Understanding sustainable and safe weight loss techniques is essential. Lifestyle management is the key to long-term weight maintenance, as 95% of dieters regain their lost weight within five years. A safe and effective weight-loss program is built on a balanced diet and regular exercise. However, many people set unrealistic body-weight goals, leading them to unhealthy weight-loss behaviors like extreme starvation, self-induced vomiting, or the misuse of drugs, laxatives, and diet pills.

Dehydration and Electrolyte Imbalance

Dehydration is often caused by excessive exercise, saunas, or the misuse of diuretics and laxatives. This can lead to a dangerous drop in potassium levels (hypokalemia), which can cause:

- Irregular heart rhythms
- Kidney and muscle dysfunction
- Neuromuscular issues
- In severe cases, muscle breakdown (rhabdomyolysis)

For example, a professional bodybuilder developed hypokalemic paralysis after using a strong diuretic combination. He recovered after three days of

hospitalization, but this case shows how electrolyte imbalances from dehydration can be life-threatening. Diuretics are also used to hide the use of banned substances and are prohibited by the World Anti-Doping Agency (WADA), particularly in weight-class sports like boxing, wrestling, and martial arts.

Weight-Loss Medications: Use and Risks

Lifestyle changes, like healthier eating and physical activity, are the first line of treatment for obesity. However, when these aren't enough, medications may be prescribed for those at high risk of obesity-related diseases, not for casual or aesthetic weight loss. Still, even athletes and active individuals sometimes misuse these drugs. Most anti-obesity medications work by suppressing appetite through the brain (anorexiant), increasing energy use (thermogenesis), blocking fat absorption and reducing blood glucose levels (e.g., GLP-1 agonists).

Important Goals of a Healthy Fat Loss Program:

- To lose weight gradually, establish a little calorie deficit.
- Maintain or improve your lean muscle mass
- Reduce the proportion of body fat gradually.
- To maintain long-term weight loss, avoid a large decline in resting metabolic rate.
- Make sure you are getting enough of the important vitamins and minerals.
- Athletes and fitness enthusiasts can reach their weight reduction objectives while preserving their best performance and general health by adhering to these guidelines.

Lowering body fat can enhance athletic performance in many sports. However, it is essential to follow scientifically backed methods for safe and effective fat loss. Unfortunately, many athletes resort to rapid weight loss techniques that negatively impact both performance and overall health. The most common harmful methods include:

- Crash dieting (extreme calorie restriction)
- Dehydration (fluid loss to reduce weight quickly)

While these approaches may lead to temporary weight loss and a leaner appearance, they often come at the cost of performance and well-being.

How Rapid Weight Loss Impacts Performance

- **Reduced Aerobic Capacity:** Losing just 2–3% of body weight through dehydration can lower aerobic performance by up to 5%, and extreme dieting can cause up to a 10% decline.

- **Decreased Anaerobic Performance:** Strength, endurance, and power output can decline with excessive calorie restriction. However, gradual weight loss may actually improve relative strength.

Health Risks of Prolonged Dieting

Long-term or extreme calorie restriction can have serious health effects, including:

- **Female Athletes:** Increased risk of menstrual irregularities, amenorrhea (loss of periods), and stress fractures.
- **Male Athletes:** Reduced testosterone production, which may impact muscle growth and recovery.
- **Increased Risk of Eating Disorders:** Athletes who diet for aesthetic reasons are more likely to develop disordered eating than those focused purely on performance.

Is repeated weight loss harmful?

Repeated weight fluctuations, or yo-yo dieting, have been linked with an increased risk of heart disease, secondary diabetes, gall bladder disease, and premature death. However, researchers are divided as to the exact reason. One explanation is that fat tends to be re-deposited intra-abdominal, closer to the liver, rather than in the peripheral regions of the body, such as the hips, thighs, and arms, and thus poses a greater heart disease risk. Another explanation is that repeated severe dieting can lead to a loss of lean tissue (including organ tissue) and nutritional deficiencies that can damage the heart muscle. Contrary to popular belief, there is no evidence that yo-yo dieting permanently slows your metabolism (it returns to its original levels once normal eating is resumed). But yo-yo dieting can be bad for your psychological health. Each time you regain weight, you experience a sense of failure, which can lower your confidence and self-esteem.

Self-Assessment Questions:

1. BMI gives information about how much of the body is fat vs. muscle. **(true/false)**
2. Muscular athletes may be misclassified as overweight due to high BMI **(true/false)**
3. Visceral fat contributes to heart disease more than fat stored in the thighs. **(true/false)**
4. In sports like squash, too much body fat can reduce agility. **(true/false)**
5. Extreme dieting can lead to a decline in both aerobic and anaerobic performance. **(true/false)**

Short Questions:

1. Why might BMI be misleading for athletes?
2. What are the risks of extreme calorie restriction in female athletes?
3. What can yo-yo dieting negatively affect besides physical health?
4. What does gradual fat loss help prevent in athletes?

