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Mustafa ÖZDAL
Fikret ALINCAK

CURRENT STUDIES IN SPORTS SCIENCES

2024

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Current Studies in Sports Sciences 2024

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Current Studies in Sports Sciences 2024

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This book was typeset in 10/12 pt. Times New Roman, Italic, Bold and Bold Italic.

Current Studies in Sports Sciences 2024

Published by ISRES Publishing, International Society for Research in Education and Science (ISRES). Includes bibliographical references and index.

ISBN

978-625-6959-44-6

Date of Issue

December, 2024

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Preface

Current Studies in Sports Sciences 2024, is published from selected articles invited by the editors.

This issue consists of 12 chapters from the field of Sports Sciences. The book consists of Immunity, Sports Performance and Immunonutrition; Investigation of Sports Injuries and Factors Causing Injuries ; Post-Exercise Recovery Factors; Future Training Perspectives in Basketball;The Basics of Recovery in Basketball; Sports Nutrigenomic ; Velocity Based Strength Training ;Massage and Organism;Energy Requırements in Modern Pentathlon;Respiratory System and Performance;The Relationship Between Delayed Onset Muscle Soreness (DOMS) and Inflammation and Oxidative Stress; Current Physiotherapy Approaches in Elite Athlete Injury Factors.

All submissions are reviewed by at least two international referees.

The book aims to provide its readers with the opportunity for scientifically peer-reviewed review on physical education, healthy living and nutrition.

Current Studies in Sports Sciences 2024, is published by ISRES Publications.

December, 2024

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Citation

Özdal, M., & Alıncak, F. (Eds.). (2024). *Current Studies in Sports Sciences 2024.* ISRES Publishing.

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Immunity, Sports Performance and Immunonutrition

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To Cite This Chapter

Eyipınar, C. D. (2024). Immunity, Sports Performance and Immunonutrition. In M. Özdal & F. Alıncak (Eds.), *Current Studies in Physical Education and Sports 2024* (pp. 1-7). ISRES Publishing

Introduction

Short-term exercise causes temporary suppression of numerous facets of immunity (lymphocyte proliferation, monocyte TLR). Postexercise immunity depression is most noticeable if the exercise is continual, prolonged (>1.5 hours), moderate to high intensity (55-75% VO2max), and done without food. The times of intense exercise lasting one week or more can lead to long-term impaired immunity. Despite professional athletes are not in practice immune deficient, small changes in several immune-related factors may reduce their vulnerability to widespread infections. For that, this is clearly an issue since an infectious incident has the potential to impair performance while exercising (Gleeson, 2007).

Aim of the Study

The aim of this study is to convey the importance of immunity in terms of sportive performance and to investigate and summarize supplements that support the immune system.

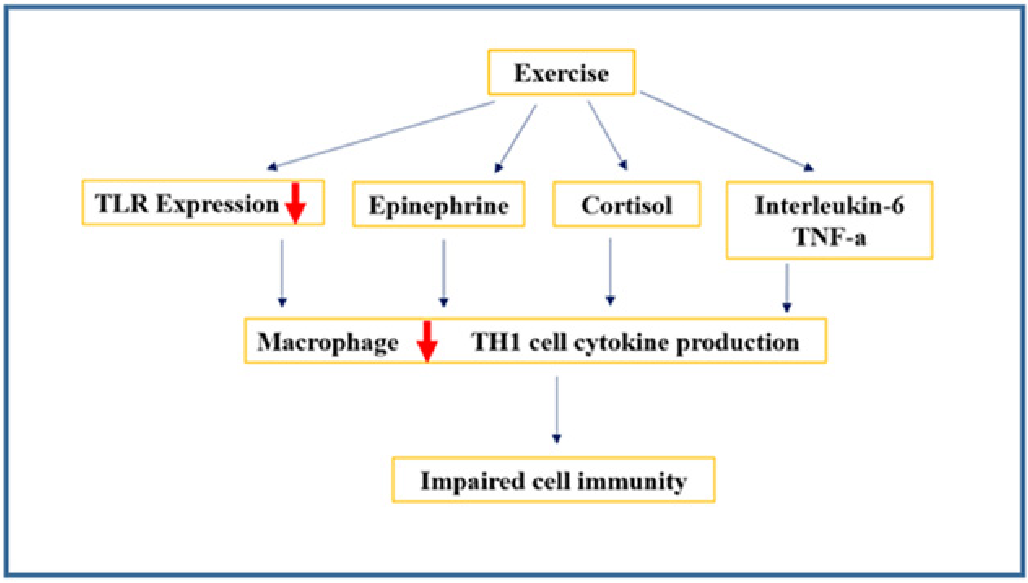
Materials and Methods

To obtain the data for this study, Google Scholar, Pubmed and Sportdiscus databases were searched for the last 10 years with ‘’Immunity AND Sport’’, ‘’Immunonutrients’’ and ‘’Sports Immunonutrition’’ keywords. The data obtained were evaluated and summarized

Immunity

An immunity is the result of an complicated relationship between organs and their surroundings. It is affected by the interaction of multiple gene sequences, antibodies, molecules, inflammatory mediators, hormones, antigens, cytokines and receptors all of which connect to and affect wellness. The immune system reaction of highly trained athletes mimics even more complicated circumstances, which are thought to follow J or S shape dynamics at times. High levels of training alter the immune system’s reaction, increasing biologic indicators of immune function and the human body’s vulnerable to disease (Cicchella et al., 2021). Maintaining of homeostasis throughout immune challenge entails activating the body’s defenses, resolving the obstacle, and protecting the host from possible harmful inflammatory processes. An infection with parasites, bacteria or fungi are examples of immune difficulties, as are tissue damage and devastation, as well as unsuitable reactions to autoantigens, which can lead to the occurrence of conditions known as autoimmune disorders. When the immune system faces obstacles, it releases a large number of hormones known as cytokines. Cytokines such as Interleukin-6 (IL-6) Interleukine-1(IL-1) and Tumor necrosis factor-a (TNF-α) play a role in the immune system's natural defenses. In aside from aiding in the development of the immune system reaction, cytokines put out during the innate or adaptive immune system reaction may stimulate the Hypothalamic Pituitary Adrenal (HPA) Axis causing the secretion of a glucocorticoids (Tada et al., 1994). In then glucocorticoids have a negative feedback effect on the immune system, suppressing further cytokine synthesis and let go, preserving the host from the side effects of a hyperactive immunity. Furthermore, glucocorticoids shape defense by affecting immune cell transporting to inflammation areas and changing downward immune responses that are adaptive, leading to a change to cellular T-helper 1 (Th1/inflammatory) to humoral T-helper 2 (Th2/anti-inflammatory) immune systems responses. As a result, rather than being viewed as immunosuppressive chemicals, glucocorticoids are better understood as immune-modulating hormones that can both boost and suppresses immunity, according to the kind of immune response, immune compartment, and cell type (Chrousos, 2000).

Figure 1
Possible Mechanisms of Exercise and Immune Response (Gleeson, 2007)



Abbreviations: TLR:Toll-like receptor, TNF-a: Tumor necrosis factor-a

Exercise additionally triggers alterations in hormonal levels, such as raising the plasma concentrations of various hormones (cortisol, adrenaline (epinephrine), prolactin) all of which have impacts on immunity. Muscle-derived IL-6 seems to be maybe part accountable for the higher production of cortisol throughout intense physical activity. Physical activity reduces the percentage of circulatory type 1 T cells but does not affect the percentage of type 2 T cells. Cortisol and epinephrine inhibit the generation of type 1 T cell cytokines, whereas IL-6 inhibits the generation of TNF-a. When the production of all these cytokines and proteins increases, the immune system is negatively affected (Starkie et al., 2003). Cytokine binding sites were found at all HPA axis phases, indicating that every stage can function as an integrating place for immune and neuroendocrine signaling (Silverman et al., 2005).

The HPA Axis and Immune Response

The HPA axis is widely recognized to regulate how the organism reacts to a stressful event, which can be described as any mentally or physically stimuli that affects an organism's homeostasis. Glucocorticoids, like catecholamines, organize the fight or flight effect, which includes the quick mobilizing of energy from places of storage to important muscles and the brain, as well as a raised blood pressure, breathing and heart rate in order to promote quick delivery of nutrients and oxygen to affected organs. In such critical circumstances, stimulating the HPA system also helps the body redirect metabolic assets such as growth, digestion, reproduction, and certain facets of the immune system to the quicker challenge at on hand (Dunn et al., 1989). The HPA axis exhibits different levels of activity in response to acute and chronic stress. Acute stress, whether or not ecological or mental in nature causes the secretion of Corticotropin-releasing factor (CRF), adrenocorticotrophic hormone (ACTH) from the anterior pituitary gland and glucocorticolds from the adrenal cortex. When acute stress triggers the HPA axis, plasma glucocorticoids (cortisol) rise momentarily and the body becomes partially resistant to the input that blocks glucocorticoid relief. This is sustained right after and during the acute stressful stimuli and is characterized by a quick desensitization of the brain's receptor for glucocorticoid. It has been demonstrated that acute stress reduces the quantity of glucocorticoid receptors in the hippocampus, which raises cortisol levels and causes obstacles to feedback suppression. The glucocorticoid level returns to its baseline level after the short-term stress response ends, corresponding with a reduction in central neuronal CRF relief. This results in a normalization of glucocorticoid receptor levels and a reset to normalcy for the feedback inhibiting system (Sapolsky & Plotsky, 1990). The accurate control of the HPA axis' action is crucial because both an excessive and insufficient release of glycocorticoids have negative effects on the immune system and metabolism. Because, monocyte and macrophage functions (it's survive or phenotype) are significantly influenced by glucocorticoids. It has long been known to enhance these vital effector cells' capacity to phagocytose, which in turn promotes the removal of inflammatory cells and other potentially dangerous substances. By a variety of harmonious genomic or non-genomic mechanisms, the steroid hormone also inhibits immunostimulatory acts and effectively prevents the generation of pro-inflammatory substances. By doing this, glucocorticoids increase the migrating activity and surviving of myeloid cells while also promoting an anti-inflammatory traits (Ehrchen et al., 2007). Ultimately, stressful situations (like intense exercise) cause the negative feedback system that controls the hypothalamic-pituitary-adrenal (HPA) axis to become less sensitive. A greater percentage of circulating glucocorticoids is the cause of a breakdown of this negative feedback system. The improper regulation of the HPA axis has biological knock-on effects and raises the risk of infection, immune system malfunction and metabolic disorders. Since impaired feedback of the HPA axis is related to decreased immune function, the best way to detect this is by examining the levels of IL-6 (Sheng et al., 2021).

Nutritional Strategies to Support Immunity

Nutritional strategies and supplements that have some supporting scientific evidence that they are effective in reducing immune perturbations or reducing the incidence of infection during exercise are as follows.

Antioxidants

Routine workouts may decrease inflammation and oxidative stress while improving immunity. even though strenuous exercise for endurance can increase the activity of antioxidant enzymes while decreasing indicators of workout-related oxidative stress, extremely intense exercise loads have been linked to an acute decrease in capacity for antioxidants and a rise in oxidative stress indicators (Neubauer et al., 2008). Antioxidants such as Vitamin-C, A and E (a-tocopherol form) shield the body from oxidative stress, avoiding harm to various parts of cells such as amino acids, lipids, and DNA. Supplements containing antioxidants are becoming more common in both the general and sporting populations, with countless promises of better immune and cardiovascular function, quicker recuperation from sport, and higher energy availability (Nieman et al., 2004).

Carbohydrate Beverage

Sport beverages may boost energy utilizes and make up for nutrients and fluid losses throughout exercise, so they have grown in popularity over the last twenty years. Carbohydrates are the main elements of sports drinks as they provide the greatest energy produce per mole of oxygen when versus proteins and fats, as well as improving athletic performance by preventing muscle glycogen decline (Jeukendrup, 2014). Consuming a high-carbohydrate (30-60 grams/hour) via carbohydrate beverages throughout prolonged workouts reduces stress hormones (adrenaline and cortisol) and anti-inflammatory cytokines (e.g., interleukins 6 and 10) responses to exercise, delaying the onset of overreaching symptoms throughout intense workout (Halson et al., 2004). If exercises take place in a fasted or low-glycogen state, with no consumption of carbohydrates throughout exercise, a greater degree of immune suppression is likely to occur. If the train-low approach is to be used to maximize exercise adaptation, it should only be used for a few days a week or the immune system will be impaired (Hawley & Burke, 2010).

Protein Ingestion

There has been some proof that consuming proteins after intense training can alleviate a few elements of after a intense workout immune depression and decrease the risk of respiratory infections in overtrained athletes (Papacosta et al., 2015). It is believed that dairy product amino acids contain numerous bioactive substances that improve immunity. Milk and whey proteins include high levels of glutamine, which may have an immune-system impact, such as decreasing neutrophil and lymphocyte death. An sufficient levels of protein is unquestionably necessary for maintaining appropriate immunity (Lagranha et al., 2008).

Probiotics

In the past few decades, multiple studies have looked into the effectiveness of oral probiotics as supplements to decrease upper respiratory symptoms in athletes, and a few probiotic products, especially those including Lactobacillus types, demonstrate pledge. Probiotics, as also known as beneficial bacteria, are ‘live germs that, as given in sufficient quantities, provide beneficial effects on the host’. As this happens, the word ‘probiotic’ can only be used to describe products comprising a sufficient number of live cells from clear harmless microbial types, in addition to an acceptable amount of scientific proof of health benefits from a body of study that includes human trials (Gleeson et al., 2016). Numerous research investigations in athletes have shown that regular probiotic ingestion reduces the number of days of respiratory illness (Cox et al., 2010; West et al., 2011; West et al., 2014), and a meta-analysis of information from both an athlete and recreational participants determined that there is a probable advantage of decreasing upper respiratory ilness prevalence (Hao & Dong, 2015).

Conclusion

In conclusion, people who are active often face immunity obstacles such as prolonged physical activity, stress, insomnia, severe weather, and inadequate nutrition. In this direction, the following recommendations can be listed for athletes to support their immune system.

- Adjust training volume and intensity to control training load. Maintain weekly volume and intensity increments of 5-10%, especially during winter.
- Start exercises for recovery shortly following heavy workouts. Think about getting a wearable device for tracking your sleep duration and quality.
- Optimize your sleeping habits in the hour before nighttime by reducing psychological stress and going 'screen-free'.
- In winter, vitamin D3 (cholecalciferol form-1000 IU) and vitamin C, probiotics and glutamine supplements should be taken, and zinc supplements can be included in the daily diet plan to minimize the risk of upper respiratory tract infections.
- Carbohydrate restriction should be avoided and nutrition plans should be periodized appropriately, as leaving an energy deficit during heavy training will reduce immunity (Walsh et al., 2018).

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Similarity Index:

The similarity index obtained from the plagiarism software for this book chapter is 12%.

Investigation of Sports Injuries and Factors Causing Injuries

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To Cite This Chapter

Alıncak, F., Eşiyok, S., & Vural, M. (2024). Immunity, Sports Performance and Immunonutrition. In M. Özdal & F. Alıncak (Eds.), *Current Studies in Physical Education and Sports 2024* (pp. 8-15). ISRES Publishing.

Introduction

Sport can be defined as a competition or game that is carried out individually or as a team, adheres to certain rules and consists of physical activities. Sport is an important part of our daily lives. Doing sports can be chosen as a way to have fun, spend leisure time, reduce stress, live healthy, keep the body alive, increase motivation, work and profession. In addition, sport is the sum of activities that affect large masses and include the principle of gaining superiority over each other (Özbek, 2000). The health of society is always a priority. One of the most important ways to protect health physically, emotionally and mentally is to do regular sports. Because it has been scientifically proven that sports can protect health and keep the body fit. In order to get rid of negative situations, to keep the body healthy and fit, and to work the mind at the highest level, doing sports has become an important position in our lives as a necessity and a routine. The key point of sports is not only the purpose of competition, but also the idea of balancing and protecting human health. With this idea, people become more addicted to sports and are more encouraged to do sports. Regular exercise contributes greatly to increasing work performance, being more energetic, improving self-confidence, increasing motivation, reducing stress, gaining regular eating and sleeping habits, establishing easy friendship and friendship with people, developing feelings of cooperation, working together and socializing. In short, the main purpose of sports is to make sedentary life more lively, to feel psychologically better and to be physically more vigorous, to reduce mobility limitation and to reduce psychological problems such as depression and anxiety, as well as to protect physical health (Karabulut & Altun, 2018). Sport is an activity that allows people to develop and use their talents, with specific rules and each sport branch has its own unique rules with different characteristics. Sport is an effort to improve oneself physically and psychologically (Aracı, 1999).

Aim of Study

The aim of this study was to investigate the factors that cause sports injuries.

Effects of Sport

The fact that people engage in sportive activities and the social and physical development of these activities constitute the basis of the effects of sport on social development. In the emergence of the psycho-social benefits of sports, the fact that people find a place where they can express themselves comfortably in sports environments has an important role (Küçük & Koç, 2004). In addition, sport's unique rules and values, communication symbols and processes also contribute to the emergence of the social benefits of sport (Karayılmaz, 2006).

Sport is an activity that develops people's social and individual characters. People who play sports gain values such as friendship, respect, solidarity, compliance with rules, self-confidence, struggle, order, discipline, health, body awareness, aggression control and respect for opponents (Bulgu, 2003). Therefore, developed countries attach importance to sports and instill a sports culture in children. Sport encourages people to do activities together. Sport gives people the skills of competition, work, courage and struggle. Sports increase people's sense of social responsibility and social cohesion (Duman & Kuru, 2010; Şahan, 2008).

Sport is an activity that protects and improves physical, social and psychological health. Sport learns and develops values such as respect, acceptance, tolerance and cooperation. Sport positively affects individuals' self-confidence and emotional state. Sports also increase individuals' skills such as perception, focus, concentration, problem solving, adaptability, productivity, imagination and practical intelligence (Yazarer et al. 2004; Şahan, 2007).

Sports is an important activity that enables people to live healthy lives. Doing sports not only protects people's physical health, but also positively affects their mental health. The negative energy accumulated in the body during sports is expelled through sweating. In this way, people can avoid negative emotions and behaviors such as stress, anxiety, anger, aggression and violence. The benefits of sports on psychological health are also supported by research in the literature. It has been observed that people who participate in sports have better psychological health and are happier (Şenyüzlü, 2013; Haryey et al. 2005).

Sports Injuries

Sports injuries are a condition that causes treatment or recommendation due to multiple factors during sports, such as inadequate warm-up, adverse weather conditions, inadequacy of the sports field, wrong sports technique, etc. (Kalyon, 1994). Sports injuries can leave traumatic effects, temporary or permanent damages (Kalyon, 1994). Sports injuries can leave damage in the body (Türker et al., 2011).
According to the effect of sports injuries on the athlete's body, it may be necessary for the athlete to take a break from training and competitions. In order to minimize the injury process, the correct treatment and rehabilitation program should be programmed together with the doctor and physiotherapist (Junge et al., 1998). Sports injuries are injuries that occur in our body during sports. In other words, they are situations that occur as a result of exceeding the limits of endurance as a result of our body encountering more resistance than normal (Sakallı, 2008). Exercise-related damage to the body can occur for many reasons. Several factors need to be examined in detail to determine the severity of a sports injury (Baker et al., 1985). As a result of the researches among the most injured

sports, soccer ranks first with 10% and wrestling ranks second with 6%. Handball and boxing follow with 3%, athletics with 1% and skiing with 0.5% (Kılıç et al., 2014). In wrestling matches with severe injuries, athletes use intense power to dominate their opponents. In this process, it is seen that the resistance that athletes put on each other increases the risk of injury and causes damage to various parts of the body (Kalyon, 1997). Correct diagnosis and treatment are important to minimize sports injuries and to improve the athlete's health as quickly as possible. Athletes who regain their health can be successful in sports once again (Özdemir, 2004).

Definition of Sports Injury

Sports injuries are a condition that causes treatment or recommendation due to multiple factors such as inadequate warm-up, adverse weather conditions, inadequacy of the sports field, wrong sports technique, etc. during sports. Sports injuries can leave traumatic effects, temporary or permanent damages. Injuries are divided into 3 according to their duration

1-7 days for injuries with less damage; 8-21 days for sprains, strains and injuries with moderate damage; 21 days and more can be evaluated and analyzed as injuries with serious traumatic effects (Petrie and Falkstein, 1998).

Van Mechelen et al. (1992) state that there are 6 elements that indicate the importance of the injury;

1- the nature of the injury (anatomical part and cause),

2- the nature and duration of medical treatment,

3- lost time before you start exercising,

4- loss of working time,

5- permanent damage,

6- they explain it as the price of a sports accident.

Factors Causing Injury

Sports activities require the body to work above its normal functions. Therefore, the risk of injury is quite high for individuals who do sports (Ergen et al., 2003). There are many factors that facilitate the occurrence of sports injuries. Some of these factors are as follows (Kalyon, 1997);

- Disruption of biorhythm
- Inability to tolerate training fatigue
- Overload
- Insufficient rest
- Return to sport without complete cure
- Muscle stiffness due to various environmental and internal causes
- Muscle weakness due to various causes
- Strength differences between muscles
- Lack of full physical preparation
- Inadequate and unbalanced nutrition

Due to some reasons of sports injuries, the athlete may stay away from the sports environment as a result of the deterioration of the athlete's body as external causes and internal causes. When the causes of sports injuries are examined, the factors that are effective on sports injuries are handled in two categories: personal factors and socio-environmental factors. We should give importance to these questions when taking

anamnesis as a result of injuries.
Socio-environmental reasons; sports branch, type of branch, duration of the sport, materials, weather conditions, place of the event, coach and etc. rules are some of the reasons. Personal reasons consist of the athlete's age, gender, physical characteristics, previous injuries and illnesses, etc. (Kanbir, 2017).

Internal factors

Age and gender

Anatomical and physiological differences in the level of growth and development between men and women play an important role in the frequency and pattern of injuries. Ossification is completed at the age of 17 in women and continues until the age of 20 in men. Maturation continues until 20-22 years of age in women and 25-28 years of age in men. Trainability is known to reach its highest level at the age of 18 in men and 16 in women. Sports injuries are one times more likely to occur in men than in women. It has been reported that the risk of sports injuries increases around the age of 29. Serious injuries increase with age. Under 15 years of age, the risk of injury is less. According to the Italian National Olympic Committee, the age range for sports injuries is 15-24 years. Women account for 7% of all injuries. Women have more knee injuries than men due to loose ligament structure and imbalances in strength between anterior and posterior muscle groups (Kanbir, 2017).

Physical structure and fitness for sport

Although it varies from branch to branch, the physical structure of athletes is important in terms of injury prevention and health. Athletes should choose a branch according to their physical characteristics and structure. For example, female swimmers are endomorphic and mesomorphic. Marathon runners are mesomorphic and soccer players are endomorphic. Although the body type changes over time according to the sports branch of the athlete, the somatotype effect that the athlete is born with continues. In addition to the somatotype of the athletes, they should have sports-motoric characteristics such as strength, endurance, speed, coordination and flexibility as required by the branch. Overweight, inappropriate height for sports are risk factors for injuries. For example, tall goalkeepers are less likely to suffer skull fractures than medium-sized goalkeepers. Flexibility is desirable in gymnastics and taekwondo. However, skiers and cyclists are not so flexible. Inadequacy of spormotiric characteristics in the application of branch-specific technique causes injuries (Kanbir, 2017).

Psychosocial reasons

The stress of athletes is caused by individual and socioeconomic reasons. If athletes cannot cope with this stress, their performance deteriorates and they face injury. Therefore, psychological problems of athletes are much more important than they seem. Motivation is at the root of athletes' behavior to survive in the social environment. Sometimes over-motivation or under-motivation of athletes is also a risk factor for injuries. While the unmotivated athlete exhibits loose and reluctant behaviors, the highly motivated athlete prepares the ground for injuries by taking the field like a warrior (Kanbir, 2017).

Previous injuries and inadequate rehabilitation

It is known that due to the pressure in professional sports, athletes often return to the competition environment without full recovery. Returning to the field without fully recovering in the sports environment is one of the biggest risk factors for re-injury. In particular, the most common type of recurring injury is an ankle sprain. In order for an injury to be fully healed, there should be no pain, joint movement should be able to be performed fully, and muscle strength should be at least at the level before the injury (Kanbir, 2017). In order for the athlete to return to sports again, the physiological value of the movement at a certain speed must reach 90% strength when measured with the healthy side and reach the level before the injury (Kalyon, 1997). Fear of previous injury in athletes increases the risk of re-injury (Murphy, Connolly, & Beynnon, 2003).

Lack of Sporting Technique

Unconscious sports techniques cause sports injuries. Wrong sports technique is the cause of overuse. For example, in tennis players, a backhand hit without correct technique causes lateral epicondylitis. In skiers, 40% of back and knee injuries are due to poor technique. Again, most of the shoulder injuries in throwing in athletics are related to poor throwing technique. In handball, 20-40% of elbow and shoulder injuries are related to poor throwing technique. In judo, most elbow injuries are caused by poor falling technique. Hand and thumb injuries seen in goalkeepers in soccer are caused by poor ball handling technique (Kanbir, 2017).

Inadequate Warming

Inadequate warm-up is a cause of injury in itself. As a result of inadequate warm-up, muscle fiber tensions, ruptures, tendon tears may occur. Inadequate warm-up is a risk in muscle tendon injuries, especially in movements such as serving, dunking, throwing in tennis, shooting and volleyball branches (Kanbir, 2017).

External Factors

Characteristics of the Branch

The characteristics of the type of sport are an important factor in injuries. Especially in soccer, injuries occur very often. In a study conducted in 1997, it is stated that soccer is the branch with the highest number of injuries among sports injuries. Each soccer player has a 4.2% chance of injury. Injuries in soccer can occur due to opponent, ball, ground. In football, 75% of the injuries occur in the lower extremities. The ankle is the area where most injuries occur in soccer. Among all sports branches, 40% of meniscus injuries belong to soccer. Goalkeeper is the position with the highest number of injuries in soccer players. The most common injuries in goalkeepers are fractures, dislocations and sprains, respectively. Duration of sporting activity. The longer the duration of the competition, the greater the risk of injury as the level of fatigue increases. Trainings require longer periods of work than competitions. As a result of statistical data in sports branches, most of the sports injuries occur during training and this rate is 29% while it is 7% during the competition. (Kanbir, 2017).

Floor

Floor is one of the causes of sports injuries. In sports branches such as wrestling, gymnastics and boxing, the flexible structure of the floor prepares the ground for falls.

Hard grounds in athletics, poor quality of the mat in high jumping, slippery and uneven grounds in running increase the risk of injury. In soccer, a major cause of ankle sprains is due to uneven ground. In dirt fields, the main cause of swimming is the ground (Kanbir, 2017).

Sports Fields

Sports fields should have safety gaps. There should be a space where athletes can stand safely when they go out of the field due to their movements. In addition, a safe zone should be created in throwing and jumping branches (Kanbir, 2017).

Lighting

Inadequate lighting poses a risk for injuries due to impaired coordination. In particular, inadequate lighting can cause both decreased efficiency and injuries as it affects distance determination, perception of the environment, and the ability to easily select game equipment (Kanbir, 2017).

Sportswear and Footwear

The choice of sportswear and footwear can also increase the risk factors that cause sports injuries. Especially in indoor sports, shoe selection is important (Kanbir, 2017). In soccer, goalkeepers wearing supported jerseys and shorts reduces the injury rate (Kalyon, 1997).

Climatic Conditions

Sports injuries are affected by climatic conditions. Cold weather, hot weather, wind, rain, snow, etc. climatic events and environmental conditions affect sports injuries. In an extremely cold environment, the athlete may get sick, and in an extremely hot environment, heart palpitations and premature fatigue may occur. In many indoor sports, a temperature between 20-24 is sufficient. The international volleyball federation considers it appropriate to play competitions at 16-25 degrees (Kanbir, 2017). Competitions should not be held where the temperature is high and the humidity is high. It is known that sweat cannot be removed from the body and cooling will not take place, especially at temperatures close to body temperature with high humidity. Therefore, it may lead to fatal consequences (Ergen, et al., 2003).

Conclusion

In conclusion, sports injuries are affected by many conditions. By taking these situations into consideration, training plans can be made to prevent injuries.

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Post-Exercise Recovery Factors

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To Cite This Chapter

Polatbilek, B. E. (2024). Post-Exercise Recovery Factors. In M. Özdal & F. Alıncak (Eds.), *Current Studies in Sports Sciences 2024* (pp. 16-38). ISRES Publishing.

Introduction

Exercise encompasses physical activities performed regularly with a specific purpose in mind. It is an activity aimed at improving overall health and has well-known positive effects on various body systems, including the cardiovascular, respiratory, and musculoskeletal systems (Akgün 1989; Wilmore, Knuttgen 2003; Pancar et al., 2023; Ay et al., 2023). In addition, regular exercise leads to a reduction in body fat percentage, an increase in bone mineral density, improvements in muscle strength and endurance, and the development of neuromuscular adaptation (Lenze, Wetherell, Hickman, Sinacore 2016). Moreover, exercise is known to have both preventive and therapeutic effects on many diseases, including cancer, type II diabetes, obesity, cardiovascular diseases, hypertension, osteoporosis, and several others (Anderson et al. 2016; Santos, Elliott-Sale, Sale 2017). During exercise, skeletal muscles utilize stored glycogen, blood glucose, lactate, free fatty acids from adipose tissue or intramuscular triglyceride stores, and creatine phosphate (CP) to synthesize ATP (Powers, Howley 2017). The main factors influencing the use of these substrates are the intensity and duration of the exercise. In high-intensity and prolonged exercise, as the oxygen supply to the muscles decreases, the metabolism shifts to anaerobic energy production. The transition from the aerobic to the anaerobic energy system is referred to as the anaerobic threshold. Exercises performed below this threshold are defined as aerobic, while those performed above it are classified as anaerobic (Wilmore, Knuttgen 2003).

