CHAPTER 4
SPORT AND EXERCISE SCIENCE AND HEALTH

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CONTENTS:

Learning outcomes

This chapter will enable readers to understand:

- What is *Sport and Exercise Science* and which disciplines contribute to the study of human sporting performance, health and fitness
- The scientific principles underlying sport and exercise performance and health
- The scientific methods used by sport and exercise scientists, specialists in sport physiotherapy, rehabilitation and medicine
- The contribution of sport and exercise science to the analysis of physical aspects of human health and exercise performance.
- The health benefits of sport and exercise

Overview

Sport and Exercise Science is a scientific discipline that considers the theoretical principles of anatomy, physiology, biomechanics, biochemistry, nutrition, and psychology. Sports and Exercise Science contributes to the study of health by providing knowledge of the mechanisms underpinning the body's functional and structural responses to physical activity and sport. Using rigorous experimental, observational and scientific modelling methods, it seeks to explain how exercise can improve human health and performance. Investigations in the field of Sport and Exercise Science collect data through controlled laboratory-based measurements and field studies of human movement and behaviour to improve understanding of the physiological adaptations to physical activity and exercise from cellular to whole body level. Sport and Exercise Science also researches the benefits from participation in exercise and sports for improved mobility, physical and mental health, and community development.

Within Sport and Exercise Science, physical activity and exercise can be viewed not only as a training stimulus that produces enhanced physical abilities through short- and long-term functional and structural improvements, but also as a physiological stressor that perturbs biological homeostasis. The integrated processes of exercise can serve as a model for understanding the challenges the body experiences in ill-health and disease. For example, exercise can cause muscle damage, inflammation and tissue hypoxia, and taxes bodily systems such as the cardiac and respiratory systems. Exercise stress also modulates metabolic processes such as glucose uptake, lipid mobilisation, blood flow and vascular mechanics, which can be studied to understand how to improve digestive and musculoskeletal health and prevent disease. In healthy individuals, strenuous physical activity and exercise can cause a transient sensation of fatigue, which may impact adversely on sporting performance, activities of daily living and mental health.

Analysis of human movement as the main subject of study in Sport and Exercise Science can aid diagnosis of neuro-motor, cardiorespiratory, metabolic, and mental health disorders. The study of exercise performance in extreme environments (e.g. cold and hot climates; altitude; microgravity) can assess and expand the limits of human performance. Lessons learned from Sport and Exercise Science's investigations contribute to the development of exercise protocols as well as monitoring and training technologies that aim to reduce fatigue, prevent and rehabilitate injury and systemic disorders, identify sporting talent, maximise athletic performance and facilitate recovery. Knowledge of the benefits of exercise for the general public underpins the notion that 'exercise is medicine'.

Sport and Exercise Science is concerned with sport, an activity involving physical exertion and skill, in which an individual or a team competes against another or others for exercise and entertainment. Sport and Exercise Science is also concerned with physical activity, defined as any bodily movement produced by skeletal muscles that requires energy expenditure and including activities undertaken while working, playing, carrying out household chores, travelling, and engaging in recreational pursuits. It is also concerned with exercise, which represents any planned, structured or repetitive physical activity performed with the aim to improve or maintain physical fitness and health.

Part 1 of this chapter describes the major physiological systems that support human body movement during physical activity and examines why exercise is recommended for the improvement of general health. Part 2 outlines the current approaches used by Sport and Exercise Science to measure, assess and affect human function in order to design and deliver effective programs for rehabilitation, exercise prescription and promotion. The chapter concludes with a case study focusing on the contribution of Sport and Exercise Science, from a physiological perspective, to the treatment and management of obesity.

Introduction

What is Sport and Exercise Science?

The British Association of Sport and Exercise Sciences (BASES) defines Sport and Exercise Science as an area of study that applies scientific principles to understand the effect of physical activity, exercise, and sports on the body (BASES, 2020). An integrated interdisciplinary approach is taken to contribute to the body of knowledge or solve real-world health, sporting or social problems. The three core sub-disciplines of Sport and Exercise Science are biomechanics, physiology, and psychology. **Biomechanics** is the examination of the causes and consequences of human movement through the application of mechanical principles. **Physiology** is concerned with how the body responds to exercise and training. **Psychology** seeks to provide answers to questions about human behaviour in sport and exercise settings.

Connections: Chapter 1 discusses the discipline of biology

Sport and Exercise Science can be applied within a broad range of contexts:

- **Sports Science** refers to the application of Sport and Exercise Science principles within high performance sport, with the aim of maximising the performance of an athlete or team.
- **Sports Medicine** focuses on the prevention, diagnosis and treatment of injuries sustained while engaged in athletic events. Sports Medicine aims to maintain athletes' optimal health and maximize their peak performance
- **Exercise Science** applies Sport and Exercise Science principles to the health and fitness domains in order to improve the general population's physical and mental health through exercise. This includes both the prevention of poor health and chronic diseases such as diabetes, and the treatment of a variety of physiological and psychological disorders. Exercise Science creates evidence to inform the development of physiotherapy and rehabilitation programmes, which use exercise for retraining posture, gait balance and coordination resulting from injury, clinical conditions or illnesses.

Sports Science has its origins in Ancient Greece, where Hippocrates (c. 460-360 BC), the so-called 'Father of Medicine', had an interest in the treatment of athletic injuries. The first scientific works on the value of exercise and hygiene are attributed to Galen (130-201 AD), while an understanding about exercise as part of a healthy lifestyle was presented first by Ibn Sina (c. 980-1037) in his Canon of Medicine. Modern-day physiologists do benefit from the scientific discoveries and models created by AV Hill (1886-1977), considered a 'giant in the field of exercise physiology' (Bassett, 2002: page no.?). Hill's most important and lasting contributions were in the areas of muscle calorimetry, muscle mechanics, and applied exercise physiology.

Today, Sport and Exercise Science is a well-respected academic discipline that has been developed on the foundation of physical education and has clearly defined professional roles across a variety of sports and health fields. There are a number of national bodies and organisations, such as the American College of Sports Medicine (ACSM) and the British Association of Sport and Exercise Sciences (BASES), that deliver accreditation of sport professionals and laboratories, and offer services related to the discipline. Sport and Exercise scientists are an integral part of the professional set-up within elite sports teams such as premiership football clubs, but also within clinical practice (e.g. exercise physiologists and cardiac rehabilitation practitioners), health, sport and fitness related industry (e.g. Gatorade and FitBit) and general health establishments (e.g. fitness trainers; wellbeing advisors). Sport and Exercise Science no longer serves only professional sports people and athletes, but also the general population, as the rise in sedentary living and the "diseasome of physical inactivity" (ref??) have increased in recent years.

A societal drive towards increasing not only the lifespan, but also the health-span of the population, has placed particular importance on the theoretical and practical applications of research for healthy living. With the global challenge of ageing societies, which pose significant health and social costs, countries are starting to invest in education and data-driven innovation and seek to learn discoveries made by Sport and Exercise Science which are of relevance to health care. Healthy individuals can maintain an independent, active and productive lifestyle for longer, and thus help to improve the size of the workforce and productivity in their community and country. In 2017 the UK government made a commitment to invest in production of health data to inform early diagnostics of life-changing diseases and precision medicine' programme and develop precision treatments to cure them (Industrial Strategy Building a Britain fit for the future, 2017.).

PART 1: CONTRIBUTION OF SPORT AND EXERCISE SCIENCE TO HEALTH STUDIES

Why is Sport and Exercise Science important to health studies?

Sport and Exercise Science provides knowledge of how movement is learned, how the body produces and responds to movement, and the impact of exercise on the body and health. Such topics can be applied to health care by helping:

- To tackle global health challenges through research and evidence building to inform physical activity guidelines and public health policy tackling obesity, physical inactivity and mental health
- To develop specific global recommendations for fitness instruction and programming, exercise interventions and rehabilitation across different sub-group populations and individuals;
- To prevent and manage age-related conditions such as osteoporosis and sarcopenia;
- To improve recovery from excessive athletic performance and the ill-effects of exercise stress by informing programs for prevention from injury and overtraining and the development of nutritional supplements and ergogenic aids;
- To support human performance in challenging environments caused by occupational conditions (e.g. military, police and firemen training and practice), hot and cold climates, high altitude, and microgravity;
- To inform and assist clinical rehabilitation e.g. recovery from surgery, illness and disorders, and clinically assess patients' functional capacity.

How the body moves

The human body is composed of several organ systems that work together to perform the functions necessary for maintaining life (figure 3.1). These functions include separating the body from, and connecting it to, the outside world, responding to environmental changes, producing movement, digesting nutrients for generating energy, carrying out metabolism, disposing of waste, and growth and reproduction. Many different organ systems are involved in producing movement during physical activity. The nervous system and the musculoskeletal system directly contribute to movement but all the other systems are involved in processes associated with its production, regulating homeostasis, and the consequences from movement on the body.

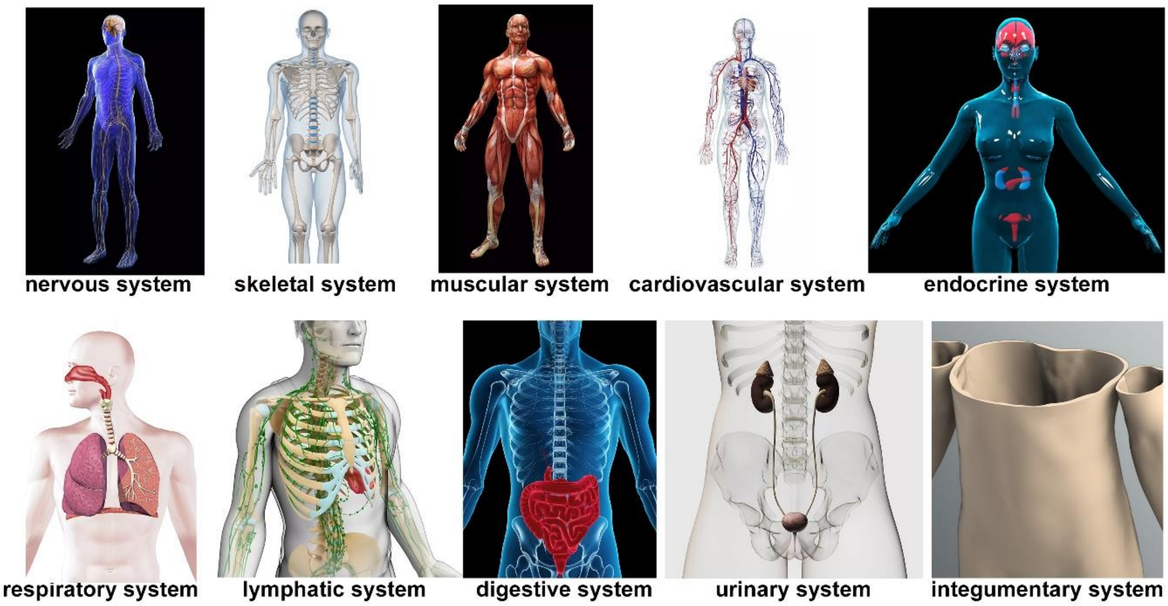

Figure 3.1. Schematic illustration of the physiological organ systems supporting the functions of human life.

Each system supports a different function and plays a unique role, the most important being: supporting shape and posture (skeletal and muscular), energy metabolism (digestive, respiratory and urinary), responsiveness to internal and external stimuli (integumentary and nervous), protection against internal and external pathogens (lymphatic), movement (nervous and muscular), development (endocrine), and procreation (reproductive).