Activity-Based Questions:

1. Use the Harris–Benedict equation to estimate your Resting Metabolic Rate (RMR) and design a daily meal plan that meets your RMR without falling below it and includes:
 - 20–25% calories from fat
 - 1.6 g protein/kg body weight
 - 4–7 g carbs/kg body weight
2. Take waist, hip, thigh, and upper arm measurements weekly, record any changes over 4 weeks and note your physical activity.

Recommended Books:

Antonio, J., Kalman, D., Stout, J. R., Greenwood, M., Willoughby, D. S., & Haff, G. G. (2008). *Essentials of sports nutrition and supplements*. Humana Press.

Driskell, J. A. (2007). *Sports nutrition: Fats and proteins*. CRC Press.

Fink, H. H., Mikesky, A. E., & Burgoon, L. A. (2011). *Practical applications in sports nutrition* (3rd ed.). Jones & Bartlett Learning.

Lanham-New, S. A., Stear, S. J., Shirreffs, S. M., & Collins, A. L. (2011). *Sports and exercise nutrition*. Wiley-Blackwell.

Maughan, R. J. (Ed.). (2000). *Nutrition in sport: The encyclopedia of sports medicine*. Wiley-Blackwell.

Soldavini, J. (2019). Practical applications in sports nutrition. *Journal of Nutrition Education and Behavior*, 51(3), 379. <https://doi.org/10.1016/j.jneb.2018.11.013>

Williams, M. H., Anderson, D., & Rawson, E. (2012). *Nutrition for health, fitness, & sport* (10th ed.). McGraw-Hill Education.

Williams, M. H., Anderson, D., & Rawson, E. (2019). *Williams' nutrition for health, fitness and sport* (11th ed.). McGraw Hill Education (UK).

Unit -8

WEIGHT MANAGEMENT-I

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INTRODUCTION

The metabolism of human energy sources is complex, and although the caloric theory is valid relative to body-weight control, one must be aware that weight changes will not always be exactly in line with caloric input and output, and that weight losses may not be due to body-fat loss alone. Also, keep in mind one of the concepts advanced in the last chapter relative to individual variability in metabolic rates; two individuals with the same body weight may consume the same amount of Calories, yet one may gain weight while the other may maintain or even lose weight. It is also important to remember that genetics may affect the rate of weight loss. Other than differences in metabolism, this possibility also may be related to the type of calories in the diet; research has suggested that the body may store dietary fat calories in the adipose tissue more efficiently than carbohydrate or protein calories. In essence, compared to dietary fat, it may take more energy to convert dietary carbohydrate and protein into body fat. A comprehensive weight-control program involves three components: (1) a dietary regimen stressing balanced nutrition but with reduced caloric intake; (2) an aerobic and resistance exercise program to increase caloric expenditure and maintain lean body mass; and (3) a behavior modification program to facilitate the implementation of the first two components. Although proper dieting and exercise are the two keys to weight control, the same diet and exercise plan may not be appropriate for all individuals. It is suggested that there is large inter-individual variability in weight-loss success due to environmental, genetic, and epigenetic influences.

LEARNING OBJECTIVES

After studying this unit , you should be able to:

1. Determine how many calories per day are needed to maintain one's current body weight with either a sedentary or physically active lifestyle.
2. Calculate the amount of weight loss needed to attain a healthier BMI or body-fat percentage.
3. Identify behavior modification techniques that are appropriate to incorporate into a recommended weight-loss program.
4. State the key principles underlying a weight-control diet designed to maintain a healthy body weight for a lifetime.

8.1 BASICS OF WEIGHT CONTROL

When it comes to weight loss, these principles remain consistent, and following guidelines like the 2020–2025 Dietary Guidelines for Americans can help individuals lose weight effectively while promoting long-term health. However, achieving and maintaining weight loss is challenging due to the complex interplay between biology, behavior, and environmental factors. Experts note that about 80–95% of individuals who lose weight tend to regain it within two years, emphasizing the need for sustainable and realistic weight-loss strategies.

For individuals who are overweight or obese, the CDC recommends gradual, steady weight loss. Losing 1–2 pounds per week has been proven to be an effective method not only for shedding pounds but also for maintaining the weight loss. Weight loss requires dedication, motivation, and a support system. Below are key nutrition guidelines that can support healthy, sustainable weight loss.