Aim of The Study

The aim of this study was to examine the factors affecting the recovery protocols applied to support the improvement of sportive performance after exercise.

Aerobic Exercise

Aerobic exercise refers to activities performed with rhythmic movements over an extended period, requiring less force and without causing oxygen debt (Kitzman et al. 2016). These exercises improve the cardiovascular system, enhance respiratory parameters, and increase both the oxygen-carrying capacity to muscles and the muscles' capacity to store oxygen and ATP (Hsu 2016; Tuzcuoğulları et. al., 2017;Pancar et al., 2023). Aerobic exercise significantly increases the amount of oxygen delivered to active muscles. Long-term aerobic exercises lead to an increase in the number of blood vessels through angiogenesis in active muscles, an increase in myoglobin content, and consequently, an enhancement in ATP storage capacity (Hall 2015). At the time to peak torque, the contraction speed is at the forefront and its unit is the second. This refers to the time to reach peak torque. It is used in evaluating athletes that require explosive power and available condition (Vural, 2019).

Additionally, during prolonged and intense exercise, the amount of oxygen consumed increases after a certain point. This value, determined during exercise tests and representing the maximum oxygen consumption, is referred to as “maximal oxygen consumption (VO2Max)” or “maximal aerobic capacity” (Rowell, O’Leary 1990). Aerobic capacity is a significant indicator of the capabilities of the cardiovascular, pulmonary, and neuromuscular systems, and it depends on the physiological capacity of certain hematological components, such as blood volume, red blood cell count, and hemoglobin levels, as well as the efficiency of oxidative mechanisms in muscle cells during exercise (Astrand, JB 1992; Foss, Keteyian, Fox 1998).

The higher the physiological functional capacities of these systems, the greater the maximal oxygen consumption capacity (VO2Max) (Karamizrak, Ergen, Töre, Akgün 1994). The value of aerobic capacity over a unit of time is referred to as “aerobic power.” Aerobic power is defined as the amount of oxygen consumed per kilogram per minute and is measured in milliliters (O2 mL/kg/min) (McArdle, Jackson 2000). Aerobic capacity is typically measured using a treadmill or cycle ergometer. During maximal or submaximal exercise tests, heart rate, ECG, and blood pressure changes are monitored. The peak torque values of knee isokinetic force measurement were taken into account by H/Q ratios, performance, and recovery after injury, training planning and such as these parameters were taken into consideration (Vural & Özdal, 2019).

In these tests, the workload is increased until the individual reaches maximal oxygen consumption or maximum heart rate. As the effort level rises, oxygen consumption increases in parallel with the increasing workload. However, once exercise intensity reaches a certain point, the oxygen intake begins to plateau, despite further increases in exercise intensity. This plateau represents the individual’s VO2Max. At this stage, blood lactate levels should be 79-80 mg or higher, the heart rate should reach its maximum, and the respiratory exchange ratio should rise to between 1.07 and 1.15 (Foss, Keteyian, Fox 1998; McArdle, Jackson 2000; Cooper, Sowash, Taylor, Storer 2003). During exercise, heat production increases in active tissues, leading to the formation of significant amounts of acidic compounds and carbon dioxide. The increased oxygen consumption in active tissues causes a decrease in oxygen pressure. This, along with the presence of these surrounding factors, facilitates the release of oxygen from hemoglobin. In prolonged and intense exercise, the insufficient supply of oxygen and other metabolites needed for ATP synthesis through the circulatory system makes it difficult to sustain exercise. Additionally, the accumulation of byproducts under these conditions can negatively impact muscle performance (Zimmerman, Granger 1992).

However, the lack of examining the peak torque values produced by quadriceps and hamstring muscles in isokinetic measurements from joint angle and duration has created the idea that there is a deficiency in this respect in the literature. Because the joint angle at the stage of producing an athlete’s peak torque strength is actually directly related to the muscle section and the contraction capacity of the muscle and strength programs (Vural et al., 2017).

Anaerobic Exercise

Short-duration, high-intensity physical activities are classified as anaerobic exercises.

In this type of exercise, the individual's oxygen intake is insufficient, reaching maximal or supramaximal levels, which exceeds the anaerobic threshold. This lack of oxygen triggers the anaerobic energy system.
The anaerobic glycolysis pathway involves the breakdown of glucose or glycogen to pyruvic acid. In this process, pyruvic acid is converted to lactic acid. This metabolic transformation leads to the accumulation of citric and lactic acids in the environment, as well as an increase in the levels of nicotinamide adenine dinucleotide (NADH). As a result, the pH level within the cell decreases (pH 6.4), which causes metabolic acidosis and fatigue.

As a result, the prolonged maintenance of anaerobic exercise is not feasible due to the adverse effects brought about by these metabolic changes. This situation is a significant factor that affects athletes' performance and endurance, and it is a critical point to consider during the planning and implementation of anaerobic exercises.
Lactate produced through anaerobic glycolysis is removed from the muscles via the cardiovascular system and transported to the liver and heart. This process enables the conversion of lactate into glucose or glycogen in the liver and its use for energy production in the heart. This mechanism is crucial for the sustainability of energy production (Åstrand, Rodahl, Dahl 1986; Morton et al. 2007).

However, during intense and sustained exercise, the decrease in ATP activity leads to the impairment of cellular functions. This situation results from the insufficiency of the sodium-potassium ATPase pump in the cell membrane; this deficiency causes sodium accumulation within the cell and potassium efflux outside the cell. Consequently, these events lead to intracellular water retention, triggering the formation of cellular edema.
Additionally, under these conditions, a reduction in the ability of the sarcolemma to retain creatine kinase and myoglobin has also been observed. Creatine kinase and myoglobin play significant roles in energy production and oxygen storage in muscle cells; therefore, the decrease in these proteins adversely affects muscle performance (Newham 1988; Proske, Morgan 2001). On the other hand, the time for the muscle to reach peak torque at a certain movement angle is important for performance athletes, especially in activities that require explosive power especially anaerobic power (Tahhan et al., 2018a; Tahhan et al., 2018b).

In this context, understanding the negative effects that intense and prolonged exercise can have on both energy production and cellular homeostasis is critically important for planning exercise programs aimed at optimizing athletes' performance and preventing injuries.

The work capacity generated by muscles through the anaerobic energy system during maximal or submaximal physical activities is defined as "anaerobic capacity." This definition refers to the total amount of work performed by the muscles utilizing the anaerobic energy system over a specific period. The value of this work per unit of time is termed "anaerobic power," which is typically measured in kilograms per second (kg/s), kilograms per minute (kg/min), or watts.

Anaerobic power is a concept that defines the expression of explosive strength and encompasses workloads above the anaerobic threshold. These types of physical activities are typically associated with short-duration, high-intensity exercises and demonstrate a parallel interaction with fatigue. Although anaerobic power cannot be precisely measured, it can be partially determined using various tests and indirect measurement methods. Determining anaerobic power is critically important for assessing sports performance and optimizing training programs. This is because anaerobic capacity is a significant factor affecting athletes' endurance, power output, and overall performance. Therefore, deepening research in this area holds a significant place in the literature of sports sciences. These applications encompass laboratory and field tests. Additionally, blood lactate levels are considered an important indicator of anaerobic power. Therefore, it is recommended that studies measure blood lactate levels before and after exercise (McArdle, Jackson 2000; Myers, Ashley 1997). In short-duration, high-intensity sports activities, high-energy phosphates (creatine phosphate) serve as an immediate energy source for the muscles. In this system, energy is provided anaerobically while preventing lactic acid formation. Creatine phosphate produces ATP by phosphorylating ADP. This reaction is reversible in nature and is catalyzed by creatine kinase (Powers, Howley 2014).

Sports Performance

During a physical activity, the bodily, physiological, and psychological efficiency required by that activity is defined as "sports performance." Additionally, sports performance is also known as the actions and work accomplished during competition or training. However, when this concept is approached from a competitive perspective, it can also be related to athletes' abilities to effectively showcase their current conditioning. Therefore, the success in achieving this efficiency is an important factor that determines the performance level of an athlete (Cadegiani and Kater, 2019).

In this context, developing training programs and strategies to enhance athletes' performance levels is critically important for improving efficiency. It should also be noted that sports require not only physical skills but also mental resilience.

The determinants of sports performance encompass various components and differing levels of importance specific to different sports. Each sport has its unique dynamics, requirements, and performance criteria, which means that athletes must be able to cope with adverse factors they may encounter during training or competition.

In addition to individual factors such as the athlete's conditioning level, nutrition habits, and health status, environmental factors such as the condition of the playing surface and weather conditions also significantly impact sports performance. For example, when an athlete maintains a healthy nutrition regimen and achieves an adequate level of conditioning, their performance will improve; however, adverse environmental conditions or health issues may diminish this performance.

In this context, in order to optimize athletes' performance, it is essential to consider not only training programs but also nutrition plans and environmental conditions. Adopting a multidimensional approach for the sustainability of performance is critically important for enhancing athletes' achievements (Venhorst et al., 2018).

Factors Affecting Sports Performance

Enhancing sports performance is undoubtedly one of the most emphasized topics for athletes and coaches. Improving performance directly impacts not only competition results but also the overall development of athletes. The various actions an athlete takes before, during, and after training or competition are among the factors that can positively or negatively influence their performance. In this context, one of the primary goals of athletes is to identify the factors that affect performance and manage them in a way that contributes positively. For example, elements such as structuring the training program, reviewing nutrition habits, and mental preparation are among the factors that directly influence performance.

When examining the factors affecting athletes' performance, it becomes evident that not only physical conditioning and technical skills but also psychological factors, environmental conditions, and social support systems play significant roles. Therefore, efforts to enhance performance require a multidimensional approach (Weinberg and Gould, 2007). This multifaceted examination allows coaches to develop effective strategies in the development processes of athletes, ultimately contributing to achieving higher performance levels.

The Impact Of Internal And External Factors On Sports Performance

Factors affecting sports performance can be generally classified into two main groups: internal and external factors. Each of these factors plays a significant role in determining the performance levels of athletes.

Internal Factors

1. Physical Structure:The genetic makeup, age, skill level, and gender of athletes are intrinsic components that directly affect performance. Genetic makeup determines an individual's physical abilities, while age is critically important for development and conditioning.
2. Psychological Variables: Psychological factors such as stress, anxiety, worry, tension, and aggression can influence athletes' mental states, thereby shaping their performance. Such psychological elements can directly affect an athlete's concentration and motivation.
3. Physiological Characteristics: Energy metabolism, cardiovascular, and respiratory system performance play a determining role in athletes' endurance and efficiency during physical activities. Maintaining these characteristics at an optimal level contributes to improved performance.
4. Bio-motor Characteristics: Attributes such as strength, speed, endurance, flexibility, and coordination are fundamental components of athletes' physical abilities. The development of these characteristics has the potential to enhance athletes' effectiveness and performance (Walker and Nordin, 2010; Bali, 2015).

External Factors

1. Nutrition Habits:The dietary patterns of athletes have a direct impact on their energy levels and overall health. Adequate and balanced nutrition is crucial for sustaining performance.
2. Family-related Issues: Financial constraints and familial problems can adversely affect athletes' psychological states and motivation. Such circumstances can create additional pressure on the athlete.
3. Coaching and Management Factors:The experience, education, and management skills of coaches play a decisive role in the development of athletes and the enhancement of their performance levels. Effective coaching can unlock an athlete's potential.
4. Equipment Quality: The inadequacy or poor quality of equipment stands out as an

external factor that negatively impacts athletes' performance. The use of appropriate and high-quality gear can enhance athletes' effectiveness.

5. Environmental Factors: Elements such as climate, weather conditions, altitude, surface conditions, and spectators directly influence athletes' performances. The suitability of these factors can positively affect performance.

6. Bad Habits:Negative habits such as alcohol, smoking, and drug use can adversely affect athletes' physical and mental health, thereby diminishing their performance.

7. Sleep Patterns: Adequate sleep significantly influences the physical and mental performance of athletes. Regular and quality sleep can accelerate recovery processes and enhance performance (Wilmore et al., 2008; Siegel and Laursen, 2012).

In conclusion, the interaction between internal and external factors affecting athletic performance plays a critical role in determining the success of athletes. Careful examination and management of these factors can assist athletes in maximizing their potential and enhancing their performance.

Performance Variability In High-Intensity Exercises

High-intensity physical activities can lead to significant changes in both the physical and psychological states of athletes. These changes are considered important factors that affect the overall performance of athletes. Below are the key parameters that are regarded as indicators of performance decline in athletes.

1. Decrease in Running Duration and Speed
2. Shortening of Walking and Running Distances
3. Reduction in Bio-motoric Characteristics
4. Deterioration in Reaction Time
5. Increase in Perceived Difficulty.
6. Increase in Blood Pressure
7. Delayed Decrease in Heart Rate
8. Increase in Body Temperature

These factors are defined in the literature as elements leading to a decline in athletes' performance and represent critical criteria that must be considered in performance monitoring (Enoka & Duchateau, 2016; Jones et al., 2017). It is essential for athletes to optimize their training programs by taking these variables into account, as this can significantly enhance their performance.

Fatigue

Fatigue is defined as the inability to continue performing at the same intensity due to physical exertion, resulting in a decline in performance (Coutts et al., 2007). According to another definition, fatigue is considered one of the important factors affecting performance and is expressed as a reduction in maximal effort (Knicker et al., 2011). Sogaard (2008) describes fatigue as a phenomenon characterized by a gradual decrease in muscle force capacity or a measurable reduction that signifies the endpoint of sustained activity. In this context, it can be stated that fatigue is directly proportional to the intensity of exercise (Sogaard et al., 2016).

Fatigue: Causes And Contributing Factors

Fatigue is a critical aspect in many contexts, presenting a complex structure that is studied across various scientific disciplines (Coutts et al., 2007). Therefore, it can be stated that fatigue is a fundamental element to be considered in the management of training and performance for athletes. The factors that lead to fatigue and contribute to its development can be classified as follows, in direct correlation with the intensity of exercise.

Table 1.

Factors Contributing to Fatigue (Enoka & Duchateau, 2016)

NERVOUS-MUSCLE ACTIVATION	PHYSIOLOGICAL INDICATORS	PSYCHOLOGICAL
Changes in strength capacity	Decrease in glycogen stores	Decrease in focus
Decrease in muscle contractions	Increase in metabolic acidosis	Impaired decision-making ability
Motor neurons	Decrease in blood sugar levels	Motivation
Afferent feedback	Increase in body temperature	Sleep quality

Factors Influencing Fatigue

* Individual’s age and gender differences
* Fitness level
* Dietary habits and the types of consumed foods
* Adequate and quality sleep
* Circadian rhythm
* Psychological factors
* Social quality of life
* Current health status (Finsterer & Mahjoub, 2014).

It can be emphasized that fatigue is influenced by a specific set of factors, each playing a significant role in an individual’s overall performance and health. Given that fatigue is affected by individual differences such as age, gender, fitness level, and dietary habits, as well as external factors like circadian rhythm and psychological state, it is evident that athletes and individuals need to develop strategies for managing fatigue. Moreover, classifying fatigue could contribute to the development of more effective assessment and intervention methods in sports sciences and health fields (Fatigoni et al., 2015).

Classification of Fatigue

Fatigue, being a multifactorial symptom with both biological and psychosocial characteristics, can be classified into different types based on various aspects (Fatigoni et al., 2015).

Table 2.

Classification of Fatigue by Type (Zwarts et al., 2008)

Based on Structure	Based on Duration	Based on Pathophysiology
- Physiological: central and peripheral, - Perceived: physical and psychological	- Acute, - Subacute, - Chronic	- Pathophysiological: primary and secondary, - Non-pathophysiological

Exercise And The Endocrine System

Hormonal changes during exercise are initiated by the influence of the central nervous system. In this process, the secretion of growth hormone (GH), adrenocorticotropic hormone (ACTH), prolactin (PRL), antidiuretic hormone (ADH), and thyroid-stimulating hormone (TSH) increases. Additionally, while insulin secretion is suppressed, the release of renin, angiotensin, ADH, pancreatic polypeptide (PD), glucagon, parathyroid hormone (PTH), and gastrin is stimulated. ACTH, in particular, influences the adrenal cortex to promote hormone release (Astrand, 1992). The intensity of the hormonal response depends on the individual's pre-exercise state and capacity (Astrand, 1992; Foss, Keteyian, & Fox, 1998).

Hormones are synthesized in very small amounts by endocrine glands on a daily basis and are released into the bloodstream, where they act as biocatalysts, exerting specific effects on target tissues. Despite their low concentrations in the blood, these hormones are measured in micrograms, nanograms, or picograms (Rowell & O'Leary, 1990; McArdle & Jackson, 2000).

In this context, monitoring hormonal changes during exercise is crucial for evaluating performance and enhancing individuals' physical capacities. Hormones play a significant role in post-exercise recovery, energy metabolism, and overall health. Therefore, the secretion and effects of hormones are key factors to consider when aiming to optimize athletic performance.

At the onset of physical activity or exercise, a disruption occurs in the body's internal conditions, leading to an imbalance in homeostasis. In response, the body activates autonomic systems that help maintain stable internal conditions. One of the primary mechanisms engaged to restore balance when homeostasis is disturbed is the endocrine system. By responding to stress, the endocrine system triggers a series of hormonal changes throughout the body. In this context, the balanced functioning of organs and body systems is regulated by hormones produced in specific areas of the body (Kraemer & Rogol, 2005; Meriç et al., 2014).

As exercise intensity increases, there is a rise in serum levels of various hormones, including catecholamines such as epinephrine, norepinephrine, and dopamine, as well as growth hormone, prolactin, testosterone, cortisol, ACTH, and endorphins (Anthony, 2006). It is particularly noted that after high-intensity exercises, these hormones help reduce fatigue during the recovery process by regulating blood flow, fluid balance, heart rate, and respiratory rate.

After the cessation of exercise, as the stress on the body decreases, hormones like epinephrine and norepinephrine quickly return to resting levels. However, hormones that indicate physiological stress, such as cortisol, ACTH, CRH, and endorphins, take longer to return to baseline levels (Ünal et al., 2001; Mori et al., 2004; Manoogian & Panda, 2017). It is believed that the rapid clearance or reduction of these elevated hormones following high-intensity exercise could contribute to faster recovery for athletes. This evaluation highlights the importance of hormonal responses in the recovery process after intense exercise and suggests that these processes are critical for improving performance.

Physiological Recovery After Exercise

After exercise, the increase in metabolic rate continues for a while, during which phosphagen and carbohydrate stores are replenished, myoglobin becomes saturated with oxygen, and lactic acid accumulated in the tissues is removed. This period is known as "recovery." The sustained energy consumption following exercise is essential for the recovery process (Cochrane, 2004; Özdemir, 2006). To better explain the metabolic recovery process, it is important to focus on the following four key areas (Ergen, 1992; Wilmore & Costill, 1999):

1. Restoration of resting oxygen levels
2. Replenishment of energy sources
3. Removal of lactic acid
4. Renewal of oxygen reserves

These points detail how the body restores its energy and oxygen balance after exercise, explaining the biological foundations of the recovery process.

Restoration of Resting Oxygen Levels

During high-intensity exercise, the total oxygen content in venous blood, supported by myoglobin in the muscles, is approximately 600 ml. In trained athletes, the values defined as "oxygen debt" can reach up to 30 liters. This suggests that the amount of oxygen in the body is not sufficient to create such a large debt when compared to oxygen consumption post-exercise (Özdemir, 2006; Fox, 1999). After training, as the body is no longer engaged in exercise, its energy requirements decrease. However, oxygen consumption remains elevated for a period following exercise. This increased oxygen consumption, which exceeds the amount typically consumed at rest, is referred to as "excess post-exercise oxygen consumption" (EPOC). EPOC encompasses processes such as the replenishment of energy stores and the removal of lactic acid that accumulates during training, ultimately facilitating the body's return to its pre-exercise state (Özdemir, 2006; Muratlı, 2005). This phenomenon underscores the significance of the recovery process after exercise and elucidates how oxygen contributes to the body's energy balance.

Replenishment of Energy Sources

The resynthesis of muscle glycogen lost during exercise is described as a two-phase process. The first phase, termed the "fast phase," occurs within the first 30 to 60 minutes following exercise, during which muscle glycogen is rapidly replenished. This swift glycogen synthesis occurs through an insulin-independent mechanism, arising from the sudden decrease in energy demand after exercise, which directs glucose toward glycogen synthesis rather than glycolysis. In the second phase, referred to as the "slow phase," glycogen synthesis continues due to the increased insulin sensitivity of muscle tissue. This phase progresses at a markedly slower rate compared to the fast phase, and the process slows further as muscle glycogen stores become replenished (Özdemir, 2006).

Removal of Lactic Acid

The removal of lactic acid requires additional energy after exertion, which is most effectively provided through aerobic metabolism. Lactic acid can be converted into glucose, glycogen, and protein, and it can also be metabolized into water and carbon dioxide. The heart and skeletal muscles possess the ability to utilize lactic acid as an energy source. Evidence suggests that post-exercise cooling methods can reduce the time required for lactic acid removal following exercise. Determining the recovery time after intense exercise is critical for trainers. Engaging in training before the body's recovery processes are completed and energy stores are replenished may not only fail to promote development but can also lead to harm (Özdemir, 2006; Ergen, 1992). The most important point in winning or losing is to work and make an effort. Afterwards, success often comes naturally. However, it should also be known that working and making efforts will not always produce successful results. When the result fails despite the team's best efforts; It should be accepted and accepted that the entire Team in front of you deserves to win more than you. In other words, it should be accepted that the other team made fewer mistakes and the luck factor was on the side of this team (Erdoğan, 2023; Erdoğan, 2022).

Replenishment of Oxygen Sources

Myoglobin, a protein that facilitates the transport of oxygen to muscle cells, shares a structure similar to that of hemoglobin and is found in higher concentrations particularly in red muscle fibers. Research indicates that the amount of oxygen bound to myoglobin in the body is approximately 11 ml per kilogram of muscle mass, totaling around 300-350 ml overall (Cochrane, 2004). During exercise, myoglobin plays a crucial role in supplying oxygen to tissues prior to the activation of the oxygen transport system. While mitochondria are critical for energy production within muscle fibers, they also play significant roles in the diffusion of oxygen from hemoglobin in capillaries. The capacity of myoglobin to bind oxygen is directly related to the partial pressure of oxygen in the surrounding environment. In this context, myoglobin exhibits a greater affinity for oxygen at low partial pressures, whereas higher partial pressures promote the release of oxygen. Therefore, the transport and utilization of oxygen in muscle tissue are determined by the effective interaction between mitochondrial functions and oxygen diffusion in capillaries (Özdemir, 2006; Ergen, 1992).

Physical Recovery

The human organism is structured to maintain the internal balance necessary for life, enabling the organs and body systems to work together in a coordinated manner. This functional operation is achieved through the varying levels of activity of certain organs. In contemporary sports that involve high exercise intensity, athletes often engage in multiple training sessions throughout the day and are subjected to demanding workloads (Amann et al., 2015). Such continuous loads or competitions can lead to a decline in athletic performance. In this context, repeated workloads without a fully effective physical recovery process can result in increased fatigue, sports injuries, and decreased performance (Taylor et al., 2016).

In the field of sports science, the concept of recovery plays a crucial role in describing the process of alleviating fatigue that occurs after training or competition. As emphasized by Barnett (2006), the physical, physiological, and mental reconstitution of athletes is considered a critical necessity for the sustainability of maximal performance. Recovery encompasses the effective removal of metabolic waste accumulated in the body after high-intensity workloads, as well as the physical and mental rejuvenation processes that allow athletes to return to their previous states. In this context, the systematic integration of effective recovery strategies into athletes' daily lives is essential for performance enhancement. Thus, it can be concluded that the implementation of regular and effective recovery methods is necessary for athletes to maintain optimal performance levels.
The general purpose of respiratory muscle exercises is to improve the functions of the respiratory muscles to increase the risk of shortness of breath and to prevent shortness of breath during exercise. It is based on improving performance. For this reason, rehabilitation is often while used for purposes24, recently it has been used by sports scientists for athletes, frequently used acutely and chronically in order to increase performance is being implemented (Bilgiç, Özdal and Vural, 2022).

The physical recovery phase is a critical process that enables athletes to recover from fatigue experienced after training or competition and facilitates the replenishment of their energy metabolism (Bishop et al., 2008). Energy expenditure during exercise varies depending on the intensity of the activity, and accordingly, the energy sources utilized by the body also differ. Following the completion of training, the organism begins to repair the damage incurred during exercise based on the energy sources used. Continued energy consumption after exercise emerges as an essential stage for the healthy progression of the recovery process. In this context, the reconstitution of energy metabolism is vital for the sustainability of athletes' physical performance.

To explain the metabolic aspects of the recovery process, certain key criteria must be considered. Among the prominent criteria highlighted in the literature are:

- O2-myoglobin oxygenation,
- The return of energy sources to resting levels,
- The removal of lactic acid as a waste product from the blood and muscle, along with the clearance of the oxygen debt (Günay et al., 2013; Murray et al., 2018).

These criteria are critical for understanding and optimizing athletes' recovery processes.

Objectives of Physical Recovery

The primary goal of the recovery process is to heal the damage incurred during training or competition and to minimize fatigue, effectively eliminating it. The fundamental objectives of an effective recovery process include:

- Restoring the basic functions of the organism,
- Re-establishing the body's internal balance to resting levels,
- Replenishing energy stores depleted as a result of high-intensity activities,
- Returning enzyme functions to normal levels.

Effective recovery can provide the following benefits:

- Acceleration of local or general blood flow,
- Removal of accumulated waste products from the blood and muscles,
- Reduction of inflammation and edema resulting from trauma,
- Decrease in muscle stiffness and pain thresholds,
- Increase in muscle flexibility,
- Faster recovery of physical conditioning,
- Enhancement of the recovery process by reducing the onset of delayed muscle soreness.

These parameters emerge as significant factors that determine the efficiency of the recovery process (Bishop et al., 2008; Cochrane, 2004).

Factors Influencing the Physical Recovery Process

Factors that affect the recovery process can be classified as follows:

- Biological age, gender, and the individual's experience,
- Current health status and whether a sports injury or disability is ongoing,
- Maximal oxygen consumption capacity,
- Genetic factors (e.g., distribution of muscle fibers),
- Energy metabolism of actively performed activities,
- Requirements and characteristics of the sport being practiced,
- Similar studies related to overtraining,
- The individual's dietary habits and disruptions in fluid-electrolyte balance due to fluid loss,

- Environmental factors (temperature, altitude, climate, field and surface conditions),
- Psychological factors (anxiety, fear, stress, motivation),
- Personal lifestyle (sleep patterns, alcohol and tobacco use, social environment),
- Jet lag effects, referring to changes and differences that occur in the body due to shifts in time zones as a result of travel.

These factors significantly influence the effectiveness of the recovery process (Jemni et al., 2003).

Classification of Physical Recovery

In general terms, recovery can be categorized into three main types based on duration. This classification is important for effectively managing recovery and enhancing individuals' performance.

Quick Recovery Time

The type of recovery that occurs between repeated activities in short intervals plays a significant role, especially in dynamic sports such as walking competitions. This process can be defined as the recovery that takes place between each step. The aim during this phase is to replenish ATP energy in the muscles and remove metabolic waste products. This recovery process enables walking athletes to take quicker steps and complete competition distances in better times, facilitated by recovery in the lower extremities. Therefore, quick recovery is critical for enhancing performance in such training and competitions (Bishop et al., 2008).

Short-Term Physical Recovery

Short-term recovery refers to the rest periods between sets during repeated speed or strength exercises. This process allows the individual to rest after performing a movement, enabling subsequent performance to continue without loss. Effective recovery during high-intensity activities permits continuation of the activity without any degradation in performance. For instance, a scenario in which an athlete lifts a 50 kg weight, takes a short rest to renew energy metabolism, and then lifts the same weight again exemplifies this situation (Gümüşdağ et al., 2015).

In a study conducted to investigate the effectiveness of this recovery process, similar activities were performed with varying recovery durations. The results indicated that recovery times of 15 and 30 seconds negatively affected performance compared to recovery durations of 60 and 120 seconds (Gümüşdağ et al., 2015). These findings provide significant insight into determining the effectiveness of short-term recovery.

Long-Term Physical Recovery

This type of recovery is characterized by the ongoing process that occurs between two training sessions or competitions and is defined as complete recovery. Athletes in various sports may experience significant fatigue when participating in multiple training sessions or competitions within the same week or even on the same day. This situation clearly underscores the critical importance of the post-exercise recovery process (Bishop et al., 2008).

For instance, insufficient rest following a low-intensity exercise can negatively impact subsequent performance. It is recommended to allow a rest period of at least 8 to 24 hours after completing aerobic activities. Complete recovery typically requires at least 24 hours or more. Additionally, the replenishment of depleted energy stores emerges as a significant factor influencing this process (Sporer and Wenger, 2003; Burke et al., 2006).

Physical Recovery Methods

To enable athletes to achieve efficient physical recovery, coaches, researchers, and sports scientists have long conducted various studies to identify the most effective recovery methods. Understanding the effects of implemented recovery methods and the underlying principles behind them is of great importance. In recent years, a variety of methods have been employed to ensure effective physical recovery and expedite this process, especially after intense training or competition (Haff and Triplett, 2015).

Currently, the following recovery methods are commonly used and considered effective:

Commonly Used Recovery Methods

- Traditional Recovery: Activities such as exercise, jogging, stretching, walking, and low-intensity running.
- Massage: Classic massage, sports massage, and ice massage.
- Cryotherapy: Cold applications and cold water immersion.
- Hydrotherapy: Water-based therapies.
- Contrast Applications: Alternating use of cold and hot treatments.
- Nutrition: Fluid intake and the use of ergogenic aids.
- Acupuncture
- Ultrasound
- Compression Garments
- Use of Anti-inflammatory and Analgesic Medications
- Hyperbaric Oxygen Therapy
- Electromyostimulation: Electrical stimulation of muscle tissue.
- Psychological Relaxation Therapy
- Lifestyle Improvement
- Combined Recovery Methods

These methods are frequently employed to enhance athletes' recovery processes and improve their performance (Wilcock et al., 2006; Tessitore et al., 2007).

