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THE EFFECT OF MUSCLE FIBRIL TYPES ON PERFORMANCE IN FOOTBALL: A TRADITIONAL REVIEW

Muhammed Zahit KAHRAMAN
Asst. Prof. Dr., Muş Alparslan University, Muş, Turkey, mzkahraman04@gmail.com
ORCID: 0000-0003-1295-7611

Tayfun İŞLEN
PhD Student, Muş Alparslan University, Muş, Turkey, tayfun_spor@outlook.com
ORCID: 0000-0002-6226-6029

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ABSTRACT

Muscle structure is critical to achieving good performance in football, one of the most popular sports in the world. This review article aims to explain the effect of muscle fiber types on athletic performance in football based on the current literature. The muscles in the human body can be divided into cardiac, smooth, and striated (skeletal); the last of these affects athletic performance. Muscle fibers are classified into three different types. Type I (oxidative), which is red in color, is generally employed in long-term and slow-paced physical activity and is well-developed in athletes who engage in endurance sports. Type II muscle fibers are further divided into Type IIa (glycolytic oxidative) and Type IIb (glycolytic). Type IIb muscle fiber is white and contracts with great force in short-term physical activity and is crucial for sports requiring speed and strength. Type IIa is pink in color and possesses the shared features of Type I and Type IIb muscle fibers, including prolonged speed and strength. A literature search of the electronic databases Web of Science, PubMed, Medline, Cochrane Library, ULAKBİM (Turkish Academic Network and Information Center) and Google Scholar was conducted. Examination of acute and chronic studies investigating the metabolic effects of muscles on performance in football revealed that muscle fiber types differed according to the physical characteristics and training principles employed by the players. In addition, muscle fiber types were also different based on gender. The latter finding is explained by the fact that men have a larger body structure and greater muscle mass than women. Given that endurance, speed, and strength are key components of football, both Type I and Type II muscle fibers are important. Since the tasks undertaken by football players differ based on the position they play, the ratios of their muscle fiber types may also vary. Hence, the level of development of various muscle fiber types in football players constitutes an important aspect of athletic performance.

Keywords: Football, striated muscle, fibril type.

INTRODUCTION

There is no definite information as to when, where, or how the sport of football originated. Although games such as football can be traced back to pre-Christian times, football in its modern form was created in accordance with rules developed by a football association founded in England in 1863. While various assumptions have been made as to the time or place of its origin, no conclusive proof exists, and naturally, there are claims of many different civilizations contributing to the still-popular sport that has roots in these civilizations. The ball game, considered the basis of football in ancient Greece, Pharaonic, pre-Confucian China, and pre-Columbian civilizations of the Americas, is known from various historical sources (Kaplan, 2004). In truth, with the increase in football's popularity and the contributions of numerous societies, it will likely become a common heritage of societies (Akçınar, 2014). The first football club was founded in 1872 in the French city of La Havre, and subsequently, the establishment of other football clubs proceeded at an accelerated pace. The International Football Federation (FIFA) was founded in Paris, the capital of France, in 1904 with the participation of football associations representing France, Sweden, Denmark, Belgium, Switzerland, and Spain. Other European countries followed (Bernard, 2008), and Turkey became the 26th member of FIFA on 21 May 1923 (TFF, 2022).

Football is played by two teams with a maximum of eleven players each, with each match usually lasting 90 minutes. Each team attempts to score as many goals as possible against the other team. Players on each team play different positions on the field, fulfilling different duties and responsibilities (Ateş, 2005). The rules established for football, recognized worldwide, that must be adhered to include the dimensions of the football field, specifications for the ball, and general prohibition of the use of hands or arms (Kahraman & Bilici, 2021). The popularity of football may be attributed to the fact that it is played over a large area, its rules are simple, it does not require much equipment, and it can be played almost anywhere (Elik, 2017). It is one of the most popular sports in Turkey as well as the world and is a major sport due to its adaptability, accessibility, and potential for fun (Doğan et al., 2016).