- **How is Caloric Intake Related to Weight Loss?**

You may have heard that 1 pound of body fat is approximately equivalent to 3,500 kcal. This is based on the fact that 1 pound equals about 454 grams, and adipose tissue (fat) is roughly 86% fat, with the remaining mass being protein, minerals, and water. The kcal content of body fat is calculated as:

$$0.86 \times 454 \text{ g} \times 9 \text{ kcal per gram of fat} = 3,514 \text{ kcal}$$

The principle behind weight control is relatively simple. If you consume more calories (kcal) than you burn, you enter a positive energy balance and gain weight. If you burn more than you consume, you enter a negative energy balance and lose weight. To maintain weight, the number of calories consumed must equal the number of calories burned. You might experience temporary weight gain after consuming a high-salt meal, or changes in weight due to the menstrual cycle. Similarly, you might lose several pounds through sweating, but this weight is primarily water. In a healthy weight-loss program, the goal is typically to reduce body fat while preserving muscle mass. Effective weight-loss strategies aim to maximize fat loss while minimizing muscle loss.

- **General Dietary Recommendations to Support Weight Loss**

The guidelines emphasize the importance of consuming a variety of nutrient-dense foods from all the food groups, including vegetables, fruits, grains, dairy (or dairy alternatives), and protein sources. 85–15 guide by the USDA suggests that 85% of your daily calories should come from nutrient-dense food sources, while the remaining 15% can be allocated for foods that may be higher in added sugars and saturated fat. This helps individuals aiming for weight loss to stay on track while still allowing a limited amount of flexibility in their food choices.

- 1. Limit Intake of Added Sugars and Saturated Fat**

The 2020–2025 Dietary Guidelines for Americans recommend limiting added

sugars and saturated fat as part of a weight loss strategy. Here's a breakdown of the recommendations:

- **Added Sugars:** Limit added sugars to less than 10% of daily kcal. Added sugars are primarily found in foods like Sugar-sweetened beverages, Desserts, Sweet snacks and candy, and Sweetened coffee and tea.

On average, adults in the U.S. consume about 266 kcal from added sugars daily. Reducing this intake can significantly decrease overall calorie consumption, aiding in weight loss.

- **Saturated Fat:** Limit saturated fats to less than 10% of daily kcal. Saturated fats are found in foods like Fatty cuts of meat, Full-fat dairy products, and processed snacks and baked goods.

Not all fats are harmful. The guidelines recommend replacing saturated fats with healthier unsaturated fats, such as monounsaturated fats (found in olive oil and avocados) and omega-3 fatty acids (found in fish and flaxseeds).

2. Practical Changes for Reducing Saturated Fat:

For individuals aiming to lose weight, it is important to choose lean cuts of meat and consume fats in moderation. Some practical tips are:

- Opt for low-fat dairy (e.g., low-fat milk instead of whole milk).
- Replace snacks high in saturated fats (such as chips or cookies) with nuts, seeds, or avocados.
- Keep in mind that while all fats provide 9 kcal per gram, healthier fats (like those from nuts and seeds) offer more nutritional benefits and can still be part of a balanced, weight-loss-friendly diet when consumed in moderation.

8.2 Behavior Modification

Step 1: Set realistic goals

Before embarking on a weight loss plan, write down your goals clearly, as research has proven that by writing down your intentions, you are far more likely to turn them into actions. These goals should be specific, positive and realistic ('I will lose 5 kg of body fat') rather than hopeful ('I would like to lose some weight'). Try to allow a suitable time frame: to lose 15 kg in one month before a summer holiday is, obviously, unrealistic! Make sure, also, that you are clear about your reasons for wanting to lose weight: many normal-weight women wrongly believe that losing weight will solve their emotional or body image problems.

Step 2: Monitor body composition changes

The best way to ensure you are losing fat, not muscle, is to measure your body composition once a month. The simplest method is to use a combination of simple girth or circumference measurements (e.g. chest, waist, hips, arms, legs). Exercise physiologists recommend keeping a record of the skinfold thickness measurements

themselves rather than converting them into body fat percentages. This is because the conversion charts are based on equations for the average, sedentary person and may not be appropriate for sportspeople or very lean or fat individuals. Monitoring changes in measurements at specific sites of the body allows you to see how your shape is changing and where most fat is being lost. This is a far better motivator than weighing scales!

Step 3: Aim to lose no more than 0.5 kg/week

Weekly or fortnightly weighing can be useful for checking the speed of weight/fat loss, but do not rely exclusively on this method as it does not reflect changes in body composition! Avoid more frequent weighing, as this can lead to an obsession with weight. Bear in mind that weight loss in the first week may be as much as 2 kg, but this is mostly glycogen and its accompanying fluid (1/2 kg glycogen is stored with up to 1 1/2–2 kg water). Afterwards, aim to lose no more than 0.5 kg of fat/week. Faster weight loss usually suggests a loss of lean tissue.

Step 4: Keep a food diary

A food diary is a written record of your daily food and drink intake. It is a very good way to evaluate your present eating habits and to find out exactly what, why, and when you are eating. It will allow you to check whether your diet is well-balanced or lacking in any important nutrients, and to take a more careful look at your usual meal patterns and lifestyle. Weigh and write down everything you eat and drink for at least three consecutive days – ideally seven. This period should include at least one weekend day. It is important not to change your usual diet at this time and to be completely honest. Every spoonful of sugar in tea, and every scrape of butter on bread, should be recorded.