Impact of Recovery on Metabolic Response

Lactic acid is produced when the intensity of exercise exceeds metabolic thresholds and glucose utilization accelerates. The accumulation of lactic acid leads to a decrease in pH levels, negatively affecting muscle contractions and inhibiting the enzyme phosphofructokinase. Consequently, energy and metabolite levels decline due to the slowing of the glycolysis process. The buildup of lactic acid in the muscles and blood causes fatigue, thereby decreasing performance. Therefore, the removal of lactic acid from the body during rest is crucial (Kerstholt, 2015; Stupnicki et al., 2010).

Post-exercise recovery occurs through the resynthesis of energy substrates, removal of metabolic waste, increased oxygen consumption, reduction of body temperature, and maintenance of fluid-electrolyte balance (Fox, 1998). Restoring the organism to its pre-exercise state and allowing for recovery are fundamental goals of post-exercise recovery. This process reduces fatigue, minimizes the risk of injury, and accelerates recovery time between training sessions. The removal of lactic acid from the body initiates the recovery and rest process.

The process of removing lactic acid from the body after maximal training or competitions takes approximately 2 hours with passive rest and about 1 hour with active recovery (Brent, 1994). This process is characterized by an increase in cardiac output and blood flow, accompanied by a rise in systolic blood pressure, pulse rate, and heart rate, while diastolic pressure decreases (Chidakel et al., 2005).

Furthermore, the absorption of glucose and increased glucose uptake in cells lead to a rise in insulin resistance, stimulating carbohydrate metabolism (Güllü et al., 2004). While findings indicate that training can enhance thyroid metabolism in sedentary individuals, there is insufficient reporting to suggest that athletes fall within this risk group (Sterling, 1978; Akkoyunlu et al., 2002). This situation highlights the importance of evaluating athletes' metabolic adaptation processes and training programs.

The metabolic response of lactate during recovery, regardless of gender, remains consistent in substrate metabolism and active recovery (Horton et al., 2002). Hormonal fluctuations do not significantly impact the changes in fuel metabolism affecting the rate of lactate removal from the blood and muscles. Comparatively, during and after recovery in the lactate fast phase (LF), a higher rate of lactate elimination has been observed when contrasted with the moderate intensity phase (MF) (Jurkowski et al., 1981; Güneş, 1995).

Delayed Onset Muscle Soreness (DOMS)

The term Delayed Onset Muscle Soreness (DOMS) was first defined by Hough as a syndrome experienced by individuals after exercise, typically felt about 8 to 10 hours post-exercise. This condition not only contributes to fatigue but also leads to various other effects. Since then, research has continued to investigate the physiological mechanisms underlying this distressing condition following exercise (Böning, 1995).

During high-intensity exercises, excessive strain can cause micro-tears in the weak myofibrils of muscle fibers, leading to the sensation of delayed muscle soreness. These tears result in circulatory disturbances within the muscle tissue and subsequent edema. As a result of ongoing reactions, ion imbalances that trigger pain in the muscle tissue are observed (Gulick & Kimura, 1996).

DOMS varies depending on the type of exercise, as well as its intensity and duration (Armstrong, 1990). This variability is an important factor for optimizing athletes' training programs and recovery processes.

Delayed Onset Muscle Soreness (DOMS) begins to be felt approximately 8 to 10 hours after activity or exercise, reaching its peak pain level within 24 to 48 hours, and its effects can last for 5 to 7 days post-exercise (Hody et al., 2013; Finsterer, 2012). Muscle fatigue is defined as a reversible decrease in performance during exercise, showing a significant reduction in the initial hours of recovery. In contrast, while muscle damage indicates a decline in performance, the recovery process from muscle damage is generally slower compared to muscle fatigue. The key distinction between muscle fatigue and muscle damage lies in the fact that muscle fatigue is shorter in duration and does not cause structural damage to myofibrils (Clarkson & Sayers, 1999).

Assessment of Delayed Onset Muscle Soreness (DOMS)

The evaluation of DOMS post-exercise involves the following parameters:

a) Range of Motion (ROM)
b) Muscle Function and Strength Decline
c) Perceived Pain Level
d) Elevations of Specific Muscle Proteins in Blood (McHugh et al., 1999).
These assessments provide critical insights into the effects of DOMS and inform strategies for its management.

The Relationship Between Recovery And Exercise

Recovery is defined as the process by which the organism returns to its normal state after exercise. During periods of competition or training, the optimal reduction of fatigue levels caused by intense exertion is expressed as psychological and physical rejuvenation aimed at restoring athletes' mental and physical conditions to their previous levels (Bishop et al., 2008). The primary goal of post-exercise recovery is to help athletes return to their pre-exercise conditions and to rest all muscle groups and bodily systems (Juel, 1998). In this context, the recovery process is viewed as a mechanism for restoring the muscles and entire body systems to their pre-exercise state (Fox et al., 2011). This process is crucial for ensuring performance continuity and reducing the risk of injury among athletes.

Effective recovery is a critical period following training or competition, vital for replenishing lost energy reserves and alleviating fatigue. Insufficient recovery can lead to muscle injuries and chronic fatigue among athletes, which may result in them being sidelined from their sports for a certain period. It is known that athletes in various sports engage in demanding training sessions at least 2-3 times a day (Bompa & Gregory, 2000). Such intense training, when combined with psychological and physiological stress, exceeding three hours of daily training, and factors such as repeated overloads, deficiencies in training systems, lack of variety in training loads, and insufficient rest days, further elevates stress levels (Alemdaroğlu & Koz, 2011).
Therefore, it is critical for athletes to effectively manage their recovery processes to sustain their performance and reduce the risk of injury.

Professional athletes in league competitions may participate in international tournaments, leagues, or national events within the same week. The journeys undertaken after these competitions also constitute a separate source of stress. These factors can lead to temporary declines in athletic performance (Reilly & Ekblom, 2005; Waterhouse et al., 2003; Barnett, 2006). If complete recovery is not achieved following intense workloads, fatigue can become chronic, potentially resulting in injuries (Silva, 1990).
Therefore, it is crucial for professional athletes to optimize their recovery processes following training and competitions in order to maintain their performance levels and ensure their long-term health. The psychological and physiological recovery of athletes should be considered an integral part of training. To achieve optimum performance, it is essential to avoid excessive training methods (Alemdaroğlu & Koz, 2011). Sports scientists and coaches have long conducted research to ensure that athletes achieve complete recovery (Bompa & Gregory, 2000).

To better prepare athletes for their next competition and enhance their performance, systematic recovery programs must be developed and implemented. The optimal balance between loading and recovery plays a critical role in improving athletes' performance. In this context, various activities such as immersion in water at different temperatures, massage, stretching, showering, aerobic running, contrast baths, and walking in a pool have the potential to accelerate the recovery process (Burke, Loucks, & Broad, 2006). The effective integration of such activities promotes muscle relaxation while enhancing blood flow, thereby accelerating the elimination of metabolic waste. Additionally, these methods provide not only physical recovery but also psychological relaxation, thus supporting the overall well-being of athletes. Therefore, the implementation of an effective recovery strategy is vital for the sustainability of athletes' performance and the reduction of injury risk (Burke, Loucks, & Broad, 2006).

Respiratory Physiology During Rest and Exercise

The healthy functioning of the respiratory system depends on the coordination of lung mechanics, respiratory muscles, and chest wall movements (McConnell, 2011; Tukanova et al., 2020). At rest, pressure fluctuations descend into the abdominal cavity, increasing volume and creating negative pressure in the thoracic cavity. This process occurs due to the autonomic contractions of the diaphragm (West, 2000). When the diaphragm contracts, the volume of the thoracic cavity increases while the air pressure in the alveoli decreases, facilitating airflow. This mechanism plays a critical role in meeting the energy needs of the body at rest by facilitating the transfer of oxygen from the alveoli into the bloodstream. During exercise, however, the respiratory muscles must exhibit increased activity, leading to enhanced respiratory rate and depth. Consequently, these processes induce significant physiological changes aimed at meeting the body's oxygen demand and increasing carbon dioxide elimination. Therefore, respiratory physiology is a fundamental component that affects athletes' performance.

The negative pressure generated by the contraction of the diaphragm facilitates inspiration by increasing airflow into the lungs (Aliverti, 2008). Expiration during rest involves the energy expended to achieve thoracic extension, which occurs passively through the elastic properties of the respiratory system, allowing the functional residual capacity to be reached following the cessation of inspiration (Dominelli & Sheel, 2012).

This process begins with the relaxation of the diaphragm and other inspiratory muscles; as these muscles return to their anatomical positions, thoracic volume decreases relative to inspiration, leading to an increase in intrathoracic pressure. This increase facilitates the expulsion of air from the lungs, resulting in expiration. Therefore, the respiratory mechanism during rest plays a significant role in both the generation of negative pressure and energy expenditure. These processes enhance the efficiency of the respiratory system by regulating oxygen intake and carbon dioxide elimination.

The elastic structure of the respiratory mechanism refers to the energy required for the anatomical components related to respiration to deform, while resistive respiration defines the energy necessary to overcome the resistance to airflow in the airways (Dominelli & Sheel, 2012). During exercise, respiratory muscles must perform both elastic and resistive work. The expansion of the lungs and thoracic wall occurs through an elastic recoil mechanism that increases the pressure of the air entering the airways during high airflow (Sheel & Romer, 2012).

The respiratory workload during exercise is based on the principle of minimal effort. This principle indicates that the natural ventilatory response during exercise is associated with the minimum energy requirements of the respiratory muscle system. This notion is

supported by experimental data and mathematical modeling (Batzel et al., 2012).
Ventilation occurs within a range of lung volumes that provides the highest total lung compliance during exercise. This refers to the pressure changes required to achieve a change in volume. The dynamics at play during exercise enhance the efficiency of the respiratory system, optimizing oxygen uptake while facilitating the expulsion of carbon dioxide.

In conclusion, the management of respiratory workload during exercise plays a critical role in enhancing athletes' performance. In this context, considering the effectiveness of respiratory mechanisms in the design of exercise programs is essential for achieving optimal performance.

The combination of increased tidal volume and respiratory frequency occurs at a level that minimizes dead space ventilation. This enhances the efficiency of the respiratory system, optimizing oxygen uptake while facilitating the expulsion of carbon dioxide (McConnell, 2011).

At the onset of exercise, alveolar ventilation is increased to meet the demand for maintaining acid-base balance close to homeostatic levels. During this process, arterial oxygen levels are expected to remain stable despite rising demand, while a decrease in venous oxygen tension is observed. Additionally, any increases in carbon dioxide production must be effectively eliminated (Des Jardins, 2012).

The changes in respiratory mechanisms that occur at the onset of exercise are associated with neural changes in the brainstem centers that actively increase oxygen intake and coordinate the respiratory muscles moving the thoracic cavity (Aliverti, 2008). These neural adaptations optimize oxygen uptake during exercise, ensuring the efficient continuation of bodily functions. Consequently, these dynamic processes play a critical role in sustaining exercise performance.

To maintain metabolic efficiency during exercise, it is essential to preserve the respiratory regulation without excessive demand on alveolar ventilation (John, 2011). Adaptations in respiratory mechanisms to meet the increased ventilation demand are reflected in changes in both tidal volume and respiratory frequency, leading to increases in minute ventilation. Minute ventilation progressively rises with the increase in exercise intensity (McConnell, 2011).
During light exercise, the increased load on inspiratory muscles and a moderate rise in respiratory frequency lead to significant changes in tidal volume. This occurs as the respiratory workload increases, resulting in an elevation in respiratory frequency to compensate for changes in tidal volume platitudes when reaching 60% of vital capacity. These dynamic mechanisms maximize oxygen uptake throughout the exercise while effectively facilitating carbon dioxide elimination. Therefore, these adaptations play a critical role in optimizing exercise performance.

Changes in tidal volume are associated with the expansion of the thoracic cavity, which allows for the utilization of both inspiratory lung volume and end-expiratory lung volume. This process occurs through the coordinated action of the respiratory muscles, enabling an effective increase in alveolar ventilation. The expansion of the thoracic cavity triggers changes in intrathoracic pressure, facilitating airflow and thereby optimizing oxygen intake while supporting carbon dioxide expulsion. This dynamic significantly enhances the efficiency of respiratory mechanisms, playing a crucial role in exercise performance.

Determination of Respiratory Muscle Fatigue

Peripheral respiratory muscle fatigue can be assessed through non-invasive voluntary evaluation methods, such as measuring maximal inspiratory pressure (MIP), maximal expiratory pressure (MEP), maximal transdiaphragmatic pressure, or cough pressure. These measurements are utilized to detect respiratory muscle fatigue following high-intensity exercise (Bostancı et al., 2019; Romer et al., 2002; McConnell, 2011; Volianitis et al., 2001).

However, these techniques have certain limitations; results may vary based on individual effort levels and can be influenced by learning effects (ATS/ERS, 2002). Additionally, respiratory muscle fatigue can be evaluated through frequency domain analysis of electromyography (EMG) signals recorded via surface electrodes placed on the relevant muscle group or by using an electrode catheter inserted intranasally into the participant's nasal cavity to reach the lower esophagus (Luo et al., 2008). There are ongoing discussions regarding the validity of EMG power spectrum measurements. Neural or sarcolemmal events may contribute to spectral shifts associated with fatigue, and these shifts can occur independently of the processes related to excitation-contraction coupling. Consequently, a weak correlation has been observed between EMG spectral shifts and mechanical fatigue indices.

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Future Training Perspectives in Basketball

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To Cite This Chapter

Ulema, M. S. (2024). Future Training Perspectives in Basketball. In M. Özdal & F. Alıncak (Eds.), *Current Studies in Sports Sciences 2024* (pp. 39-45). ISRES Publishing.

Introduction

Exercise and training are systematic activities to improve physical performance, endurance and general health. Exercise generally refers to physical activities that individuals perform regularly to maintain their health, increase their fitness or improve their physical capacity. Training, on the other hand, consists of planned and goal-oriented programs to improve performance in a particular sport. Training aims to improve individuals' specific abilities such as strength, speed, agility, flexibility, and coordination and usually requires careful regulation of elements such as intensity, volume, and rest periods of exercises (Cinar et al., 2016; Pancar, 2021).

Exercise and training positively affect different systems of the body (Kiriscioglu et al., 2019; Cinar et al., 2019). Aerobic exercises increase cardiovascular endurance, while strength training improves muscle strength and muscle mass (Ay and Pancar, 2022). At the same time, exercises strengthen the musculoskeletal system, increase bone density and reduce the risk of injury by improving flexibility (San et al., 2019). As well as physical development, the mental health benefits of exercise and training are huge, with effects such as lowering stress levels, alleviating anxiety and improving overall mood. Training programs are aimed at more specific goals. These programs are structured according to a specific order to optimize athletes' performance (Ünlü et al., 2023; Pancar et al., 2017). Training sessions are designed to increase the athlete's skills, tactical awareness and mental endurance. For training to be effective, rest periods and recovery processes should also be meticulously planned and athletes should be protected from fatigue and overload. In general, exercise and training push the physical and mental limits of individuals, making them healthier and more efficient in both daily life and sportive activities (Özer et al., 2017). At the time to peak torque, the contraction speed is at the forefront and its unit is the second. This refers to the time to reach peak torque. It is used in evaluating athletes that require explosive power and available condition (Vural, 2019).

The most important point in winning or losing is to work and make an effort. Afterwards, success often comes naturally. However, it should also be known that working and making efforts will not always produce successful results. When the result fails despite the team's best efforts; It should be accepted and accepted that the entire Team in front of you deserves to win more than you. In other words, it should be accepted that the other team made fewer mistakes and the luck factor was on the side of this team (Erdoğan, 2022; Erdoğan, 2023).

Basketball is a fast-paced sport that maximizes players' physical, technical and tactical abilities. In this context, training practices are structured based on scientific foundations to maximize players' individual and team performance (Bompa & Buzzichelli, 2018). In addition, development by age refers to the physical, mental and emotional maturation of children and adolescents through certain stages. Each age period offers different needs and potentials in terms of motor skills, muscle strength, coordination and social-emotional development, which requires training and education processes to be organized in accordance with these stages (Tuzcuogulları et al., 2017). Modern training practices go beyond traditional approaches in the light of sports sciences and offer customized programs according to the individual needs of the players. Success in high-tempo sports such as basketball is not limited to physical competence. Technical skills, tactical awareness and mental toughness are also important components of success (Weinberg & Gould, 2014). Training processes aim to maximize both the physical and psychological capacities of players. Periodized training programs are meticulously planned to ensure that players perform at their maximum throughout the year (Bompa & Carrera, 2005). In this chapter, we will take an in-depth look at the importance of training in basketball and how it is developed through scientific approaches. We will also discuss the methods used to develop physical and mental skills and their effects on players.

Aim of The Study

The aim of this study is to discuss the methods used to develop physical and mental skills in basketball and their effects on players.

Training Models and Approaches

Physical Training

Basketball is a sport that emphasizes explosive power, endurance, flexibility and speed. Physical training involves various methods to develop these elements. Strength training specifically aims to strengthen the lower body muscles and helps players make significant improvements in areas such as vertical jump height and sprint performance (Panjan & Sarabon, 2010). Research has shown that basketball players who regularly engage in strength training show significant increases in explosive power and endurance performance during matches. In particular, periodized strength training is known to reduce the risk of injury and increase endurance in the long term (Zatsiorsky & Kraemer, 2006). Strength training is of great importance for the development of skills such as explosive power, jumping ability and speed in basketball. Research shows that strength training significantly improves players' jump heights and sprint performances by increasing lower body strength (Kraemer & Spiering, 2007). In particular, lower body strength training improves basketball players' vertical jumping capacity, while upper body strength is important in areas such as ball control and rebounding. Endurance training is vital for players to maintain their physical capacity throughout the high-paced game. The combined development of aerobic and anaerobic endurance enhances players' ability to cope with fatigue and perform at a consistently high level in a match (Hoffman, 2014). Research shows that endurance training optimizes energy systems, making players more resilient to physical loading throughout the match (Spencer et al., 2005).

Plyometric training is effective in developing explosive strength and provides significant improvements in skills such as speed, jumping and changing direction. Plyometric exercises make it possible to perform faster and more effective movements by strengthening the muscle-tendon complex (Meylan & Malatesta, 2009). In basketball, movements such as fast breaks and sudden changes of direction can be made more efficient with plyometric training. Flexibility training, on the other hand, increases players' mobility and reduces the risk of injury. Flexibility allows muscles to remain more flexible under tension, especially in high-intensity matches. In the long run, this reduces the risk of injury and increases players' range of motion (Behm et al., 2016).

Technical Training

In basketball, technical skills directly affect a player's dominance over the game. Proper teaching of shooting mechanics, passing, dribbling and rebounding techniques is critical for a player to be effective on the court. For example, the right shooting mechanics can increase a player's shooting percentage, while a wrong technique can hinder success in the long run. Studies have shown that repetitive technical training is especially effective in improving the basic skills of young players (Erculj & Supej, 2009). Technical training has also been proven to contribute to improvements in in-game speed and accuracy. Shooting mechanics is one of the most important technical skills in basketball that directly affects the accuracy and efficiency of players. Proper teaching of shooting mechanics allows players to achieve higher success rates by expending less energy (Miller, 2012).

Technical shooting drills improve both hand-eye coordination and body balance, which in turn improves accuracy in the game. Teaching players the correct shooting techniques during training can lead to more consistent shooting performances in later years, especially for young players. In addition, individual skills as well as the ability to create shooting positions within the team can be improved through these trainings (Erculj & Supej, 2009).

Passing and dribbling, one of the fundamental techniques of basketball, are directly related to the ability to control the flow of the game and communicate effectively with teammates. Passing drills improve players' ability to share the ball by making the right decisions at the right time (Gómez et al., 2013). Dribbling, on the other hand, is important in terms of individual attacking skills as well as the ability to break through the defense and organize team attacks. In passing training, various training methods are applied for players to make both short and long distance passes correctly. Dribbling drills, on the other hand, are used to improve players' ball control and increase their ability to move quickly.

Mental Training

Basketball is a sport that requires not only physical but also mental endurance. Mental training is used to improve players' concentration during the game, to cope with stress and to improve their decision-making skills. Players with developed mental skills provide a strategic advantage to their team by making the right decisions in difficult moments. Studies on the effect of mental training on in-game performance show that players who work under pressure are more successful (Vealey & Greenleaf, 2001). Therefore, mental training plays an important role in basketball (Weinberg & Gould, 2014).

Visualization techniques allow players to mentally rehearse in advance the situations they may encounter during the match. Visualization especially increases players' self-confidence, allowing them to make the right decisions in difficult moments (Vealey & Greenleaf, 2001). Meditation, on the other hand, helps players to keep their stress levels under control and act with a clearer mind during the game (Hardy et al., 2009). Pressure and stress during the match can negatively affect players' performance. Therefore, it is of great importance to develop focusing skills in training programs. Focusing techniques help players to concentrate their attention on a single goal during the game (Weinberg & Gould, 2014). At the same time, stress coping skills are also improved through mental training.

Periodization

In basketball, training planning is of great importance for players to stay in shape over a long season. Periodization is a strategy that allows training to be performed at different intensities and volumes throughout the year. This approach is designed to enable players

to perform at their physical best and minimize the risk of injury (Bompa & Haff, 2009). Periodization includes preparation, competition and recovery periods. According to research, correctly planned periodization programs enable players to perform at the highest level throughout the year (Issurin, 2008).
The relationship between training load and rest periods plays a critical role in performance enhancement. In case of overload, players may experience physical and mental exhaustion, which can lead to injuries. Therefore, it is essential to provide adequate rest periods following the load. Recovery training allows the muscles to fully recover and be more ready for the next training session (Kraemer et al., 2009). It is emphasized that as the training load intensity increases, rest periods should be extended in parallel.

New Generation Training Methods in Basketball

Technology-based training has an important place among the new generation training methods in basketball. GPS tracking systems, heart rate monitors and video analysis software are used to optimize training processes (Spencer et al., 2005). Thanks to GPS data, data such as the distance, speed, and number of sprints that players cover on the field can be analyzed in detail. This data guides training planning and allows the determination of the specific training that the player needs (Gabbett, 2016).

In recent years, training methods supported by sports science have been used to improve players' performance and minimize the risk of injury. Functional strength training and individualized training programs are shaped according to the physiological needs of players (Noyes et al., 2005). For example, individualized strength training programs for basketball players have been shown to be effective in improving performance and preventing long-term injuries.

Conclusion and Future Perspectives

Basketball training practices are complex processes that require a multidisciplinary approach to maximize players' physical, technical, tactical and mental capacities. Modern basketball training not only focuses on improving athletes' physical abilities, but also their game intelligence, decision-making skills and endurance. These approaches, developed in the light of today's sports sciences, provide a systematic and planned acquisition of the multifaceted skills required by basketball. Physical training is indispensable for players to be successful on the court. Basic physical characteristics such as strength, endurance, speed, flexibility and agility are at the forefront in the fast-paced game that basketball requires. Research shows that strength training significantly improves players' jumping, speed and endurance performance (Hoffman, 2014; Kraemer & Spiering, 2007). In particular, periodized training programs have been proven to reduce players' risk of injury and allow for long-term performance improvements (Issurin, 2008). Developing technical skills is also an integral part of basketball training. The correct teaching of basic skills such as shooting mechanics, passing and dribbling plays a critical role for players to be effective during the match. Studies show that the repetition of technical training accelerates players' motor learning processes and makes these skills more permanent (Miller, 2012). In addition to technical skills, improving in-game strategic decision-making processes through tactical training increases team success.

Mental toughness in basketball is another important factor in which high performing players stand out. Mental preparation and resilience work integrated into training programs increases players' ability to make correct decisions under pressure. Visualization, meditation and stress coping techniques help players to keep their performance at its peak (Hardy et al., 2009). In particular, it has been supported by research that pre-match mental preparation increases players' confidence during the match and allows them to achieve more successful results (Weinberg & Gould, 2014).

The use of periodization principles in the planning and implementation of training allows players to perform at the highest level throughout the year. Periodic training cycles aim to ensure that players are in optimal physical and mental condition at different stages of the season. These cycles, planned as periods of preparation, competition and recovery, allow players to follow a balanced program between load and rest. Furthermore, these approaches are critical for injury prevention and fatigue minimization (Issurin, 2008).
In recent years, the integration of technology with sports science has drastically changed training processes. Wearable technologies, devices such as GPS and heart rate monitors make it possible to track players' training loads and physical condition in real time. In this way, training programs have become more precise and customized to the individual needs of players (Gabbett, 2016). Furthermore, video analysis tools and performance monitoring systems allow technical skills to be analyzed and improved in more detail. These technologies contribute to a more scientifically based examination of shooting mechanics, defense and passing techniques in particular (McGarry, 2009).

Future Perspectives

Training practices in basketball will become more individualized and data-driven in the future with the further development of technology and the deepening of scientific knowledge. Thanks to the developing technology, players' performance data can be measured more precisely and training programs can be optimized in line with these data. In particular, artificial intelligence-supported systems will allow players' physical, technical and mental development to be analyzed instantaneously, allowing individual training programs to be designed more effectively (Gabbett, 2016).

The use of wearable technologies and data analytics systems in basketball training will continue to increase. Devices such as GPS data, heart rate monitors and accelerometers allow to monitor and analyze players' performance in real time. In the future, more sophisticated versions of these devices will be able to track players' training load levels and recovery processes more precisely, so that training programs can be further customized according to players' individual needs (Bangsbo et al., 2006). At the same time, these technologies will enable earlier detection of injury risks and preventive interventions.

In the future, individualized training programs will gain more importance in basketball. Customized training programs will be created for each player, taking into account factors such as their genetic makeup, physiological capacity and playing style. These individualized approaches will be designed to strengthen players' weaknesses and further develop their strengths. Furthermore, advanced biomedical methods such as genetic testing and biomarker analysis can help identify players' performance potential (Mujika, 2013).

In the future of training practices in basketball, mental preparation and psychological resilience will be at the forefront. Developing not only the physical but also the mental capacity of players has become the key to success. Mental resilience and stress management will improve players' performance during the match and will enable them to achieve sustainable success in the long run (Vealey & Greenleaf, 2001). Research in this area suggests that mental training should be integrated into more training programs in the future.

In conclusion, training practices in basketball continue to evolve thanks to both current scientific approaches and technological innovations. Training programs designed in accordance with the individual needs of players will help them maximize their performance and minimize the risk of injury. Considering the complex nature of basketball, it is inevitable that more holistic, scientific and technology-supported training methods will come to the fore in the future. Collaboration between coaches, sports scientists and technologists will be among the most important elements that will shape the future training approaches in basketball.

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The Basics of Recovery in Basketball

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To Cite This Chapter

Karaca, B. (2024). The Basics of Recovery in Basketball. In M. Özdal & F. Alıncak (Eds.), *Current Studies in Sports Sciences 2024* (pp. 46-65). ISRES Publishing.

Introduction

Basketball is a high-intensity and intermittent team sport. Players rapidly change direction, sprint and jump throughout the match (Stojanovic et al., 2018; McInnes et al., 1995; Ben Abdelkrim et al., 2007). It has been reported that male and female basketball players cover a distance of approximately 5-6 km in a game and have a maximum heart rate above 85% (Stojanovic et al., 2018). In the game of basketball, both aerobic and anaerobic energy systems are engaged and glycolysis plays an important role in ATP production during high-intensity movements (McInnes et al., 1995). Therefore, carbohydrates are the main source of energy for basketball players (Williams and Rollo, 2015). In addition, a large amount of sweat loss has been observed during training and competitions. Protein and collagen supplementation is also important for muscle repair and recovery (Heaton et al., 2017).

Aim of The Study

The aim of this study was to investigate various recovery strategies for the improvement of sportive performance in basketball.

Energy Requirements in Basketball

The energy requirements of each sport vary depending on factors such as contact, duration, distance and intensity. This is related to the content of the training program rather than the type of training (Fox & Bowers, 1988). Aerobic capacity, which increases endurance in basketball, is an important physiological requirement for game performance (Bompa, 2011). Activities such as changes in direction, sudden runs, explosive power, jumps and sprints emphasize anaerobic energy consumption in the body (Ziv & Lidor, 2009).

Basketball is a sport that requires approximately 4/1 of aerobic energy and 4/3 of anaerobic energy. In practice, 80% of the anaerobic energy system (60% phosphogen and 20% lactic acid) is used for sustained high-intensity exercise. Basketball-specific short duration high-intensity movements are supported by the energy produced by lactic acid and the ATP-PC cycle in a short time. In this respect, basketball can be defined as a high-intensity team sport (Ziv and Lidor, 2009; Castagna and Abt, 2008). Therefore, both energy parameters (aerobic and anaerobic) should be considered when creating a training program for basketball and planning the recovery process after training and competitions. The need for high-level motoric characteristics in basketball makes anaerobic energy an important factor in energy capacity (Dündar, 1999; Sen, 2000).

In addition, the fluent integration of technical movements with coordination, explosive power and sprinter characteristics in the game provides high performance statistics depending on the playing time (Fox & Bowers, 1988; Sheppard, 2006).

Performance Elements in Basketball

Assessing and optimizing performance in basketball requires a detailed examination of a wide range of elements. These elements range from physical capacity to technical skills, from psychological resilience to tactical adaptations. Thus, basketball performance is a multi-layered construct that results from the effective combination of individual abilities and team strategies.