Football, among the most popular and exciting sports in the world, has attained a unique position with regard to sports by virtue of the sheer number of players and the contact inherent in the game (Marancı & Müniroğlu, 2001). It is a team sport in which factors such as strength, speed, flexibility, agility, balance, and muscle strength all affect the athlete's performance. Explosive forces such as jumping, ball interception, and acceleration are also common phenomena as performance indicators. Football players must possess these skills in order to achieve success (Stolen et al., 2005). As well as incorporating physical aspects, football also involves cognitive powers, requiring a high level of game intelligence. For many, football is an important passion that requires balance and connects people of all age levels. Although it is highly competitive, with aggressive struggle and even harsh interference between teams during play, there is nonetheless a limited risk of damage to athletes' vital functions or physical condition. Along with features such as technical tactics and endurance, which form the basic structure of football, spiritual and pedagogical factors are also inherent in football. Most people's interest in football is represented by its physical aspect, game technique, strategy, and financial conditions, which are among the sport's characteristics. In the presence of compatible people, football constitutes an important sport, even providing an educational environment (Nas & Çolakoğlu, 2017).

Recognized as today's most popular sport, football has had a great impact and left its mark on societies around the world (Apaydın, 2000). The physiological and anatomical features of the athletes' body structures are among the primary factors that allow them to perform at the highest level. The correct execution of these functions is vital to improving performance, and muscle strength, muscle fibers, and physical fitness are critical for this system (Tortop, 2009). In football, overall physical fitness and coordination are the main characteristics affecting athletic performance (Biçer, 2003).

Although it is a sport in which aerobic and anaerobic energy systems are used together, football also requires asymmetric movements that determine the outcome of anaerobic efforts. The game of football consists of physical, physiological, and mental activities such as rapid and asymmetric deceleration, quick ball passing, throwing, jumping, and consistent combat with one player up against another (Akgün, 1992). In football, it is important to maintain aerobic and anaerobic metabolism throughout the match. A good aerobic capacity for the duration of a football game allows the player to increase the total distance traveled and to be more active. It also ensures a higher anaerobic threshold and less lactate production throughout the game (Edwards et al., 2003). The most important factors affecting anaerobic performance are age, gender, muscle structure, fiber composition, enzymes, and exercise. In addition to these, the length of muscle fibers, muscle cross-sectional area, muscle mass, and leg size and weight all play an important role in the power produced by the muscles under anaerobic conditions (Taş et al., 2013). Football is a team sport that requires both aerobic and anaerobic strength, endurance, and muscle on the part of its players (Canüzmez et al., 2006). Physical fitness parameters such as strength, speed, and endurance are of critical significance for technical and tactical effectiveness in football (Weineck, 2011).

Successful performance in football, as in most sports, depends on the maximum number of movements of the skeletal muscles and the ability to reproduce these movements. Dynamic or static muscle endurance enables the movement of muscles over a long period (McArdle et al., 2006). In order to reap the benefit of physical activity while exercising to increase activity, it is necessary to simultaneously examine the changes in the energy pathways involved in physical activity. Regardless of the intensity of physical activity, it causes a decrease in the rate of cellular catabolism under all conditions, creating the need for additional energy during the healing process (Proske & Morgan, 2007). In order for a football player to give the ball maximum speed, he must possess great muscle strength and contraction speed in addition to his striking technique. One of the factors that determine the rate of decrease of resistance is the magnitude of the force to be applied to the resistor. The external load applied to a living being moves in a counter-compression force. Therefore, in the absence of resistance, the rate of contraction of the muscle increases to its maximum, and at the same time, the increase in the resistance of the muscle causes a decrease in the rate of contraction (Guyton & Hall, 2001). The present study aimed to analyze information regarding the effect of muscle fiber types on athletes' performance in football, suggest starting points for field research, and provide relevant recommendations.