- Nervous System

The nervous system is the body's highly responsive and fast-acting control system. It consists of the brain, spinal cord, nerves and sensory receptors. Nerves are bundles of neurons (nerve cells), which are located in the spinal cord and the brain and connect via axons (nerve fibres) to each other and all organs throughout the body. Structurally, the nervous system has two distinct parts: the *central nervous system* (CNS; brain and spinal cord) and the *peripheral nervous system* (PNS; the nerve fibres extending outside the brain and spinal cord to muscles and glands). The PNS is subdivided into an *afferent* (sensory) division, which sends information from the organs to the CNS, and an *efferent* (motor) division, which sends information from the CNS to peripheral organs. The efferent division is further subdivided into the *somatic nervous system*, which sends motor impulses to skeletal muscle, and the *autonomic nervous system,* which sends motor impulses to cardiac and smooth muscle and the glands. The somatic system is also known as the voluntary nervous system since it permits conscious control of skeletal muscles, while the autonomic system is called the involuntary nervous system because it regulates involuntary functions.

The nervous system performs *sensory, integrative*, and *motor* functions. The body's internal and external environments are monitored by millions of sensory receptors (the endings of the nerve fibres). These receptors detect stimuli such as temperature, light, pressure and sound on the body surface, as well as chemical changes, muscle stretch, and gas concentrations within the body. These receptors provide sensory input to the CNS for integration, and this information is conveyed via electrical impulses called nerve impulses, which are transmitted to the CNS through the afferent nerves. The CNS then co-ordinates a response by sending nerve impulses to activate the appropriate muscles and glands - the effectors - causing them to contract or produce secretions - the motor response of the nervous system. Traditionally, movements have been divided into involuntary reflexes and voluntary purposeful actions. Cognitive processes initiate volitional movements, which are considered to be singular events, although in reality they are often a continuous cycle of action-intention-action.

Question: *What happens prior to initiating exercise such as running?*

Answer: The autonomic nervous system prepares the body by increasing the heart rate, altering blood pressure and exciting the muscles that are involved. The brain recalls a motor pattern – a learned set of muscle instructions - and sends the signals through the spinal cord, the PNS and somatic system to the muscles and organs involved in the exercise.

- Muscular System

The human muscular system is composed of more than 600 muscles and, in general, accounts for nearly half the mass of the body. Muscle is a highly-specialized soft tissue that is designed to shorten, or contract, to produce tension and generate force. The contraction and relaxation of skeletal muscles is responsible for whole-body movement. In one way or another, muscles function to produce movement, whether whole-body movement such as locomotion, or the movement of substances within the body (e.g. air, food, blood). Muscles can be divided according to how they are stimulated to contract (either *voluntarily* or *involuntarily*), and morphologically by their cell structure (*striated* or *non-striated*). The three different types of muscle are: *smooth, cardiac*, and *skeletal* muscle. Skeletal muscle differs from cardiac muscles of the heart and smooth muscles in internal organs such as blood vessels and the digestive tract because, although it can also contract involuntarily, skeletal muscle is under voluntary control. Skeletal muscles' contractile units, called sarcomeres, are visible as bands throughout the muscle, giving it a striated appearance.

Skeletal muscles are composed of tubular myocytes (muscle fibres) enclosed in a connective tissue called the *endomysium*. Myocytes contain numerous specialized cellular structures, which facilitate their contraction and therefore that of the whole muscle. These myocytes are bound together within a fibrous tissue – the *perimysium*, to form a muscle fascicle, which is further bundled together within a tough connective tissue, the *epimysium* that covers the entire muscle. The *epimysium* extends to form a tendon or aponeurosis, which attaches to bone, cartilage, or other connective tissue. As a result, the contraction of skeletal muscle causes joint movement.

Question: *What happens to the quadriceps muscle during running?*

Answer: The quadriceps muscle is located at the front of the thigh and consists of 4 muscles: rectus femoris, vastii lateralis, intermedialis and medialis. The contraction of these muscles produces knee joint extension and the rectus femoris also contributes to hip joint flexion during running. The rectus femoris muscle descends anteriorly over the femur bone in the thigh, originates at the ilium of the pelvis and inserts at the base of the patella (knee-cap). During running, this muscle contracts and shortens and the resulting movement is extension of the knee joint; relaxation of the anterior thigh muscles and contraction of the posterior thigh muscles – the hamstrings, results in knee joint flexion.

- Skeletal System

The skeletal system, composed of bones, joints, and cartilage tissue, works to protect soft organs within the body, produce blood cells, and store fat and essential minerals. The skeleton's bones provide an internal framework of levers for the attachment of muscles. The skeletal system is divided into the *axial skeleton* (skull, vertebral column, and thoracic cage) and the *appendicular skeleton* (shoulder girdle, upper limbs, pelvic girdle, and lower limbs). The 206 bones in the adult human body are classified as either compact or spongey bones, depending on their structure and function. Bones are also classified by shape and size into: long bones (e.g. femur of the thigh); flat bones (e.g. cranium in the skull); short bones (e.g. carpals of the wrist); and irregular bones (e.g. vertebra of the spinal column). Apart from the hyoid bone in the neck, each bone forms an articulation – a *joint,* with one or more other bones. These joints link bones and provide mobility. Joints are classified according to their structure and function. Functional classification is based on the amount of movement the joint permits. Joints can be *synarthroses* – immovable joints (such as those in the skull); *amphiarthroses* – slightly moveable (e.g. between vertebrae); and *diarthroses* – freely moveable (e.g. knee joint). Synarthroses and amphiarthroses dominate the axial skeleton as they function mainly to protect organs and support the body, whereas diarthroses joints dominate the appendicular skeleton, where mobility is needed for movement to occur.

Where bones meet, the presence of a joint cavity, fibrous tissue, or cartilage determines the structural classification of the joint into *synovial*, *fibrous*, or *cartilaginous,* respectively. In the limbs, all joints are synovial. Synovial joints possess articular cartilage, an articular capsule, a joint cavity, and reinforcing ligaments, however they differ in shape and are classified into several types (Table 3.1).

Table 3.1. Types of synovial joints in the human body

Joint type	Movements permitted	Example
Plane joint	Small gliding/sliding	Intertarsal joints of the foot
Hinge joint	Uniaxial flexion and extension	Knee and ankle joints
Pivot joint	Uniaxial rotation	Median atlantoaxial joint (between neck and skull)
Condyloid joint	Flexion, extension, abduction, adduction	Radiocarpal joint in wrist
Saddle joint	Flexion, extension, abduction, adduction; greater range of motion than condyloid joints	carpometacarpal joint of the thumb
Ball and socket joint	All movements except gliding	Hip joint

Question: *How does the skeletal system contribute to movement during running?*

Answer: During running exercise the skeletal system acts as a kinetic chain, which consists of series of joint movements. These are activated by the contraction of the muscles, which are pulling the bones. The leg actions in running are primarily alternating and bilaterally coordinated flexion/extension joint movements in the sagittal plane (front-to-back) about a frontal axis at the hip, knee, and ankle joints. The femur and pelvic girdle form a ball and socket joint at the hip; the femur and tibia form a hinge joint at the knee; the tibia and fibula connect with the foot via the ankle joint, which is a hinge type synovial joint. Weight-bearing (e.g. running) exercises can slow bone loss due to disease or ageing and stimulate new bone formation of new bone tissues and thus are beneficial for skeletal health.

Discussion: Obesity is known to be a risk factor contributing to osteoarthritis due to increased weight load and altered mechanical axis on weight bearing joints including the knee (Jiang et al, 2012). 98,591 primary total knee replacements (TKR) were reported to the National Joint Registry in 2015. The average Body Mass Index of these patients was 30.9 (obese).

Should TKR be performed on obese patients?

- There is a decrease of implant survival especially in patients with a body mass index of >40 (Rodriguez-Merchan 2014).
- Obese and morbidly obese patients can have similar improvements in functional scores and measures of quality of life (HRQL) at 12 months after TKR (Nunez et al 2011).

- Cardiovascular System

The cardiovascular system has a vital role in maintaining homeostasis.

Connections: Chapter 1 describes homeostasis and its importance to the body.

It consists of the *heart* and a closed circuit of vessels called *arteries*, *veins*, and *capillaries*. Blood contained within this system is continuously circulated within the vessels through the coordinated contraction of the heart, which acts as two simultaneous pumps - one on the right and one on the left. The normal adult heart pumps about five litres of blood every minute. The contraction and relaxation of the heart muscle tissue is regulated by its intrinsic conduction system. The basic rate of the heart is set by its pacemaker – the sinoatrial node, which rhythmically initiates impulses around 70 – 80 times per minute. The alternating contraction and relaxation of the cardiac muscle (myocardium) contained in the walls of the heart chambers during one heartbeat is called the cardiac cycle. The atrioventricular node of the conduction system decreases or increases heart rate to adjust the amount of blood pumped by the heart to meet the changing needs of the body. The cardiac centre in the brain primarily mediates changes in heart rate. The *sympathetic* component of the cardiac centre increases heart rate while the *parasympathetic* component decreases it. Both central and peripheral factors such as emotions, ion concentrations, and body temperature can affect heart rate.

The contraction phase of the cardiac cycle is known as systole, and the relaxation phase as diastole. During diastole, the heart's chambers fill with blood. During systole, deoxygenated (without oxygen) blood flows from the right atrium of the heart down into the right ventricle where it is pumped to the lungs via the pulmonary artery. Here it becomes oxygenated through gaseous exchange. Blood then flows through the pulmonary vein to the left atrium and down to the left ventricle and is pumped into systemic circulation to deliver oxygen (and other nutrients) to the bodily tissues. Blood vessels permeate every tissue of the body; they range from the macroscopic veins which carry blood towards the heart (with the exception of the pulmonary vein), and arteries which carry blood away from the heart (with the exception of the pulmonary artery), to the progressively smaller venules, arterioles and capillaries. It is in the microscopic capillaries that blood performs its ultimate transport function. Through diffusion, filtration and osmosis, nutrients and other essential substances pass from capillary blood into the fluid surrounding cells, while waste products such as carbon dioxide are removed. White blood cells and chemicals in the blood help to protect the body from bacteria, viruses, and tumour cells.

Question: *What happens to the cardiovascular system during running?*

Answer: The role of the cardiovascular system during running is to transport oxygen from the lungs to the muscles where it is utilised. As exercise intensity increases the heart works harder (increased heart rate and cardiac output), pumping more blood to the working muscles. This ensures that adequate nutrients are delivered to the muscles and waste by-products of energy production, such as lactic acid and carbon dioxide, are efficiently removed.

Example 3.1. *Clinical assessment of functional capacity*

Cardiopulmonary exercise testing (CPET) is an important clinical tool to evaluate exercise capacity and monitor functional status in patients. CPET assesses integrative exercise responses involving the pulmonary, cardiovascular and skeletal muscle systems, which are not adequately reflected through the measurement of individual organ function. CPET is used primarily within cardiovascular, respiratory and pre-operative medical care; its validated uses include investigation of the underlying mechanism in patients with breathlessness, monitoring functional status in patients with cardiovascular disease, and pre-operative functional state assessment. Professor Karlman Wasserman worked extensively in this field and founded the Wasserman 9-panel plot -the standard graphical representation of cardiovascular, ventilatory and gas exchange parameters. An understanding of the underlying physiology of exercise, and the worries associated with pathological states, is essential for healthcare professionals to optimise patient care.