Basketball is a sport that requires high physical skills. The performance of players on the court is largely related to physiological parameters such as endurance, strength, speed, agility and flexibility. In particular, aerobic capacity (VO2max) and anaerobic power are critical for players to perform at an optimal level throughout the match. Research shows that athletes with high VO2max have lower fatigue levels and are able to perform at high levels for longer periods of time (Csataljay et al., 2009). At the same time, anaerobic power plays an important role in the sustainability of immediate high-intensity efforts such as short-distance sprints, explosive jumps, and fast reactions (Malarranha et al., 2013). At the time to peak torque, the contraction speed is at the forefront and its unit is the second. This refers to the time to reach peak torque. It is used in evaluating athletes that require explosive power and available condition (Vural, 2019).

Technical skills are one of the most decisive elements of basketball performance. Factors such as shooting accuracy, passing ability, dribbling and defensive skills affect players' individual and team roles. For example, field goal shooting percentage and three-point accuracy are critical indicators often used to measure a player's offensive performance (Oliver, 2011). However, passing ability and ball control increase the efficiency of offensive organizations by ensuring fluidity in team play. A good passer not only delivers the ball to the right place at the right time, but also optimizes the positioning and strategy of his teammates on the court (Yu et al., 2008).

In basketball, psychological endurance, as well as physical abilities, is a factor that greatly affects the performance of players. Basketball games are high-paced competitions that are often played under stress. Therefore, players' mental toughness is directly related to their ability to perform under pressure. Research shows that high levels of motivation, concentration, self-confidence, and the ability to cope with stress improve players' performance during games (Csataljay et al., 2009). Furthermore, social psychological factors such as leadership and team communication contribute to collective success by increasing team cohesion (Oliver, 2011).

Basketball is also a game of strategy and tactics. The team's game plan, offensive and defensive strategies ensure that the players' individual performances are used effectively. A well-planned strategy optimizes the team's overall performance while maximizing the players' abilities. For example, fast attacking strategies can break defensive resistance by controlling the tempo of the game (Malarranha et al., 2013). On the defensive side, a well-organized zone defense increases the team's probability of winning a match by reducing the offensive efficiency of the opposing team (Csataljay et al., 2009).

Performance in basketball is a multifaceted structure in which physical abilities, technical skills, psychological endurance and tactical elements work in harmony. These elements not only affect the individual performance of the players, but also directly determine the overall success of the team. Therefore, athletes and coaches who want to improve basketball performance should give equal importance to each of these elements and develop training programs supported by scientifically based studies. A holistic approach to performance will improve not only individual development but also the effectiveness of team strategies.

Physical Recovery Process

The human body is designed to ensure the harmonious functioning of organs and systems by maintaining internal balance. This functioning is achieved through different levels of organ functioning. Especially in some sports, athletes are exposed to overloads by training at high intensity (Amann et al., 2015). Such intense overloads can lead to a decrease in athletes' performance. It can lead to problems such as inadequate recovery, increased fatigue, injury risks and loss of performance (Taylor et al., 2016).

Researchers and coaches aim to effectively clear metabolic wastes after sport and improve performance. The physical, physiological and mental recovery of athletes is a critical factor for maximum performance (Barnett, 2006). Recovery refers to the fastest way to eliminate fatigue after training or competition and return the athlete to their previous state. This process also contributes to the reorganization of energy metabolism (Bishop et al., 2008).

The energy expended during exercise varies depending on the intensity of the exercise and this affects the energy sources in the body. After training, the organism starts to repair the damage, depending on the energy expended. Recovery is a period in which this energy consumption continues. To understand metabolic recovery, some important metrics should be taken into account, including O2-myoglobin oxygenation, return of energy sources to resting levels, removal of lactic acid, and closing the oxygen debt (G¸nay et al., 2013; Murray et al., 2018).

The recovery process can vary depending on many factors and is therefore still an important area of research in sports science. Depending on the intensity of the training or competition, recovery time may vary. For example, athletes from different sports, such as basketball players and swimmers, may have different recovery techniques and processes. The physical and mental fatigue that occurs during training and competitions can lead to a decrease in performance and have detrimental effects on the body. The main purpose of recovery is to eliminate these negativities and ensure that the athlete is best prepared for the next training or competition.

Objectives of Physical Recovery

The main goal of the recovery process is to repair the damage caused during training or competition and to minimize and completely eliminate fatigue. In an effective recovery process, factors such as returning the organism's functions to their previous level, restoring the body's internal balance and compensating for the energy loss caused by high-intensity activities come to the fore (Bishop et al., 2008). In addition, recovery provides benefits such as accelerated blood flow, cleansing of waste materials in the blood and muscle, reduction of inflammation and edema. Other positive outcomes of effective recovery include reduced muscle stiffness and soreness, increased muscle flexibility, faster recovery of fitness and reduced effects of delayed onset muscle soreness

(Cochrane, 2004).

There are also various factors that affect the physical recovery process. The biological age, gender, experience, health status and ongoing injuries, if any, are among these factors. In addition, maximal oxygen consumption capacity and genetic characteristics, energy metabolism and the requirements of the sport also play an important role. Factors such as overload, eating habits and fluid-electrolyte balance can also affect the recovery process. Environmental factors, mental state and personal lifestyle are other factors that determine how recovery progresses. For example, sleep patterns, alcohol and smoking habits, stress and motivation can all have an impact on recovery. In addition, time changes after the journey can also negatively affect the recovery process (Jemni et al., 2003).

Classification of Physical Recovery

Physical recovery is broadly classified in three different ways according to duration: quick recovery, short-term physical recovery and long-term physical recovery. Rapid recovery refers to muscle regeneration between short-term and repetitive activities. For example, during walking, the recovery process between steps is related to the regeneration of ATP in the muscles and the removal of waste. This process improves athletes' performance by increasing their speed (Bishop et al., 2008). Short-term physical recovery is the type of recovery seen between sets. It aims to maintain the performance of the next movement by resting the muscles after an exercise movement and restoring energy metabolism. Studies have found that short recovery times (15-30 seconds) negatively affect performance (G¸m¸sdag et al., 2015). Long-term physical recovery takes place between training sessions or matches and aims for full recovery. Especially after aerobic exercises, 8 to 24 hours of rest is recommended, while more than 24 hours are required for full recovery (Bishop et al., 2008; Sporer and Wenger, 2003; Burke et al., 2006). In addition, many different methods are used to accelerate physical recovery in athletes (Alemdaroglu & Koz, 2011). These include low-tempo running, massage, cryotherapy, hydrotherapy, contrast applications, nutrition and fluid intake. In addition, acupuncture, ultrasound, pressure garments, electrical muscle stimulation, psychological therapy and lifestyle changes are also considered effective methods (Wilcock et al., 2006; Tessitore et al., 2007).

Traditional Recovery

Traditional recovery is a common method to reduce muscle fatigue and damage after high intensity exercise. The main purpose of this method, also known as active recovery, is to remove waste materials accumulated in the muscles and blood after exercise, re-synthesize high-energy phosphates, transport oxygen to the muscles and blood, regulate the body's internal balance and increase blood flow. This process makes the body's defense mechanisms more effective (Anderson et al., 2010; West, 2013). Active recovery increases metabolic rate and blood flow, allowing lactate to be removed faster through oxidation and gluconeogenesis, and thus fatigue decreases more quickly (Peifei et al., 2021). However, the duration and intensity of recovery should be well-tuned; too long or intense a recovery period may cause the athlete to become overtired or accumulate waste materials. Optimal recovery can be achieved with activities such as low-paced running, jogging, stretching, cycling, and swimming lasting 10-30 minutes at 30% to 50% of maximal heart rate (Warren et al., 2014). Research has shown that traditional recovery accelerates the electromyographic activity of muscles and reduces muscle spasms (Cheung et al., 2003). In addition, this method can help increase oxygen levels, hemoglobin and myoglobin levels in muscles (Koizumi et al., 2011).

Massage

Massage is an important recovery method used to alleviate exercise-related fatigue and stress. Massage, which has been used throughout history to improve human health, treat diseases and strengthen the body, is also frequently preferred in the physical recovery of athletes (Mori et al., 2004). First defined in 1863 with various techniques, massage is a set of systematic movements that improve the body physically, functionally and anatomically by acting on muscle tissues (Noble et al., 2007). This method is applied to increase muscle tone, stimulate circulation and balance the nervous-muscular systems (Benjamin et al., 2005).

Massage produces various reactions on the organism through mechanical stimuli. These reactions occur at different levels depending on the technique applied and are locally effective on the skin, subcutaneous tissues and muscles and can reach the internal organs through reflexes. The physiological, mechanical and psychological effects of massage are seen in the locomotor system, cardiovascular system and other body structures. The benefits of massage include accelerating cell regeneration, removing toxins and waste products accumulated in the muscles, increasing blood circulation, reducing muscle fatigue and pain, preventing muscle damage and accelerating the recovery process. It also reduces pain and lowers the level of stress hormones by increasing endorphin release (Powell et al., 2015; Kara & İnver, 2019). Especially sports massage is widely practiced to accelerate recovery during and after physical activity and exercises (Budak, 2018). One of the reasons for the use of massage in sport recovery is the assumption that it helps to rapidly remove lactate accumulation from the body. With lactate accumulation, the body pH decreases, which suppresses the activity of the enzyme phosphofructokinase and slows down glycolysis. Energy production is reduced and this limits the effective contractile capacity of muscles. The lactate accumulated in the muscles and bloodstream causes fatigue (Bangsbo et al., 1994; Sahlin, 1992). Many studies have been conducted to investigate the effect of massage on this fatigue-inducing metabolite; however, these studies revealed that massage did not have a significant effect on the elimination of lactic acid from the body. However, there are also studies indicating that massage has positive results on performance measures such as fatigue index and total work done (Kˆseoglu and Kin. 2000; Ogai et al., 2008; Ernst 1998; Appell et al., 1992). In a recent study, massage was found to increase heart rate variability, increase parasympathetic activity and decrease sympathetic activity in college basketball players (Kaesaman, 2019). The massage was performed at halftime of a simulated basketball game, with players receiving a 10-minute traditional Thai massage or simply resting. These indicators may suggest a reduction in fatigue in basketball players (Edwards et al., 2008); however, it is not clear whether these results are beneficial or detrimental to players at half-time and how they relate to on-court performance or post-match recovery. Although seen as an innovative approach, it may be difficult to implement massage at half-time in practice. At this stage, players may need to focus more on energy intake, hydration and the coach's strategic plans for the second half. Future research should elaborate on these results to better understand the effects of such massage techniques on post-match recovery (Davis et al., 2022).

Hydrotherapy

Hydrotherapy is a recovery method that has recently increased in popularity and is frequently used especially among athletes. In this method, which is applied to accelerate post-exercise regeneration, factors such as the duration, frequency, depth and temperature of the water affect the recovery process. Generally, a water immersion therapy at normal temperature lasts between 10 and 30 minutes (Wilcock et al., 2006). Hydrotherapy creates various physiological changes by entering the water to refresh the body after intense physical activities. These changes start with the hydrostatic pressure of the water and continue with positive effects such as fluid exchange in the body, increased circulation rate, improvement in cardiovascular functions, and reduction of edema accumulated in muscle groups (Vaile et al., 2008). It has also been stated that it has benefits such as relaxing the person mentally and increasing alertness (Jeffreys, 2005). Hydrotherapy is recognized as an effective method that supports physical and mental recovery.

Cryotherapy

Cryotherapy involves the application of cold or immersion in cold water and is frequently used both to accelerate recovery after intense exercise and to treat trauma and injury. This application causes changes in skin, muscle and joint temperature, while heart rate and cardiac output decrease, blood pressure and peripheral resistance increase (Cheung et al., 2003; Wilcock et al., 2006). The main effect of cryotherapy is to reduce pain and inflammation after exercise by lowering local tissue temperature and blood flow (Barnett, 2006). The pain relief effect occurs by decreasing the nerve conduction velocity and altering the pain perception of the central nervous system. However, this may also affect muscle contraction rate and strength capacity, leading to a short-term decrease in performance. Therefore, the most effective application time of cryotherapy is recommended to be performed immediately after exercise for approximately 15-20 minutes (Rutkove, 2001).

Cryotherapy applications in the literature are as follows:

1. A 14-minute bath at 15°C for the whole body except the head and neck (Vaile and Gill, 2007).

2. One-minute baths at 10°C, followed by 15°C and 20°C for the whole body except the head and neck, and 2 minutes of rest out of the water after each session (Vaile et al., 2008),

3. Applying water at 15°C to the legs for 15 minutes (Lane and Wenger, 2004). Applying water at 8°C to the legs for 10 minutes (Burke, 2000).

Although it is a common method for post-exercise recovery, scientific evidence supporting the efficacy of cryotherapy is limited. Some studies suggest that cryotherapy has little effect on muscle damage after exercise (Howatson et al., 2009). However, in a study conducted by Demirhan (2013) on elite wrestlers, it was found that eight minutes of cold application significantly reduced myoglobin and Creatine Kinase levels and accelerated recovery. Abaidia et al. (2017), in a study conducted in trained individuals, reported that cold water immersion positively affected active jump performance at 72 hours after exercise, while subjects felt less pain and perceived recovery levels were higher between 24-48 hours. There are studies examining the effect of cryotherapy on post-match recovery in basketball players. (2018) investigated the effects of cryotherapy on 24 French national team players participating in the European Championship. In the study, the thermal sensations (cold perception) of international level male and female basketball players to cold exposure at -130°C for 3 minutes were evaluated. Cryotherapy was applied to the whole body, except the head and neck, every afternoon for 2 weeks. The results showed that the 3-minute cryotherapy sessions were well tolerated by both male and female elite basketball players and could be used during intense periods of matches or training. However, significant individual differences in thermal sensations between players were reported. These differences were largely attributed to differences in the body mass index (BMI) of the players. In particular, it was emphasized that female basketball players with lower BMI are more sensitive to cold and this may affect compliance with cryotherapy. Other studies with similar temperatures (-110°C) and exposure times (3 minutes) show a reduction in muscle soreness (Ferreira-Junior et al., 2015) and accelerated recovery in eccentric muscle performance.

Contrast water application

Contrast water application is a widely used and increasingly popular method to accelerate recovery, especially after sports. In this application, alternating hot and cold water is used to regulate blood flow in muscle cells. The temperature of cold water should generally be between 10-15°C and hot water between 36-42°C. The application time is 20-30 minutes on average, starting with hot water and ending with cold water. In the first stage, hot water is used for five minutes, followed by cold water for one minute and this cycle is repeated until the end of the duration. Contrast water therapy is applied especially after intense physical activity in order to remove waste substances from the body, reduce edema and restore internal balance. It also alleviates inflammation and edema by reducing spasms and stiffness in muscle groups (Bieuzen et al., 2013). In a study conducted by Hamlin in 2007 on rugby players, it was reported that this method did not have a direct effect on repetitive sprint performance, but it was beneficial on delayed muscle soreness. In another study conducted by Forghani et al. in 2015 with male university students, contrast water application was found to significantly reduce blood lactic acid levels after intense exercise.

Nutrition and Fluid Intake

To replenish glycogen stores in the muscles after high-intensity exercise or racing, it is important to consume foods with a high glycemic index and high carbohydrate content. Such foods, taken intermittently in the first five hours after exercise, are effective in rapidly replenishing glycogen stores in the muscles.

Carbohydrate and protein intake promotes greater glucose entry into muscle tissues by increasing insulin and glycogen secretion (Jentjen and Jeukendrup, 2003). High-intensity exercise increases protein synthesis in muscles, but also accelerates its breakdown. Therefore, without post-load protein intake, there is a risk of a negative protein balance. Reducing protein breakdown and maintaining a positive protein balance after vigorous exercise is necessary to rapidly eliminate muscle damage (Beelen et al., 2010).

Oxidative stress occurs when the body's capacity to defend itself against free radicals is inadequate. Reactive oxygen species are the main source of oxidative stress and play an important role in the onset and progression of damage to muscle fibers after exercise (Bloomer et al., 2004). Various antioxidants such as vitamins C and E, carotenoids and flavonoids have been proposed to protect cells against free radicals (Packer, 1991).

Oxidative stress may be associated with the aging process, cell damage, muscle fatigue and overtraining, especially in a strenuous sport such as basketball (Finaud et al., 2006). Given that more aerobic metabolism is utilized in basketball than expected, the effects of oxidative stress may be more pronounced at maximal levels of exercise. For example, VO2 values for female basketball players were 33.4-4.0 mL/kg/min and 36.9-2.6 mL/kg/min for men (Narazaki and Berg, 2009). In this context, consumption of vitamins C and E may strengthen the antioxidant defense system by reducing reactive oxygen species in athletes performing high-intensity exercise (Naziroglu et al., 2010). Looking at the dietary habits of players, it has been shown that multivitamins are the most commonly used supplements (50.9%), followed by sports drinks (21.8%) (Schroder et al., 2002).

In case of decreased fluid intake, it has been observed that post-exercise drinks containing simple carbohydrates contribute positively to the recovery process in muscle function. In particular, milk, as an easily accessible post-match option, is beneficial in the recovery process as it is a carbohydrate and protein-rich food. It is thought that milk and similar drinks containing 20 grams of protein and approximately 9 grams of amino acid intake is sufficient for the organism after exercise. In a study, it was reported that chocolate milk taken after training increased protein synthesis in the cell and decreased the level of pain threshold, and also increased the amount of creatine kinase (Cockburn et al., 2008; Nedelec et al., 2013).

Compression garments

Nowadays, compression garments, which have gained popularity especially among team athletes, are frequently used to accelerate recovery and heal trauma to muscle tissues. This method, which is thought to be effective on parameters such as muscle damage, swelling and pain threshold after maximal loads, aims to reduce muscle damage and lower lactate dehydrogenase levels by providing pressure and relaxation in the applied areas (De Glanville and Hamlin, 2011).

The effectiveness of compression garments depends on accurately adjusting and maintaining the applied pressure (Cockburn et al., 2008; Davies et al., 2009). In a study conducted on this subject, Gill et al. (2006) reported that the use of a full-leg compression garment for 12 hours following the end of a race had positive effects on creatine kinase clearance and physical recovery in elite rugby players. These findings suggest that compression garments may help to improve athletes' recovery processes. The most important point in winning or losing is to work and make an effort. Afterwards, success often comes naturally. However, it should also be known that working and making efforts will not always produce successful results. When the result fails despite the team's best efforts; It should be accepted and accepted that the entire Team in front of you deserves to win more than you. In other words, it should be accepted that the other team made fewer mistakes and the luck factor was on the side of this team (Erdoğan, 2022; Erdoğan, 2023).

To date, only one study has investigated the use of compression garments (CGs) in the measurement of post-exercise muscle damage in a basketball context. Montgomery et al. (Montgomery et al., 2008b) showed that wearing a CG for 18 hours after a basketball game did not result in a significant benefit in measures of muscle damage, including blood biomarkers such as creatine kinase, fatty acid binding protein, myoglobin, interleukin (IL)-6 and IL-10, and thigh circumference (Brown et al., 2020; Zinner et al., 2017; Davies et al., 2009). These results contradict research indicating that post-exercise CG use leads to a reduction in markers of muscle damage. Furthermore, several meta-analyses show that CG use is effective in reducing creatine kinase levels and muscle swelling after exercise (MarquÈs-JimÈnez et al., 2016; Hill et al., 2014). A possible reason for these lackluster results reported in Montgomery (2008b) and other compression studies is that the exercise protocols used were not intense enough to cause enough muscle damage. Supporting this, a meta-analysis suggests that the use of QA is more beneficial after resistance training than after endurance or running activities. Studies by Montgomery (2008) and Atkins (2020) showed that wearing a lower body KG after basketball exercises did not improve performance recovery. However, previous research has shown that the use of CG after exercise improves performance recovery (Brown et al., 2020; Hettchen et al., 2019; Jakeman et al., 2010). A possible reason for the lack of any benefit in performance recovery in these basketball studies may be that the KG does not apply sufficient pressure. For example, in Atkins' study, 7-10 mmHg pressure was applied to the lower body, but >14 mmHg pressure is effective for exercise recovery, while >20 mmHg pressure is recommended to increase blood flow. It has also been reported that venous and muscular blood flow in the lower limbs of basketball players increased with various types of CG (tights, socks, shorts) (O'Riordan et al., 2021). These findings suggest that CG is an effective strategy to increase blood flow in basketball players and that this is the underlying mechanism behind its benefits in recovery (MacRae et al., 2011; Brown et al., 2017).

Sleep

Sleep stands out as one of the most effective recovery strategies in athletes (Walsh et al., 2021). Sleep plays a critical role in performance, mental functioning, energy metabolism, muscle repair, mood and disease prevention (Halson, 2019). In high-paced team sports with intense match schedules, such as basketball, maintaining and improving sleep is of great importance as recovery time may be limited. Although studies on sleep in professional basketball are limited, research on lower-level athletes and other team sports can shed light on sleep problems in basketball players.

A recent study reported that elite athletes need 8.3±0.9 hours of sleep to feel rested (Sargent et al., 2021). However, 71% of athletes do not meet this requirement and sleep an average of 6.7±0.8 hours. This leads to an average sleep deficit of 96±60 minutes. When different sports branches were compared, it was observed that basketball players woke up the latest (07:54±00:24 hours) and had the longest sleep duration (7.5±0.4 hours).

One of the studies supporting the positive effects of sleep on performance in basketball is the study conducted by Mah and colleagues (2011). As a result of increasing sleep duration in male university basketball players for 5-7 weeks, it was observed that sprint times, shot accuracy rate and reaction times improved. As a result of increasing the time athletes spent in bed to 10 hours, their sleep time increased by 110.9±79.7 minutes.

Many elite athletes report experiencing poor sleep, especially after night matches. This situation becomes even more difficult during busy match schedules. In one study, it was found that the total sleep time of basketball players during double match weeks was 11% shorter than during normal match weeks (Lastella et al., 2020). In addition, it has been observed that adrenaline and noradrenaline levels are higher in elite athletes before and after night matches than on rest days. This suggests that athletes with high arousal tendencies are more prone to sleep problems after night matches (Staunton et al., 2017; Juliff et al., 2018).

Training and competition loads can also affect sleep quality. Studies have shown that on training days with moderate to high loads, athletes have later bedtimes and reduced total sleep time. Similar findings have been observed among other elite athletes; high running speeds and training loads negatively affect sleep quality (Fox et al., 2020).

Sleep patterns may also be associated with injury and illness. In a study of netball athletes, low sleep duration increased the risk of injury, while poor sleep quality or excessive sleep increased the risk of illness. These findings suggest a possible link between sleep and health problems (Lalor et al., 2020).

It is recommended that basketball players benefit from sleep monitoring, feedback and education to improve their sleep quality. Reducing screen time, avoiding inappropriate caffeine intake, and raising awareness about sleep habits can improve athletes' sleep quality (Bei et al., 2017). Furthermore, research in elite athletes emphasizes that comfortable travel with quality sleep can have protective effects on performance (Horgan et al., 2021).

Hyperbaric Oxygen Therapy

Oxygen debt of the organism, especially after anaerobic exercises, can have various negative physiological consequences. In this context, frequent ventilation of athletes' spaces, entering environments with higher oxygen levels if possible, and performing low-paced activities can improve recovery processes. Hyperbaric oxygen therapy promotes the uptake of more oxygen into the organism, where it is dissolved in the plasma and transported to the damaged tissue. This process can also lead to indirect increases in blood flow rate and muscle strength.

In various studies, hyperbaric oxygen therapy has been reported to have positive effects on delayed muscle soreness, pain threshold, perceived tenderness, edema, isometric contraction, muscle cross-sectional area and serum creatine kinase levels (Harrison et al., 2001). These findings suggest that hyperbaric oxygen therapy can be used as a potential therapeutic method in the recovery process of athletes.

Electric Stimulation

Methods such as galvanic, interference and transcutaneous electrical nerve stimulation (TENS) are widely used in rehabilitation processes for pain in the skeletal-muscular system after strenuous work. The TENS device has increased in popularity in recent years and can be applied by patients themselves at home. The electrodes of the device are recommended to be placed on the painful area and used for approximately 30 minutes (Babault et al., 2011). There are many types of TENS method; the most commonly used are superficial electrodes placed on the skin and low-frequency methods operating in the frequency range of 10-100 Hz. Electrical stimulation, which stands out as a popular passive recovery method among both team athletes and individual athletes, provides effective benefits, especially in the removal of waste substances from the body (Tessitore et al., 2007). This method can help improve the performance of athletes by contributing to the muscle recovery process.

Effects of recovery on performance in basketball

Various studies on the effects of recovery on performance in basketball show that recovery processes have significant effects on muscle damage, performance sustainability and general well-being of athletes (Calleja-Gonz·lez, et al., 2016). In particular, different recovery protocols applied after training play a critical role in preventing muscle damage and sustaining performance (Mihajlovic, et al., 2023).

One study examined cold water immersion, hot water immersion, active recovery (e.g. light jogging) and passive rest and found that cold water immersion in particular was more effective than other methods in reducing muscle damage and accelerating recovery. Among these protocols, recovery was found to have different effects on delayed muscle soreness, body temperature and creatine kinase levels. Cold water immersion was observed to accelerate the recovery process and reduce muscle soreness, especially after 48 and 72 hours (Çelebi, 2018). The effect of recovery on basketball performance becomes more evident in post-match and intensive training processes. Effective recovery methods help athletes maintain muscle strength and endurance, while helping to prevent injuries and prevent performance decline (Çelebi, 2018). Uygur et al (2010) examined the effect of fatigue on free throw kinematics and reported that fatigue did not affect free throw kinematics and was not an important factor.

Gülü et al (2021) examined the relationship between running distance and technical parameters in basketball and reported that as the players stayed in the game longer during the competition, their shooting percentages decreased with the increase in fatigue. Kılıç (2010) examined the effects of basketball tournament on muscle damage and recovery time and reported that athletes who had 10 minutes of active rest returned to normal faster than athletes who had passive rest.

In the study investigating the physiological correlates of Yo-Yo intermittent recovery test level 1 (Yo-Yo IR1) in basketball players, maximum oxygen uptake (VO_{2max}), ventilatory threshold (VT) and running economy (RE) were tested in twenty-two male basketball players. There was no difference between CMJ and 15 mSR performances in pre- and post-game tests, while LD performance decreased significantly. Yo-Yo IR1 results showed significant relationships with VO2max and speed. These findings suggest that the Yo-Yo IR1 is a valid test for aerobic fitness and endurance in basketball (Castagna et al., 2008a).

In a study investigating the effect of recovery methods on repeated sprinting ability in young basketball players, sixteen players tested passive and active recovery methods during a 30-meter 10-repetition sprint. The results showed that the fatigue index was higher during active recovery than passive recovery. Furthermore, no significant relationship was found between VO2max and fatigue index and total sprint time. These findings suggest that passive recovery provides better performance and reduces fatigue in repeated sprints (Castagna et al., 2008b). In a basketball tournament, the effects of different recovery methods were examined in 29 players. Players were divided into carbohydrate + stretching, cryotherapy (11°C) or compression garments groups. Slight decreases in performance due to fatigue were observed during the tournament. Sprint performance decreased by 0.7% and agility by 2%. Vertical jump decreased significantly after the first day. Cryotherapy was the best method to maintain 20 m acceleration performance. Cryotherapy and compression garments had similar effects on line drill performance. Overall, cryotherapy was more effective in recovery (Montgomery et al., 2008a).

Conclusion

Recovery is considered one of the most important parts of the training program in basketball as in other sports. Carbohydrates and fluids play an important role in maximizing the efficiency of recovery after training and competition. Having high muscle glycogen concentrations and adequate fluid intake can be achieved by high carbohydrate consumption plus leucine (amino acid) and adequate fluid consumption. Cold water immersion can be an effective strategy to reduce delayed onset muscle soreness 24 hours after a match. A combination of massage and stretching has shown positive effects on recovery immediately after a match. Several nutritional factors have been suggested that may influence recovery: for example, a high glycemic index diet and a balanced diet before bedtime to improve sleep may be beneficial. Strategies such as skin warming, hydrotherapy and proper sleep hygiene practices are other tools used to promote sleep. Ensuring that athletes get adequate quantity and quality of sleep can be important for optimal athletic performance. Applying hydrotherapy in different combinations in a personalized way can be effective. It is important to take a tailored approach to recovery strategies, taking into account factors such as the athlete's playing time, hydration and nutritional needs, muscle soreness and fatigue level. Overall, a strategic and balanced approach that encompasses both nutrition and recovery methods should be carefully considered and implemented to support the basketball player's recovery throughout the season. Finally, more research is needed to identify resources that best provide individualized recovery strategies.

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Sports Nutrigenomic

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To Cite This Chapter

Eyipınar, C. D. (2024). Sports Nutrigenomic. In M. Özdal & F. Alıncak (Eds.), *Current Studies in Sports Sciences 2024* (pp. 66-73). ISRES Publishing.

Introduction

Every human has a unique genetic the template for nutrition. The study of gene-nutrient relationships, or nutrigenomics, can result in the creation of individualized dietary guidelines for preserving good health and warding off disease. The bioavailability of nutrients and their metabolism may be impacted by the genetic diversity among different ethnic groups. As a result, testing for particular genetic polymorphisms may prove to be beneficial in managing weight loss and fully understanding the relationships between genes and nutrients. Genes control the intake and metabolism of various nutrients, and nutrients can influence the expression of multiple genes in a positive or negative way (Kiani et al., 2022). By customizing nutritional advice to a person's genetic profile, personalized nutrition for athletes and fitness fans seeks to optimize nutrition status, body composition, and exercise performance. The genetic makeup has been shown to impact food biological agents and nutrient uptake, absorbtion, excretion, which can change the activity of metabolism. Utilizing genomic data and DNA testing methods, nutrigenomics and nutrigenetics are experimental methodologies that investigate how individual genetic variations affect an athlete's reaction to nutrients or other chemicals found in food and nutritional supplements. Nonetheless, an increasing quantity of study is establishing a connection between gene-diet relationships and nutrient intake and health biomarkers (Guest et al., 2019).