METHOD

In this review study, scientific texts and books on the effect of muscle fiber types on sportive performance in football were examined. Electronic databases of Web of Science, PubMed, Medline, Cochrane Library, ULAKBİM and Google Scholar were searched using relevant keywords. In the literature review, the titles and abstracts of the articles examining the effect of muscle fiber types on performance in football were reviewed by the researchers. Studies found to be suitable for the research subject were examined in detail. In addition, by examining the books, magazines and similar printed sources that can be accessed by the researchers, it has been tried to create an integrity on the effect of muscle fiber types in football on sportive performance.

EXERCISE AND TYPES OF EXERCISE

Generally speaking, exercise refers to physical activities performed in one's leisure time to improve or maintain physical strength, physical performance, and/or quality of life. The main goal of exercise involves planned, structured, repetitive, and purposeful activities in the process of improving or maintaining one or more components of physical fitness (Durusoy & Mutuş, 2021). Defined differently, exercise consists of actions planned at repetitive intervals and regularly involving basic body movements, in coordination with muscles and joints, and performed at light, medium, or high intensity depending on energy expenditure and metabolic rate, causing physical fatigue with an increase in heart rate and respiratory rate (Çelik, 2018). According to Özer (2013), exercise, as with a number of other components of the body's physical defense system such as balance, flexibility, etc., aims to improve or increase regular physical activity and to repeat this approach. Exercise includes various activities that help maintain an ideal body weight ratio, lower blood pressure and cholesterol, improve respiratory system functions, and reduce the risk of heart attacks. At the same time, exercise is an important factor in helping an individual attain self-efficacy, combatting the worries and stresses of daily life, and improving psychology and self-confidence (Stanton & Reaburn, 2014; Nogueira et al., 2018). As an effective method of stress reduction, we can assert that exercise positively affects people both physically and psychosocially (Demir & Türkeli, 2019). Exercise can be divided into two main types: aerobic and anaerobic.

Aerobic exercise includes activities requiring long-term rhythmic movement while expending less effort, without accessing the body's oxygen reserves (Kılınç et al., 1998). Aerobic exercise improves the cardiovascular system and respiratory parameters and increases the oxygen capacity carried to the muscles as well as the muscles' capacity to store oxygen and ATP (adenosine triphosphate) (Günay et al., 2008). During aerobic exercise, the amount of oxygen delivered to active muscles increases significantly. With prolonged aerobic exercise, angiogenesis in active muscles and increases in the number of blood vessels, myoglobin level, and ATP storage capacity all occur (Hall, 2015). Aerobic exercise employs the aerobic energy system used in the categories of sports that generally require endurance.

In contrast, anaerobic exercise involves brief yet very intense movements or activities. Since the oxygen uptake of athletes is insufficient in exercises performed at the maximal and supramaximal levels, the muscles use the anaerobic energy system (Morton et al., 2007). According to their positions in the field, short-term sprints performed by football players may be considered anaerobic exercise. In such exercise, lactate, the end product of anaerobic glycolysis, is removed from the cardiovascular system and muscles and subsequently transported to the liver and heart. It is then converted to glucose or glycogen in the liver, while the heart utilizes its own muscle to provide energy (Astrand et al., 2003).

MUSCLE TYPES AND WORKING PRINCIPLES

Movement is the main function of the body. Bones and joints act as the body's arms, and although they form a skeleton, they cannot move on their own. Muscle tissue membrane is formed by the coupling of stimulated cells by electrical changes resulting from their surface properties or shortening, and mechanically it can reduce conduction capability lengths (Akdeniz et al., 2012).

Muscle contractions generate the movement of the skeletal system, pump blood, and perform organic movements such as respiration and digestion. Skeletal muscles are of major importance in the development of athletic performance, as every kind of physical movement inherent in athletic activities is produced by muscles. Most physical activity generally occurs by virtue of muscle contractions. Relaxable muscles comprise 40-45% of the body weight of the organism (Akgün, 1992).