- Respiratory System

The respiratory system consists of the nasal passages, pharynx, larynx, trachea, bronchi and lungs. Alongside the cardiovascular system, it functions to provide a continuous supply of oxygen for metabolism and to remove waste by-products. *Respiration* involves the processes of oxygen and carbon dioxide exchange between the atmosphere and the body. It involves *external*, *internal*, and *cellular* respiration. In external respiration, during ventilation (breathing), air is moved into and out of the lungs. Within the lungs are located tiny air sacs called alveoli and gases are exchanged with blood through their thin walls. Internal respiration is the exchange of gases between blood and tissues. Cellular respiration involves cells using oxygen to perform specific metabolic activities.

Breathing is accomplished by the coordinated activity of the diaphragm and inspiratory rib cage muscles and normally no expiratory muscles are used. During ventilation, air moves through the conducting passages from the atmosphere to the lungs due to pressure differences inside and outside the body. During inspiration, contraction of the diaphragm and thoracic muscles increases the volume inside the thoracic cavity and air is drawn into the body (*inhalation*). During expiration, air is moved out of the lungs (*exhalation*), the diaphragm relaxes and the thoracic cavity volume decreases.

The control mechanisms of the exercise ventilatory response involves complex cyclical neural processes within the respiratory centres in the medulla oblongata in the brain. They are governed by a mix of neural information from the brain, lungs, muscles, and joints, and chemical centres that work to maintain appropriate gas concentrations of oxygen and carbon dioxide. When arterial oxygen content and the acid-base balance changes during exercise, changes in ventilation are co-ordinated to meet the metabolic demand.

Question: *What happens to breathing during exercise such as running?*

Answer: During running, when more oxygen is required for energy production, the ventilation rate can increase to 40-50 times per minute. The increased ventilatory demands determine an increased neural drive to the respiratory muscles. During steady-state running, increases in ventilation are proportional to the increase in carbon dioxide production and oxygen consumption. During exercise the expiratory muscles play an active role in breathing, which is highly coordinated with that of the inspiratory rib cage muscles. During inspiration, while the rib cage muscles contract, the abdominal muscles gradually relax, and *vice versa* during expiration. This mechanism prevents rib cage distortion, allows the diaphragm to act as a flow generator and reduces the volume of the abdomen, resulting in optimised mechanics of breathing.

- Endocrine System

The endocrine system, like the nervous system, regulates the body's activities but its actions are more generalized, slower, and longer-lasting. The endocrine system consists of glands and cells and acts through releasing potent chemical messengers called hormones into the blood stream to travel to other relatively distant organs and tissues. These hormones influence growth, development, and metabolism. There are eight major endocrine glands: pineal, pituitary, thyroid, thymus, adrenal, pancreas, ovary (female), and testes (male). *Exocrine* glands possess ducts that carry their secretory product to a surface, such as sweat glands. *Endocrine* glands secrete hormones directly into blood circulation. Hormones only affect cells that possess receptor sites. Hormones bring about their characteristic effects on target cells by modifying cellular activity.

Question: *What happens to the endocrine system during running?*

Answer: During running, the brain signals the adrenal glands to release adrenaline and noradrenaline which are involved in cardiovascular and respiratory adjustments and in substrate mobilization and utilization of extracellular fuels. This triggers physiological changes such as an increase in heart rate and blood pressure, and the release of glucose from energy stores, that prepare the body for action. Blood vessel dilation and constriction is also stimulated to divert blood flow to working muscles and decrease the flow to other tissues such as gastrointestinal organs.

- Lymphatic System

The lymphatic system is a network of lymph organs (tonsils, adenoids, thymus and spleen), nodes and vessels that are distributed throughout the body. The network collects and carries lymph fluid and transports other substances throughout the body in one direction - away from tissues and into circulation through the venous system. Since blood capillaries continuously leak water, proteins and other substances into the surrounding tissues, the lymphatic system plays an integral role in fluid balance by removing excess fluid and returning it to the blood stream. The lymphatic system also plays a role in fat absorption and transport, and the production of immune cells. Lymph nodes and other lymphatic organs are involved in filtering and cleansing blood. The lymphatic system regulates blood volume and pressure by carrying the leaked fluid and plasma proteins back to the cardiovascular system. If fluid is not returned to the blood system at the same rate as it leaves oedema can develop.

Question: *What happens to the lymphatic system during running?*

Answer: During steady-state exercise such as running, the muscle contractions act as a pump to the fluids in the body. Pressure gradients caused by muscular contractions can cause plasma fluid to leak from blood capillaries into interstitial spaces between cells. During running the lymph flow can increase to levels approximately 2- to 3-fold higher than when at rest; this makes the system more effective for collecting excess substances such as water, proteins, fatty acids etc. and defends the body against infections and swelling. Exercise also stimulates the production of immune cells (such as lymphocytes, monocytes, and antibody producing cells called plasma cells) by the lymphatic system.

- Digestive System

The digestive system consists of the gastrointestinal tract (mouth, oesophagus, stomach, small intestine, large intestine, and anus) and the accessory organs such as the tongue, salivary glands, pancreas, liver, and gallbladder. It is responsible for the processes of *digestion*, *absorption* and *elimination*. During digestion food macromolecules (proteins, fats, and carbohydrates) are processed into smaller molecules (amino acids, fatty acids, and glucose) and other micronutrients (minerals and vitamins). Digestion begins in the mouth and ends in the small intestine. During absorption, the nutrients pass through the lining of the small intestine and are absorbed into blood circulation where they are dispersed throughout the body and utilised during cellular respiration or processed for storage. The liver aids digestion as its bile helps to break down fats, while the pancreas produces digestive enzymes and hormones. Food molecules that cannot be digested or absorbed are eliminated from the body as waste during the process of defaecation. The intake of energy supplements, e.g. carbohydrate-based drinks, during exercise such as prolonged running, is known to delay the onset of fatigue. Carbohydrate mouth-rinses can also improve exercise performance, and are speculated to trigger stimuli within the oral cavity to initiate a chain of neural messages in the CNS. Other components of the digestive system are critical for providing fuel for performance, for example, the absorption of glucose into the bloodstream for delivery to the working muscles, or the breakdown of fats into fatty acids for use by muscles.

- Urinary System

The urinary or renal system consists of the kidneys, ureters, bladder, and the urethra. It functions to filter blood and store and eliminate waste by-products such as urea, extra salt, or extra water in the form of urine. Water is the single most abundant chemical substance in the body and accounts for 60-80% of body weight, depending on the age of the individual. It provides the fluid base for body secretions and excretions. The urinary system helps to regulate body fluid composition and volume, and the pH of blood within normal limits. The respiratory system also gets rid of waste products e.g. carbon dioxide and water from the body, while sweat glands also secrete urea, water, and salts. In addition to fluid homeostasis, the urinary system secretes the hormone erythropoietin and the enzyme renin, that regulate red blood cell production and blood pressure respectively. During exercise, body temperature is regulated through sweating. Kidneys adjust the concentration of urine for the regulation of body fluids and the recovery process after training.

- Integumentary System

The integumentary system - the skin and accessory structures - externally covers the body. It is vital for providing a barrier between the internal and external environments, protecting superficial organs and providing insulation, the excretion of salts (electrolytes) through perspiration, and the regulation of body temperature. Receptors in the skin provide feedback about the external environment. The integumentary system helps regulate body temperature through its close interaction with the nervous system. During continuous running, if body temperature increases, sweat glands are stimulated and as much as 1.5 litres (Henkin et al.,

2010) of sweat is produced per hour for an active person. As the sweat evaporates from the skin surface, the body is cooled and body heat dissipated.

> Example 3.2 *Assessing physical condition*
>
> Knowledge acquired by Sports and Exercise Science has led to the development of simple and practical validated tests to monitor the physical condition, progress and recovery of patients. Such examples are the 6-minute Shuttle walk and the Timed Up and Go tests. Further, the classic Borg Scale was developed as a simple method for assessing perceived exertion during exercise as a means of determining fitness by estimating heart rate changes. Dr. Gunnar Borg, who created the scale, set it to run from 6 to 20; multiplying the Borg score achieved during the exercise test by 10 gives an approximate heart rate for a particular level of activity.

Physical activity and public health

Health benefits of physical activity for patients with clinical conditions

Evidence for the health benefits of leading a physically active lifestyle and the notion that '*Exercise is Medicine*' is unequivocal. Regular moderate and vigorous intensity physical activity, including activities at work, play and home, such as walking, cycling, sports or dance participation, can manifest significant health benefits. Research into exercise and physical activity and their effects on health began in the 1950s when Morris and colleagues (1953) investigated risk factors related to the then new major public health problem of cardiovascular disease (CVD; Morris et al., 1953). The findings of such studies led to the hypothesis that men in physically active jobs suffer less coronary disease than those in sedentary jobs. This pioneering work in the field of physical activity and epidemiology initiated follow-up studies and research, which showed physical activity to be instrumental in the primary and secondary prevention of diseases such as diabetes, cancer, musculoskeletal disorders and mental illness. Since 2011 evidence to support the health benefits of regular physical activity for all groups has become more compelling (Table 3.2). Regular physical activity has wider social benefits for individuals, communities and society. Benefits include increased productivity, reduced congestion and air pollution, and cost savings for health and care systems.

Table 3.2. Level of scientific evidence for the benefits of physical activity (Brukner and Brown, 2005).

Health problem	Primary prevention Prospective cohort studies	Secondary prevention Randomised controlled trials	Management Cohort studies and RCTs
Cardiovascular disease (including hypertension, coronary artery disease and stroke)	✓✓	✓✓	✓✓
Type 2 diabetes	✓✓	✓✓	✓✓
Colon and breast cancer	✓	-	✓
Mental health problems (especially depression)	✓	-	✓
Obesity (effects of activity must be considered in light of energy intake)	✓✓	✓✓	✓✓
Asthma	-	-	✓
Cognitive function in older people	✓	-	-
Osteoporosis	✓	✓✓	-
Falls and fractures	✓	-	-

Within Sport and Exercise Science, evidence of the benefits of physical activity has been acquired through a variety of studies. Observation of the body's acute responses to a single bout of physical activity shows how different organ systems, such as the cardiovascular system and respiratory system, are stimulated, and provides insight into the potential mechanisms underlying these protective effects.

Similarly, study of the chronic effects of exercise-training shows the potential for regular physical activity to stimulate physiological adaptations that lead to improvements in physical capacity and function, and therefore health. The beneficial relationship between physical activity and health has been demonstrated primarily through cross-sectional, longitudinal, and randomised clinical trials.

- **Physical activity, cardiovascular disease, and all cause-mortality**

Example 3.4 *Physical activity and cardiovascular disease (CVD)*

Early work in physical activity epidemiology investigated the associations between physical activity, cardiovascular disease and all-cause mortality. Physical activity was shown to confer a cardio-protective effect (Morris et al, 1953) reducing the risk of CVD-related death by up to 50% (Paffenberger et al., 1978). Evidence suggests that individuals with CVD risk factors who adopt an active lifestyle reduce their risk of premature death to a greater extent than do sedentary individuals with no other risk factors (Myers et al., 2004; Blair et al., 1996). The benefits of physical activity also extend to individuals with CVD, where regular exercise can halt or even reverse the disease process. Cardiac rehabilitation programmes involving exercise can reduce the incidence of premature death by 32% (Eijsvogels et al., 2020) and in some cases, increasing physical activity levels can even promote regression of atherosclerotic plaques (Kurose et al., 2016).