Use your food diary to find out about:

- The main sources of saturated fat in your diet that you need to eliminate
- The GI of your meals and snacks. Aim to consume low-GI food during the day and before exercise
- Check that most meals are based on fiber-rich foods
- The timing of your meals and snacks
- Aim to eat approximately six times a day.

Step 5: Never consume fewer calories than your RMR

Calorie intake should never be less than your RMR; otherwise, you risk losing excessive lean tissue, severely depleting your glycogen stores, and having an inadequate nutrient intake. It is erroneous and potentially dangerous to prescribe low-calorie diets of 1000 kcal or less. Keep to the 15% rule.

Step 6: Trim saturated and hydrogenated fat

Look carefully at your food diary and identify the foods containing saturated and hydrogenated fats that you are currently eating. Fat puts on more body fat than any

other nutrient. When protein or carbohydrate is eaten in excess, the body makes metabolic adjustments to promote glycogen storage and increase the use of protein or carbohydrate for fuel. Excess saturated fats cause virtually no change in metabolism and are readily converted into body fat. Focus on cutting saturated rather than unsaturated fats.

Step 7: Include healthy fats

Don't cut fat out of your diet completely. You need a certain amount each day to provide essential fatty acids, stimulate hormone production, keep your skin healthy, and absorb and transport fat-soluble vitamins. The essential fatty acids in foods such as nuts, seeds, and oily fish help burn fat by assisting the transport of oxygen to the body's tissues. So, if you want to lose weight, cut down on saturated and trans fatty acids; the remainder should come from unsaturated fats. Aim for 15–20% of your total calories.

Step 8: Go for the (slow) burn

Make all of your meals low GI. This helps improve appetite regulation, increases feelings of fullness, and delays hunger between meals. Remember that adding protein, fat, or soluble fiber to carbohydrate always reduces the speed of absorption and produces a lower blood sugar rise. In practice, this is easy to achieve if you plan to eat a carbohydrate source (e.g., potatoes) with a high-protein source (e.g., fish) and add vegetables. Better still, choose low-GI carbohydrates, such as lentils and beans.

Step 9: Bulk up

The most filling foods are those with a high volume per calorie. Water and fiber add bulk to foods, so load up on foods naturally high in these components. Fruit, vegetables, pulses, and wholegrain foods give maximum fill for minimum calories. If you can eat a plate of food that is low in calories relative to its volume, you're likely to feel just as satisfied as eating smaller amounts of high-calorie food.

Step 10: Eat more fiber

Apart from reducing your risk of various cancers and heart disease, fiber slows down the emptying of food from your stomach and helps to keep you feeling full. Fiber also gives food more texture, so you need to chew your food more. This slows down your eating speed, reducing the chances of overeating, and gives better meal satisfaction. Fiber also slows the digestion and absorption of carbohydrates and fats, resulting in a slow, steady energy uptake and stable insulin levels. Non-fluctuating glucose and insulin levels will encourage the use of food for energy rather than for storage as body fat; it also reduces hunger and satisfies the appetite.

8.3 DIETARY MODIFICATIONS

8.3.1 How Much Carbohydrate, Protein, and Fat Should You Consume for Weight Loss?

To successfully reduce body fat while maintaining performance, it is recommended to:

- Reduce dietary fat intake to 20–25% of daily calories.
- Moderately lower carbohydrate intake by 15%, in proportion to overall calorie reduction.
- Maintain an adequate carbohydrate intake of 4–7 g per kg of body weight per day to support training volume and intensity.

The Role of Carbohydrates

If carbohydrate intake falls below 4 g/kg body weight per day, glycogen stores become depleted, leading to increased fat and protein oxidation. While fat oxidation may seem beneficial, protein breakdown results in muscle loss, which is undesirable for athletes. Losing lean muscle mass reduces metabolic rate, making it harder to maintain weight loss.

The Importance of Protein

A higher protein intake can help prevent muscle loss during fat loss. Most researchers recommend:

- 1.6 g of protein per kg of body weight per day
- This aligns with the general range for athletes (1.2–1.7 g/kg BW/day)

For example, a 75 kg athlete would require approximately 120 g of protein daily.

8.4 EXERCISE & OTHER COMPREHENSIVE WEIGHT-CONTROL PROGRAMS

Strategies to Promote Weight and Fat Loss

• Managing Energy Intake

The most influential external factors controlling body weight are total energy intake and expenditure. When energy intake consistently exceeds energy needs, body mass increases; conversely, insufficient intake results in weight loss. Energy needs can be directly measured by assessing body heat production or estimated through indirect methods like calorimetry (based on oxygen consumption). However, due to individual variations, accurately determining specific energy requirements can be difficult.