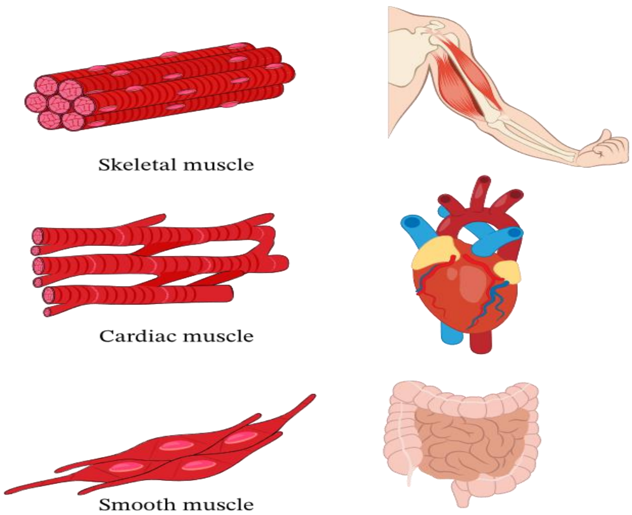

Figure 1. Structural View of Muscle Tissue Types (Nawga, 2022)

The five basic properties common to muscles are known as excitability, the ability to transmit impulses, contractility, elasticity, and viscosity.

- Excitability: Nerve tissue has a structure that can be stimulated by nerve impulses.
- Transmissibility: Nerve tissue can transmit nerve impulses across membrane surfaces.

- Contraction: The muscle’s response to a stimulus is muscle contraction. During contraction, changes such as shortening, lengthening or tightening of the muscle occur.
- Flexibility: The muscle can return to its original state when it relaxes after contraction.
- Viscosity: Muscles also possess a viscous mass feature. As the muscles contract with internal friction, they become resistant to internal and external forces that want to change shape. Therefore, when stopping occurs during muscle contraction, viscosity is responsible for protecting the muscles from dangers such as rupture and tearing (Günay, 1996).

Smooth Muscles

Stimulation occurs as a result of the involuntary contraction of the filament due to the random distribution of actin and myosin of the smooth muscles and the autonomic nervous system (not in any particular order). From a microscopic point of view, smooth muscle fibers do not show transverse streaks. Smooth muscles are known as involuntary contraction muscles due to their neural control and are found in organs such as blood vessels, viscera, and the intestines (Balnave & Thompson, 1993). They compose the muscles that cover a large part of the human body and function involuntarily, mediating the transmission of blood and fluids to veins and organs. This is also one of the muscle types affecting the expansion and contraction of blood vessels. Smooth muscles are structurally spindle-shaped and their nuclei are centrally located (Barrett et al., 2010). They are found throughout the human body, in artery walls, hair follicles, the bladder, intestines, uterus, throat, lungs, and many internal organs. The latter are known to play a role in involuntary actions. Contractions occur in smooth muscles at a slower rate than in other muscle types, rhythmically and very slowly, thus providing more time for contraction than skeletal muscle tissues. Smooth muscles have been reported not to fatigue (Wray et al., 2005).

Striated (Skeletal) Muscles

Skeletal muscles, in which the actin and myosin filaments are distributed in a specific order, have a striated appearance and are known as voluntary muscles. Movement is produced by the contraction of striated muscles stimulated by the somatic nervous system. The brain acts as the control center of striated muscles, which work in line with messages originating from the brain. In contrast with smooth muscles, striated muscles are fast working, contracting more rapidly than other muscle types; as voluntary muscles, they also tire quickly (Powell et al., 1984). Striated muscle cells are cylindrical and elongated and contain many nuclei. Striated muscles play a role in controlling the movement of the human body (Meyer et al., 2009). They are found in many parts of the body, including arms, back, legs, chest, fingers, and toes; in fact, they are present in every part of the body subject to voluntary movement. As the muscles attached to the skeletal system, they are therefore known as skeletal muscles (Campbell & Reece, 2006).