The beneficial effects of physical activity for CVD are due to its ability to condition the cardiovascular system. Regular exercise leads to cardiac and vascular changes. Exercise increases the heart rate and the amount of blood the heart pumps out during each beat. Regular exercise results in adaptations to improve cardiovascular function such as improving blood pressure (Cornelissen et al., 2013). During an exercise session, small arteries and arterioles widen to increase blood flow to the skeletal muscles. Repeated exercise leads to increased number of blood vessels and greater ability to deliver blood where it is demanded most. An increase in the oxygen carrying capacity of blood also occurs with exercise training due to greater blood cell production immediately following exercise (Bonsignore et al., 2002). Other changes in blood, such as more favourable blood lipid profiles, may also play a role in the primary and secondary prevention of CVD.

- **Physical activity and type 2 diabetes mellitus**

Example 3.5 *Physical activity and diabetes*

The incidence of type 2 diabetes, which constitutes a component of metabolic syndrome, is reduced with regular physical activity. It has been reported that for every 500 kcal increase in weekly energy expenditure, the risk of developing diabetes is reduced by 6% (Helmrich et al., 1991). Moderate intensity activity performed for at least 40 min per week and moderate fitness levels also protect against the development of type 2 diabetes (Lynch et al., 1996). Undertaking moderate activity for at least 150 min per week is more effective then drug treatment for reducing the incidence of diabetes (Knowler et al., 2002). For individuals with established type 2 diabetes, physical activity is also important for the management of the condition. Amongst people with diabetes physical activity leads to a nearly two-fold decrease in the risk of premature death compared to inactive individuals (Wei et al., 2000).

Question: *How might exercise be beneficial for a person with diabetes?*

Answer: Exercise interventions for people with diabetes are beneficial because they improve glucose homeostasis. Exercise can reduce glycosylated haemoglobin to levels similar to those amongst people receiving drug-therapy, which is associated with a 42% reduction in diabetes-related mortality (Knowler et al., 2002). Research has shown that individuals with insulin-dependent and non-insulin-dependent diabetes mellitus have improved sensitivity to insulin and improved glycaemic control after exercise training (Koivisto et al., 1986).

- Physical activity and osteoporosis

Musculoskeletal unloading during immobilisation, prolonged bed rest, or space flight causes a loss in bone mass and even osteoporosis. Regular physical activity is an effective secondary strategy for preventing osteoporosis and maintaining bone health. When performed routinely it also helps to prevent the bone loss associated with ageing. Exercise training can prevent or reverse almost 1% of bone loss per year in the lumbar spine and femoral neck in pre- and post-menopausal women (Wolff et al., 1999). Further, exercise-training appears to significantly reduce the risk of falls (Sherrington et al., 2019) and the risk and incidence of fractures (Gregg et al., 2000). High-impact activities, especially weight-bearing and resistance exercises, appear to have the greatest effects on bone mineral density (Warburton et al., 2001) particularly in women with poor bone health (Yu et al., 2019).

- Physical activity and mental health

Mental health refers to cognitive, behavioural, and emotional wellbeing. Conditions such as stress, depression and anxiety can affect how people think, feel and behave. Other types of mental disorders include conditions such as schizophrenia and addictive behaviours.

Example 3.6. *Evidence on the beneficial effects of physical activity on mental health*

While it is often moderate-to-vigorous physical activity (e.g., exercise, playing sports, cycling to work) that are associated with better mental health, positive changes (e.g. light ambulation) can occur from light physical activity too. People have widely varying preferences for the types of activity they wish to engage in and thus, benefit from doing something they "want to" and enjoy. Researchers have addressed the effects of both single session and training programs of physical activity on a wide variety of psychological outcomes, including effects on mood, self-esteem, cognitive functioning and decline, depression, and quality of life. Evidence points to:

- Positive effects from regular physical activity on cognition and emotion and reduction of distress and negative affect (Archer et al., 2014);
- Reduced anxiety and depression from engagement in aerobic exercises e.g. walking, jogging and cycling (Guszkowska, 2004) as well as resistance training (Gordon et al., 2017);
- Exercise playing role in reducing alcohol and drug dependency and enhancing smoking cessation (Zschucke et al., 2012);
- Strong link between physical activity and improved sleep outcomes (Faulkner and Taylor, 2005).

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Question: *What might explain the beneficial effects of exercise on anxiety?*

Answer: Anxiety disorders are chronic and debilitating psychiatric conditions, which impact multiple aspects of one's life. The prominent anxiety disorders defined in the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV) are General Anxiety Disorder (GAD), Panic Disorder (PD), Posttraumatic Stress Disorder (PTSD), Obsessive Compulsive Disorder (OCD), Social Anxiety Disorder, and Specific Phobia. The exact ethology and pathophysiology of these conditions is not fully understood. Exercise, especially aerobic exercise, increases blood circulation to the brain, which may improve mood by influencing the pituitary-adrenal axis, which in turn may impact stress reactivity (Pietrelli et al., 2018). Exercise facilitates self-efficacy and social interaction, and thus improves self-esteem and lessens social withdrawal.

Physical activity for population-based health

The huge body of evidence about the benefits of exercise for health have led to a consensus that engaging in regular physical activity underpins improved health outcomes across a wide spectrum of conditions. This is linked to the association between physical inactivity, a modifiable risk factor, and the development of chronic disease and premature death. This evidence has led to national governments recommending guidelines for physical activity levels. For adults aged 19 to 64 years old, the following is currently recommended (UK Chief Medical Officers' Physical Activity Guidelines, 2019):

- For good physical and mental health, adults should aim to be physically active every
- Adults should do activities to develop or maintain strength in the major muscle groups. These could include heavy gardening, carrying heavy shopping, or resistance exercise. Muscle strengthening activities should be done at least two days a week, but any strengthening activity is better than none.
- Each week, adults should accumulate at least 150 minutes (two and a half hours) of moderate intensity activity (such as brisk walking or cycling); or 75 minutes of vigorous intensity activity (such as running); or even shorter durations of very vigorous intensity activity (such as sprinting or stair climbing); or a combination of moderate, vigorous and very vigorous intensity activity.
- Adults should aim to minimise the amount of time spent being sedentary, and when physically possible should break up long periods of inactivity with at least light physical activity.

How much physical activity?

Prescribing the right dose of physical activity to enhance health is an important but challenging task. The dose of physical activity refers to a combination of the intensity of activity, the duration of activity and the frequency of performing the activity. A low intensity workout performed for 60 minutes every day may be equivalent to a higher intensity activity performed daily for a much shorter duration of time.

Discussion:

- Recent physical activity guidelines recommend engaging in moderate-intensity activity for 150 minutes per week or vigorous-intensity activity for 75 minutes per week. **What might be some of the limitations of this guidance?**

To think about:

- This implies that the total volume of physical activity, regardless of its intensity, is important for gaining health benefits.
- This is a generalisation applicable to most of the population but does not take into account the effects of different health disorders
- The complexity of different types of activity and diverse health conditions frustrates any effort to provide a single specific prescription of activity to provide health benefits for everyone.

What type of activity?

A key consideration is the level and intensity of the recommended exercise. Initial thinking was that exercise should be vigorous. Beneficial physiological changes, such as improved cardiopulmonary endurance, were believed to be maximised by high-intensity exercise training. However, many studies have since shown that health benefits still exist at lower intensities of exercise. The positive effects of physical activity in reducing the risk of premature death are graded according to the amount of physical activity, and display a curvilinear relationship. While modest increases in activity levels amongst previously sedentary individuals can bring about large improvements in the relative risk of death, significant risk reductions are also observed with small increases in activity levels (Myers et al., 2002). Although more physical activity is generally regarded as better, increasing exercise further produces smaller risk reductions. An American study that assessed the degree of risk reduction amongst those adhering to national physical activity guidelines, which are similar to those of the UK, suggested that CVD reduction comprised 75% of the maximum benefit (Kraus et al., 2019). However, studies have confirmed that physical activity below the recommended guidelines still confers substantial health benefits (Eijsvogels et al., 2016).

Whilst research within Sport and Exercise Science offers a wealth of information for exercise programming and prescription to achieve desired training goals and health outcomes, physical activity guidelines to improve general health amongst the population address the challenging task of promoting physical activity to inactive people. Guidelines are developed to provide an effective and consistent message that is comprehensible to the majority of the population and which can be easily integrated into daily living. Understanding the psycho-social factors that influence physical activity engagement is also important for promoting active lifestyles and physical activity messaging.

In 1990, exercise referral schemes were built into public health pathways to initiate physical activity among sedentary individuals with signs of lifestyle disease, and to facilitate reduction in their risk factors. These 'exercise on prescription' interventions constitute referrals by a primary care clinician (including general practitioners (GPs), nurses, physiotherapists, and condition-specific specialists) to a tailored programme of increased physical activity delivered by third party service providers, and preceded by health and fitness assessments, with monitoring and supervision throughout. Thus, these schemes are more than just simple advice on physical activity given by the GP, but also work differently to other clinical exercise interventions as they are delivered in a non-clinical environment.

Since the publication of the National Quality Assurance Framework for exercise referral schemes (Exercise Referral Systems: A National Quality Assurance Framework, 2001, n.d.) there has been a rapid spread of such schemes involving supervised exercise sessions taking place in public leisure facilities throughout the UK. The National Institute for Health and Care Excellence (NICE) recommended that such schemes should last for at least 12 weeks (NICE, 2014). So such schemes typically last 10–12 weeks in England and Ireland, and 16 weeks in Wales. However, there is no strong evidence of superior benefit from schemes lasting longer than the recommended minimum of 12 weeks, or from different types and modes of exercise. Typically schemes offer one-to-one supervised gym based exercise sessions combining cardiovascular and resistance exercises, group aerobic classes, swimming, walking groups, and chair-based exercises. The main reasons for referral into an exercise referral scheme are health conditions including cardiovascular, metabolic, respiratory, musculoskeletal, mental health, digestive and behavioural disorders.

Research undertaken to evaluate the effectiveness of such schemes in improving and sustaining participation in sedentary adults has established that they are beneficial predominately for individuals who were slightly active and/or overweight at entry point, but not sedentary and/or obese (Morgan 2005). This has resulted in NICE recommending that exercise should only be prescribed if part of a properly designed and controlled research study, able to determine effectiveness (NICE, 2006). Main reasons for the low adherence to such schemes, showing that nearly 80% of participants dropped out before the end of the programme, are also under scrutiny. Factors such as individual differences in self-determination and behavioural regulation, or readiness to engage in behavioural change, as well as the ability to offer a variety of types and intensity of physical activity, have been identified as essential for increased uptake and adherence.

Example 3.7. *Exercise on prescription for weight loss*

A 12-week exercise on referral scheme funded by the NHS and delivered in 2008-2009 by the local Culture and Leisure Trust was evaluated by Health Care and Sport and Exercise Science researchers from London South Bank University. 458 individuals, currently inactive but willing to increase physical activity levels, were referred with the following conditions: obesity (52%), hypertension (45%), diabetes, joint and back pain, anxiety and depression. Assessment including medical history, readiness to change, desired goals, 7 day physical activity recall, and knowledge of the health effects of physical activity, as well as measurements of height, weight, blood pressure, and hip and waist circumferences were made at entry point, at the end of the 12-week programme, and 6 months later.

Only 53% of participants completed the full exercise programme, and only 26% the 6-month assessment. Significant reductions in weight, blood pressure and waist circumference, as well as self-reports of poor health, were found upon completion of the programme. The time spent in moderate-to-vigorous physical activity per week significantly increased, and was still largely preserved six months later.