Resting metabolic rate (RMR) is largely influenced by lean body mass (more lean mass equals higher RMR), and also by age, sex, and genetics. RMR can be estimated using prediction equations such as Harris–Benedict, Schofield, and Cunningham. Although useful in clinical settings, these equations may not accurately reflect RMR in elite athletes. Recommended Dietary Intakes often rely on these equations and published data to guide energy recommendations for various levels of physical activity, from sedentary individuals to those doing heavy work.

- **Energy Requirements in Athletes**

Estimating total daily energy needs in athletes is more complex due to variations in training duration, intensity, environmental factors (temperature, humidity, wind), and individual characteristics such as body composition, age, gender, and skill level. Children, for instance, often expend more energy per kilogram of body weight than adults due to lower efficiency in movement. Women also typically have a lower energy cost during activity compared to men, largely due to differences in lean mass.

- **Creating an Energy Deficit**

For athletes aiming to reduce weight or body fat, a mild to moderate energy deficit (about 10–20% below the level needed for energy balance) is usually effective. Larger deficits can compromise macronutrient and micronutrient intake, cause fatigue, hinder recovery, and increase the risk of energy deficiency and overtraining.

Athletes with minor fat loss goals can often achieve results with small dietary adjustments, especially by reducing fat intake, since dietary fats are energy-dense and often overconsumed in Western diets. This less restrictive strategy maintains micronutrient intake and avoids the risks associated with severe energy restriction. However, low-fat eating on its own may not produce enough of a deficit for significant fat loss.

- **Biological Adaptations in Athletes**

Athletes are generally less prone to fat accumulation due to their elevated energy expenditure and metabolic adaptations from aerobic training. These include improved oxygen delivery to muscles (via increased capillarization), greater mitochondrial density, and higher enzyme levels that support fat metabolism.

However, athletes in aesthetic or skill-based sports (e.g., gymnastics, diving, figure skating) may not develop the same capacity for fat oxidation, even with rigorous training. As a result, they often burn less energy and face more challenges with weight management. Even these athletes typically need to monitor and restrict energy intake to meet body composition goals, especially females, who are often expected to maintain levels of body fat below what is biologically ideal. This can increase the risk of energy deficiency, disordered eating behaviors, and related health concerns.

Nutrition Strategies for Enhancing Athletic Performance

1. Managing Arousal, Anxiety, and Fatigue

Nutrition plays a pivotal role in regulating arousal and anxiety levels in athletes. Proper hydration and balanced meals can help maintain emotional and physical well-being during intense physical activity.

2. Body Composition, Skill, and Technique

An athlete's body composition significantly influences their agility, speed, and endurance. Excessive body fat can hinder performance, while insufficient fat levels may lead to decreased endurance and nutrient deficiencies. It's essential to set individualized body composition goals aligned with training demands.

3. Carbohydrates: Fueling Performance

Carbohydrates are vital for sustaining energy levels and delaying fatigue during exercise. Consuming carbohydrates during prolonged or high-intensity activities can improve endurance and skill execution. Mouth rinsing with carbohydrate solutions during exercise has also been shown to activate brain regions associated with motivation and reward, potentially enhancing performance.

Recommendations:

- **Daily Intake:** 3–12 g/kg/day, adjusted based on training intensity.
- **Pre-Exercise:** 1–4 g/kg of carbohydrates 1–4 hours before activity.
- **During Exercise:** For sessions exceeding 90 minutes, 0.5–1.0 g/kg/hour is advised.
- **Post-Exercise:** Combining carbohydrates with protein aids in glycogen replenishment and muscle recovery.

4. Protein: Supporting Muscle Repair and Growth

Adequate protein intake is crucial for muscle repair and growth. Athletes should aim for 1.2–2.0 g/kg/day, depending on their training regimen. Distributing protein intake evenly throughout the day, especially around training sessions, can maximize muscle protein synthesis.

5. Hydration: Maintaining Cognitive and Physical Performance

Proper hydration is essential for optimal cognitive function and physical performance. Even mild dehydration can impair mood, concentration, and decision-making abilities.

Guidelines:

- **Pre-Exercise:** Ensure adequate hydration before starting any activity.
- **During Exercise:** Drink fluids at regular intervals, considering individual sweat rates and environmental conditions.
- **Post-Exercise:** Rehydrate to replace fluids lost during activity, using electrolyte-containing beverages if necessary.

6. Caffeine: Enhancing Alertness and Performance

Caffeine can improve attention and reduce perceived exertion during exercise. Doses of 3–6 mg/kg body weight consumed approximately 60 minutes before activity have been shown to enhance performance. However, individual responses vary, and excessive intake may lead to side effects such as increased anxiety and disrupted sleep.