Functions of striated (skeletal) muscles:

- Movement: Muscle contractions for all kinds of actions, such as running, walking, and jumping, are performed by an organism's skeletal muscles.
- Protection: They protect the internal organs of the human body.
- Heat production: Some of the energy produced in the muscles is converted into mechanical work; the remainder turns into heat.
- Mechanical working ability: Skeletal muscles perform mechanical work through muscle contractions and relaxation. In other words, they ensure that the load is applied to a certain distance.
- Keeping the body upright: These muscles determine the position of the body in space in accordance with the effect of gravity, hence allowing the body to stand upright (Proske & Allen, 2005).

Heart Muscles

Cardiac muscles, which are structurally similar to striated muscles, are found only in the heart and have the appearance of striated muscles. Similar to smooth muscles, cardiac muscles work involuntarily. Although each heart muscle cell contains a nucleus, it also has the ability to be self-stimulated (automatic) (Demirel & Koşar, 2002). The cardiac muscle is located in the section of the heart called the wall. The heart muscle is necessarily involuntary because it is connected to the heart, which acts as its control center via the sinoatrial and atrioventricular nodes. The contraction force of the heart muscle is controlled by the neurohumoral mechanism of the autonomic system. The latter plays a role in the regulation of hormones coming to the heart, and therefore some hormones cause the heart's operating frequency to increase. A number of the disorders that occur in the heart muscle may take the form of severe contractions in the muscle and serious enlargement of the heart itself.

SKELETAL MUSCLE FIBRIL TYPES

Skeletal muscles, one of the fundamental organ systems that enable and control the movement of limbs in the human body, are directly connected to the bone tissue through tendons. This organization ensures that mechanical energy is transferred to the bones in case of narrowing of the fibrils and allows movement in the area of the joint where the bone is attached (Kraemer & Spiering, 2006; Astrand et al., 2003).

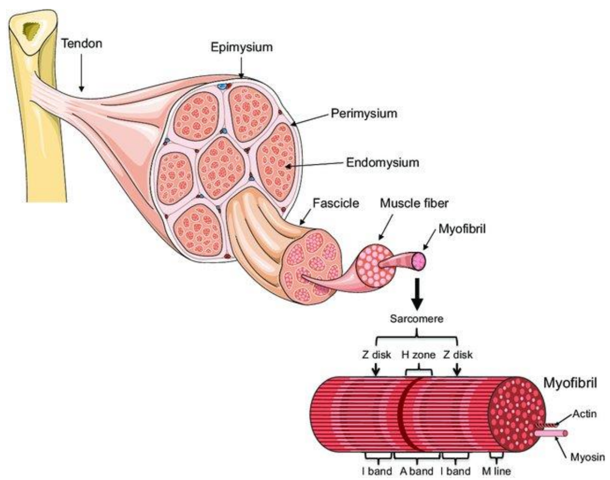

Figure 2. Muscle Organization (Bonetta & Bonewald, 2019; originally adapted from Servier Medical Art.)

Skeletal muscles are composed of fibrils and are differentiated from each other according to their morphological and physiological characteristics. Muscle fibers vary morphologically in diameter and color. White fibers have a thick diameter, while red fibers have a thin diameter. Skeletal muscle fibers also differ from each other in terms of vascular richness. Whereas there are few capillaries surrounding white muscle fibers, red fibers are very rich in capillaries (Öner & Öner, 2004). Muscle fibers are divided into slow contraction (Type I) and fast contraction (Type II) depending on the contraction rate and metabolic characteristics. Type II muscle fibers are further divided into Type IIa and Type IIb (Akalın, 2013).