Aim of The Study

The aim of this study is to examine the relationship between food-gene-sports and to summarize the current literature on the subject.

Material and Methods

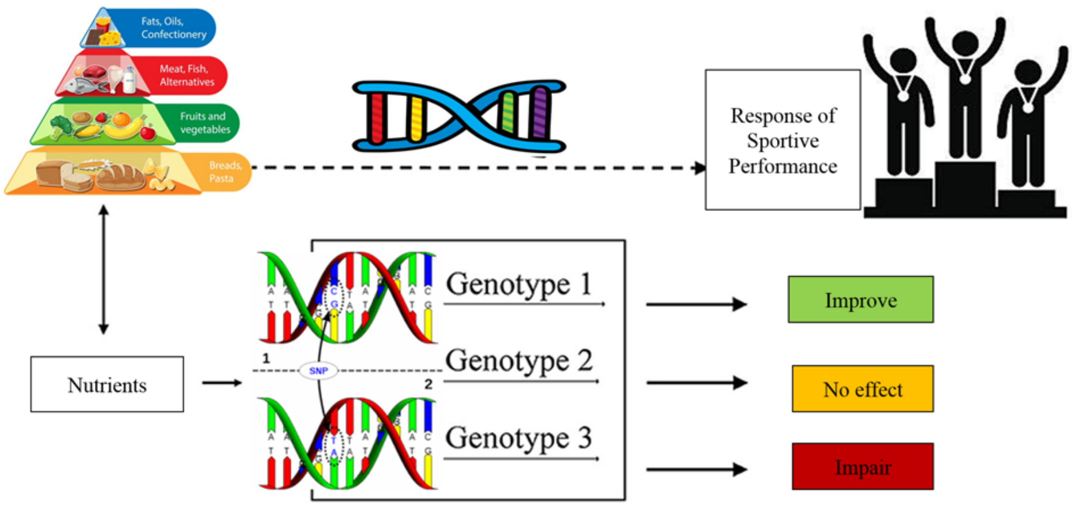
To obtain the data for this study, Google Scholar, Pubmed and Sportdiscus databases were searched for the last 10 years with the keyword ''Sports Nutrigenomic''. The data obtained were evaluated and summarized.

Nutrigenomic

In the developing field of nutrigenomics, the impacts of dietary nutrients on the DNA and gene activity, as well as the impact of genetic variants on the consumption of nutrients, are investigated using cutting-edge genomics techniques. The relationship between nutrients and genes is referred to as nutrigenomics. Thus, biochemistry, transcriptomics nutrition, metabolomics, bioinformatics, genetics and proteomics are all linked by nutrigenomics (Sales et al., 2014). Enhancing sports performance may represent one of the greatest beneficial uses of nutritional genomics. To be able to optimize the development of muscles and sports outcomes, athletes participating in sports like bodybuilding, running, soccer, etc., these days need to combine exercise with a customized nutritional regimen. Genetic variation amongst people can impact a variety of human specific phenotype including strength of muscles, skeletal organization heart and lung stature, tendon flexibility, etc., which may eventually affect an athlete's performance. According to DNA testing, the likelihood of an individual possessing an ideal sporting genetic makeup is less than one in twenty million cases, and the score reduces in proportion to the number of polymorphisms. Athlete performance may additionally be impacted by nutritional factors, psychological factors, muscle fiber structure, hormonal activity, and variations in genetic makeup. In addition, in order to decide what kinds of nutrients ought to be coupled for every person and which are unnecessary or potentially harmful, additional study is required to explain the complex structure of gene-nutrient connections (Puthucheary et al., 2011).

Figure 1.

Nutrigenomic Response in Sportive Performance (Guest et al., 2019).



Briefly, individuals' responses to the product they consume depend on their own version of the gene or genotype. In words one of syllable, fast metabolizers with the AA genotype in the Cytochrome P450 1A2 (CYP1A2) gene show a positive or improved (sportive performance) to caffeine. Those who have the CYP1A2 AC or CC genotype report none from caffeine use, or performance impairment (Guest et al., 2018).

Genes Associated with Sports Nutrition

Both genetic and environmental factors have an impact on humans; therefore, both must be taken into account equal in order to sustain an individual's normal state of health. Studies on the connection between genes and nutrition has just been developed (Elsamanoudy et al., 2016). This section examines how genetic variation affects how different macro or micronutrients, as well as biologically active substances like caffeine, respond to outcomes related sportive performance (Table 1).

Table 1.
Genes that Association between Dietary Factors and Outcomes Related Sportive Performance (Guest et al., 2019).

Genes	Dietary factor and sources	Outcomes related sportive performance
CYP1A2	Caffeine (choclate, tea, energy drinks and coffee)	Endurance and CV health
ADORA2A		Fatique
GSTT 1	Vitamin-C (strawberry, pineapple, red pepper, orange)	Exercise-induced ROS production
PEMT	Choline (fish, egg, salmon, poultry)	Muscle damage
LAT 1-2	Protein (tofu, chicken, cheese, lentil, red meat, egg, fish, yoghurt)	Optimizing body composition

Abbreviations: CV: Cardiovascular; ROS: Reactive oxygen species

Caffeine

Caffeine (1,3,7-trimethylxanthine) is one of the more commonly utilized ergogenic substances. Caffeine's ability to improve sportive performance has been understood for more than a century (Guest et al., 2019). The differences in reactions after consuming caffeine are multifaceted phenomena, driven by several interacting genes. Single nucleotide polymorphisms linked to this actions have been found in some genome-wide association investigations (Guest et al., 2019). One single nucleotide polymorphism in the CYP1A2 gene influences how quickly caffeine is metabolized. Those who are fast metabolizers, or AA homozygotes, usually generate more of this enzyme and as a result, break down caffeine faster. On the other hand, people with the C allele who are slow metabolizers typically clear caffeine more slowly (Pickering & Kiely, 2018). While slow metabolizers are more likely to experience the long-term adverse consequences of adenosine blockage and/or restricted blood flow, fast metabolizers can rapidly metabolize caffeine and reap the advantages of caffeine metabolites as physical activity progresses or exceed the brief duration of harmful consequences. The overwhelming body of research points to CYP1A2's function in regulating the impact of caffeine consumption on physical activity that involves muscular endurance or aerobics (Higgins & Babu, 2013). An additional possible genetic alteration of the impact of caffeine on athletic performance is the Adenosine A2A receptor (ADORA2A) gene. It has been demonstrated that the adenosine Adenosine 2A receptor, which is created by the ADORA2A gene, controls the demand for oxygen in the heart and increases coronary flow through vasodilation (Pickering & Kiely, 2018). Additionally expressed in the brain, the Adenosine 2A receptor controls the flow of glutamate and dopamine, which has implications for pain and sleeplessness. Caffeine's antagonistic effects on adenosine receptors may vary depending on the ADORA2A genotype, which could impact dopamine signals. Dopamine may play a role in the manifestation of varying responses to caffeine because it can be linked to enthusiasm and exertion in exercisers (Salamone et al., 2018). Moreover, the cerebral cortex expresses the Adenosine 2A receptor, which controls the release of glutamate and dopamine and has implications for pain and sleeplessness. The way that caffeine binds to adenosine receptors can vary depending on the ADORA2A genotype, which can change how dopamine is signaled. Dopamine has been linked to drive and dedication in exercisers, and this could be the process underlying the manifestation of different reactions to caffeine (Bodenmann et al., 2012). Literature suggests that people with the ADORA2A gene's TT genotype may perform more effectively, respond more quickly, and experience less sleep disturbance after consuming caffeine (Guest et al., 2018).

Choline

In carbon metabolic processes, which provides the majority of the methyl donors for cellular methylation reactions, choline plays a crucial role. These reactions consist of DNA methylation, cell division, crucial DNA synthesis and fix steps, and amino acid synthesis (Morton & Close, 2015). Spesifically, acetylcholine synthesizing, cell-membrane signals (phospholipids), methyl-group metabolic processes, and the production of neurotransmitters are just a few of the biological processes in which choline is essential. A number of these processes may be strained during prolonged physical activity, which would raise the need for choline as a metabolic material (Penry et al., 2008). Although people may synthesize choline endogenously via the hepatic phosphatidylethanolamine N-methyltransferase (PEMT) pathway, a single nucleotide polymorphism in the PEMT gene, was demonstrated to increase the risk of choline a shortage and the distribution of more dietary choline toward PC biosynthesis instead of betaine synthesis. In contrast to people with the GG genotype, those who carry the C allele of the PEMT gene have been demonstrated to exhibit symptoms of choline deficiency and organ dysfunction, specifically in the liver and skeletal muscles (da Costa et al., 2014). Damage to the muscles is a natural result of extensive, high intensity training for athletes. There are reports of decreases in plasma choline linked to intense exercise, including marathon running and triathlons. Because acetylcholine, a neurotransmitter that regulates attention, recall, and learning, requires enough choline, a decrease in its release may be a factor in the emergence of fatigue and damage in sporting efficiency. Supplementing with choline may also enhance lipid metabolism because it has been linked to a more desirable body type and the capacity to facilitate quick muscle loss in weight class sports (Elsawy et al., 2014). Briefly, choline deficiency or inadequate status can put further strain on an athlete's capacity to heal, rebuild, and adjust to a given training stimuli.

Vitamin-C (Ascorbic Acid)

Oxidative stress-related variants in genes are currently linked to numerous possibly significant discoveries. Reduced defense against oxidative stress may arise from variations in the amounts or activities of antioxidant enzymes caused by a number of single nucleotide polymorphisms (SNPs). A family of phase 2 detoxify enzymes known as glutathione S-transferases (GSTs) is present in all eukaryotic cells. They are essential for the detoxification of xenobiotics (substances that are not found naturally) as well as tumor-causing agents, contaminants from the natural world, and reactive oxygen species. glutathione S-transferase Theta-1 (GSTT1) and glutathione S-transferase Mu-1 (GSTM1) are the two main isoforms (Block et al., 2011). The cytoplasmic enzymes GST-μ (mu) and GST-θ (theta) are encoded by the glutathione S-transferases M1 (GSTM1) and T1 (GSTT1) genes, as well. The conjugation responses among decreased glutathione (GSH) and various electrically conductive substances are catalyzed by these enzymes. Thus, variations in that family of genes may have an impact on the oxidative stress brought on by exercise as well as athletic performance (Cho et al., 2005). A class of water-soluble, non-enzymatic antioxidants, vitamin C (ascorbic acid), can react with singlet oxygen and eliminate radicals from various sources. It performs several vital cofactor roles in various reactions, including hydroxylation (Peterkofsky et al., 1991).Vitamin C has the potential to keep the mitochondria and lessen the production of excess ROS. Moreover, it can lessen inflammation in muscle mass as well as other tissues. As a result, it might enhance both sports performance and recovery duration (Beck et al., 2021). For instance, inside human muscle cells, consuming 1000 mg/day of vitamin C inhibits the development of Peroxisome proliferator-activated receptor-a coactivator (PGC1-α) and mitochondrial biogenesis, along with important endogenous antioxidant enzymes. Thus, elevated mitochondrial biogenesis is a significant response to skeletal muscle exercise training, with PGC1-α regarded as the primary controller of mitochondrial biogenesis (Fernandez-Marcos & Auwerx, 2011). People have a number of widespread GST polymorphisms that have been linked to either a higher or less prone to disease, especially if paired with other biological and environmental variables like smoking, exposure, or eating habits. Deletion polymorphisms in the GSTM1 and GSTT1 genes, which are significant members of the GST family, cause a whole lack of GSTM1 and GSTT1 molecules (Polinikov et al., 2010). It appears that the GST enzymes guard against serum Vitamin-C deficiency when dietary vitamin C is inadequate because those with GST null genotypes were more likely to develop a lack of it if they did not reach the Recommended Dietary Allowance for vitamin C (Cahill et al., 2009). According to the literature, it is recommended that athletes, regardless of genotype, should receive adequate levels of vitamin-C (Peterkofsky et al., 1991).

Protein

Building muscle is dependent on protein consumption as well as the digestion and utilization of amino acids. Variations in genetic makeup can impact the quantities of biologically active peptides obtained from proteins and, in turn, their utilization for muscle development and action. The quantity of restricting amino acids present in proteins varies amongst foods. For instance, leucine is essential for the synthesis of proteins and increases the activity of important kinases that control the initiation of the transformation procedures, like the regulatory Mammalian target of rapamycin (mTOR) path. Genetic variations in the L-type amino acid transporters, (LAT1 and LAT2 genes) which code for the Branched-chain amino acid (BCAA) carriers (Kühne et al., 2007). Neutral amino acid sodium independent transporters, such as L-type amino acid transporters (LAT) 1 and LAT2, are responsible for carrying out branched-chain amino acid transportation. BCAAs can be transported in cells by LAT1, LAT2, and other mechanisms. The brain, spleen, liver, skeletal muscle, stomach, and placenta all exhibit LAT1 and LAT2 (Fraga et al., 2005). Branched-chain amino acids regulate the metabolic process of muscle proteins by preventing the catabolism process and promoting anabolism through the action of mTOR. Leucine plays a major role in maintaining the equilibrium of glucose via the glucose-alanine cycle by promoting a rise in serum levels of insulin, which in turn has a flexible effect on the production of proteins in the absence of amino acids and affects the sustainability of muscle protein synthesis (Kawaguchi et al., 2008). Genetic variations that cause the mTOR paths to work abnormally have an effect on the creation of proteins and nutrient absorption, which in turn affects muscle development and sports performance. Nutritional techniques pertaining to the amount of protein and carbohydrates consumed through diet and supplements need to be appropriately implemented in light of this genetic proof (Chou et al., 2012).

Conclusion

Future research should concentrate on this as there aren't many gene-diet interaction investigations that have been done in professional athletes and have established outcomes related to performance. Nonetheless, it is known that dietary consumption and/or serum concentrations of a number of nutrients and food biologically active substances can affect the physique and general health, which can then have minor to significant effects on the performance of athletes. With many studies showing the altering impact of genetic modifications with athletic results, caffeine seems to have the most powerful proof to date on endurance performance. In order to optimize sports performance, sport medical professionals, dietitians, and mentors may find that DNA analysis for specific food preferences is a further instrument that they can use to guide the preparation of food and dietary advice (Guest et al., 2019). In conclusion, by creating individualized nutrition plans based on a person's genetic composition, the emerging field of nutrigenomics presents an intriguing strategy toward improving sports performance.

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Velocity-Based Strength Training

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Cagdanlıoglu, M. B., & Vural, M (2024). Velocity-Based Strength Training. In M. Özdal & F. Alıncak (Eds.), *Current Studies in Sports Sciences 2024* (pp. 74-78). ISRES Publishing.

Introduction

Velocity-based strength training (VBT) is one of the strength development training methods. This method is achieved by tracking the movement speed of the exercise and measuring this speed using some technological devices. VBT provides feedback to coaches and athletes about the speed at which the movement should be performed (Dahlin 2018). Verbal or visual feedback of speed can improve the athlete's performance and motivation level. Velocity-based training can be applied to all parts of a strength training program and supports the number of sets, repetitions, load and programming method used (Weakley vd 2020a). VBT is a current resistance training method that accounts for fluctuations in the athlete's physical characteristics and daily changes (Mann vd 2015). In addition, the application of VBT can enable coaches to accurately set speed loss thresholds (e.g. 10% speed loss threshold) targeting specific kinetic and kinematic outcomes (Pareja-Blanco vd 2017a). Speed loss thresholds are calculated from the maximum speed achievable during a workout, typically determined from the first repetition of the first workout, and allow the coach to decide when to terminate a workout (Padulo vd 2012).

Aim of The Study

The aim of this study is to give information about speed-based strength training and to present the techniques related to the subject.

Velocity Measurement Methods

In velocity-based training, some technological equipment is needed to calculate movement speed accurately and quickly. These include devices such as linear position transducers (LPT), video cameras or three-dimensional motion capture systems, low-cost smartphone apps and inertial measurement units (Balsalobre-Fernandes ve Torres-Ronda 2021, Hirsch 2018). However, cost, portability and time constraints associated with data processing limit the use of some of these methods. LPT and inertial measurement units are the most commonly used methods by researchers and exercise professionals to measure movement speed. LPT is often used to record position data of an object (Hirsch 2018). It works by being attached to an object such as a weight bar or directly on an athlete performing a vertical jump (Dahlin 2018). As the person or object moves, changes in the length of the cable in the device are converted into an electrical signal that is measured and recorded by a computer system. Data on displacement, speed of movement and acceleration are collected. Velocity is calculated through the difference in displacement and time (velocity = displacement/time) (Harris vd 2010). LPT devices instantly display velocity-based feedback via a display screen or a second device, allowing to measure several different velocity values during exercise (Dahlin 2018). It is an important aid for coaches and athletes in achieving their training goals. It provides athletes with immediate feedback on the actual velocity of movement, regardless of the load being lifted, and helps them work at maximum effort. Direct velocity measurement allows speed-specific training to be optimized and monitored. Feedback of real-time performance, such as peak velocity, enables adaptation and great impact (Randell vd 2011).

Load - Velocity Relationship

Creating a load-velocity profile is a positive contribution for coaches to monitor the development of an athlete over time. It is especially important for coaches who are interested in speed-specific adaptations and not just focusing on maximal power development. Measuring speed during training sessions helps to determine 1TM values that can be used to evaluate the effectiveness of training programs and the athlete's training status (Jovanovic ve Flanagan 2014). The load-velocity profile of the athlete is determined by instruments such as LPT during exercise. There is an inseparable relationship between load and velocity in order to be able to predict one from the other during execution. The speed of concentric muscle movement decreases with increasing force output and increasing load (Gonzalez-Badillo ve Sanchez-Medina 2010, Sanchez-Medina vd 2010). There is an optimal balance between force and speed for each individual that will maximize power output and this is also known as strength velocity profiling. Through load-velocity profiling, training can be personalized by determining whether the athlete is lacking in strength or speed during a given movement, regardless of their strength capabilities (Samozino vd 2014). It is possible to determine the maximum load, defined as the load at which an individual produces the highest amount of power, through the load-velocity profile. To most effectively increase power output, athletes need to train with the highest resistance possible. Theoretically, maximal loads provide an ideal combination of force and velocity magnitude that produces high power outputs (Dahlin 2018).

Physical and Physiological Responses to Velocity Based Training

When we examine the responses of velocity-based training, it is seen that there are chronic and acute effects. In acute responses, as speed loss decreases, training scope, perceived difficulty, metabolic responses and neuromuscular exhaustion decrease, while these responses increase as speed loss increases. At higher speeds in chronic adaptations, there are smaller responses in muscle volume change, an increase in Type IIx myosin heavy chains, a decrease in Type I myosin heavy chains, less improvement in muscle endurance and greater improvement in strength. At slower speeds, there are larger responses in muscle volume, a decrease in Type II myosin heavy chains, an increase in Type I myosin heavy chains, a larger improvement in muscle endurance and a smaller improvement in strength (Pareja-Blanco vd 2017a, Pareja-blanco vd 2017b, Weakley vd 2020a).

Programming Velocity-Based Training

Understanding the various programming methods that can be used in strength and conditioning through velocity-based training is critical to designing effective training programs. Velocity associated with 1TM percentage appears to be consistent throughout the training (Soslu ve Çuvalcıoğlu 2021). However, the speed in the 1TM percentage can vary, influenced by fatigue or a short period of power-oriented resistance training (Weakley vd 2020b). The speed at each 1TM percentage is very stable when individual load- velocity profiles are calculated. The application speed with a constant absolute load is therefore a good indicator of effort and actual performance (Balsalobre-Fernandes ve Torres-Ronda 2021). Estimating 1TM on a daily or weekly basis and assessing daily variables in training readiness helps coaches to adjust workouts appropriately when using 1TM% to program training load (Jovanovic ve Flanagan 2014). The individual load-velocity profile may show different effort levels depending on age, gender, training level and anthropometric profile. Therefore, it is very important to create individual load-velocity profiles for each athlete. Velocity-based training programs allow flexibility in the number of sets and repetitions compared to traditional methods, reducing differences in athletes and physiological characteristics (Weakley vd 2017). The use of velocity bands or velocity limits in the training program instead of the traditional absolute load, set, repetition count allows for automatic regulation of training volume and load for both intra-set repetitions and sets, identification of fatigue responses, calculation and personalization of daily preparation, while ensuring a high level of consistency in both velocity and power output within and between athletes (Dankel vd 2017, Weakley vd 2017). Therefore, the load-velocity relationship must be periodically evaluated in order to correctly adjust the relative loads (Weakley vd 2020b). Between athletes and between workouts, relative losses in exercise velocity result in consistent internal and external responses of a given intensity (Weakley vd 2019).

Conclusion: Why Velocity Based Strength Training?

Velocity is commonly used in strength training over other kinetic or kinematic outputs (e.g. power) for 3 reasons. First, it is well known that as the external load increases, losses in lifting speed occur (Izquierdo vd 2006, Weakley vd 2020a). This loss of velocity continues until a load of 1TM corresponding to the minimum velocity threshold is achieved (Izquiero vd 2006). Second, there is an almost perfect linear relationship between velocity and intensity as a percentage of maximal power. This has been consistently demonstrated across a range of exercises and submaximal loads (Cook vd 2018, Garcia-Ramos vd 2018). Third, a common element of many definitions of exercise-induced fatigue is a transient decline in the capacity to generate force, resulting in reductions in muscle fiber shortening rates, relaxation times, and movement speed as fatigue increases (González-Badillo vd 2017, Sanchez-Medina ve Gonzalez-Badillo 2011). Simply put, as fatigue increases, movement speed decreases. By recognizing these basic concepts, practitioners can use speed parameters to accurately and objectively determine external loads and training volumes for each workout, regardless of fatigue and fluctuations in the athlete's readiness to train (Izquierdo vd 2006, Weakley vd 2020a).

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Massage and Organism

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To Cite This Chapter

Abakay, Z., & Abakay, U. (2024). Massage and Organism. In M. Özdal & F. Alıncak (Eds.), *Current Studies in Sports Sciences 2024* (pp. 79-86). ISRES Publishing.

Introduction

As it is known, the main purpose of those working in the field of sport is to increase the sportive performance of individuals. With the developing technology, we see that intensive scientific studies are carried out in the fields of physiology, neurology and sports sciences in the modern sense. In this context, the subject we deal with in our study is sportive massage. We think that the effects of sportive massage on the human organism are undeniably important. Massage consists of many manipulation sequences with therapeutic, relaxing and soothing properties. The history of massage dates back to ancient times and has been used for many years. It has a number of anatomical and physiological effects on the individual as well as psychological effects (Sehlikoglu 1986).

In general, massage is considered as a method that can be applied by hand or with a set of tools and which primarily has effects on the skin and muscle structure (Sengir 1989). While massage is used for healing purposes in terms of health, it is expressed as a set of rhythmic movements performed for the purpose of preparing the organism for exercise, psychological motivation and rest in sports (Sökmen 1999). Massage is an application performed in order to use physical power more effectively. Massage is used to increase the efficiency of the athlete and to maintain this efficiency, to rest sufficiently after the exercises and to make it ready for the next exercise. In sports massage, all manipulations used in classical massage application can be used. However, it is important to choose the appropriate method for the structure of the massaged area as well as the time of the massage application (Turgut 1993). The main aim of this study is to reveal the physiological and psychological effects of sports massage on the human organism.

Aim of The Study

This study aims to explain the effects of massage on the organism.

Definition and History of Massage

It is quite difficult to find the theories about massage practices in the literature. Because in the studies conducted in the field, theories are presented without testing the objectives and hypotheses, and information is not given in detail. It is seen that the majority of the studies focus on the effects of massage. The scientific theoretical part and mechanism are not sufficiently explained (Brennan and DeBate, 2006). We can say that touching and being touched always have a deep effect on people, because the fact that people take their hand to the area where they feel discomfort in their body and rub it also indicates that massage has an instinctive origin (Kanbir 1998, Hazır 2001, Tuna 1997).

It is known that the human hand is one of the most developed limbs in terms of sensation and movement. Massage is a method that includes a series of movements such as touching, pressing, stroking, squeezing and kneading. Therefore, performing these movements by hand is considered to be an easier, smoother, faster, more economical and reliable method. It is a known fact that touching the human body with the hand stimulates the pressure receptors on the skin and under the skin, as well as changing the blood circulation there, and that bodily touches provide people to relax mentally (Basmajian 1985).

It is stated that massage is generally seen as a method of curing diseases, protecting health and ensuring that people are physically strong (Kanbir 2005). Massage has been accepted as the oldest therapy (treatment) method throughout its history, it was used as a basic treatment method until the pharmaceutical revolution in the 1940s, and it has gained great popularity by taking its place in alternative medicine (Field and Tiffanny 1998).

Massage is defined as a set of movements performed on the organism in order to rehabilitate a painful and tired limb or to ensure its return to its former solid position, which has a certain systematics and creates functional, physiological and anatomical effects with mechanical energy (Turgut 1977, Lauber 1989, Pamuk 1976). It is seen that massage is used in almost all societies that have taken place on the stage of history. Basically, it is expressed as movements that fall within the scope of hand movements, touching, kneading, pressure, rubbing, shaking style methods are used. We see that this series of movements is collected under a single name in various societies. For example, mass in Arabic, massem in Greek, massage in French, mashesh in Hebrew and massagio in Italian (Licht 1963, Stamford 1985). In the light of written documents obtained from Chinese sources in 3000 BC, it can be said that touching and touching the human body as a source of healing is the oldest natural treatment method. In the relevant sources, it is also stated that the massage method is used not only for the treatment of diseases and injuries, but also as a primary method of protection from such situations. The historical origin of the massage method dates back centuries and has come to the present day as an important therapy method used to achieve happiness and health by touching with hands (Rowshan 2003).

Galen (130-200 A.D.), who lived during the Pergamon kingdom in Anatolia and is considered by some to be the first sports physician in history, was a physician who was assigned to treat wounded soldiers. He recommended that Roman nobles, who were fond of eating and drinking and had a lazy life during his time, should exercise for a healthy life and stated that regular massages along with these exercises would improve health. Again, we see that Ibni Sina, a Turkish medical scientist and thinker who lived between 980-1037 A.D., had opinions about the benefits of massage in his works. In his work titled "Külliyat", which is the first book among his series of books titled El Kanun Fit Tıp, he emphasized the importance of preventive health services based on his views on physical education and healthy life and mentioned the applications of massage along with exercise for health (Kanbir 1998).

In the 16th century in Europe, where religious pressures were intense, Dr. Abroise Pare (1510-1590) is known to have applied methods similar to massage along with the prescribed treatment in the process of getting rid of diseases. By the 19th century, there was an increase in the number of physicians interested in massage in the world. It has become a matter of debate that massage should be seen as a sub-branch within the gymnastic movements that are widespread especially in Europe. In addition, whether the massage should be performed on the naked body or over the clothes was also an important subject of debate (Kanbir 1998, Tuna 1997).

Swedish Ling (1178-1839) argued that massage and gymnastics were intertwined, while Kleen (1847-1928) treated massage and gymnastics as two half subjects in his Massage manual written in 1895. In 1893, Hoffa, in his book Massage, discussed today's classical massage techniques in five groups: eflöraj, petrisage, friction, tapotment and vibration. After World War II, massage was started to be used for treatment purposes in medical clinics in England and massage schools were opened throughout the country (Kanbir 1998, Tuna 1997).

Effects of Massage on the Organism

When we look at the effects of massage on the organism, it is seen that it is considered as a component of physical, physiological and psychological factors. With mechanical stimuli in the form of rhythmic pressure movements and stretching applied to the tissues with the help of the hand, the receptors at the nerve endings in the structures of the soft tissues consisting of the said and subcutaneous tissues and muscles, which are stretched and compressed, are modulated. Compression and stretching also cause dilation in the diameters of blood and lymphatic vessels, which in turn stimulates flow and affects the copillary, venous, arterial and lymphatic circulation (Birk et al. 2000).

Nerve endings of the skin that can receive superficial and deep stimuli, proprioceptive receptors in muscles and tendons and internal receptors in the tissue are stimulated. The effects and changes that occur in the human organism as a result of the stimuli are related to the intensity, duration, tempo and quality of the force applied in the form of pressure and stretching (Tuna 1997).

It is appropriate to use materials such as oil, pomade and powder to ensure easy lubrication of the hands on the skin and to prevent possible irritation. However, it is not considered appropriate to massage immediately after meals, pregnant women, new open wounds, skin and heart diseases and infectious diseases (Scott 1990, Arnheim 1989, Beard and Wood 1989).

In summary, massage increases blood and lymph circulation, thus helping to maintain optimum nutrition of muscles and soft tissues (Tuna 1986, Başaran 1999). It reduces muscle stiffness and restriction, thus perfecting flexibility and relaxation as well as providing muscle balance. It provides faster healing of sports injuries and reduces the possibility of further injury (Grisogono 1995).

Reduces muscle fatigue, thus enabling more consistent, higher levels of training and performance. Reduces body pain and increases relaxation (Weerapong 2005). Increased circulation in the massaged muscles reduces injuries. It provides psychological support and builds self-confidence (Brian 2001).

Physiological effects of massage

The reflex effects seen as soon as the massage application begins reach the brain through the spinal cord with the stimulation of the peripheral nerves in the skin and a general state of relaxation occurs in the individual. In addition, there is relaxation in the muscles and dilation of small arteries. In addition, providing a state of sleep (sedation) is seen among the important effects of massage (Tuna 1986). Increased venous blood and lymph circulation and resolution of involuntary muscle contractions are also considered as mechanical effects of massage (Tuna 1986, Yao et al. 2007).

Effects on the Circulatory System

In the light of scientific results obtained in clinical settings, the most important effect of massage is the one on blood and lymph circulation. In addition, the removal of lactic acid and the acceleration of blood flow are important advantages of massage (Antonio 1997).