Implementing these nutrition strategies can help athletes optimize their performance by managing arousal, reducing fatigue, and enhancing skill execution. It's important to tailor these recommendations to individual needs, considering factors such as sport-specific demands, training intensity, and personal tolerances.

Self-Assessment Questions:

1. What are the health risks of consuming fewer calories than your resting metabolic rate (RMR)?
2. How does dietary fiber help in reducing appetite?
3. What is the recommended protein intake for athletes trying to lose fat but maintain muscle?
4. How much carbohydrate should an athlete consume post-exercise?
5. List three factors that influence total daily energy expenditure in athletes.

MCQs

1. Measuring skinfold thickness helps track:

- a) Changes in weight
- b) Changes in fat distribution
- c) Hydration level
- d) Bone density

2. The recommended rate of fat loss is no more than:

- a) 1 kg/day
- b) 1 kg/week
- c) 0.5 kg/week
- d) 3 kg/month

3 . Recommended protein intake for fat loss with muscle maintenance is:

- a) 0.8 g/kg/day
- b) 1.6 g/kg/day
- c) 3.0 g/kg/day
- d) 2.5 g/kg/day

4 . The minimum recommended carbohydrate intake for athletes is:

- a) g/kg/day

- b) g/kg/day
- c) 1 g/kg/day
- d) 0.5 g/kg/day

5 . Caffeine enhances performance by:

- a) Slowing metabolism
- b) Increasing fatigue
- c) Improving alertness and reducing exertion
- d) Causing dehydration

Activity-Based Questions:

1. Pick 3 packaged foods from your kitchen. Check and note the Total sugar (including added sugars and Saturated vs. unsaturated fat content.
2. List and discuss five strategies to help reduce the hazards associated with exercise in a hot environment.

Recommended Books:

Antonio, J., Kalman, D., Stout, J. R., Greenwood, M., Willoughby, D. S., & Haff, G. G. (2008). *Essentials of sports nutrition and supplements*. Humana Press.

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Unit -9

WEIGHT MANAGEMENT-II

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INTRODUCTION

When advising athletes in weight-category sports, practitioners must have in-depth, sport-specific knowledge. This includes understanding competition rules such as weight classes, how often weigh-ins occur, and the time available for recovery after a weigh-in. These factors significantly impact how athletes manage their body weight and recover nutritionally. It's important to recognize that rules can vary widely between sports and events, influencing an athlete's approach to weight management. For instance, in taekwondo, although there are typically eight weight classes, only four are used in the Olympics. In wrestling, international competitions often allow up to a full day between weigh-in and competition, whereas in US collegiate wrestling, this window can be as short as 1–2 hours. There may be a variety of reasons an individual is underweight, and the cause should be determined before a treatment is recommended. For those who want to gain weight, a weekly increase of 0.5–1.0 pounds is a sound approach, but the desired weight gain should be muscle tissue and not body fat. In essence, adequate rest and sleep, increased caloric intake, adequate intake of high-quality, highly digestible protein, and a proper resistance-training program should be effective in helping to increase lean body mass.

LEARNING OBJECTIVES

After studying this unit, the students will be able to:

1. Describe the steps an individual might take to gain body weight, mainly as muscle mass.
2. Identify the potential health benefits of resistance exercise and compare them to the health benefits associated with aerobic endurance exercise, noting similarities and differences.

9.1 EXERCISE CONSIDERATIONS

9.1.1 Exercise-Related Strategies to Promote Weight and Fat Loss

- **Exercise Intensity and Cross-Training Methods**

Continuing regular exercise is crucial for athletes aiming to reduce body fat and maintain an ideal physique. Cross-training, using a variety of physical activities in a training program, not only helps develop different physiological capabilities but also supports fat loss and muscle preservation or gain. Traditionally, fat loss efforts have focused on lower-intensity, longer-duration endurance exercises, as these activities increase overall energy expenditure and enhance the body's ability to burn fat. At low to moderate exercise intensities, the body relies more on fat for fuel. However, research has shown that well-trained athletes can burn considerable amounts of fat even at moderate to high exercise intensities, as long as they stay below the anaerobic threshold.

Since higher-intensity workouts use more total energy in a shorter time, they may actually result in more fat burned overall. Furthermore, some studies have observed greater fat loss from high-intensity workouts, sometimes even when these workouts involved less total energy expenditure than lower-intensity endurance training. However, cross-training programs must be customized to each athlete's needs to avoid overtraining or injury.

9.1.2 Fat Adaptation and 'Train Low' Strategies

Although not primarily intended for weight loss, some strategies designed to improve endurance performance can indirectly support fat loss by enhancing the body's ability to burn fat.

- Fat adaptation involves following a high-fat, low-carbohydrate diet for a period to increase the muscles' reliance on fat as a fuel source.
- 'Train low' strategies involve intentionally exercising with low carbohydrate availability, such as training after fasting or in a glycogen-depleted state. These methods promote metabolic adaptations that upregulate fat oxidation, especially valuable in endurance sports.