Characteristics of slow twitch fibers (Type I):

- Due to the high number of myoglobins, the color of the muscle is reddish. This slow muscle fiber type is also known as “red muscle”.
- Although they do not tire easily, they also do not generate great power.
- They have a smaller surface area.
- They have difficulty growing.
- Their red color results from the iron-rich proteins they contain.
- They have excessive mitochondria.
- They possess high aerobic capacity but low anaerobic capacity.
- They are responsible for long-term endurance and low-intensity activity.

Characteristics of fast twitch fiber (Type II):

- These fast muscles are often called “white muscles” because their lack of myoglobin muscles gives them a whitish appearance.
- They generate great power but tire quickly.
- They enable rapid growth.
- They possess high anaerobic capacity but low aerobic capacity.
- They are responsible for short-term, high-intensity activity.
- They are divided into two types: Type IIa and Type IIb.
- Type IIa fibrils have more mitochondria than Type IIb, and are referred to as “fast oxidative”. They produce medium to high resistance in short- and medium-term activity.
- Type IIb fibrils are known as “glycolytic”, although they also possess oxidative properties. They do not have the aerobic capacity or endurance of slow-twitch fibrils.
- They provide instant and high-force generation for extremely brief periods of activity.

Table 1. Some Properties of Muscle Fibers (Ziyagil, 1995)

Fibril Characteristics	Type I	Type IIa	Type IIb
Muscle fiber diameter	Small	Medium	Large
Color	Red	Red	White
Mitochondria	Numerous	Numerous	Limited
Myoglobin content	High	High	Low
Myosin ATPase activity	Low	High	High
Glycolytic enzymes	Low	Medium	High
Oxidative enzymes	High	Medium	Low
Glycogen content	Low	Medium	High
Contraction rate	Slow	Fast	Fast
Main source of ATP	Oxidative phosphorylation	Oxidative phosphorylation	Glycolysis
Fatigue rate	Slow	Medium	Fast

METABOLIC EFFECTS OF MUSCLE FIBRIL TYPES IN FOOTBALL

Football is a versatile athletic discipline. Physiologically, both aerobic and anaerobic energy systems are employed, depending on the position played throughout the course of the game. The properties of "coordination, agility, flexibility, endurance, power, and speed", in which basic motor features are fully utilized during the game, are effective in achieving a high level of performance (Akgün, 1992).

There are basically two types of muscle fibers in the human body: fast-twitch and slow-twitch. The former ensures a great advantage in explosive-based sports. Short-distance runners have proportionally more of these muscle fibers. However, they do not represent an advantage for every sport, as muscles that contract rapidly and produce instant power also quickly become exhausted (Akyüz, 2007). Therefore, they constitute a disadvantage in sports that require medium- or long-term performance. Slow-twitch muscle fibers provide an advantage in sports that require long-term performance due to their ability to use energy longer than fast-twitch muscle fibers (Goldspink & Ward, 1979); in other words, these are the muscle fibers employed in endurance sports.

A comparison of athletes engaged in various athletic activities according to muscle fiber types reveals a difference in fiber distribution related to the type of sport and whether slow-twitch or fast-twitch muscles are utilized more (Malliou et al., 2003). In some sports, fast-twitch muscle fibers are more dominant than slow-twitch muscle fibers, while in others the opposite holds true. These distributions play an important role in the performance of the athletes. However, there is no apparent difference between training regimes and muscle fiber types, and genetic potential can limit success in sports. Nonetheless, it is known that some athletes are effective in long-term activities, while others are more effective in short-term activities (Amelink et al., 1991). Endurance athletes usually have more slow-twitch muscle fibers, while those engaged in sports requiring strength and speed have more fast-twitch muscle fibers. An excess amount of fast-twitch muscle fibers represents a great advantage for athletes who need speed and strength, whereas slow-twitch muscle fibers are advantageous for sports requiring endurance (Vincent & Vincent, 1997).