In classical massage applications, the circulation is activated by stimulating the lymph and venous system with patting and kneading processes applied on the skin in the direction of the heart. The mobility that occurs in the circulation accelerates the fluid exchange in the tissues, thus the nutrition of the tissues and the amount of oxygen reaching the cells increase and the excretion of waste substances in the organism is accelerated (Yao et al. 2007).

This acceleration of blood flow does not increase the amount of oxygen consumed by the metabolism. It is a temporary situation that occurs as a result of purely mechanical interaction. In the majority of the studies on massage, researches examining the effects on blood and some blood parameters are generally found. The effects on the circulatory system in the studies can be listed as follows. There is an expansion in vessel diameters. With the increase in sympathetic nerve activity and tissue temperature, vasodilating substances are secreted in the treated area. When an area is massaged, the pressure of the manipulation does not directly increase blood flow. There is a temporary drop in blood pressure for a short period of time as the blood in the small veins empties, the blood in the capillaries fills the venules and thus the arterial blood flow increases. Therefore, while massage increases the blood pressure in small veins, it also has an effect on the discharge of blood in capillaries (Gürel and Doğdu 2014).

Since the venous return is in the direction of the heart, it is strongly recommended to massage in the direction of the heart. By expelling the lymph fluid, it is ensured that it joins the venous circulation and in this way, it is ensured that metabolic wastes are easily removed from the area (Kanbir 2005). It is known that deep-acting manipulations have more therapeutic effect in a massage application. By increasing fluid exchange in tissues, excess nutrients are provided. In addition, the increased amount of oxygen in the blood facilitates faster regeneration of damaged muscle tissues and accelerated blood flow provides rapid excretion of residual substances in metabolism (Tuna 1986, Kanbir 2005).

Effects on Muscles

It should be noted that there will be no increase in muscle volume or strength of the individual with massage application. Because muscle strength can only be increased through regular exercises. Massage can help muscles regain their existing functional abilities (Gürel and Doğdu 2014, Goldberg et al. 1994). In particular, it contributes to reducing the time needed for tired muscle groups to rest. With massage application, circulation is revitalized and muscle groups are better nourished, resulting in a muscle structure that is more resistant to injuries and can adapt to strains more easily. In cases where there are movement restrictions in the joints and muscles for different reasons, it is stated that massage application before exercise will contribute to easy and comfortable exercise (Field and Tifanny 1998). The primary target of massage application is muscle tissues. Massage applications produce a number of physiological effects on muscle groups. As the blood circulation increases, there is an increase in the internal temperature of the muscle and in a way, a passive warming state can be achieved (Kanbir 2005).

Thanks to the acceleration in blood flow and the removal of residual substances such as lactic acid from the body, there will be no accumulation. It has been demonstrated by clinical studies that after a certain period of time (7-8 sessions), the hypertonic muscle relaxes under the hand (Gracies 2001).

Effects on the Nervous System

It is difficult to determine what effect massage has on the nervous system. First of all, it should be known that massage does not help to regenerate a severed nerve. However, the stimuli and heat in the form of pressure and stretching that occur during the contact of the hands on the skin are received by the receptors in the skin and transmitted to the central nervous system through nerve fibers, creating a general effect (Moyer et al. 2004) and contributing to the acceleration of regeneration (Gürel and Doğdu 2014). Studies have shown that massage applications accelerate the regeneration of nerves (Cambron et al. 2007). It is known that the touch stimulus creates certain effects that are perceived in different ways depending on the intensity and severity of the massage application and the size of the treated area. While a large surface and slow patting has the effect of relaxing, soothing the nervous system and relaxing the muscles, deep pressures and kneading applied point by point can have positive effects on muscle tone reflexively (Goldberg et al. 1994).

Effects on Internal Organs

As a result of stimulating some parts of the body structure with different methods, it can be effective on some internal organs. Especially in stomach, abdominal pain, gall bladder and gas pains, it is stated that certain areas can be relieved by rubbing with hands. In this context, acupuncture, acupressure and shiatsu methods are also considered as complementary medicine in order to have an effect on internal organs (Cambron et al. 2007, Mackereth 2007, MacDonald 2007).

Psychological Effects of Massage

Massage increases the willingness of individuals to do work and leads to an increase in productivity. The state of relaxation that occurs after massage causes the individual to radiate positive energy to his/her environment. In addition, while providing stimulation, it also creates relaxation, which reveals that it has an important effect on the autonomic nervous system. In addition to the physiological effects of massage in terms of hyperemia and mechanical effects, it also helps to calm down the athletes who are nervous before the competition and stimulates and activates the passive ones. In this context, the most important psychological effect can be considered as positive motivation and stress relief (Gürel and Doğdu 2014).

High levels of stress may occur in individuals due to various stimuli before the competition. At this point, massage application provides various benefits in reducing and preventing stress (Güney 2001). In a study conducted on individuals with high levels of aggression, it was stated that 20 minutes of massage application had an effect on the subjects to feel less anxiety (Diego et al. 2002).

The most important benefit of having a massage is that our body relaxes, rests and gives a feeling of vigor. Conscious massage practice removes the individual from the chaos of stress and provides a healthy rest (Güney 2001). On the contrary, unconscious and haphazard massage practice is likely to have adverse psychological consequences (Gürel and Doğdu 2014).

It is stated that anxiety, stress and depression levels are reduced with massage. In addition, it is emphasized that massage applications have positive effects in the treatment of disorders such as post-traumatic stress, eating disorder, attention deficit hyperactivity disorder, depression migraine, back pain (Shulman and Jones 1996). Another Far Eastern massage method used for stress reduction and relaxation is Shiatsu. Seen as a safe and effective massage method to get rid of psychological traumas caused by injuries, Shiatsu, based on eastern philosophy and medicine, is an effective method used in the protection of health, reduction of stress and treatment of some diseases as a result of contact with certain points of the body with the help of hand fingers. It is important to establish and maintain a harmonious balance between the body and the outside world. Disturbance of the balance may cause various disorders in the body. With this method, the pressure applied to various points provides a regular flow of energy and blood circulation and helps to eliminate these disorders (Rowen 2008).

In a study conducted on working individuals, 18 participants were massaged regularly for 15 minutes each during rest breaks for 6 weeks by using the massage method in order to reduce the anxiety levels of the employees in the working environment. At the end of the study, it was revealed that there was a significant decrease in the anxiety levels of the massage group compared to the control group (Shulman and Jones 1996). In another study, 82 nurses working in a hospital and caring for inpatients were given 10 minutes of massage during coffee breaks and significant decreases were found in the stress levels of nurses compared to the control group (Brennan and DeBate 2006).

Conclusion

As a result, there are many studies on the psychological effects of massage. The results obtained in these studies show that there are positive decreases in the anxiety levels of athletes (Brennan and DeBate 2006, Moyer et al.2004, Elbir 2003, Cafferelli and Filint 1992, Field et al.1996, Sharper et al.2007, Arslan 2004) and that massage positively affects the motivation of athletes (Abakay 2017).

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Energy Requirements in Modern Pentathlon

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To Cite This Chapter

Demiryol, M. B. (2024). Energy Requirements in Modern Pentathlon. In M. Özdal & F. Alıncak (Eds.), *Current Studies in Sports Sciences 2024* (pp. 87-95). ISRES Publishing.

Introduction

Modern Pentathlon is an Olympic multidisciplinary branch that includes 5 disciplines. In this Olympic branch consisting of Swimming, Fencing, Shooting, Running and Riding, the obstacle branch was introduced instead of the Riding branch after the 2024 Paris Olympics. It is known that the Running and Shooting branches are held together and are called Laser-Run, while the other branches are held separately, proceed within a certain framework of rules and the rules are determined by the International Pentathlon Union (UIPM). Athletes competing in the Modern Pentathlon branch do the running-shooting-swimming branch until the age of 15 and the running-shooting-swimming-obstacle-fencing branch after the age of 15. As the age category changes, the race distances of the athletes in swimming and laser-run change. In the fencing branch, epee competitions are held and in line with the decision taken at the 72nd UIPM congress in November 2022, the obstacle branch was changed to equestrian competition after the 2024 Paris Olympics. In Modern Pentathlon, it is necessary to explain each branch within itself and to define all the requirements that each branch requires for itself. Although each branch in the pentathlon is a separate branch in its own specialty, these branches are combined with the modern pentathlon branch and are made together in a way that is most suitable for this branch.

Aim of The Study

The aim of this study is to give general information about the energy requirements of the sub-branches of modern pentathlon.

The Sub –Disciplines of Modern Pentathlon

Sub-disciplines of Modern Pentathlon have been created in order to increase the number of competitions, to increase the recognition of the branch and to compete in age categories suitable for athletes. These are;

1. Laser Run
2. Biathle
3. Triathle
4. Tetrathlon
5. Para-Pentathlon
6. Modern Pentathlon (UIPM, 2023).

Laser Run

In this discipline, known as Laser Run and given by the UIPM as a sub-discipline of pentathlon, participants are asked to run 300 or 600 meters according to their age category and then shoot with a laser gun from a distance of 5 or 10 meters depending on the category they are competing in. This competition, which is held in every age category, is the most exciting competition of Modern Pentathlon.

Biathle

One of the sub-disciplines of Modern Pentathlon, created to create opportunities to train the Running and Swimming sections of the Pentathlon in real racing conditions. It can also be seen as a sport in its own right. Biathle is a competition involving a Run-Swim-Run sequence, with a running distance of 200 to 1600 meters and a swimming distance of 50 to 200 meters. The competitions are usually combined with triathle competitions, swimming in the sea, river, pool, ocean or lake, and can also be run on surfaces such as sand, asphalt, stone or concrete.

Triathle

It is a sub-discipline of Pentathlon in which Running, Swimming and Shooting are performed together under real racing conditions. Unlike Biathle, it is a competition that is done in the form of shooting-swimming-running-shooting and ends with a run at the end.

Tetrathlon

In this discipline, which is known as a branch of Modern Pentathlon, athletes do swimming, fencing, running and shooting on the same day.

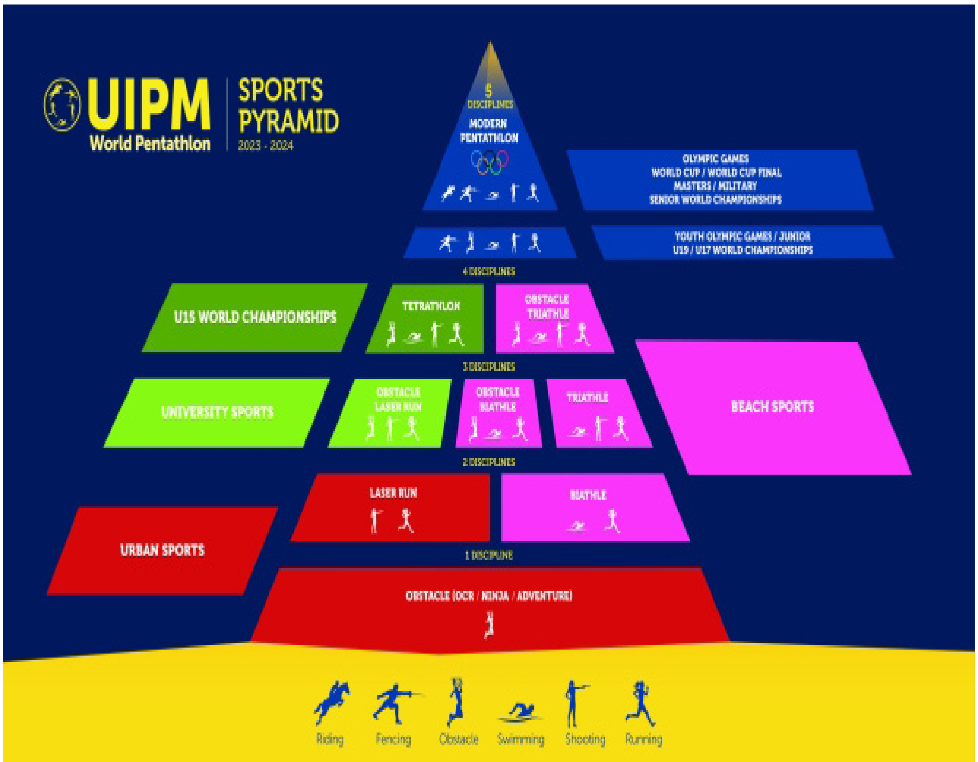
Para-Pentathlon

In this discipline, which was started by UIPM in 2017 and organized every year in order to enable individuals with special needs to recognize and compete in this branch, branches are provided according to the disability of the athletes. Firstly, amputees or other disabled individuals with lower limb disabilities and whose performance is hindered by the lower limb were first included in the branch with the laser run event. The vision of para pentathlon by the UIPM is to make Modern Pentathlon in all its disciplines (and sub-sports) more accessible to everyone, regardless of gender, age or ethnicity, also at the Paralympic level, and to provide a therapeutic multidisciplinary approach for people with disabilities, providing a valid basis for formulating an intelligent recommendation for people with disabilities in both physiological and analytical models. As a mission, it is aimed to be the basis for a complete multidisciplinary approach for people with physical disabilities, allowing a wide range of participants within the framework of the Paralympic Movement, for all disabilities, regardless of the injuries sustained.

Modern Pentathlon

This multidisciplinary branch, which includes 5 branches and is one of the oldest sports branches in Olympic history and aims to complete 5 branches in one day, is an Olympic branch in which almost all motoric features are included in the competition and both aerobic and anaerobic energy systems are used. Swimming is done in the 50- 100- 200 meter freestyle branch according to the age category. Fencing branch consists of an epe competition played over a single 1-minute button and where all opponents face each other. The obstacle branch was added to this branch after the 2024 Olympics and according to certain rules, it is necessary to press the button by passing through various obstacles where upper extremity strength is intense and finally climbing the tsunami wall. Finally, the points collected from other branches are made into a certain list with the handicap system and the athletes start the last branch, laser running, according to the handicap between them and the 1st place athlete. Shooting and Running branch are done together and they shoot laser from a distance of 5 or 10 meters between 600-900-1800-2400-3000 meters according to the age category and between certain distances by dividing these meters equally. This event is the most important, exciting and fiercely competitive event of the Modern Pentathlon branch and increases the pleasure of watching.

Figure 1.
Modern Pentathlon Sport Pyramid (UIPM,2023[1])



In order to perform this multidisciplinary branch, which includes many branches, athletes must be at a certain level both motorically, psychologically and physiologically. In order to meet these requirements, it is important for athletes to use their energy systems well and to develop these systems.

Energy Systems

Athletes convert the energy they need during training and competition into energy by some metabolic events (Kraemer, Fleck, Deschenes, 2011). This converted energy is used in all cellular activities and is called ATP in its chemical form. The athlete gets this energy in 2 ways, aerobic and anaerobic, according to the duration, intensity and type of exercise and also according to the training level of the athlete. The energy taken by anaerobic way is divided into two and is known as 3 energy systems in the literature (Wells, 2009).

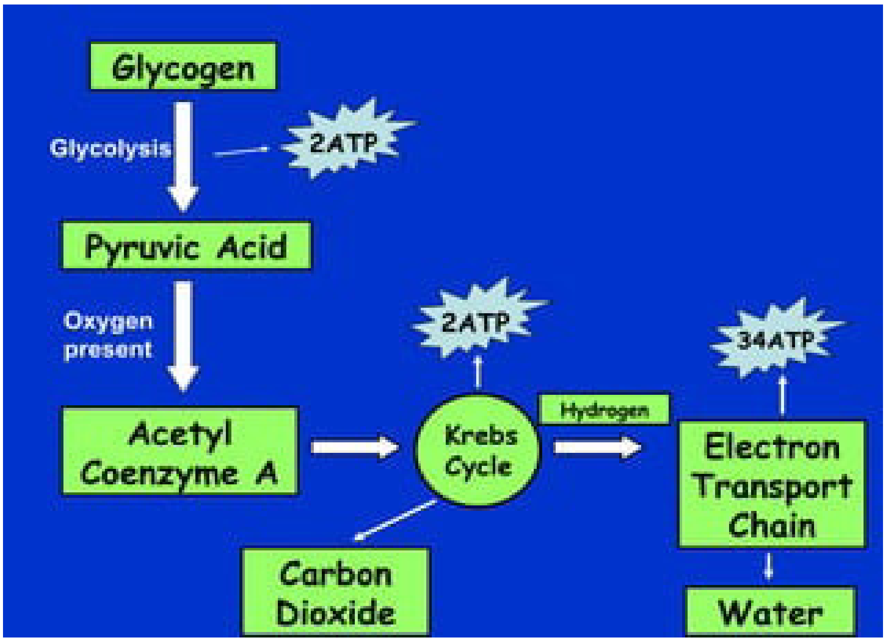
Aerobic (Oxidative) Energy System

In this energy system, it is known as a system that enters into metabolic activities using glucose, glycogen and fats as resources and can be used for the longest time compared to other systems in terms of energy, but can provide the slowest energy contribution and requires oxygen in ATP production (Turner & Stewart, 2013). It has been stated that

1 https://www.uipmworld.org/vision-mission-values-and-strategic-plan

energy production in this system is in an oxygenated environment and takes place in mitochondria cells, that one mole of glucose converted into energy by burning in this environment is equivalent to 39 moles of ATP and that this energy is the highest yield that can be obtained in any system (Scott, 2005). In low intensity and prolonged exercise lasting between 2 minutes and 2 hours, the oxygenated system is used and energy is provided from carbohydrates and free fatty acids (Bompa, 2007). In the aerobic energy system, ATP production is provided by a series of processes such as aerobic glycolysis, Kreps cycle and electron transport chain. In aerobic glycolysis, the energy required for 2 moles of pyruvic acid and 3 moles of ATP from 1 mole of glycogen in the presence of sufficient oxygen is synthesized in cytoplasmase. In addition, 2 NAD+ is reduced to 2 NADH and sent to the electron transport chain to form 6 moles of ATP. In the Kreps cycle, pyruvic acid, which is first produced as a product of aerobic glycolysis, undergoes 2 chemical reactions. In the first reaction CO2 is released and CO2 is removed through the lungs in the second. Hydrogen carrier molecules called NAD and FAD participate in the oxidation, separating hydrogen and electron ions and sending them to the electron transport chain for further chemical reactions (Power & Howley, 2007). Finally, water is produced from glycogen, which continues to be burned in the electron transport chain, resulting in 38 moles of ATP from 1 mole of glycogen (Farrell, Joyner & Caiozzo, 2011; McArdle, Katch, Katch, 2010).
The chemical reaction of the aerobic energy system is as follows.
$C_6H_{12}O_6 + 6O_2 \Rightarrow 6CO_2 + 6\ H_2O + ENERGY$
ENERGY + 38 ADP + 38 Pi => 38 ATP (Bompa, 2007).

Figure 2.
Conversion of Energy to ATP in the Aerobic System [2]



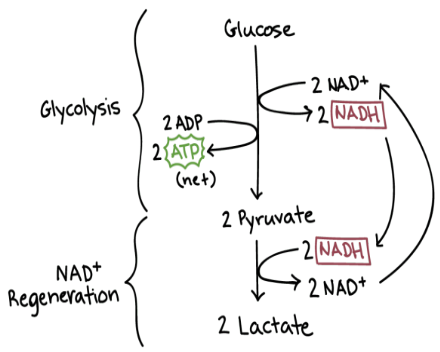
Anaerobic Glycolysis (Lactic acid) Energy System
In this system, glucose, one of the carbohydrates that can be used in muscles, is partially broken down into pyruvic acid in an oxygen-free environment. Since pyruvic acid cannot find enough oxygen in the muscles in a certain chemical reaction, it turns into lactic acid and starts to accumulate in the muscle (Bishop, 2003). As a result of the burning of

2 https://www.caludoncastle.co.uk/wp-content/uploads/2020/05/Energy-Systems.pdf

glucose, hydrogen ions affect muscle contraction and as lactic acid accumulates in the muscles, the acid-base balance in metabolism changes and this balance affects human physiology and causes fatigue in the body (Noyan, 1993). This system is the system that provides energy to the muscles during exercise between 15 seconds and 3 minutes and meets most of the body's ATP production in high intensity and up to 3 minutes of exercise (Kin, 1994). At the time to peak torque, the contraction speed is at the forefront and its unit is the second. This refers to the time to reach peak torque. It is used in evaluating athletes that require explosive power and available condition (Vural, 2019). This system is also known as the second fastest way to synthesize ATP (Bishop, Girard, Mendez-Villanueva, 2011). A certain portion of the lactic acid accumulated in the muscle is converted back into pyruvic acid with oxygen from the body through resting and converted back into energy by being included in the aerobic energy system. It has been stated that a certain part of it is converted back into glucose by being included in the cori cycle process through the blood, and at the same time, a very small part is converted into some amino acids (Turner, 2013; Powers, Howley, 2007). The chemical reaction of the anaerobic energy system is as follows.

C6H12O6 ===> 2C3H6O3 + ENERGY ENERGY + 3 ADP + 3Pi ==> 3 ATP (Sonmez, 2002).

Figure 3.
Anaerobic Glycolysis System (Wu, Preskitt, Gresham-Fiegel , 2021)



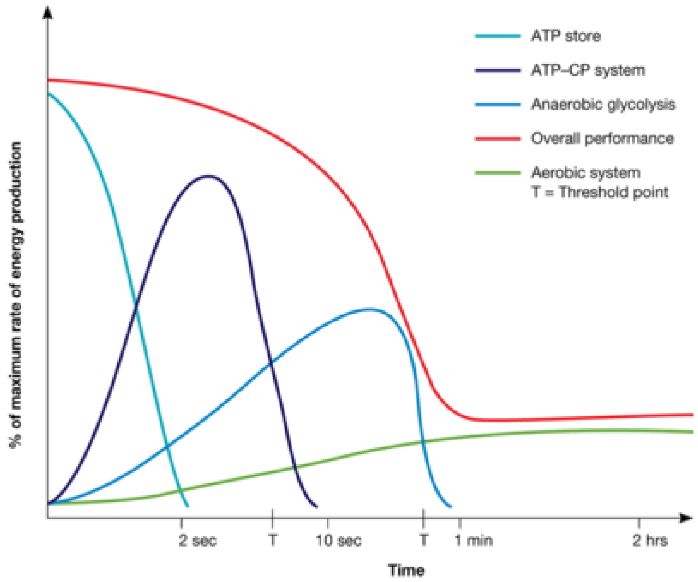
ATP-PC (Phosphogen) Energy System

This system ensures that ATP is obtained in the fastest and easiest way, at the same time, a phosphate is separated from the structure of PCr (Phosphocreatine), binding to ADP and forming the process of forming ATP, which takes place anaerobically in an oxygen-free environment (Cox, Desbrow et all, 2002). In this system, although it provides the majority of the energy required at the beginning of the exercise or in exercises that will last less than 10-15 seconds and when the exercise is performed at the maximal level, it is the most effective energy system in the completion and success of movement wholes such as sprinting, shooting, jumping (Smith, Hill, 1991; Gastin, 2001; Özer et al., 2017). The main reason why this system plays a leading role in situations requiring short-term and maximal energy is the limited number of PCr stored in the muscles, so that the reaction takes place and ATP production is limited (Gaitanos, Williams, Boobis, Brooks, 1993).

The chemical reaction of the ATP-PC system is as follows
CP ==> Creatine + Pi + Energy Energy + ADP+Pi==> ATP (Fox, Bowers, Foss, 1993).

Participation in regular movement and physical activities in early childhood is important for healthy growth, especially in terms of bone, muscle, cardiovascular development and prevention of obesity (Vural et al., 2017; Vural et al., 2010).
In summary, energy systems are divided into 3 and the predominant energy system used during exercise depends on the duration and intensity of the activity, the level of training, aerobic and anaerobic capacity of the individual. It is understood that the phosphogen system is used in activities that are not longer than 10 seconds and should be performed at maximum level, the lactic acid system is used in short-term exercises that continue at high intensity between 15 seconds and 3 minutes, and finally the aerobic system is used in moderate, low tempo and long-term activities of 3 minutes or more. At the same time, there is no complete inactivity of a system during an exercise, but the level of dominance varies in energy systems according to the level and duration of the exercise (Franchini et all, 2011; Zafeiridis, et all, 2005; Powers & Howley, 2007).
In the picture below (Figure 4.) the energy systems that people will use depending on the duration of exercise are clearly expressed.

Figure 4.
Utilization of different energy systems according to exercise duration (Wells, 2009).



Energy systems in Modern Pentathlon

Since Modern Pentathlon is a multidisciplinary sport, the explanation of the energy systems must be done separately for each discipline. In addition, an attempt has been made to explain the energy system in each event according to the Olympic Games. Because the energy system needed by the athlete in each branch will be different. First of all, it is necessary to look at the energy system required by the athlete in the 200-meter freestyle swimming competition.

Swimming is an endurance sport in terms of distance and duration, a sport in which aerobic energy gain becomes more important in terms of swimming times, and anaerobic endurance is required for short distances such as 100m-200m. The importance of anaerobic capacity increases in proportion to the increase in swimming speed. In speed events such as 100m and 200m, anaerobic capacity is important and studies to increase anaerobic power are at the forefront. In a good 200m swimmer, O2 debt and blood lactate levels are high. Since the swimming distance in Modern Pentathlon is 50-

100-200 meters depending on the age group, athletes use the lactic acid energy system anaerobically as their energy system. Because the swimming events last a maximum of 3 minutes and the need for ATP arises very quickly due to the high intensity of the pace during the competition. It is known that the dominant system used by the body at such a high pace and in such a short time is the lactic acid system (Fox, Bowers, Foss, 1993). The energy demands that are met anaerobically during the competition lead to muscle fatigue at the end of the competition, and the athlete needs to remove the lactic acid in the muscles from the body through various resting methods until the next competition.
The movements used in fencing are movements that require explosive force and can last less than one second. However, when successive movements are combined, they form a whole movement that exceeds 60 seconds. Therefore, fencing by its nature uses the phosphogen energy system more and it is explained that there is a high demand on this system (Enzo, 2005). Attacks include many positions in which long-term submaximal power is used, immediately followed by a short-term, sudden movement to touch the opponent (Roi and Pittaiuga 1997, Lavoie et al, 1985). Since the fencing competition applied in Modern Pentathlon is within 1 minute and sudden defensive or offensive movements are made in a very short time, it is understood that 90% phosphogen energy system and 10% lactic acid system are used. However, if we take the competition as a basis, an average Modern Pentathlon fencing competition lasts 1-2 hours. In this process, both anaerobic and aerobic endurance of the athlete should be high, and it is believed that the oxidative energy system is also used in the competition. In this respect, fencing involves both aerobic and anaerobic metabolic systems. However, research suggests that fencers have an average aerobic capacity (52.9 ml/kg/min), although higher than sedentary individuals (Roi & Bianchedi, 2008).

In the obstacle branch, which is the new branch of Modern Pentathlon, the obstacles must be passed within a certain period of time depending on the aerobic and anaerobic endurance of the athlete with intense upper extremity strength. The obstacle branch is completed between 30 seconds and 1 minute on average, depending on the time spent in obstacle crossings and the transition time between obstacles. It is known that the dominant energy system in activities lasting less than 3 minutes is the lactic acid energy system and in activities lasting less than 15 seconds is the ATP-PC energy system (Bompa, 2007). In this branch it has been stated that in short bursts and the muscles of the upper extremities go through a course that includes a certain number of short, regular and intermittent interruptions in the crossing of obstacles and that in these transitions the ATP-PC system and the anaerobic glucose energy system are used in a certain percentage ratio (Earle, 2024). In Laser-Run, since a 3000-meter course is run in 5 sets of 600 meters, athletes largely use the oxidative energy system. In track and field, the percentage of energy provided by aerobic and anaerobic pathways is approximately equal in the 3000 meter run. In the 1500-meter race, the energy provided by the anaerobic pathway is slightly higher. The 1500 meter run time is three minutes and forty-five seconds, while the 3000 meter run time is around nine minutes. The aerobic-anaerobic energy sources are equally important for both distances run in such different times. With the exception of the three minutes and forty-five seconds and the nine minutes, the energy sources are completely opposite in all other events. The anaerobic pathway is dominant in exercises performed in sports that last less than three minutes and forty-five seconds, and the aerobic pathway is dominant in exercises that last more than nine minutes (Günay, 1998). It can be said that the athlete changes to the shooting branch every 600 meters and hits 5 targets 10 meters away, and the energy system used here is both lactic acid and oxidative. However, no information on this subject was found in the literature.

Conclusion

In conclusion, in this chapter of the book, it is assumed that athletes in the Modern Pentathlon branch are intertwined with all energy systems in terms of use, that in order to meet the energy requirements of this branch, a general aerobic and anaerobic endurance should be at a high level in each discipline, and that the level of training condition should be increased in order to prolong the lactic acid tolerance time during competition by using various recovery methods before, between and after training and to remove lactic acid from the body faster.

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Respiratory System and Performance

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To Cite This Chapter

Yılmaz, O. F., & Avcı, N. (2024). Respiratory System and Performance. In M. Özdal & F. Alıncak (Eds.), *Current Studies in Sports Sciences 2024* (pp. 96-110). ISRES Publishing.

Introduction

The efficiency of the respiratory system, which is considered one of the important criteria in determining individuals' work and performance capacity, also holds significant importance in athletic performance. As the oxygen requirement of tissues increases during physical activity, the amount of oxygen delivered from the respiratory system to the body must also increase. The rising demand of tissues necessitates that the respiratory system functions regularly and adequately to tolerate the excess carbon dioxide produced and the metabolic heat generated (Fox, et al., 2012). The primary function of the respiratory system is to maintain the partial pressures of oxygen (O_2) and carbon dioxide (CO_2) in arterial blood. During exercise, there is an increased O_2 consumption (need to be protect) and an increased CO_2 (need to be eliminate) production by the working muscles that must be managed. Therefore, the primary reason for the increased ventilation during exercise is to enhance alveolar ventilation in proportion to O_2 consumption and CO_2 production, while maintaining acid-base homeostasis. The respiratory system achieves this with remarkable precision and minimal energy cost to the body through the coordination of lung parenchyma, airways, respiratory control systems, and respiratory muscles (Mills, 2013).