One popular approach is fasted training, typically performed in the morning before breakfast. Studies show that this method can also increase fat oxidation, though most of the evidence supports its effectiveness primarily in endurance-trained athletes. It's important to note that while these methods increase fat-burning efficiency, their impact on actual fat or weight loss has not been proven. If any fat loss benefits exist, they are likely to be modest and only applicable to athletes engaging in high volumes of endurance training.

9.2 NUTRITIONAL CONSIDERATIONS

Macronutrients contribute different amounts per gram:

- Protein: 17 kJ/g
- Carbohydrate: 16 kJ/g
- Fat: 37 kJ/g
- Alcohol: 29 kJ/g

It was once believed that all kilojoules were equal, regardless of the macronutrient source. Excess energy intake, beyond immediate needs, was thought to be stored as fat. However, research in the 1990s questioned this, especially the role of de novo lipogenesis—a costly process where excess carbohydrates are converted to fat, believed to occur only in overfeeding conditions. Because fat is more energy-dense and easier to overconsume, it became the main dietary target linked with weight gain. This led to the promotion of low-fat, high-carb diets, which gained popularity among both the general public and athletes.

Concerns with High-Carbohydrate, Low-Fat Diets

Many low-fat products contained high amounts of **high fructose corn syrup (HFCS)**, which has been linked, though controversially, with fat storage and obesity. Furthermore, individuals often fail to recognize the high energy density in such foods, leading to passive overconsumption. Sports foods, which are intentionally energy-dense, also contributed to this problem when consumed without adjusting overall daily intake.

9.2.1 Modern Perspectives on Macronutrient Distribution

High-Protein, Moderate-Carbohydrate Diets

Recent research supports moderate-carb, high-protein, and moderate-fat diets for weight loss. Many athletes now adopt diets like the Zone Diet or modified low-carb plans to reduce fat while maintaining performance. While these approaches often yield quick results due to energy deficits and high activity levels, extreme versions (e.g., Atkins) can lead to health and performance issues if followed long-term.

Protein Leverage Hypothesis (PLH)

PLH suggests that protein intake is tightly regulated and often leads to overeating if diets are low in protein. This is particularly relevant in modern diets high in fat and carbs but low in protein. Athletes, who may have higher protein needs, could be more affected by this mechanism, though more research is needed.

Low-Carbohydrate Diets

Popular low-carb diets like Atkins, South Beach, and Zone reduce glycaemic load and insulin response, and in severe cases (e.g., Atkins), induce ketosis. Short-term studies show better weight and fat loss results compared to traditional diets, but long-term results are not sustained, with weight often regained after 6–12 months.

- Initial weight loss is largely water loss from glycogen depletion.
- Reduced appetite from high protein intake also contributes to lower calorie consumption.
- Success often comes from the structure, novelty, and simplicity of such diets, not necessarily their composition.

Long-term use of strict low-carb diets may pose health risks, including:

- **Nutrient deficiencies** (e.g. fiber, B vitamins, calcium, magnesium)
- **Ketosis-related side effects** (e.g. high cholesterol, cognitive impairment, osteoporosis)
- **Reduced sports performance** due to low glycogen levels

Many athletes adapt moderate low-carb approaches, increasing protein while reducing carbs and glycemic index, rather than following extreme diets.

Low GI and High-Fiber Diets

Low-Glycaemic Index (GI) and high-fiber diets have been shown to improve satiety and aid weight loss. Unlike strict carb restriction, these approaches support overall health and are more sustainable.

- High-fiber, low-GI foods increase meal volume, reduce hunger, and are helpful for energy control.
- Fiber-rich snacks between meals may help manage appetite during the day.

Dairy and Calcium-Rich Diets

Several studies have found a negative association between dairy intake and BMI. Clinical trials suggest dairy intake (particularly over 800 mg calcium/day from food) may:

- Aid in appetite regulation
- Support fat metabolism and storage
- Increase fecal fat excretion, leading to modest energy loss

Importantly, dairy foods (e.g., milk, yogurt) seem more effective than calcium supplements for weight management. Low-fat dairy can be a valuable part of a fat-loss diet for athletes.

9.3 PROTEIN & DIETARY SUPPLEMENTATION DURING A WEIGHT-GAINING PROGRAM

Gaining weight is not always the result of eating too much protein. The nitrogen (amino) portion of protein is eliminated by the body when it is taken in excess, and the remaining amount is either stored as glycogen instead of fat or used as energy.

Additionally, protein increases thermogenesis, which means that a significant portion of its calories is converted to heat.

Additionally, protein helps you feel full. Your brain quickly detects when you've had enough protein and lowers hunger signals since the body is unable to keep excess. Because of this, eating meals that contain adequate protein can help you regulate your hunger while trying to lose weight.