Participants who completed the full programme experienced significant health benefits, but the study found high dropout rates. The researchers recommended using follow-up phone calls and support to improve adherence rates. Recommendations included improving the information available to referring health professionals about the scheme, and improving the feedback loop between health professionals, deliverers and participants.

Sedentarism and physical inactivity – getting people moving

Even individuals who are sufficiently active are at increased risk of ill-health if they spend large amounts of time sitting (Physical Inactivity and Sedentary Behaviour Report 2017 ABOUT THE BRITISH HEART FOUNDATION (BHF), n.d.). Sedentarism, defined as *‘any waking behaviour characterised by an energy expenditure ≤1.5 metabolic equivalents (METs), while in a sitting, reclining or lying posture’ (Sedentary Behaviour Research Network, 2012),* is a risk factor that is independent of physical inactivity. The relationship between physical activity and sedentary behaviour is still not clear. Being physically active can reduce risk factors of ill-health. Lower body mass index has been observed when physical activity is performed for more than 60 minutes daily and TV viewing is less than 60 minutes daily compared to the same TV viewing time and less than 60 minutes physical activity per day (Dunton et al., 2009). However, the research is equivocal, with some studies showing that low levels of moderate-vigorous physical activity are associated with a higher risk of obesity, regardless of TV time or total sedentary behaviour (Maher et al., 2013). Even for adults performing the recommended levels of daily physical activity, prolonged sitting during the day increases the risk of all-cause mortality (van der Ploeg et al., 2012). Using longitudinal cohort studies, researchers have estimated that 11.6% of deaths from any cause were associated with sedentarism (ref??). The British Heart Foundation estimates that the average man in the UK spends the equivalent of 78 days each year sitting and almost 64 days each year watching TV (Physical Inactivity and Sedentary Behaviour Report 2017 ABOUT THE BRITISH HEART FOUNDATION (BHF), n.d.). Replacing sedentary time with light physical activity can lead to health improvements that are not observed by simply adding bouts of moderate to vigorous physical activity to a sedentary lifestyle *what does this mean??* (Duvivier et al., 2018). Thus, population-based interventions to increase general physical activity and reduce sedentary time in the population are vital for addressing the rise in obesity and poor health.

The causes of physical inactivity are multifactorial and include societal and political drivers. Of note are economic and geographic inequalities, in which those with lower incomes and those living in the north west of England are less active than those in the south east. Individual factors such as age, race and gender are also factors that affect physical activity levels.

Considering an ecological approach to the drivers of physical inactivity reveals that some groups of individuals are at greater risk. National bodies such as Sport England have undertaken a lot of research in order to understand physical activity levels across populations that are least likely to be active e.g. women, older adults and those from Black, Asian and minority ethnic groups.

Physical activity amongst women

- Women are 36% more likely than men to be classified as physically inactive (BHF 2017.).

- Men do more sports and physical activity than women in almost every age group. In England, boys (5-16 years old) are more likely to be active than girls (51% vs. 43%) (Sport England, 2019b)
- Participation in sport begins to drop from the age of 10 to 11 (Public Health England, 2014).

Reasons for physical inactivity in females include fear of judgement, lack of time, and lack of confidence in their ability to exercise (Sport England, 2020a). Interventions therefore focus on addressing these factors to improve physical activity participation in the female population.

Example 3.8. *Tackling physical inactivity in girls and young women*

Launched in 2015 the national campaign of Sport England 'This Girl Can' aimed to get women and girls moving 'regardless of shape, size, and ability'. In a powerful TV advert it emphasized that physical activity can be re-imagined and can take many forms – if it increases heart rate it counts.

Local level initiatives that focused on specific groups of females were also implemented. The *'This Girl Can – Lambeth'* project ran from 2016-2019 and aimed to improve physical activity engagement in young urban-dwelling females (14-25 year olds). Physical activity programmes were co-designed with local stakeholders including the Clinical Commissioning Groups and, importantly, sports deliverers who were experienced in providing community-based activities to young people. By targeting schools and drawing upon local knowledge from community networks, the project was successful in engaging 5000 young females living in the London's Borough of Lambeth. Physical activity promotion was achieved through providing role models and tailored female-only activities and workshops such as body empowerment.

Sports and Exercise Scientists from London South Bank University conducted research to understand the barriers and facilitators to active living from an ecological perspective. The project provided insight and formulated recommendations for developing good practice and designing physical activity to improve health amongst this population.

Older adults

Physical inactivity increases with age. The latest figures from the UK Government show that 29% of those aged 65-74 years, and 52% of those over 75 years, are inactive (HM Government, 2019). Physical inactivity is not necessarily connected to physical ability. Different reasons relating to work, family and caring responsibilities, and social attitudes to active living, can have an impact. However, there are large differences across this age group

(55+ years) concerning the barriers to physical activity. Individuals of the same age may differ in their experiences, motivations and capabilities for active living. Research on recently retired people suggests that the social component and enjoyment of exercise are important motivators. To engage older adults in physical activity, Sport England's Understanding Participation in Sport report (2006) recommends simple actions, such as using positive messaging and reassurances about safety, promoting the opportunities available to this age group, arranging taster sessions, making opportunities as local as possible, and avoiding the word 'sport'.

Ethnic minorities

Research shows the type and volume of sports and physical activity that people undertake varies depending on ethnicity. Findings from the latest Active Lives Adult Survey (Sport England, 2019a) show that *Mixed* and *White Other* adults have the highest activity levels. In 2017/2018 people from the *Asian*, *Black* and *Other* ethnic groups were more likely to be physically inactive, with levels at 31%, 29%, and 30% respectively (Sport England, 2019a). For some ethnicities, larger differences between men and women's levels of physical activity are also observed. For example, females from White backgrounds are more likely to take part in sport and physical activity compared to women from Asian, Other and Black backgrounds.

The generally lower level of involvement of Black, Asian and minority ethnic (BAME) groups and communities in sport and physical activity is not confined to participation; it also extends to spectating, volunteering and sport and physical activity administrative roles. The lack of role models within sport for individuals of minority ethnic backgrounds may contribute to their lack of participation. A systematic review (Long et al., 2009) recommends good practice for sports providers, including: (1) training for those working in sport on the needs of minority ethnic communities and on challenging exclusion; (2) ensuring that racial equality objectives in policies are converted into practice; (3) training sports facilitators from BAME communities.

Example 3.9. *Ethnicity-dependence of preferred physical activity type*

Insight from Sport England's research (2019a) shows that people's choices of sport and physical activity varies depending on ethnicity:

White British

- More likely to walk for leisure than any other ethnic group
- 2.6% play golf (higher than any other ethnic group)
- 4.1% take part in football
- 6.4% take part in team sports
- 11.1% take part in swimming, higher proportion than any other ethnic group.

South Asian

- 7.3% play racket sports
- 7.3% take part in football
- 2.6% play cricket, a higher proportion than all other ethnic groups.

Black

- 16.9% take part in gym sessions, a higher proportion than most other ethnic groups
- 11.9% take part in team sports
- 7.6% take part in football.

Mixed

- Most likely of all ethnic groups and communities to take part in sporting or fitness activities generally
- 12.1% take part in team sports, higher than any other ethnic group
- 21.1% engage in running, a higher proportion than all other ethnic groups

Active travel – walking and cycling for health

Daily bouts of walking and cycling can have a major influence on health and longevity due to increased rates of energy expenditure (Ainsworth et al., 2000). Up to 40% reduction in mortality rates was found in Danish men and women who cycled daily to work (Andersen et al., 2000). European citizens with high rates of walking and cycling have less obesity than do people in Australia and North America who are very car dependent (Bassett et al., 2008). Active commuting was found to be positively associated with aerobic fitness among men and women and inversely associated with body mass index, obesity, triglyceride levels, resting blood pressure, and fasting insulin among men (Bassett et al., 2008). A recent large prospective population based cohort study, using data from the UK Biobank study, found that cycling and walking commuting is associated with a lower risk of cardiovascular disease, cancer and all-cause mortality (Celis-Morales et al., 2017). The risk reductions are probably related to active commuting, and cycling in particular, due to the greater exercise intensity, contributing to overall daily physical activity and cardiovascular fitness. Whilst approximately

90% of cycle commuters and approximately 80% of mixed mode walking-cycling commuters achieved current physical activity guidelines, only 54% of walking commuters did; a similar proportion to non-active commuters (51%).

Only 3% of UK's commuters cycle to work and 11% walk, which compares unfavourably to 43% of the Dutch and 30% of Danes cycling daily. To promote healthier journeys to work and reduce environmental pollution the Finance Act 1999 introduced the Cycle to Work scheme as a UK Government tax exemption initiative. It allows employers to loan cycles and cyclists' safety equipment to employees as a tax-free benefit.

Example 3.10. *Dose–response relationship between cycling and health outcomes*

Recent research on the relationship between multiple levels of cycling and the extent of change in health outcomes has found:

- Significant correlations between the total weekly energy expenditure of cycling and the **change in fitness** (peak VO_2max) for both men and women. Positive gain in fitness is achieved at approximately 1000 and 1500 kcal/week of energy expended for women and men respectively (de Geus et al., 2009)
- In a 16 year study, increased cycling was associated with reduced weight gain in premenopausal women, especially amongst the overweight and obese. Conversely, weight gain increased with decreased cycling time. (The Nurses' Health Study II (not in refs); Lusk et al., 2010).
- Cycling for up to 3.5 hours per week protects against weight gain compared with non-cycling, but cycling for more than 3.5 hours per week does not provide additional protection (Hoevenaar-Blom et al., 2011).
- There is a 23% reduction in the risk of **coronary heart disease** incidence with sports participation for up to 3.5 hours per week and a further reduction to 34% with more than 3.5 hours per week participation. There is a 36% reduction in risk amongst those participating in both cycling and sports compared to those engaging in neither cycling nor sports.
- There is a decreased hazard ratio for **colon cancer** in men from 1 to 0.81 with daily cycling of up to 30 minutes, and up to 0.41 if cycling for more than 120 minutes per day, with similar changes observed for women (Hou et al., 2004)

What health and healthcare problems can Sport and Exercise Science help us to understand?

- Sedentarism and obesity (Exercise promotion and adherence)
- Metabolic disorders (Exercise referral)
- Motor learning and control (Rehabilitation)
- Nutritional complications (Dietetics)
- Sleep disorders (Cognitive behavioural therapy)
- Recovery from fatigue, injury and burnout (Human performance evaluation)

Sport and Exercise Science methodology

As an interdisciplinary science, Sport and Exercise Science considers the content and aims of the classical social sciences, whilst employing methods predominantly from natural sciences (figure 3.2). *Natural science* is the broad group of studies examining the objects of living (e.g. biology) and inert nature (e.g. physics, chemistry). *Social sciences* examine humans as social creatures, human society, and the relationship between the two (e.g. sociology, psychology, economics, and pedagogy). Sport and Exercise Science have built their own focus and research methods, conceptual frameworks and terminology, as well as their own academic institutions and theories.