Aim of The Study

The aim of this study is to summarize the effects of respiratory system on athletic performance.

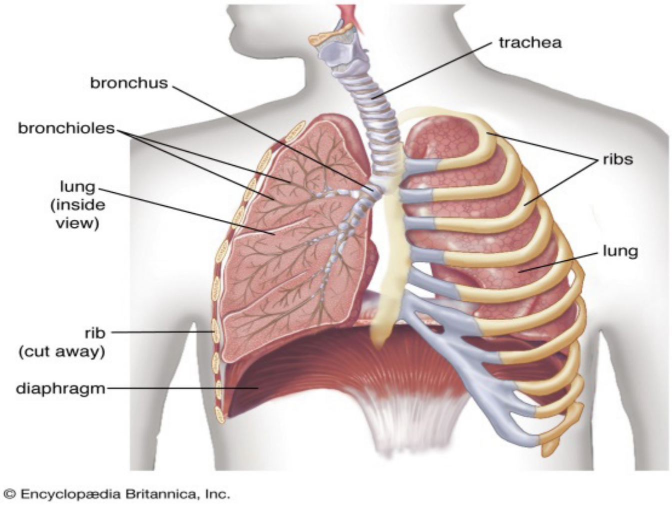
Respiratory System Organs

The air we breathe passes through a series of airways before reaching the millions of tiny sacs deep inside the lungs. The respiratory system consists of the nose, nasal cavity, pharynx, larynx, trachea, bronchi and lungs. This system is usually divided into the upper respiratory system (nose, nasal cavity, pharynx), which includes structures in the head and neck, and the lower respiratory system (larynx, trachea, bronchi and lungs), which consists of structures in the thorax (Marieb, 2008; Tate, 2011; Saladin ve ark., 2018). Solunum sistemi bireyin günlük yaşamı, iş performansı ve sportif performans kapasitesi açısından oldukça önemlidir (Vural, Özdal and Pancar, 2019). Within lung tissue, there are numerous small air sacs (alveoli) where respiration occurs. The thorax, pleura, and respiratory muscles allow for the expansion and contraction of the lungs, facilitating the process of breathing. The lungs do not have the ability to move actively; their movements are provided by the rib cage and respiratory muscles. One structural feature of the respiratory organs is that many of them have a cartilaginous framework in their walls. Therefore, they do not have the ability to constrict and always contain air within them. (Demirel & Koşar, 2002).

Additionally, through the respiratory organs:

- Foreign particles in the inhaled air are filtered out.
- Along with the CO_2 produced from the combustion of carbon, water vapor and heat are also generated. This heat helps maintain body temperature between 36.5-37.5ºC.
- Sounds are produced as a result of the vibrations of the air passing through the respiratory pathways.
- The sense of smell is facilitated, and blood pH is regulated.
- Gas exchange between air and blood in the lungs is ensured (Akgün, 1975; Aktümsek, 2001).

Figure 1
Thoracic Cage



Respiratory Mechanics

The lungs and the rib cage that encase them are elastic structures. In reality, there are no structures connecting the lungs to the walls of the rib cage. The force that pulls the lungs toward the rib cage and prevents them from separating from the chest wall is the fluid and negative pressure present between the two pleural layers. (Faller & Schuenke, 2000). The negative pressure between the pleural layers prevents the lungs from separating further from the rib cage during exhalation (expiration) and pulls the lungs back toward the chest wall. If, for any reason (such as injuries, lung diseases, or rib fractures), air enters between these two layers (pneumothorax), it causes the lungs to collapse. The entry of air eliminates the negative pressure in the pleural space. (Decramer, 1999). Respiration consists of inspiration (inhaling) and expiration (exhaling). For inspiration to occur, the intrapulmonary pressure must be lower than the atmospheric pressure. Conversely, expiration requires a pressure change in the opposite direction. (Guyton & Hall, 2013).

Respiratory Muscles

The respiratory muscles are anatomically classified as skeletal muscle type. However, they differ from skeletal muscles due to their specialized functions. While skeletal muscles are designed to generate movement against mobility, respiratory muscles are specialized to overcome resistance and elastic load (Eston & Reilly, 2001). Skeletal muscles contract rhythmically only during movement, while respiratory muscles contract rhythmically continuously (Edwards & Faulkner, 1995). Respiratory muscles are vital for life, and for this reason, they are resistant to fatigue, have a high oxidative capacity, a dense capillary network, and high blood flow (Decramer, 1999). Slow fibers (Type I), which have a high oxidative potential, are particularly suited for prolonged aerobic activities and are more resistant to fatigue. Fast fibers (Type II), on the other hand, are less sensitive to fatigue and are less efficient in oxygen use, making them beneficial for high-intensity, short-duration anaerobic exercise (Qaisar, Bhaskaran, & Van Remmen, 2016). The composition of respiratory muscles, with the presence of fast and slow fibers, reflects the type of task these muscles need to perform; that is, slow fibers are predominantly used during normal inspiration. However, when the respiratory rate increases, fast fibers are recruited. This change in muscle fiber recruitment has been clearly demonstrated in animal studies. (Cretterio et al., 1982; Sekiguchi et al., 2018).

Muscles Involved in Respiration

Respiration mechanically consists of inspiration and expiration. Inspiration is an active process that occurs with the help of respiratory muscles. Expiration, on the other hand, is a passive process that occurs due to the elastic properties of the chest wall and lungs. (Bartter,et al., 2003; Guyton and Hall, 2013*)*. During inspiration and expiration, the rib cage and lungs expand or contract with the upward and downward movement of the diaphragm. The elevation and depression of the ribs also increase or decrease the anteroposterior diameter of the rib cage. Normal quiet breathing primarily involves this mechanism, facilitated by diaphragm movement. During inspiration, the contraction of the diaphragm pulls the lower parts of the lungs downward, resulting in lung expansion. In expiration, the diaphragm relaxes, and the elastic recoil forces of the lungs and chest wall, along with the compression from abdominal structures during forceful expiration, cause the lungs to shrink and air to be expelled. (Fox, et al., 2012; Hall, 2016). The diaphragm muscle performs two-thirds of the respiratory pump work. Its convex surface faces the rib cage, while its concave surface faces the abdominal cavity. The edges of the diaphragm are muscular, while the center is tendinous; upon contraction, its dome shape decreases and increases the vertical diameter of the thoracic cavity. The lungs expand downward, resulting in inspiration. Meanwhile, as the diaphragm is pushed downward, intra-abdominal pressure increases, pushing abdominal organs backward, relaxing the abdominal muscles, and causing the abdominal wall to expand outward. Respiration that occurs due to the movement of the diaphragm is referred to as diaphragmatic or abdominal breathing (Arıncı & Elhan, 1997; Bartter, Pratter, & Irwin, 2003). All the muscles that elevate the rib cage are classified as inspiratory muscles, while all the muscles that pull it downward are classified as expiratory muscles. The most important muscle of inspiration is the diaphragm (m. diaphragma). The key muscle that elevates the rib cage is the external intercostal muscle (m. intercostales externi). Additionally, the sternocleidomastoid muscle (m. sternocleidomastoideus), the serratus anterior muscle (m. serratus anterior), which lifts several ribs, and the scalene muscles (m. scaleni), which elevate the first two ribs, assist in inspiration. (Guyton and Hall, 2013). During maximal exercise, the trapezius muscle and the extensors of the neck and back are also thought to assist in inspiration. (Fox, et al., 2012). The most important muscles of expiration are the internal intercostal muscles (m. intercostales interni) and the rectus abdominis muscle (m. rectus abdominis). (Guyton and Hall, 2013). These muscles not only pull the rib cage downward but also work with other abdominal muscles to compress the abdominal organs toward the diaphragm. In another study examining the morphology and muscle fiber type of respiratory muscles in human cadavers, it was noted that 60% of the internal and external intercostal muscles consist of Type I fibers, while 49% of the diaphragm is made up of Type I fibers, with the vastus lateralis having a similar fiber type to that of the diaphragm (Mizuno and Secher, 1989). Therefore, it has been expressed that the superior oxidative capacity of the diaphragm, which is the primary muscle of respiration, is related not only to muscle fiber type but also to various enzyme activities, vascular systems, and mitochondrial density. (Emchrc et al., 2019; Nair et al., 2019). The general purpose of respiratory muscle exercises is to improve the functions of the respiratory muscles to increase the risk of shortness of breath and to prevent shortness of breath during exercise. It is based on improving performance. For this reason, rehabilitation is often while used for purposes24, recently it has been used by sports scientists for athletes, frequently used acutely and chronically in order to increase performance is being implemented (Bilgiç, Özdal and Vural, 2022). These additional morphological adaptations are not present in the accessory respiratory muscles. This situation can be explained by the fact that the primary functions of these muscles are merely to provide stability and facilitate the movement of the thorax. (Hodges et al., 2001; Mills et al., 2015; Ratnovsky et al, 2008). Another feature that distinguishes respiratory muscles from skeletal muscles is their unique characteristics that make them less sensitive to fatigue. (Sheel ve Romer, 2012). A large number of vascular sources nourish the respiratory muscles. (Dempsey et al., 2006). While skeletal muscles receive blood from a single artery, the diaphragm is supplied by multiple sources. (Dempsey and Smith, 2014). Although the accessory respiratory muscles and diaphragm have similar muscle fibers, the ratio of capillaries to muscle fibers in the diaphragm is higher. (McConnell, 2013). This helps reduce the volume of diaphragm muscle fibers, thereby decreasing the diffusion distance. All these physiological mechanisms contribute to enhancing tolerance to the increased respiratory demands during exercise. (Sheel and Romer, 2012).

Viscoelastic Properties of Respiratory Muscles

The general viscoelastic properties of muscle include stress relaxation, creep, and static elasticity. içerir (Wang, et al., 2016). Viscoelasticity is determined by the mechanical properties of intracellular and extracellular proteins. An important feature of the viscoelastic structure is hysteresis in the stress-strain relationship, meaning that at any muscle length, the tension generated during passive stretching exceeds the tension during passive shortening. (Jannapureddy, et al., 2003; Patel, et al., 2003). In hysteresis, both viscous and elastic forces resist passive elongation, with the elastic response leading to passive shortening, which is countered by viscous forces. Thus, energy is lost during the stretching-shortening cycles (Campbell, et al., 2000; Sieck et al., 2013). Respiratory muscles exhibit hysteresis that depends on the initial muscle length, strain, and direction of tension. (Kumar, et al., 2004; Patel, et al., 2003). If the stretching-shortening cycles begin in a long position, the viscous and elastic forces of the diaphragm increase. (Syme, 1990). The viscous resistance to the tension applied along the long axis of the diaphragm and abdominal muscle fibers is greater than that to the tension applied transversely. (Jannapureddy, et al.,2003). Considering that the diaphragm muscle is similar to skeletal muscles, the short-range elastic component of diaphragm muscle fibers will contribute to the hysteresis of the stretching-shortening cycles and will affect respiratory mechanics. At the end of expiration, lung volume increases above or below functional residual capacity following respiratory effort. (Homma and Hagbarth, 2000; Izumizaki, et al., 2006; Izumizaki, et al., 2004). These changes have been associated with transient impairments in the mechanics of respiratory muscle cells following movement. (Izumizaki, et al., 2006). The hysteretic properties of respiratory muscles are physiologically very important. (Faffe & Zin, 2009). The rates of elongation of these muscles are significant determinants of their viscoelastic properties. Rapid stretchings in research, when outside the physiological range of elongation-shortening speeds, result in excessive energy loss due to viscous resistance, which reduces the contribution of thixotropy to the viscoelastic properties. (Sieck, et al., 2013). Therefore, it is expected that the viscous resistance of respiratory muscles increases inversely with body size during respiration. beklenir (Isaza, et al., 2003; Koo, et al., 2010). Another factor affecting viscoelastic properties is temperature. When temperature increases, the viscosity and elasticity of a material decrease, and this concept also applies to skeletal muscles (Behm, 2018).

Respiratory System and Exercise

Adaptation of the Respiratory System to Exercise

As the oxygen (O_2) requirement of tissues increases during physical activity, it is essential for the amount of O_2 delivered from the respiratory system to the body to also increase. The heightened demand from tissues, along with the excess carbon dioxide (CO_2) produced and the need to manage metabolic heat, requires both the circulatory and respiratory systems to work effectively. Minute ventilation increases in response to the rising levels of CO2 produced and O2 consumed by the muscles. Minute ventilation does not limit the capacity of the cardiorespiratory system (Fox, et al., 2012). During exercise, accessory respiratory muscles become active during inspiration. Specifically, muscles that elevate the chest cavity assist with inspiration. Expiration occurs through the pressure generated by the intercostal muscles and abdominal muscles. The strength of the accessory respiratory muscles ensures that ventilatory airflow reaches its maximum level (Ergen et al., 2002).

During exercise, there is an increase in both respiratory volume and frequency to meet the body's oxygen (O_2) demands. At maximal exertion, the amount of air exchanged in one minute can reach levels as high as 200 liters, achieved through increases in both tidal volume and breathing frequency. (Fox, et al., 2012). The minute ventilation, which can vary based on respiratory muscle strength, can reach 200 liters per minute during high-intensity physical activities, while in individuals not engaged in any physical activity, this number is estimated to be around 100 liters per minute. During maximal exercise, minute ventilation is regulated more by carbon dioxide (CO_2) production than by oxygen (O_2) consumption. In exercise, increases in the depth and frequency of breathing lead to significant increases in minute ventilation. In severe exercise, the respiratory rate in adult males has been reported to reach between 35-45 breaths per minute in some sources (Ergen et al., 2002) and 40-50 (McConnell, 2011) in others. For Olympic athletes, this number can rise to between 60-76 during maximal exercise (Ergen et al., 2002). Tidal volume during intense exercise can increase to 3-4 liters, resulting in minute ventilation approaching 120-160 liters. In Olympic athletes, tidal volume can reach around 5 liters, with minute ventilation rising to approximately 250-300 liters. (McConnell, 2011).

As an athlete's maximal oxygen uptake ($MaxVO_2$) increases, minute ventilation also rises. A rapid increase occurs within the first few seconds after the onset of exercise. After a certain period, this increase continues gradually. The rise in ventilation is driven by stimuli received by the nervous system from joint receptors. The duration of this increase is directly proportional to the intensity of the exercise. (Fox, et al., 2012). In moderate-intensity exercises, the increase in ventilation is primarily due to the rise in respiratory volume. This increase in ventilation is closely related to oxygen (O_2) consumption (Günay, 1998). Such an increase can even be observed in excited individuals just before exertion. At the same time, at the beginning of exercise, the respiratory volume increases more than the respiratory frequency. However, if the intensity of the exercise reaches a level that induces metabolic acidosis, the increase in respiratory frequency is greater.

This is a key indicator of metabolic acidosis (Akgün, 1989). During exercise, maximal oxygen uptake ($MaxVO_2$) and the amount of carbon dioxide (CO2) expelled from the lungs per unit of time (pulmonary carbon dioxide output, VCO2) increase linearly up to about 60% of the athlete's maximal work capacity. The respiratory rate during exercise can reach 30 breaths per minute or even higher. (Guyton and Hall, 2013).

The Effect of Respiratory Mechanics on Performance

During exercise, maximal oxygen uptake ($MaxVO_2$) and the amount of carbon dioxide (CO_2) expelled from the lungs, known as pulmonary carbon dioxide output, indicate that there is an increase in $MaxVO_2$ of approximately 60% of the athlete's maximal work capacity. (Guyton and Hall, 2013). With the cessation of exercise, there is a rapid decline in ventilation. This decrease is attributed to the cessation of motor activity as sensed by muscle and joint receptors. The higher the intensity of the exercise, the longer it takes for ventilation to return to resting levels (Özdal, 2015). Athletes breathe heavily during exercise, and just like skeletal muscles, the respiratory muscles require sufficient levels of oxygen to function effectively. During high-intensity exercise, the respiratory muscles work significantly harder than at rest. Therefore, a high level of metabolic activity is needed to sustain respiration. (Sheel, 2002). In response to this metabolic stress, the respiratory muscles also adapt. Generally, muscles undergo structural changes to accommodate training, leading to alterations in muscle function. It has been noted that the positive effects of exercise on the respiratory system will also yield positive results on overall performance (Boutellier, et al., 1992). Studies have shown that there is a direct relationship between respiratory muscle strength and endurance and exercise capacity. This is because delaying fatigue in the respiratory muscles ensures that blood flow is sufficiently directed to these muscles. As a result, the respiratory muscles can perform their functions more easily. (Gigliotti, et al., 2006*).* During exercise, there is an increase in both the rate and depth of breathing to allow the respiratory muscles to contract more forcefully and rapidly. At rest, the expiratory muscles are relaxed, and respiration is primarily driven by the mechanical effect of the inspiratory muscles. However, during exercise, the expiratory muscles also actively participate in breathing to enhance the increase in tidal volume and expiratory airflow. Considering that the respiratory muscles utilize about 16% of the oxygen consumed during high-intensity exercise, it is clear that effective respiratory muscle strength is crucial for meeting the demands of exercise. (McConnell, 2011).

Respiratory Muscle Training

Inspiratory Muscle Training

The onset of fatigue in the respiratory muscles leads to a decrease in their contraction strength. As a result of fatigue in the respiratory muscles, alveolar ventilation decreases, causing an increase in arterial carbon dioxide (CO_2) levels. When this increase reaches a peak level, respiratory function can no longer be maintained. (Macklem et al., 1979*).* As the exercise intensity increases, the respiratory load also rises. As a result of this increase, athletes may experience not only fatigue in the respiratory muscles but also insufficient oxygen delivery to the tissues, leading to a decline in performance. This fatigue can result in an energy loss of up to 15% for the athlete. (St Croix, et al., 2000; Lomax and McConnell, 2003). To reduce energy loss, proper breathing exercises and diaphragm muscle development mechanisms should be practiced. In a study on respiratory muscles, it was found that diaphragm-oriented correct respiratory muscle training can improve respiratory muscle strength and function more positively than standard training (Vural, et al., 2024). Respiratory muscle exercises can be performed with or without equipment; however, after the POWERBreathe device was observed to have therapeutic benefits for patients with respiratory difficulties such as chronic obstructive pulmonary disease (COPD), dyspnea, and asthma, sonra (Lacasse, et al.; Gosselink et al., 2011) researchers in sports science began to investigate its potential contributions to athletes (Fernández-Lázaro et al., 2021).

Respiratory Muscle Stretching Exercise

Effective respiratory mechanics depend on chest mobility, healthy respiratory muscles that can generate lung volumes, and the ability to move to ensure adequate pulmonary ventilation simultaneously. (Sonehara, et al., 2011*)*. Disruptions in respiratory mechanics are generally caused by the shortening of the respiratory muscle system (De Sa et al., 2017) The main reasons for such shortening include psychoneural factors (stress), respiratory diseases, muscle weakness, aging, and insufficient physical activity. (Moreno et al., 2007; Tumasian et al., 2021) As a result of these factors, there is a decrease in the movement of the spinal, costal, and sternal joints associated with hypertonicity of the respiratory muscles. (O'Donnell and Laveneziana, 2007) Changes in the shape and structure of the chest wall, particularly, can lead to a shortening of respiratory muscle fibers by 30% to 40%. This imbalance in the tension-length relationship results in reduced expansion of the lower thoracic cage and decreased costal mobility, thereby diminishing pulmonary function. (De Troyer, 2012; Duiverman et al.). It is believed that respiratory muscle stretching exercises can help reduce this negative mechanism. These exercises are effective in directly stretching muscle fibers and increasing thoracic mobility. (Ashwini, et al., 2017; Mohamed, et al., 2021). Respiratory muscle stretching exercises improve the parasympathetic activation of the diaphragm and respiratory muscles by regulating the autonomic nervous system, leading to an increase in pulmonary function and a reduction in fatigue and dyspnea (Fernández-López et al., 2021) These exercises promote an increase in the length of the muscle-tendon unit of the respiratory muscles. By increasing the distance between the origin and insertion of the diaphragm, they reduce the tension caused by fiber shortening, making muscle contractions more effective (Page, 2012). The respiratory muscle stretching technique causes sensory modulation and potential reflex changes due to the static load on the connective tissue, resulting in improved viscoelastic properties. In this context, it has been noted that respiratory muscle stretching exercises have a positive effect on both muscle and joint mobility. (Fernández-López et al., 2021; Rattes et al., 2018).

The Relationship Between Respiratory Muscle Training and Performance

There may be several possible mechanisms to explain the finding that respiratory muscle training (RMT) improves performance. Research suggests that improvements in performance are likely due to the moderate cardiovascular demands placed on the entire body during respiratory muscle training (Markov et al., 2001; McConnell and Jones, 2002). In some studies, the mechanisms underlying performance improvements have been explained as enhanced oxygen kinetics kinetiği (Bailey et al., 2010), reduced respiratory effort and fatigue perception (Griffiths & McConnell, 2007), weakened respiratory muscle metaboreflex (McConnell and Lomax, 2006), and decreased respiratory muscle fatigue during exercise (Verges et al., 2007). Physiological adaptations have been observed following respiratory muscle training (RMT). In patients with chronic obstructive pulmonary disease (COPD), a study showed that after 5 weeks of RMT, there was an increase in type I fiber size by 38% and type II fiber size by 21% in the external intercostal muscles (measured via biopsy). (). Potentially, this increase in respiratory muscle capacity could reduce the frequency of breathing during exercise. Similarly, a study that utilized the difference between VO2 during exercise and voluntary hyperpnea at rest reported that after 6 weeks of respiratory muscle training (RMT), the VO2 of the respiratory muscles decreased by 3.4% at VO2max. (Taylor et al., 2012). These results suggest that respiratory muscle training (RMT) may reduce the oxygen cost of breathing. Additionally, it can be inferred that the decrease in the oxygen cost of breathing following RMT is likely associated with changes in respiratory muscle improvement models during hyperpnea. Improvements in oxygen transport have also been reported after RMT. Following 4 weeks of pressure threshold RMT, the O˙2\dot{O}_2O˙2 component was found to decrease during high-intensity (from 0.60 to 0.53 $L \cdot min^{-1}$) and maximal cycling exercise (from 0.28 to 0.18 $L \cdot min^{-1}$) to voluntary tolerance limits. RMT has also reduced the intensity of respiratory muscle fatigue as measured by maximal inspiratory pressure (MIP) (Bailey et al., 2010). Many studies have shown that respiratory muscle training (RMT) improves performance during exercise below the threshold of diaphragm fatigue and respiratory muscle metaboreflex. For example, it has been demonstrated that RMT enhances performance in time trial events of 20 and 40 km, where the average power output is approximately 75% of maximum (Romer, et al., 2002). Therefore, it is likely that other potential mechanisms support the observed performance improvements at submaximal exercise intensities.

The Impact of Respiratory Muscle Training on Aerobic Power and Capacity

Aerobic power refers to the capacity to produce aerobic energy during intense exercise, and this capacity is determined by maximal oxygen uptake (VO_2max). Aerobic capacity is defined as the ability to sustain exercise for prolonged periods and is often used synonymously with endurance. Athletes with good aerobic training capacity are more likely to maintain training intensity until the end of a game compared to those with lower aerobic capacity and power. Additionally, athletes with higher aerobic capacity tend to recover more quickly during active rest periods immediately following intense training sessions. (Reilly et al., 2000).

Most of the studies covered in this systematic review used maximal inspiratory pressure (MIP) measures to determine effort intensity during IMW, given that these measures are a reference in the assessment of global inspiratory-muscle strength enabling correct individual measurement and guidance on the inspiratory intervention load (Avcı, Özdal and Vural, 2021).

Previous studies have shown that respiratory muscle training has a significant impact on the respiratory muscles. It has been observed that such training can lead to increased strength within a few days, and after four weeks of training, there is an improvement in the individual's performance. (Voliantis et al., 2001; Romer, McConnell, & Jones, 2002a; Romer, et al., 2002b; Lomax and McConnell, 2009; Kilding, et al., 2010).

The increase in respiratory muscle strength (MIP, MEP) following respiratory muscle training can affect athletes' performance. In a supporting study, after 6 weeks of respiratory muscle training performed by professional cyclists, the maximal inspiratory pressure (MIP) of 16 participating cyclists improved by 22% (Turner et al., 2012). As a result of increased respiratory muscle strength, the contribution of exercise hyperpnea to total body VO2 during maximal exercise decreased from 11% to 8% (Turner et al., 2012).

Many tests conducted on basketball players have found that VO_2max ranges between

40 (ml/kg/min) and 70 (ml/kg/min) (Matković, 2005). A study conducted on college basketball players in the United States showed that the average VO_2max was 65±6.2 (ml/kg/min) (Tavino, 1995). Additionally, research has indicated significant differences in VO_2max among players based on their positions (Marinkovich, 2013).
Respiratory muscle training (RMT) is effective in improving athletes' ability to achieve deeper and slower breathing. It also enhances the stability of the core muscles, which helps the athlete perform movements more effectively and reduces the risk of injury. (McConnell, 2011, s. 21).

In terms of pulmonary ventilation, significant decreases in maximal inspiratory pressure (MIP) and maximal expiratory pressure (MEP) have been shown to occur as a result of decreased strength and endurance in the respiratory muscles following intense aerobic and/or prolonged physical exercise (Martin & Stager, 1981). These respiratory factors limit athletes' performance; (HajGhanbari et al., 2013), therefore, it is possible to discuss the positive effects of respiratory muscle training on performance.

The Impact of Respiratory Muscle Training on Anaerobic Power and Capacity

The anaerobic energy system refers to the production of energy in the body during short-duration exercises through the ATP-CP and lactic acid systems in an oxygen-deprived environment (Dündar, 1998). Anaerobic performance encompasses an energy system that includes anaerobic power and anaerobic capacity. Anaerobic power is defined as an individual's ability to utilize the phosphagen system during short bursts of high-intensity muscle activities, while anaerobic capacity is described as the total amount of energy produced as a result of the combination of the anaerobic glycolytic and phosphagen systems. (Perrin, 1993). The energy mechanism is one of the most important topics in the field of sports. The ability of the human body to perform various movements at the desired level depends on the individual's energy capacity. Each system's ability to provide the necessary energy for exercise is dependent on the type of exercise performed. These exercises can vary from short-duration, explosive movements that require rapid energy production, such as jumping (lasting 2-3 seconds), to longer-duration activities, such as marathon running, which require slower energy production over two to three hours. Anaerobic performance is a significant factor in the success of sports that involve explosive movements (such as speed, agility, and direction changes). (Stone and Sands, 2007). Athletes are exposed to high-intensity movements during a match, and their ability to sustain these actions until the end of the game is only possible with well-developed anaerobic power. (Hoffman, 2003). In a study involving basketball players, the results of an anaerobic power test conducted after four weeks of respiratory muscle training (RMT) showed that the experimental group had increased average anaerobic power values compared to the control group. (Çevik, 2018). It was stated that there was a statistically significant difference in anaerobic power in favor of the experimental group during the anaerobic power test conducted in the 4th and 8th weeks of the respiratory muscle training (Koç, 2017). Similarly, it has been noted that a 6-week respiratory muscle training program increases anaerobic power in cyclists. (Johnson, Graham, & Peter, 2007). It has been explained that the respiratory muscle training leads to an increase in the contraction speed of the respiratory muscles. (Hajghanbari et al., 2013). Tennis is generally considered an anaerobic sport. Regular tennis training combined with respiratory muscle training may have a positive effect on athletes' anaerobic performance. (Köroğlu, 2020).

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The Relationship Between Delayed Onset Muscle Soreness (DOMS) and Inflammation and Oxidative Stress

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To Cite This Chapter

Yavuz, E. (2024). The Relationship Between Delayed Onset Muscle Soreness (DOMS) and Inflammation and Oxidative Stress. In M. Özdal & F. Alıncak (Eds.), *Current Studies in Sports Sciences 2024* (pp. 111-118). ISRES Publishing.

Introduction

Muscle is the main part of the movement system, accounting for more than 40 per cent of the body's total weight. Muscles undergo wear and tear with the activities that take place during the day and as a result, muscle soreness occurs. The general features of muscle soreness are mainly widespread pain, located in the distal somatic area and usually accompanied by changes in muscle stiffness (Mizumura & Taguchi, 2024). Delayed onset muscle soreness (DOMS) is described as muscle tension characterised by persistent pain sensations and additional stiffness with increasing inflammation (Gulick & Kimura, 1996; MacIntyre, Sorichter, Mair, Berg, & McKenzie, 2001). Delayed onset muscle soreness (DOMS) is the process in which muscle soreness manifests itself very intensely in the 24-48 hour period, which manifests itself as muscle soreness 8 hours later exercise, and gradually alleviates the pain with physiological changes in muscle tissue within an average of 6 days (Wolska et al., 2023). DOMS is a common process in elite or beginner athletes. Symptoms can range from muscle tenderness to severe pain. Delayed onset pain is a gradual process that can lead to pain in the skeletal muscle and a decrease in muscle capacity. In addition, exercise-related complications such as fatigue, haematuria, etc. can be seen in a large proportion of patients. Delayed onset muscle soreness (DOMS) is often thought of as a condition that athletes experience when they return to training after a period of holiday, but in general it is characterised by its occurrence when athletes are new to certain types of exercise, regardless of the time period (Cheung, Hume, & Maxwell, 2003). Strenuous and unusual physical exercises of sufficient intensity and time involve extreme muscle contractures, which often result in temporary skeletal muscle microdamage(SMITH, 1991; Torres, Ribeiro, Alberto Duarte, & Cabri, 2012). Exercise-caused muscle injury is a difficulty faced by all athletes in different sports. Such muscle damage can disrupt the athlete's training continuity and consequently impair the athlete's overall performance. Mechanical damage to muscle fibres caused by exercise can lead to deformation of the fibres in the muscle(Owens, Twist, Cobley, Howatson, & Close, 2019). This damage to muscle fibres may cause apoptosis of muscle fibres by disrupting the control of Ca^{+2}secretion (Gissel & Clausen, 2001). The apoptosis that occurs initiates an inflammatory chain that damages proteins and produces reactive oxygen species (ROS) that interfere with stimulation-contraction coupling, causing a negative process in muscle performance(Kozakowska, Pietraszek-Gremplewicz, Jozkowicz, & Dulak, 2015). One of the most important factors that protect our health and contribute to the prevention of diseases is regular exercise routine. On the other hand, performing physical activity at irregular intervals and with high intensity may lead to oxidative stress and inflammation, triggering numerous adverse processes in metabolism instead of promoting a positive impact on health. (Gomez-Cabrera, Domenech, & Viña, 2008).