9.3.1 Strategies for Weight Gain

Athletes aiming to increase muscle mass, common in sports emphasizing strength and power, should consider several factors: training programs, individual training status, genetic predispositions, and dietary intake. Muscle growth occurs when muscle protein synthesis surpasses breakdown, a balance influenced by nutrient intake and exercise.

Training to Optimize Lean Mass

Incorporating structured resistance training is essential for athletes seeking hypertrophy. When combined with endurance training, resistance adaptations may be compromised due to factors like fatigue and increased energy expenditure. Therefore, dedicating specific periods, such as the off-season, to focus on muscle growth can be beneficial. Muscle protein synthesis remains elevated for up to 48 hours after exercise, highlighting the importance of nutritional strategies during this window to maximize gains.

Protein Intake and Lean Mass

Adequate protein intake is vital. Athletes engaged in strength training are advised to consume 1.6–2.2 grams of protein per kilogram of body weight daily. Distributing protein intake evenly across meals and including it in snacks, especially post-workout, can enhance muscle protein synthesis.

High-quality proteins such as whey, casein, and soy differ in digestion rates and amino acid profiles. Whey protein, rich in leucine, rapidly stimulates muscle protein synthesis, making it particularly effective post-exercise.

Energy Intake and Lean Mass Gain

Beyond protein, total energy intake plays a critical role. Creating a moderate energy surplus—approximately 350 to 475 calories per day can promote muscle gain while minimizing fat accumulation. Monitoring progress through regular assessments of body mass and composition helps tailor energy intake to individual needs.

Athletes with high training volumes may find increasing energy intake challenging. Strategies include consuming energy-dense snacks and drinks, and eating more frequently to meet caloric needs without discomfort. Consistent support from coaches, conditioning specialists, and dietitians is essential to ensure effective and healthy weight gain.

9.3.2 Dietary Supplements to Support Weight Gain

Athletes aiming to increase muscle mass often consider dietary supplements to support their training and nutritional strategies. While whole foods should remain the foundation of any nutrition plan, certain supplements can offer additional benefits when used appropriately.

Creatine Monohydrate

Creatine monohydrate is one of the most extensively researched and effective supplements for enhancing muscle strength and mass. When combined with resistance training, it has been shown to increase lean body mass and improve high-intensity exercise performance. The typical supplementation protocol involves a loading phase of 20 grams per day (divided into 4 doses) for 5–7 days, followed by a maintenance dose of 3–5 grams per day. It's important to note that while creatine is generally safe for healthy individuals, those with pre-existing kidney conditions should consult a healthcare provider before use.

Protein Supplements

Protein supplements, such as whey, casein, or plant-based proteins, can be beneficial in meeting daily protein requirements, especially when whole food intake is insufficient. Consuming protein shortly after resistance training can enhance muscle protein synthesis, aiding in muscle recovery and growth. A post-exercise intake of approximately 20–25 grams of high-quality protein is often recommended. However, it's crucial to integrate these supplements into a balanced diet to avoid potential nutritional imbalances.

Post-Exercise Nutrition

After intense workouts, some individuals may experience suppressed appetite, making it challenging to consume adequate nutrients through solid foods. In such cases, liquid meal supplements rich in carbohydrates and proteins can be effective in replenishing energy stores and supporting muscle recovery. These supplements can help ensure that the body receives essential nutrients during periods when appetite is diminished.

Caution with Other Supplements

While other supplements like β -alanine, and nitric oxide boosters are marketed for muscle growth, their efficacy varies, and they may not provide significant benefits beyond those achieved through proper training and nutrition. Moreover, the supplement industry is not strictly regulated, raising concerns about product quality and potential contamination. Athletes should choose supplements that have been third-party tested to ensure safety and compliance with anti-doping regulations.

Self-Assessment Questions:**Fill in the Blanks**

1. Cross-training helps develop different physiological capabilities and supports ___ and muscle ___ or gain.
2. At low to moderate exercise intensities, the body relies more on ___ for fuel.
3. The point at which the body switches to using mainly carbohydrates for energy is called the ___ threshold.
4. A moderate energy surplus of about ___ to ___ kcal/day is recommended for lean mass gain.
5. Creatine monohydrate loading phase typically involves ___ grams/day for 5–7 days.

Short Question Answers:

1. What factors should be considered by practitioners when advising athletes in weight-category sports?
2. What are the possible benefits of high-intensity exercise in fat loss?
3. Name potential long-term health risks of strict low-carb diets.
4. Why is it important to distribute protein evenly throughout the day for muscle gain

Activity-Based Questions:

1. You are a dietitian working with a collegiate wrestler who weighs in 1 hour before a match. Design a pre-competition nutrition strategy that ensures compliance with weight class rules and promotes recovery.
2. Compare and contrast the pros and cons of in-person versus online weight-loss programs. Is one “better” than the other? Why or why not?

Recommended Books:

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