Since football is a sport played for a long time (at least 90 minutes) and over a large area, it requires endurance as well as power and speed. While a surplus of fast-twitch muscle fibers provides an advantage to football players with respect to speed and strength-based movements, the excess of slow-twitch muscle fibers offers an advantage in terms of endurance.

CONCLUSION

There may be differences in the ratio of muscle fiber types according to the physical and physiological structures of football players. Because it is a sport based on endurance, speed, and strength, football players must have muscle fiber types suitable for their positions in order to perform well. The fact that football players have dense Type I muscle fibers allows them to spend more time actually playing the game, which normally lasts 90 minutes (more when the game goes into overtime), and to resist fatigue. It may be important for front and central midfielders to possess a certain percentage of Type I muscle fiber, as they cover more distance in the game, counter the opposing team's players, and are constantly moving. As midfielders, these players may not require very good sprinting ability or high explosive force, but their aerobic capacity should be high. However, in fast attacks, hard shots, or counterattack situations, they are expected to exhibit a certain level of strength or sprinting ability. Defenders playing in the defense zone must have a good capacity for jumping in order to play the ball using their heads in corner kicks or in the middle zones. In addition, they require strong sprinting ability to reach the ball before the opponent strikers in intermediate passes made behind the defense and good leg strength for long passes. Therefore, Type IIb muscle fiber ratios should be higher in defenders in order for them to achieve high performance levels. Side players, on the other hand, use their zone as a corridor, constantly trying to transfer the ball to the opponent's area and make an intermediate pass, or by crossing the ball into the penalty area, getting the ball to their teammates, thus contributing to a goal. However, when the team of players covering the border areas faces a counterattack, they have to quickly return to their zones. The distance of sprint runs made for attack or defense in side players is usually about 40-50 m. For this reason, the ability to maintain high speed at longer distances needs to be more developed in side players; thus, these players require high Type IIa muscle fiber ratios. Forward players, who contribute to their teams by scoring and often play the biggest role in winning matches, try to score goals by striking the ball higher than the opposing defenders in the middle and by meeting the ball earlier in the intermediate passes made behind the defender. In some cases, forward players use their heads to serve balls coming from high up to their teammates. In addition, strikers, whose primary task is to score goals, also require advanced shooting skills. Such skills can only be developed when muscle groups such as the legs, hips, and back produce high levels of force. More often than not, goal kicks are achieved by striking the ball at very high speeds. Therefore, it is crucial that strikers possess advanced sprinting, jumping, and strength capabilities in order to perform all of these tasks well. Within this context, for optimal performance, strikers should have more Type IIb muscle fibers than other muscle fiber types. Regarding goalkeepers, they must have a very fast muscle contraction mechanism and good jumping ability to save shots exceeding 100 km per hour, meet balls thrown from close range, and handle the ball higher than the opposing strikers in the middle. Therefore, they also require higher Type IIb muscle fiber ratios, similar to strikers.

In conclusion, both Type I and Type II muscle fiber types are important in the sport of football, which is based on endurance, speed, and strength. Since the tasks undertaken by the players differ according to the position they play, the ratio of the muscle fiber types of the athletes playing on the same field may also vary. The level of development of muscle fiber types in football is of critical significance with regard to high performance on the part of football players.

RECOMMENDATIONS

In light of this information, it is advisable to determine which muscle fiber types the football players have to a high degree during the branching phase and steer them towards positions in line with their abilities. Furthermore, football players such as goalkeepers, forwards, and defenders should be preferentially selected from among those with muscle fiber ratios high in Type IIb, side and midfield players from those with more Type IIa, while front libero players should have high ratios of Type I.

ETHICAL TEXT

The present is a review article, and as such does not require approval by an ethics committee.

"This article complies with journal writing rules, publication principles, research and publication ethics, and journalism ethics. Responsibility for any violations that may arise regarding the article belongs to the authors."

Authors Contribution Rate: The 1st author's contribution rate to the article is 60%. The second author's contribution rate to the article is 40%.

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