Aim of the Study

The aim of this study is to summarize and explain the relationship between oxidative stress and inflammation by interpreting the doms state seen due to muscle damage within the framework of relevant studies in the literature.

Delayed Onset Muscle Soreness (DOMS) and Oxidative Stress

“Delayed onset muscle soreness” (DOMS) is clinically recognised primarily by high expression of oxidative stress and pro-inflammatory markers(Kanda et al., 2013). During and after physical activity, mitochondrial activity increases, and factors such as reperfusion, NADPH oxidase complex, and leukocyte activation contribute to the generation of free radicals within the metabolism(Thirupathi & Pinho, 2018). Mitochondria, the energy centre of the cell, have a primary role in achieving homeostasis at the cellular level (Mezhnina, Ebeigbe, Poe, & Kondratov, 2022). It is also a source of free radicals in many pathways, especially during energy synthesis (Zhao, Li, Li, & Chen, 2022). The detection of very high amounts of biomarkers of free radical damage in muscle tissue in delayed onset muscle soreness (DOMS) suggests that damaged mitochondria produce more ROS than other mitochondria(Li, Peng, Sun, & Si, 2023). Exercise-induced free radicals production is thought to be a mechanism that causes muscle damage(LEE et al., 2002). In the process in which force is obtained by muscle contraction, low ROS level positively affects the process by inducing cell signalling, while high ROS level causes a decrease in force production and leads to muscle fatigue, although it varies depending on the process and dose(Radak, Zhao, Koltai, Ohno, & Atalay, 2013). Oxidative stress is a condition that occurs when there is an imbalance in metabolism, marked by an increase in free radicals and oxidant compounds and a decrease in antioxidant levels. This imbalanced process is due to many causes, but most often occurs either due to decreased antioxidant production within the body or inadequate antioxidant intake from external sources (Fernández-Lázaro et al., 2020). Increased oxidative stress leads to oxidative damage to essential cell-based compounds such as lipid compounds, protein molecules and hereditary material. (Mittal, Siddiqui, Tran, Reddy, & Malik, 2014). In this process, inflammatory enzymes such as neutral proteases, elastase, collagenase and acid hydrolases accelerate the formation of oxidative stress by releasing reactive species such as superoxide (O_2-), hydrogen peroxide (H_2O_2), hydroxyl radical (OH-), hypochlorous acid (HOCl), nitric oxide (NO) and extracellular messengers. The combination of these compounds exacerbates inflammation and muscle damage (Biswas, 2016). During muscle contraction, free radicals are produced by activation of endothelial xanthine oxidase, high catecholamine release, electron loss in the electron transport cycle, mitochondrial reaction and inflammatory response pathways. During exercise, free radical generation surpasses the antioxidant capacity of the muscle, usually during intense and demanding training that requires high power. Since the antioxidant system of the body is limited in the acute process, oxidant compounds produced in high amounts can cause damage to the cell membrane and oxidation of cellular components. (Powers & Jackson, 2008; Powers, Nelson, & Hudson, 2011). For instance, following exercise there is an increase in plasma levels of inflammatory determinants such as the acute phase reactants “C-reactive protein (CRP)” and “creatine kinase (CK)”, which often leads to muscle soreness (de Oliveira Teixeira et al., 2015; Righi et al., 2020). If this imbalance in the antioxidant system becomes permanent, it can lead to decreased muscle power production, acute tiredness, poor sports performance, increased muscle injury, lack of regular exercise for beginners, and many other health problems(REID, 2001). At the same time, with continued exercise over the medium and long term, the capacity of the endogenous antioxidant system increases, resulting in adaptation and muscle remodelling (Righi et al., 2020).

Delayed Onset Muscle Soreness (DOMS) and Inflammation

Exercise is seen as a source of outside stressors similar to surgical intervention, shock or infection in that it causes significant physiological changes in the body by causing hormonal and immunological changes (Docherty et al., 2022).
Cytokines, which manage the immune system in case of wellness and illness, are included in the family of intracellular signalling molecules. Cytokines are divided into inflammation-promoting and inflammation-reducing groups, and the relationship among these two groups plays a crucial part in sustaining tissue balance. Disruption of both cytokine groups creates the potential for a negative process on other systems, especially on the immune system (Zhang & An, 2007). Pro-inflammatory cytokines include tumour necrosis factor- alpha (TNF-α) and interleukin 1 (IL-1). In contrast, anti-inflammatory cytokines consist of interleukin 1 receptor antagonist (IL-1ra), IL-4, IL-10, IL-11 and IL-13(Dinarello, 2000; Umare et al., 2014).

Based on the research by Scheller and colleagues, IL-6 is identified as a cytokine that exhibits both inflammation-promoting and inflammation-reducing characteristics (Scheller, Chalaris, Schmidt-Arras, & Rose-John, 2011). It is suggested that one of the main mechanisms leading to DOMS formation is inflammation. At the beginning of the mechanisms causing inflammation is the process related to the increase and aggregation of histamines, neutrophils, bradykinins and prostaglandins in the tissue, which leads to the intensification of muscle pain. The triggering of IL-6 and TNF-α via Toll-like receptor 4 (TLR4) has been reported to be of critical importance in the formation mechanisms of DOMS (Dos Santos et al., 2020).

As a result of the exercise process, a process occurs in the cytokine profile that is thought to be effective on skeletal-muscle health(Steensberg et al., 2000). Exercise activates the main source of cytokines in the body, which is skeletal muscle. It has begun to attract attention as a secretory organ in muscles due to the cytokine secretion that occurs as a result of skeletal muscle contraction (Lightfoot & Cooper, 2016). Among the cytokines called myokines, which are produced by myocytes and exceed 3000 on average, there are cytokines such as IL-6, IL-7 and IL-15 (Piccirillo, 2019). Increased Tumor necrosis factor (TNF-α), raised to increased concentrations of CK and lactate dehydrogenase (LDH) in the serum in addition to the release of IL-1β, IL-6 and IL-1, IL-1ra(SMITH, 1991). This regional inflammation results in DOMS, which is defined by increased muscle soreness, swelling and reduced muscle activity(Tan et al., 2022).
Tumor necrosis factor (TNF-α), a pro-inflammatory cytokine that is effective in inflammatory effects, has a critical structure in this environment. It has been shown that TNF-α not only initiates inflammatory gene expression, but also triggers inflammatory immune responses and disease process by indirectly inducing cell apoptosis, thus causing inflammatory responses(van Loo & Bertrand, 2023).

The main biomarkers involved in the DOMS mechanism were seen as TNF-α and IL-6. In particular, there is a linear relationship between high levels of TNF-α and inflammatory activity of skeletal muscle(Dos Santos et al., 2020). Delayed onset myalgia (DOMS) triggers an inflammatory process, leading to raised concantrions of TNF-α in the blood, which indicates that muscle damage has occurred (Calder et al., 2009). After prolonged, irregular or intense exercise that can cause muscle damage, there is an rise in circulation immunocytes, resulting in an acute inflammatory Response (Smith, 1991). As a result of this inflammatory response, macrophages promote the mechanism of tissue breakdown through the release of inflammation-related cytokines, leading to an raised in C-reactive protein (CRP) concentration (MacIntyre, Reid, & McKenzie, 1995).

With damage to muscle tissue, there is an raised in the level of CK in the circulation. Elevated CK levels are considered a member of the major biochemical signs of myofibrillar damage and this increase is often directly proportional to the severity of the injury. Therefore, the level of damage to muscle tissue can be determined by measuring CK levels(Brancaccio, Maffulli, & Limongelli, 2007). The cytokine IL-6 plays a role in B and T cell differentiation, attracting neutrophils to the site of injury and regulating the inflammatory process in the innate and adaptive immune system (Scheller et al., 2011). The reaction of IL-6 to the exercise process has led it to be recognised as the most important cytokine in exercise physiology. Immediately after the onset of exercise, IL-6 levels increase approximately 100-fold and decline rapidly after the cessation of exercise (Steensberg et al., 2000). The rate of increase in interleukin-6 varies depending on many factors such as the strength of exercise, its duration and the person's exercise capacity (Febbraio & Pedersen, 2002). Pain in the muscles is often seen during the recovery period after vigorous exercise. Some studies have reported that this muscle soreness is due to IL-6 and TNF-α, which are inflammation-promoting cytokines released during and after exercise (Tejua, Purwantob, & Ayubic, 2022).

Cytokines are small soluble proteins that can control inflammatory and defense responses and alter the behaviour of other cells (Taherkhani, Suzuki, & Castell, 2020). Exercise can modulate the defense system and significantly inhibit the spread of pro-inflammatory cytokines and their permanent degradation. When damage occurs, the body responds by releasing catecholamines, which are stress hormones. These catecholamines bind to adrenergic receptors, stimulating a variety of cellular responses. This binding triggers the release of pro-inflammatory cytokines, including TNF-α and IL-1β, which play a crucial role in the inflammatory process.These cytokines show a significant increase in the early stage of the inflammatory response. Pro-inflammatory cytokines like TNF-α and IL-1 have been demonstrated to regulate the inflammatory components of the body, facilitating the signaling of other anti-inflammatory cytokines such as IL-6 and IL-8. These cytokines are crucial for the defense system as well as for the health and healing processes, thus forming a complex network of communication that modulates the inflammatory response and tissue repair of the organism (Hartung, Ciszek, & Nackley, 2014).

The recruitment of additional leukocytes at the site of damage is assisted by raised in IL-6 and IL-8 concentrations. As the amount of leukocytes in the damaged area increases, interleukin-10 (IL-10) concentrations increase and IL-6 inhibits the expression of various inflammation-promoting cytokines (Ding et al., 2003). IL-10 inhibits the activity of immune cells and prevents tissue damage by reducing the production of other pro-inflammatory cytokines, thus supporting healing processes (Nagalakshmi, Murphy, McClanahan, & de Waal Malefyt, 2004). High levels of IL-10 help balance inflammatory responses, reducing the extended range and therefore relieving pain. In this context, the anti-inflammatory properties of IL-10 play an important role in developments, contributing to the improvement of both maintenance and healing pain (FQ, 1999; Sluka, Frey-Law, & Bement, 2018). The inflammatory process that occurs following exercise is a complex physiological mechanism that plays a crucial role in tissue healing, muscle regeneration, and the adaptations required for effective functional recovery (Ota et al., 2013). Pain is a difficult and diverse activity that makes daily activities difficult to perform, one of the main goals is to break the pain. Therefore, the use of non-steroidal anti-inflammatory drugs to alleviate pain and support the healing process is a typical practice (Nahon, Lopes, Magalhães, Machado, & Cameron, 2021). It is a non-steroidal anti-inflammatory and acts by inhibiting the cyclooxygenase (COX) family enzymes. This inhibition leads to a decrease in the synthesis of events such as prostaglandins, prostacyclins and thromboxanes. This mechanism is essential for pain management and control (Schoenfeld, 2012).

Conclusion

In conclusion, the compounds such as lipid compounds, protein molecules and hereditary material. (Mittal, Siddiqui, Tran, Reddy, & Malik, 2014). In this process, inflammatory enzymes such as neutral proteases, elastase, collagenase and acid hydrolases accelerate the formation of oxidative stress by releasing reactive species such as superoxide (O_2-), hydrogen peroxide (H_2O_2), hydroxyl radical (OH-), hypochlorous acid (HOCl), nitric oxide (NO) and extracellular messengers. This mechanism is essential for pain management and control after exercise (Schoenfeld, 2012).

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Current Physiotherapy Approaches in Elite Athlete Injury Factors

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To Cite This Chapter

Takı, F. N., Akdağ, K. Ç., & Kürekci, O. D. (2024). Current Physiotherapy Approaches in Elite Athlete Injury Factors. In M. Özdal & F. Alıncak (Eds.), *Current Studies in Sports Sciences 2024* (pp. 119-128). ISRES Publishing.

Introduction

Throughout history, sport has existed in various shapes and governed by diverse rules, adapting to each era of human development. In the early ages, sports included physical movements for various purposes such as hunting, preparation for war, protection of physical fitness, entertainment or play. As societies progressed culturally, transitioning from traditional frameworks to modern social systems, these activities experienced ongoing transformation, aligning with social and cultural evolution. As a consequence of this evolution, these physical activities, which were initially carried out with different goals, were organised within the framework of certain rules and became structured movements, which are now called sports. In this context, sport is as old and meaningful as the history of humanity (Çumralıgil and Görücü, 2007).

Engaging in physical activity and sports has numerous benefits for physical health, cognitive abilities, and overall life quality. Developing and sustaining appropriate sports habits is especially critical for young individuals. However, inadequate precautions can lead to injuries, as the physical demands of sports often result in injuries caused by both intrinsic and extrinsic factors. It is estimated that sports-related injuries make up approximately 14% of all cases that require medical attention. Nearly 6 million individuals seek medical treatment for such injuries annually, with 10% requiring at least a day's hospitalisation. Moreover, approximately 7,000 fatalities due to sports injuries occur each year (Kisser and Bauer, 2012).

These injuries can hinder athletes from pursuing their professional careers or make it challenging to regain their previous performance levels. Sports-related injuries are responsible for 30% of cases where athletes decide to leave sports entirely. In addition to threatening an athlete's career, such injuries can also have negative impacts on their physical and mental health.. Additionally, this issue imposes a considerable financial strain on the athlete, their club, and the nation (Cumps, Verhagen, Annemans & Meeusen, 2003).

Factors such as improper equipment use, unfavorable weather, uneven surfaces, excessive physical load, and a history of previous injuries are known to increase the likelihood of future sports injuries. While tools like insoles, external joint supports, and balance boards have been shown to significantly reduce injury risks, the effectiveness of other practices, including warm-up exercises and stretching, still requires further scientific exploration (Leppanen et al., 2014; Tranaeus et al., 2015).

External factors like the condition of the playing surface, footwear, equipment, and the maintenance of sports facilities play a crucial role in the occurrence of sports injuries. For instance, studies have shown that harder field and grass surfaces elevate the risk of injury (Orchard, 2002). Additionally, risks may arise from issues like surface slipperiness, uneven terrain, and variations in grass length and type. Research also indicates that selecting footwear appropriate for the playing surface can significantly reduce injury risks. These external factors, while substantial, are modifiable and thus offer opportunities for injury prevention (Donaldson et al., 2003; Dobbinson et al., 2006).

Athletes' individual traits, such as balance, flexibility, muscle strength, endurance, core stability, and proprioception, play a significant role in determining the risk of injury. To sustain performance and reduce injury likelihood, it is crucial for athletes to develop sufficient muscle strength, flexibility, and endurance tailored to their specific sport. Experts highlight the importance of designing scientifically based training programmes tailored to the athlete's physical attributes and needs, a responsibility that falls to health professionals and coaches (Sekendiz et al., 2007; Radwan et al., 2014).

In recent years, the growing young population has led to an increase in individuals participating in long-term physical activity and sports. However, without adequate precautions, the demands of high physical performance combined with internal and external factors heighten the risk of sports injuries. These injuries can disrupt healthy activity habits and strain individuals' financial conditions. Socially and economically, preventing sports injuries is more beneficial than addressing them after they occur. As a result, recognizing potential risk factors, creating preventive programs, and ensuring their execution are essential steps. (Verhagen & van Mechelen, 2010; Karabörklü & Çelik, 2018).

Risk Factors:

In general, risk factors that cause sports injuries are divided into two as internal (intrinsic) factors and external (extrinsic) factors.

Internal (Intrinsic) Factors

Athlete-related risk factors. These factors are

1.Age (training age),
2.Gender,
3.General health (previous injury, joint instability),
4.Body composition (body mass index, fat mass, anthropometry),
5.Physical structure (height, body weight, joint characteristics),
6.Ability level (sport-specific technique, postural stability),
7.Fitness status (muscle strength, max VO_2, range of motion),
8. Neuromuscular and biomechanical factors (such as tibial rotation, dynamic foot pronation, trunk proprioception),
9. Psychological factors (sense of competition, motivation, ability to cope with stress) (Bahr, 2005; Ergen, 2003).

External.(Extrinsic).Factors:
It relates to the interaction between the athlete and their environment.. Extrinsic factors; influencing the athlete's state from the moment they commence the activity:

1. Sport-related factors (sport branch, risk-taking time, opponent's condition),

2. Sport-specific equipment, protective equipment,

3. Sports fields,

4. Weather conditions (temperature, humidity),

5. Referee (game rules),

6.Trainer.(guidance,.behaviour) (Ergen,2003).

This book will explain the tests commonly used by physiotherapists in the clinic to examine biomechanical causes, focusing on both intrinsic and extrinsic factors.

Functional Movement Screening: The Functional Movement Screening (FMS) includes seven subtests designed to evaluate an individual's postural stability and functional movement asymmetries: deep squat, hurdle step, line lunge, shoulder mobility assessment, active straight-leg raise, trunk stability push-up, and rotational stability test. Each movement is performed three times, and the highest score is recorded.

The scoring system of the FMS consists of four levels:

- 3 points: Perfect execution of the movement with correct form.

- 2 points: Completion of the movement with compensatory movements.

- 1 point: Failure to perform the movement.

- 0 points: Pain during the movement.

The overall FMS score is determined by adding the results from each subtest, with a maximum possible total of 21 points. In tests involving bilateral movements (e.g. with the right and left leg), the lower score is added to the total score. During this assessment, movement errors, compensatory movements, mobility deficits and muscle imbalances are analysed (Minick et. al, 2010).

FMS has a certain threshold value, especially in predicting the risk of disability: A score below 14 points has been linked to an increased risk of injury. For instance, in a study of American football players, individuals scoring 14 or below have been reported to be at a higher risk of experiencing serious injuries. (Kiesel et. al, 2011). Nevertheless, the method's validity has been questioned because all movements are given equal weight, and the total score is accepted as an indicator of overall movement quality. (Kazman et. al, 2014).

Isokinetic Dynanometer: Isokinetic dynamometers are devices that measure muscle strength and imbalances and are widely used to evaluate muscle performance and rehabilitation processes (Dvir, 2004). These devices measure the force produced by the muscles while moving against a constant resistance at a certain speed, thus revealing maximum performance over the course of the full range of motion of the muscle (Cadore et. al, 2014). Isokinetic measurement systems play an important role, especially for the evaluation of athlete performance, analysis of muscle strength ratios and monitoring of recovery in rehabilitation processes (Coudeyre et. al, 2016). A primary function of the device is that it can reliably analyse bilateral muscle differences, agonist/antagonist muscle ratios and performance changes during the rehabilitation process (Papadopoulos et. al, 2014). In addition, since it operates at constant speed, it minimises the risks that may arise from uncontrolled movement and the reliability of the results is increased as it provides standard test conditions (Dvir, 2004).

However, isokinetic dynamometers (AID), which traditionally focus on single joint movements, have functional limitations (Cadore et. al, 2014). For instance, it has been criticised for its inability to simulate multiple joint movements that occur in daily life or during sports (Coudeyre et. al, 2016). Multi-joint isokinetic dynamometers (MID), designed to address these limitations, enable the measurement of more complex movement patterns and can assess movements involving multiple joints working together, such as the hip-knee-ankle complex (Pijnappels et. al, 2008). These devices are especially preferred to minimize the risk of falls in elderly individuals (Bily et. al, 2016), to be used in the treatment of osteoarthritis (Coudeyre et. al, 2016) and to measure leg strength in athletes (Baur et. al, 2006).

Y-Balance Test (YBT): It was developed to evaluate the dynamic postural control of the individual (Plisky et. al, 2009). During the test, the participant stands on a platform with one leg while moving the other leg in three main directions (anterior, posterolateral and posteromedial) to reach the maximum distance. The participant's leg length is measured by determining the distance from the top of the hip (anterior superior iliac spine) to the inner ankle bone (medial malleolus), and this measurement is used to normalize the scores (Plisky et. al, 2006).

During the test, the participant must stand on one leg without losing balance, move the other leg correctly to reach the box in the specified direction and go back to the initial position. If the participant loses his/her balance, leans his/her foot on the moving box or pushes the box by kicking it, these attempts are invalidated. Before the test, each participant is given six practice trials to familiarise themselves with the movements, followed by three valid trials in three different directions and the best score in each direction is recorded (Hertel et. al, 2000). The distances reached are normalised to the participant's leg length and these scores are expressed as percentages. Finally, a 'composite score' is calculated by dividing the sum of the best scores in the three directions by the leg length; this score represents the overall balance and postural control capacity of the individual (Plisky et. al, 2006).

HRCT is an effective tool for assessing an individual's risk of lower limb injury. For instance, an asymmetry of 4 cm or more in the anterior direction is associated with an increased risk of injury in high school basketball players. Furthermore, a normalised composite score below 94% indicates a higher risk of injury (Plisky et. al, 2006). The results of the test have often been correlated with modifiable factors such as hip abduction and extension muscle strength, and thus can be used for both injury risk reduction and setting rehabilitation goals (Leetun et. al, 2004; Hubbard et. al, 2007; Khayambashi et. al 2016).

Biodex Balance System (BBS): BBS, offers different test protocols to assess the dynamic postural stability of individuals. During use, the individual stands on a moving platform and the stability level of the platform can be changed during the test. These levels can range from a stable surface to a highly unstable surface, with a total of eight different stability levels. The individual's ability to maintain balance is assessed by their reaction to the movement of this platform (Parraca et. al, 2011; Pickerill and Harter, 2011; Cug and Wikstrom, 2014).

During the assessment, the individual is tested in various stance positions: open-eye on double legs, closed-eye on double legs, open-eye on single legs and closed-eye on single legs. The performance of maintaining balance in each situation is measured by the degree of deviations caused by the movements of the platform. The system evaluates metrics such as the Overall Stability Index (OSI), the Anterior-Posterior Stability Index (APSI), and the Medial-Lateral Stability Index (MLSI). OSI measures the total movement deviations on the platform, APSI determines the movement deviations in the sagittal (anterior-posterior) plane and MLSI determines the movement deviations in the frontal (lateral) plane. Higher values of these parameters indicate more movement and lower balance, while lower values indicate better stability (Winter et. al, 1990; Lee et. al, 2001, Cug and Wikstrom, 2014).

In the test procedures, three trials are performed for each position and each trial lasts 20 seconds. As a result, the three trials are averaged. Individuals are asked to keep their centre of gravity in a certain area on the platform to maintain their balance. During the test, the dominant leg of the individual is used for the assessment and a break period of 60 seconds is allowed between each trial. Whether the eyes are open or shut during the evaluation reveals the individual's dependence on visual cues. Especially when the eyes are closed, individuals need to use their proprioceptive (body position perception) senses more effectively, which provides important information about balance control (Parraca et. al, 2011; Cug and Wikstrom, 2014).

Weightbearing Lunge Test (WBLT): It is a practical and reliable test used to assess ankle dorsiflexion range of motion. The ability to dorsiflex the ankle is crucial for everyday tasks like walking, running, stair climbing, and transitioning between sitting and standing. (Powden et. al, 2015). This test differs from other measurement methods by better reflecting real-life functionality, especially due to its application in the weight-bearing position (Hoch and McKeon, 2011; O'Reilly et. al, 2017).

In the WBLT, the individual takes a lunge stance with bare feet and tries to bring the front knee closer to the wall, ensuring the heel remains flat on the ground (Langarika-Rocafort et. al, 2017). If the participant's knee does not reach the wall, the foot is gradually moved backward and the attempt is made again (Williams et al., 2013). When the maximum position is reached, the distance between the big toe and the wall is recorded (Chan et al., 2019). The test is performed on both the right and left foot, and the difference betwixt the two sides is assessed (Padua et al., 2019).

This test plays a crucial role in rehabilitation and sports performance assessments by evaluating ankle range of motion in a weight-bearing position. The results provide insights into the individual's ankle function, help identify movement restrictions, and assist in guiding the treatment process. (Zhang et. al, 2020).

Single leg hop (SLH) Test: SLH is a simple test used to determine the likelihood of lower limb injury in athletes and to evaluate functional performance. The athlete jumps as far as possible while standing on one leg and must remain balanced for 2 seconds on landing. If the athlete fails to maintain balance, makes other jumps or places the other foot on the ground, the attempt is invalidated. The test is normalized to the athlete's height, or the symmetry index is determined by calculating the dinstiction in span between the two legs.(Brumitt et. al, 2013).

SLH has been investigated as a prognostic indicator for lower extremity injuries, such as anterior cruciate ligament (ACL) tears and ankle sprains, conditions that are notably prevalent among female collegiate athletes. (Hootman et. al, 2007; Kerr et. al, 2015). Five different prospective cohort studies have examined whether SLH predicts the injury risk of pre-sport season test results. Among these studies, only one indicated that SLH alone was significantly associated with injury risk. For example, a study by Brumitt et al. found a predisposition to ankle and foot injuries in athletes with a greater than 10 per cent difference in distance between the two legs, but no association with knee or thigh injuries.

Two other studies combined SLH with performance tests such as standing long jump and lower-extremity functional test (LEFT). These combinations offered better results in determining injury risk in some areas, such as knee and thigh injuries (Brumitt et. al, 2018; Brumitt et. al, 2019). For instance, athletes with an SLH distance of less than 64% of their height were found to have a greater likelihood of knee and thigh injuries. (Brumitt et. al, 2019).

However, the use of SLH testing alone in pre-sport season screening is based on limited evidence (Walbright et. al, 2017; Warren et. al, 2019). The applicability of the results is restricted because of the differences in protocols and methods employed across the studies. For example, in some studies, athletes kept their arms stationary during the jump, while in others they were released. In addition, some studies performed a pre-test warm-up while others skipped this process (Brumitt et. al, 2013; Walbright et. al, 2017; Warren et. al, 2019)). Such differences make the standardisation of SLH difficult.

Despite these limitations, the SLH test remains a low-cost, simple method that can be easily conducted in field settings.. In particular, it is widely used in return to sport decisions after injury (Noyes et. al 1991; Hegedus et. al, 2015). To better understand the role of SLH in predicting injury risk, future large-scale studies with more consistent protocols are required. (Knowles et. al, 2006; Bahr, 2009).

Drop-Jump Test: It is a technique created to evaluate the likelihood of ACL injury. It is based on athletes jumping from a certain height (usually 30 cm), landing on the ground and then performing a maximum vertical jump. In this process, the neuromuscular control levels and landing mechanics of the athletes are observed. In particular, risk factors such as dynamic knee valgus (inward collapse of the knees) are evaluated. Research has shown that a high dynamic knee valgus angle is directly related to ACL injury (Hewett et. al, 2005). This test is an important tool for the inclusion of athletes in injury prevention programmes by screening them with a low-cost and easily applicable method (Redler et. al, 2016). In variations with fatigue, fatigue has been found to increase dynamic knee valgus, further increasing the risk of injury Liederbach et. al 2014;. Behrens et. al, 2015).

Closed Kinetic Chain Upper Extremity Stability Test (CKCUEST): This is a performance test designed to assess the stability and strength of the upper extremity within a closed kinetic chain. The athlete begins in a push-up position, placing their hands on the ground at a specific distance. The test involves performing as many touches as possible with diagonal movements between the hands within a set time limit. (Borms et al., 2018; Declève et al., 2020).

In addition to measuring shoulder strength and stability, this test also assesses dynamic control and neuromuscular coordination of the upper limb. The results of the CKCUEST allow comparing the performance of athletes according to reference populations (e.g., sport branch, age, gender) (Borms et al., 2018). In addition, the test shows a moderate correlation with shoulder strength and stands out with its applicability in the field environment (Declève et al., 2020).

Results

More comprehensively risk factors in injury prevention strategies in athletes should include their internal and external factors. Internal factors include age, sex, body type, strength and flexibility, psychological factors, prior injuries and so on. The latter also encompasses things like looking at social or environmental factors such as the surface turned on or off, the type of equipment used, outdoor climate, and even the influence of a coach. These risk factors, and more importantly, how to mitigate their potential effects, constitute an invaluable aspect of the management of training and competitional activities and protection of an athlete from trauma.

Such methods of assessment as Functional Movement Screening (FMS), isokinetic dynamometry, Y-Balance Test, and other tests for balance and stability allow researchers and in this instance coaches in particular to assess the age related physical shortcomings and movement deficiencies of the athletes. It is expected that once a loss of static or dynamic balance, associated with muscle imbalance and joint stiffness is diagnosed, training to rectify this specific problem will be possible. These devices are also useful in the evaluation of rehabilitation and reintegration of athletes into full weight bearing activities. In the area of sport injuries prevention, training devised by researchers is also multi-faceted and is supported by evidence and can be individualised according to the athlete. Warm-up and cool-down period including stretching and balance training have been found to suffice in injury prevention. Further also, internal attributes like proper quality of playing surfaces and correct types of footwear also assists in diminishing external hazards.

This helps the athlete in question to give optimum performance without compromising their health and their career duration and achievement in the long run. Finally, injury management in sports is a process which is complex and continues in nature where an emphasis is placed on the appropriate training of the athlete and reducing external factors and interdisciplinary strategies. Such practices ensure not only the physical and mental well-being of the athletes, but also enhancing the involvement in sports activities of any kind in a positive way.

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