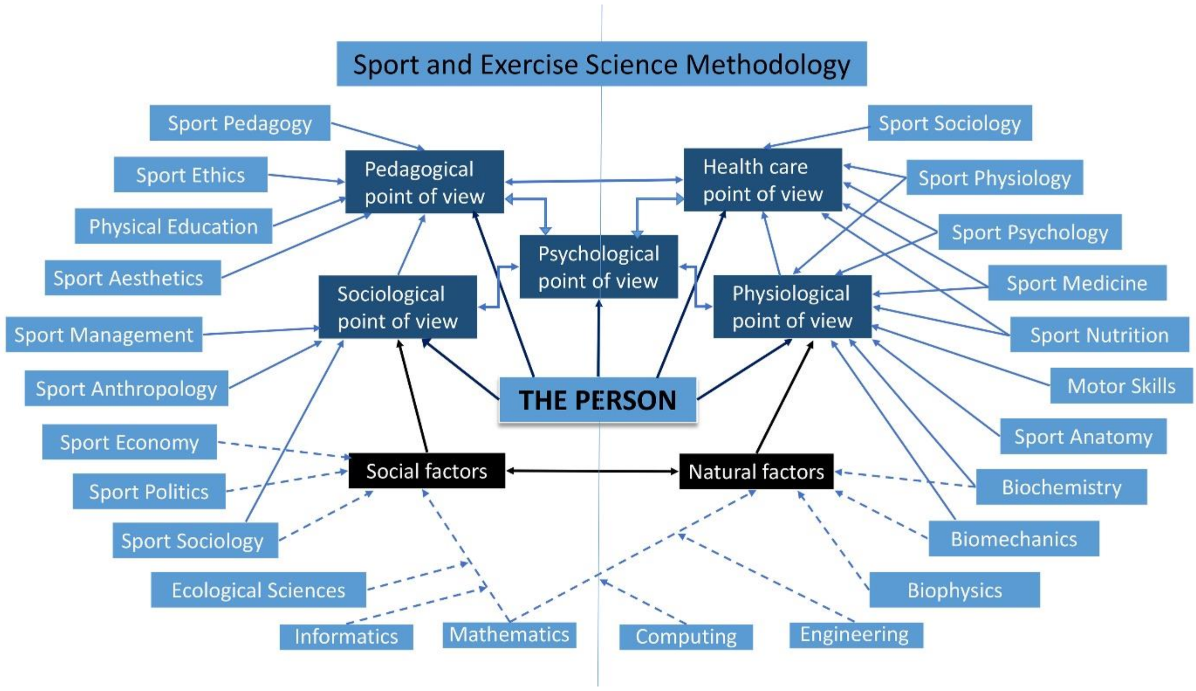

Figure 3.2. Schematic illustration of the interdisciplinary nature of the Sport and Exercise Science methodology

The research process in Sport and Exercise Science can take either a ***deductive*** or an ***inductive*** approach. When taking the deductive approach the researcher aims to test a theory, i.e. first formulates assumptions and hypotheses built on general principles and then collects evidence to prove them. The inductive approach works in reverse – first evidence is collected, which is then used to develop a theory. The main stages in the research process are shown in Figure 3.3.

Connections Chapter 1 (Biology) describes the inductive and deductive approach of science.

Chapter 2 (Epidemiology) describes some types of research study including experiments.

An example of research built on deductive reasoning would be a study aiming to evaluate the relationship between obesity (body mass index above 30 kg/m^2) and muscular strength (e.g. evaluated with a grip strength test) based on evidence that excess adipose tissue causes reduction in muscle function through a complex interplay of factors such as enhanced levels of inflammatory mediators and insulin resistance (Pasdar et al., 2019).

Sport and Exercise Science employs numerous methods, both theoretical and empirical, and follows the general **scientific principles** of study that impact on research quality:

- *Validity* - relates to whether the measure taken actually relates to what was planned to evaluate. There are two types of validity - *internal* (e.g. can the results be attributed to the tested program only?) and *external* (can the results stand in the real-world environment?). To claim internal validity the researcher must ensure full control of everything that could affect the results of the study. They must also ensure that the methods used produce similar results to those acquired using a 'gold-standard' approach (e.g. when you are using a different piece of equipment to that traditionally used). For external validity the researcher must make sure that the tested conditions can be replicated in a non-controlled real-life environment.
- *Reliability* - relates to whether, if the research is repeated, the results will be the same or similar. This can be done by the same researcher on different occasions

(test-retest reliability) or by different researchers getting the same results when applying the same test (inter-researcher reliability) . Poor reliability can be due to: applying a difficult or wrong procedure; the equipment not being calibrated well or malfunctioning; or the researcher not conducting the test properly. Some procedures and measurements are difficult or have natural high variability. For example, without experience it is difficult to make accurate assessments of body composition using the classic skinfold calliper technique, particularly from very muscular or obese individuals.

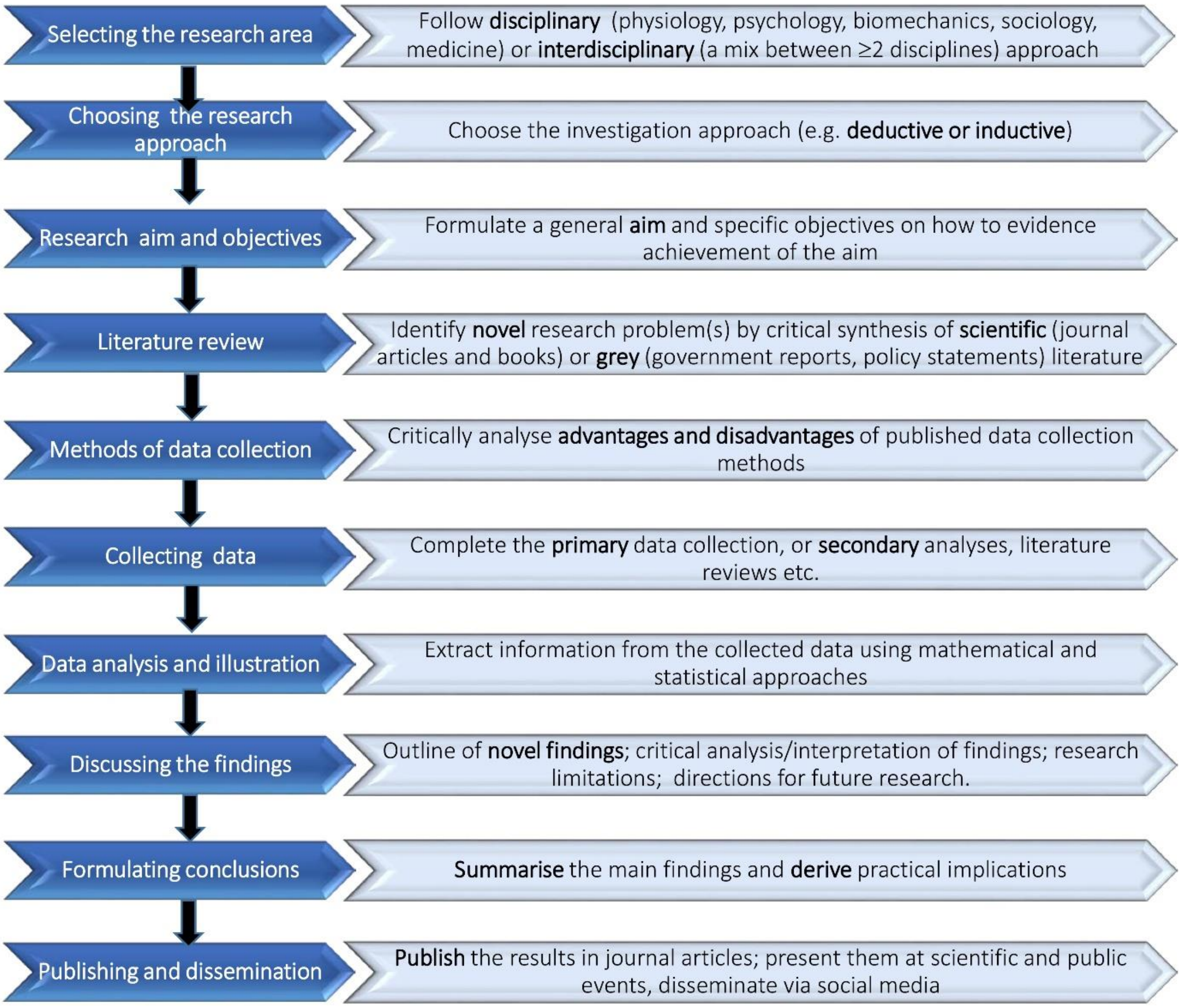

Figure 3.3. Main stages of the research process undertaken in Sport and Exercise Science investigations

- **Accuracy** - relates to how close the measurement is to a true value or a value achieved when using an accepted reference method. Generally, a difference below

1% is considered good but this cut-off level may vary for different measurements. As an example, if the true weight of a boxer is 100 kg and the weighing device shows 100.1 kg this could be taken as accurate, but if the device shows he weighs 103 kg, this cannot be taken as an accurate measurement.

- ***Precision*** – relates to how small a difference the measurement tool can detect. This information is usually provided by the manufacturers in the technical specifications of the tool and influences the repeatability of the measurement.

Sport and Exercise Science research is also concerned with the principles of generalisability and practical implications. From the very inception of an investigation, Sport and Exercise Science researchers must consider how their findings meet both professional standards for research but also might be adapted for the intended population, in the actual life setting, and how any proposed interventions can be delivered by people with diverse educational backgrounds, training and skills, using the available resources.

Types of research in Sports and Exercise Science

In Sport and Exercise Science, three major types of research are undertaken:

- ***basic research*** – focuses on understanding phenomena and principles of relevance to the world and forms the basis for future scientific work by acquiring new knowledge; e.g. which structures and processes within the neuromuscular system contribute to fatigue development.
- ***applied research*** - focuses on the practical application of research and examines the possibility of using the results from basic research; e.g. , what interventions can help to prevent and/or delay fatigue development during physical exercise and speed-up recovery after injury or illness?.
- ***developmental research*** – focuses on designing, monitoring and evaluating programmes, processes and products developed by scientists, entrepreneurs and the health industry e.g. , developing and efficacy testing of a supplementation strategy for improving endurance and performance by delaying physical and/or cognitive fatigue development.

Types of data collected in Sport and Exercise Science

Data collection methods can generally be divided into 2 categories: *primary* and *secondary* data. **Primary data** are collected first-hand by a researcher for the specific purposes of an original project. **Secondary data** have been collected in previous investigations and have been published. Rich sources of data for health-related research can be found in published data sets from epidemiological studies such as the Avon Longitudinal Study of Parents and Children (ALSPAC) dataset (http://www.bristol.ac.uk/alspac/).

In Sport and Exercise Science, data can be collected using different methodological techniques:

- ***Quantitative research*** is a formal, objective and systematic process for the collection of numerical data used to test a hypothesis or discover relationships or establish differences, relationships or causality. It usually involves measurements of functional and/or performance indicators using technology, e.g., heart rate changes during running. The use of physical activity questionnaires is the most common method for the evaluation of physical activity in public health research. There are more than 20 physical activity questionnaires proven to be valid and reliable, particularly when applied to large cohorts. The most frequently used questionnaires in clinical applications are the long and short versions of the International Physical Activity Questionnaire (IPAQ; Hagströmer et al., 2006). A modern alternative to this subjective method (i.e. based on self-reporting) is the objective measurement of physical activity using lab-based or wearable accelerometers (Freedson et al., 2012; see example 3.15).

Connections: Chapter 3 describes the associations and causal relationships investigated in epidemiology.

- ***Qualitative research*** is generally subjective and involves textual rather than numerical data. It looks at feelings, perceptions, opinions and emotions, and tries to explain why rather than what or how many. It favours the inductive approach, which develops a hypothesis through the research. It also tries to explain differences, relationships and causality. A three-stage technique is often used, which starts with a main *guiding question* (e.g. what motivates you to…?), succeeded by *probing* *questions* (e.g. can you give me a specific example….?) and concluding with a *follow-up question* to check correct understanding of context (e.g. So, am I correct in saying that…?). The data collection approach (quantitative versus qualitative) dictates the major features in the study design (Table 3.3).

- ***Mixed methods research*** requires a purposeful mixing of methods in data collection, data analysis and interpretation based on purposeful integration of the evidence (Shorten and Smith, 2017). For example, a study of the effectiveness of a school-based intervention study that targets diet and physical activity for the prevention of child and adolescent overweight and/or obesity uses a qualitative elicitation phase to inform the development of later quantitative measurements on changes in knowledge, attitudes and dietary and physical activity behaviours (Dukhi et al., 2020).

Table 3.3. Comparison of the main features of the two general data collection types.

Main differences between qualitative and quantitative data collection methods			
		Quantitative	Qualitative
Requirement	Question	Hypothesis	Interest
	Method	Control and randomization	Curiosity and reflexivity
	Data collection	Response	Viewpoint
	Outcome	Dependent variable	Accounts
Ideal	Data	Numerical	Textual
	Sample size	Large (power)	Small (saturation)
	Context	Eliminated	Highlighted
	Analysis	Rejection of null hypothesis	Synthesis

Type of study designs in Sport and Exercise Science

- ***Descriptive studies*** – these usually describe what is currently occurring in a particular field (e.g. nutritional habits, motion analyses, physiological and psychological characteristics, training practices and other observations regarding successful practice). An example of a descriptive Sport and Exercise Science's study is the audit of the training practices of swimmers, which reported differences in the balance, volume and timings of swim and strength and conditioning training sessions between athletes competing in different categories (sprint, medium and long-distance) (Pollock et al, 2019).

- **Regression studies** - usually investigate relationships between predictor variables and actual function/performance (e.g. research investigating determinants of endurance performance; Bishop, 2000). Such studies cannot directly elucidate underlying mechanisms (*how?*) but can give information on modifying the influencing factors in future studies (*what?*).
- **Observational studies -** these involve the manipulation of one variable (while controlling other variables) and measuring the subsequent effect on function/performance. Randomized, double-blind studies (with a placebo or control) are one appropriate research design for this purpose.

Connections: Chapter 2 2 (Epidemiology) describes randomised experimental studies.

- **Modelling studies** – a computer or animal-based model is used to determine whether removal of a physiological process affects other functions.
- **Determination studies** – these aim to establish best intervention characteristics (e.g. type, dose, duration, time, frequency etc) which alter controlled predictor of function/performance. Interventions include training or rehabilitation programmes, nutritional guidelines and feedback methods.
- **Efficacy studies –** these take place in either laboratory or 'artificial' field environments and aim to test whether intervention effects are substantial. Such studies are tightly controlled and randomised, and delivered to a homogenous motivated population, so do not always imply transferability to 'real-world' scenarios. However these studies do inform potential 'real-world' interventions, particularly when the effect is large enough to make a difference in an applied setting, i.e. clinical or sporting environment.
- **Implementation studies –** these studies aim to establish the effectiveness of interventions delivered in real settings within the constraints of time, technical and specialist human resources.

Example 3.11. *Sports and Exercise Science for injury prevention in cricket*

Previous **descriptive research** demonstrates that cricket fast bowlers have an increased incidence of lumbar disc degeneration (*the problem*). **Regression studies** showed that this was related to technique. Follow-up **efficacy trials** identified educational approaches that could be used to alter technique. A 3-year educational **intervention** with a fast-bowling development squad was implemented and demonstrated that such an intervention was effective in altering technique and reducing the incidence and progression of lumbar spine disc degeneration in a real-world sporting setting (Elliott and Khangure, 2002).

Laboratory-based versus field-based studies

Science and practice demand that measurement of human function and performance is accurately and repeatedly obtained using the same testing process in similar environments. However, the settings in which data is collected often limit data type and collection techniques. The most reliable research **collects data using laboratory-based measurements,** which uses expensive technology and specialist skills. Such research has high internal validity, but lower ecological validity. Laboratory based sessions produce 'gold-standard' data because the external environment is tightly controlled. However, results must also accurately reflect what happens in real-life, so sports and exercise science professionals are often challenged to test human function and performance in the field (e.g. sports grounds, gyms, clinical labs, home) rather than in the laboratory environment. Field-based data collection offers high ecological validity of the measurements and generates high quality data due to advanced technology for individualised measurements.

Example 3.12. *The largest ever field-based biomechanics study*

The 2017 IAAF (International Amateur Athletic Federation) World Championships in London were recorded by 49 high-speed cameras to capture data from 76 individual events and over 730 athletes. Three-dimensional motion techniques were used to analyse all the events. Following 6500 hours of project planning, data capture and analysis, the study resulted in 38 research reports. Highlights included the breakdown of athletic performance and key factors, which affect race time, such as water-clearance in Steeplechase and change-over time in relay races. The analysis of human movement during performance can also help to understand, manage, and mitigate injury, for example by identifying asymmetries in stride length. The IAAF has been conducting biomechanics research for over 30 years across the World Championships in Rome, Athens, and Osaka. Such findings provide useful insight for coaches and athletes, and can be used to improve athletes' health and wellbeing.

Example 3.13. *The maximal aerobic capacity (VO_2 max) test (figure 3.4A)*

The test used to assess maximal aerobic capacity (VO_2 max) is one of the most frequently measured physiological variables in exercise physiology laboratories. VO_2max is the most important indicator of individual fitness and is an objective and independent parameter of cardiovascular disease prognosis (Kubozomo et al., 2008). NB Is Kubozono et al in refs

Maximal aerobic capacity, also referred to as maximal oxygen uptake, is defined as the maximal amount of oxygen one's body can transport and utilize to function. The higher the aerobic capacity, the fitter the person. This test is the gold standard for the assessment of endurance performance in sports and is a measure of the functional capacity of the physiological systems involved in extraction, transportation and uptake of oxygen (namely the respiratory, cardiovascular and muscular systems). The measurement of VO_2 max is often used by exercise physiologists to identify differences between groups of athletes, to monitor the effects of ageing and disease, or to evaluate the effectiveness of training or therapeutic programs.

VO_2max is considered the gold standard measurement of cardiorespiratory fitness, which is influenced by everyday physical activity (Berthouze et al., 1995) and heritability (Williams et al., 2017), and which predicts both morbidity and mortality (Harber et al., 2017). Lower cardiorespiratory fitness, regardless of physical activity levels, is associated with weight gain (Brien et al., 2007) since VO_2 max is associated with measures of energy expenditure, resting metabolic rate and diet-induced thermogenesis (Ando et al., 2019).

The resting metabolic rate represents the energy needed to maintain vital life functions during resting and sleeping conditions, and thus allows the assessment of the major energy requirements and fuel oxidization of an individual. The method for performing this measurement is called indirect calorimetry and in Sport and Exercise Science’s laboratories, it is conducted using state-of-the-art gas analysis systems and standard procedures.

Example 3.14. *Measurements in a Sport and Exercise Science laboratory*

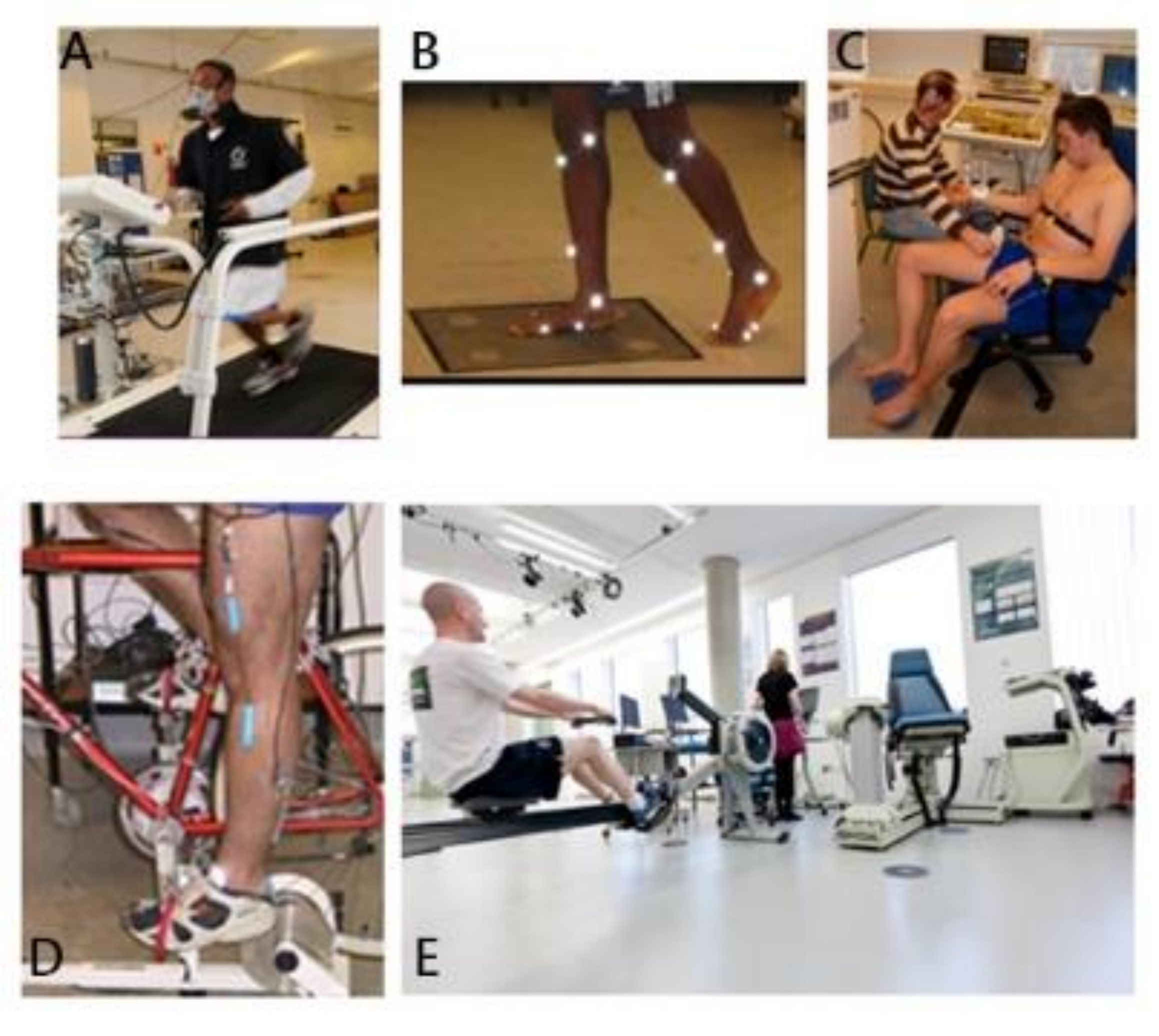

Figure 3.4. Physiological factors most often measured in Sport and Exercise Science to assess health and fitness are respiratory capacity and energy expenditure during activities such as treadmill running, VO2max test (A), mobility and flexibility using reflective markers (B), blood flow changes in peripheral arteries using Doppler Ultrasound (C) and neuromuscular function using electromyography and electrogoniometry (D), and strength, endurance and power during exercise modalities such as rowing (E). Body composition and diet as well as sleep patterns can also be critical factors in sports performance, health status and quality of lives. Scientific databases offer abundant literature detailing the best testing protocols and equipment, data analysis and interpretation approaches.

Example 3.15. *The Use of Wearables and Sport and Exercise Science*

The boom in technology innovation, particularly in the area of individualised wearable tools, has reached professional and recreational sports and exercise.

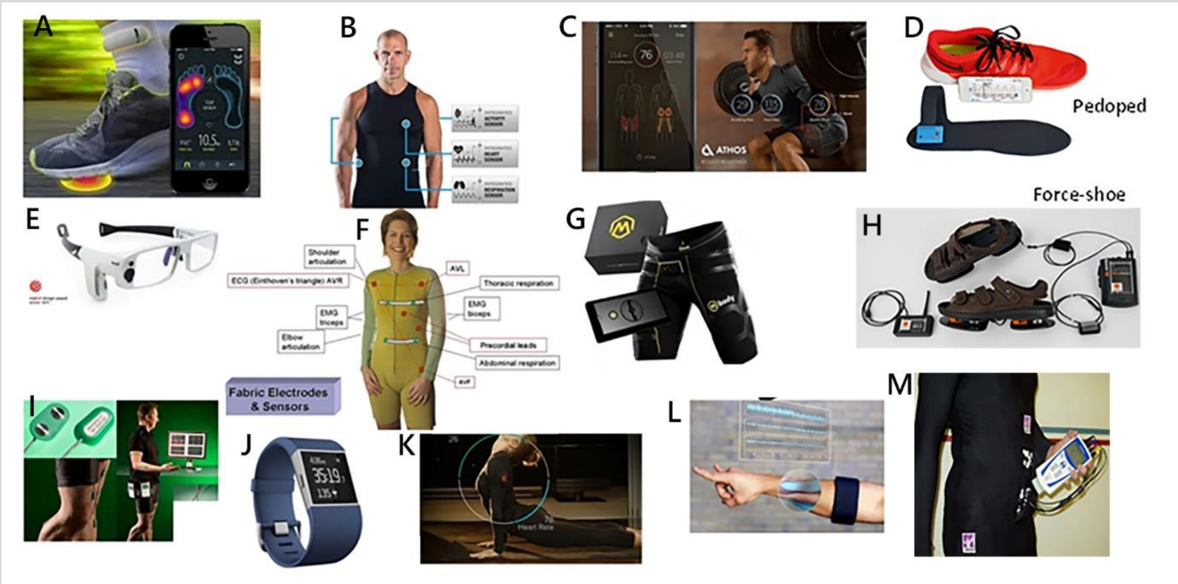

Figure 3.5. Examples of novel wearable technology developed for assessment of human function and performance in laboratory-based and field-based settings. Patented systems enable smart e-materials and clothing to be used to measure a multitude of mechanical and physiological characteristics of human movement, for example: foot-pressure distribution (A); 2- (D) or 3- (H) dimensional impact forces; velocity and accelerations (F, I, K); cardiac (B), respiratory (B, F), visual (E) and muscular (C, G, L, M) function, energy expenditure (J) etc during running, fitness exercises, every-day and occupational activities. Mobile and personalised technologies like these are driving the modern digital health revolution for health and fitness monitoring.

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CASE STUDY: SPORT AND EXERCISE SCIENCE IN THE CONTEXT OF OBESITY

Quantifying energy balance

Obesity is often considered in terms of energy balance. Using the energy balance equation: ($E_S = E_I - E_O$), the storage of macronutrients within the body (E_S) depends on the chemical energy of foods and fluids consumed (energy in; E_I) and the amount of energy expended by the body (energy out; E_O). Excessive food intake and/or insufficient physical activity results in a positive energy balance and increased fat tissue storage, reflected by a gain in body weight. Dietary measures e.g. calorie restriction, are commonly used for treating obesity. However, while such methods can result in weight loss, compensatory decreases in energy expenditure are usually observed (Hall et al., 2011), probably due to the complex nature of the physiological control systems regulating energy balance. Incorporating increased physical activity into daily living will increase total energy expenditure, requiring less food restriction, and therefore may improve adherence to- and sustained success in - weight-loss programmes (Wing and Hill, 2001). Therefore, effective intervention programmes must concentrate on dietary modification and energy expenditure.

Quantifying energy expenditure

Total energy expenditure (TEE) refers to the total amount of energy expended during a 24-hour period. TEE contains 3 main components: resting energy expenditure (REE), thermic effect of food (TEF), and activity energy expenditure (AEE) (Ndahimana and Ki, 2017). *Is Kim in refs.* On average, resting metabolic rate (RMR) accounts for about 60–70% of TEE, the remainder being accounted for by diet-induced thermogenesis (10%) and physical activity (∼20–30%) (Melzer, 2011).

In human energy metabolism, the combustion of fuel in the form of food (carbohydrate, fat, protein, or alcohol) to produce energy is a heat-generating process that involves the use of oxygen and the production of carbon dioxide. Physical activity is defined as any bodily movement produced by skeletal muscles that results in energy expenditure. Physical activity requires different amounts of energy per unit of time depending on the type of activity performed. Exercise scientists have measured the energy cost of activities in metabolic equivalents and expressed them as multiples of resting energy expenditure (1 MET).

Prescribing exercise

Carbohydrates (muscle glycogen and plasma glucose) and fats (plasma fatty acids and intramuscular triglycerides) are the primary sources of energy during exercise. Intensity of exercise largely determines the proportions of their contribution to energy. The intensity of exercise is often expressed relative to maximum oxygen uptake capacity (VO_2max). With increasing exercise intensity, the relative contribution of fat oxidation decreases whilst the relative contribution of carbohydrate as a fuel increases. Much research has sought to understand which exercise intensities are optimal for utilising fat stores (example 3.13).

Muscle: the 'exercise factor' for metabolic health?

Most interventions for managing obesity concentrate on reducing body mass through increasing energy expenditure and utilising the fats stored in adipose tissue. This is of course important given the impact of excess adipose tissue on health, its active participation in hormonal regulation of homeostasis, and the production of pro-inflammatory signals (Wisse, 2004). However, achieving better body composition is also an important factor to consider when designing interventions, and although fat reduction will satisfy this in some respect, increasing muscle mass will also help. Skeletal muscle is not only important for ensuring the body is able to perform functions of daily living such as stair-climbing and carrying goods, but is also an important organ for optimising metabolic health. Skeletal muscle has recently been identified as an endocrine organ. Researchers have found that active skeletal muscle both produces and releases cytokines or "myokines" that are involved in cellular signalling (Pedersen et al., 2013). Myokines probably produce beneficial metabolic effects during muscle-organ crosstalk. Since in healthy weight individuals skeletal muscle is the largest organ in the human body, its contraction – to produce movement for physical activity, has a great potential to influence metabolism in other tissues and organs such as the liver and adipose tissue. This link between muscle contraction and humoral changes has been termed the "exercise factor" (Pedersen and Febbraio, 2008).

Resistance training or the use of body weight or external weights to load the muscles is the primary means for increasing the size (hypertrophy) and strength of skeletal muscles. To produce specific adaptations resistance training requires appropriate programming through the manipulation of variables such as repetition number (the number of movements performed), set number (number of times the exercise is performed), the intensity of the exercise (load applied), and other factors such as type of movement, type of contraction, and inter-set rest interval. Sport and exercise science research have helped elucidate the best training programmes to optimise training adaptations. Since skeletal muscle anabolism, the building of muscle, is an energy-consuming process, adequate nutrition, particularly intake of protein to provide the building blocks of muscle, and amino acids, is required. This, along with increasing the mass of muscle – a metabolically active tissue, illustrates the value of resistance-training for increasing daily energy expenditure and improved metabolic control (Strasser et al., 2012). A recent study concluded that the most effective intervention for improving physical function and reducing frailty in older obese adults was aerobic training combined with resistance training as weight loss was associated with a relative preservation of lean mass (Villareal et al., 2017).

Summary

Using rigorous scientific methods for research, testing and monitoring of the functional and structural adaptations to physical activity and exercise, sports and exercise professionals aim to inform the development and implementation of evidence-based interventions and technology that can benefit human health by:

- revealing the physical, social, environmental and behavioural factors that influence the adoption and sustained participation in sports and exercise by population subgroups of different age, gender, ethnicity and socioeconomic status;
- promoting the benefits from exercise participation and adherence for psychosocial and personal development
- maintaining and improving physical fitness and mental well-being;
- tackling health issues caused by physical inactivity and/or inability
- rehabilitating suboptimal health and performance due to illness, immobility, malnutrition, obesity and ageing
- informing policy and development of recommendations of relevance to population health and with consideration of the specific needs of different subgroups.

Questions for Further Discussion

1. What is the difference between physical activity, exercise and sport?
2. How would you measure a person's readiness to run a marathon?
3. How would you prescribe an exercise program for weight loss?
4. What are the factors affecting people's attitude to sport and exercise?

Further reading:

1. ACSM's Exercise testing and prescription. 1st edition. Eds. Bayles MP and Swank AM. Wolters-Kluwer. ISBN-13: 978-1496338792; ISBN-10: 9781496338792

   Annotation: *This practical resource walks students through the process of selecting and administering fitness assessments, using guidelines to interpret results; explores the particulars of designing exercise prescriptions; prepares students to meet the needs of special populations; includes laboratory materials and activities that provide opportunities for hands-on learning, and a library of journal articles to help students connect research to practice.*

2. Brown S.P., Miller W.C., and Eason J.M. (2006).Exercise Physiology. Basis of human movement in health and disease. Lippincott Williams & Wilkins. ISBN-13: 978-0781735926; ISBN-10: 0781735920

   Annotation: *This text covers comprehensively both traditional basic science and clinical exercise physiology principles. The book presents clinical applications and examples that connect theory to practice and are richly illustrated with tables and graphs. Learning is reinforced via Perspective Boxes, Research Highlights, Biography Boxes, and Case Studies. Free student tutoring services are available with the text.*

3. Gratton C. and Jones I. (2009). Research Methods for sport studies. 2nd edition, Routledge: https://repository.stkipgetsempena.ac.id/bitstream/575/1/Research_Methods_for_Sports_Studies.pdf

   Annotation*: This text leads the reader step-by-step through the entire research process, from identifying a research question, collecting and analysing data to writing the research report. This is an essential read for any student undertaking a dissertation or research project as part of their studies in sport, exercise and related fields. It contains definitions of key terms, revision questions and practical research exercises. Better understanding of the topic is facilitated by sport-related case studies and examples on using social media and online applications for research.*

4. ATS/ACCP statement on cardiopulmonary exercise testing. Am J Respir Care Med. 2003, 167 (2): 211-77.

   Annotation*: This statement provides a comprehensive overview of the latest expert recommendations on the interpretation and clinical application of the CardioPulmonary Exercise Testing (CPET). Students will learn how to use CPET for the evaluation of undiagnosed exercise intolerance and exercise-related symptoms, and for the objective determination of functional capacity and impairment. They will also learn how these results can be used to assist in the clinical decision-making process*

5. Nutrition and exercise in obesity management. Eds. Storlie J. and Jordan H.A. (2013). Springer-Verlag Berlin. ISBN 978-94-011-6721-5; ISBN 978-94-011-6719-2 (eBook); doi: 10.1007/978-94-011-6719-2.

   Annotation: *Being part of a series on Obesity-Weight Control intended to guide health professionals in the growing interdisciplinary field of weight control, this book compiles specific information related to nutrition and exercise management for treatment of obese individuals. The reader will learn of the most contemporary nutritional and exercise strategies, which are critically synthesised using latest information from the fields of medicine, nutrition, exercise, and psychology. The book analyses in depth the protein fasting and behaviour therapy as well as the use of exercise as both a testing tool and a therapy for obesity.*

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