Research on Muscle Fiber Composition in Humans

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Abstract. Accounting for 30%-40% of total body mass, skeletal muscles consist of multiple types of muscle fibers according to different histochemical classifications. Twitch-speed typing and myosin ATPase typing are two popular classification systems, both dividing muscle fibers into further subtypes. Type I muscle fibers are slow twitch that are suited for low-intensity and prolonged exercise, while type II muscle fibers are fast twitch that are suited for high-intensity and short-duration exercise. The proportion of muscle fiber types in an individual is determined by both genetic and environmental factors. Athletes who compete in different sports have different percentages of slow and fast twitch fibers, with endurance athletes having a higher percentage of slow-twitch fibers and power athletes having a higher percentage of fast-twitch fibers. Additionally, different resistance training can alter the proportion of muscle fiber types in the body, and it is important to follow different training plans according to their goals.

Keywords: muscle composition, typing system, resistance training

1 Introduction

This article discusses muscle fiber composition in humans. It first provides an overview of the different types of muscle fibers in human body and how they are classified. Then it delves into the importance of muscle fiber composition for athletic success and how resistance training alters the proportion of muscle fiber types. This article aims to provide a comprehensive understanding of muscle fiber composition in humans and its impact on athletic performance. The study of muscle fiber composition is of great significance to understanding the effects of resistance training and improving athletic performance.

2 Human Muscle Fiber Type Classifications

In human body, muscle tissues are divided into three types: cardiac, smooth, and skeletal muscles. Typically accounting for 30%-40% of our total body mass, skeletal muscles are comprised of different types of muscle fibers. The discovery of this heterogeneity dates back to as early as 1678, when Lorenzini first found about the distinction between red and white muscles in rabbits' limbs. Later in 19th century, Ranvier

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pointed out the differences in stimulation as well as contraction speeds between red and white muscles. The studies of skeletal muscle fibers have gone through several stages in the past few centuries and still remain an ongoing progress.

While different histochemical classification methods were developed along the way, twitch-speed typing system and myosin ATPase typing system are two popular methods in today's literature. The former typing system, put forward by Brooke and Kaiser in 1970, divide muscle fibers into fast and slow twitch, based on their twitch speed. The latter is based on the fact that the isoforms of myosin ATPase vary in different types of skeletal muscle fibers. The main functions of myosin ATPase are to act as an enzyme that helps cleave ATP to ADP, Pi, H+ and energy, while playing a key role in crossbridge cycling. The staining intensity of muscle fiber types varies in different pH conditions, and therefore a functional classification is found, reflecting a muscle fiber's functional capability without the need to determine its "twitch speed" [1]. Under this typing system, fibers are generally divided into type I and type II muscle fibers, with each consisting of several further classification.

Type I muscle fibers are also known as "slow twitch fibers" or "red fibers". They have a slower contraction speed but stronger endurance, and therefore are suitable for prolonged low-intensity exercise such as long-distance running, cycling, and other aerobic activities. These muscle fibers have a rich blood supply with a large number of mitochondria and oxidative enzymes, and thus can reduce fatigue by using oxygen to produce energy. By contrast, type II muscle fibers, also known as "fast twitch fibers" or "white fibers," have a faster contraction speed but are more prone to fatigue. They are suitable for high-intensity exercise such as sprinting, weightlifting, and other intense sports. These muscle fibers have relatively less blood supply, lower levels of mitochondria and oxidative enzymes, and mainly rely on the creatine phosphate system to produce energy.

3 Muscle Fiber and Athletic Success

Muscle fiber compositions are a crucial determinant for athletic success. According to studies, athletes who compete in sports that demand the most aerobic and endurance capacity have slow twitch fiber percentages as high as 90-95%, while those who compete in sports that demand the most anaerobic capacity, strength, and power (such as weightlifting and sprinting) have fast twitch fiber percentages ranging from 60 to 80% [8]. For instance, weightlifters have lower percentages of type IIC fibers and higher percentages of type IIA fibers compared to non-weight-trained men [7]. In addition, the proportion of slow-twitch fibers in the vastus lateralis muscle is higher in elite long-distance runners than sedentary men. This difference may explain the superior endurance performance of elite long-distance runners compared to sedentary men, because endurance athletes benefit from a substantial ergogenic advantage due to their high proportion of slow-twitch type I fibers. Conversely, it is desirable for power athletes to possesses relatively high proportion of fast twitch fibers, as these fibers can produce 5-10 times more peak power than slow-twitch fibers [3].

What's more, it is pointed out that a lower percentage of slow-twitch fibers can contribute to power performance. During high-velocity movements, the faster-contracting type II muscle fibers experience a drag force caused by the resistance of the surrounding tissues, such as tendons and ligaments, to the rapid movement. This drag force can negatively impact the efficiency of the muscle contraction and can result in decreased power output and increased risk of injury. A smaller percentage of slow-twitch fibers is conducive to reducing the drag, thus facilitating the power production [3].

Human performance, especially explosiveness and power, decreases as we age. Scientists have long been interested in the physiological reasons behind athletes' decline in speed and power as they age. They found that muscle thickness and type II fiber area decrease as people grow older, resulting in a decline in maximal and rapid force-generating capacity of lower limb muscles [10]. In a series of studies targeting a group of sprinters from 18 through 84, it is noted that their fiber type percentage did not change. Instead, the cross-sectional area (CSA) of those fibers changes at the rate between 6 and 11% per decade, depending on the type of fiber [4]. In addition, one research supports the importance of CSA from another angle, pointing out that the greater the CSA, the larger the pennation angle of those muscle fibers, hence the greater force production [9]. In these considerations, coaches of explosive sports may need to pay close attention to their athletes' CSA.

4 Effects of Resistance Training on Muscle Fibers

In general, the proportion of muscle fiber types is determined by both genetic and environmental factors, but exercise can alter the proportion of muscle fiber types, due to the structural and functional plasticity of muscle fibers. When human body undergoes different types of exercise training, the muscles develop corresponding adaptations. For example, prolonged aerobic exercise can stimulate the synthesis of mitochondria and oxidative enzymes in muscle fibers, thereby increasing the proportion of type I muscle fibers, while high-intensity strength training can stimulate the synthesis of myofibrillar proteins and muscle hypertrophy factors in muscle fibers, thereby increasing the proportion of type II muscle fibers. In addition, the nervous system in muscles can also influence the proportion of muscle fiber types. The type and density of neurons can affect the stimulation of muscles, thus influencing the distribution and proportion of muscle fibers [1].

Early research held that muscle fibers can convert from one type to another in response to stimuli such as training or deconditioning [6]. Recent research, however, has disproved the theory that resistance training can convert type I fibers to type II fibers, or vice versa. It is pointed out that, early studies finding increases in the percentage of type I or type II fibers after endurance and heavy resistance training were probably deceived by their misclassification of muscle fibers. Experts in muscle physiology agree that it is fiber sizes that change instead of fiber types. For instance, heavy resistance training can lead to hypertrophy of type II fibers, thus altering the percentage of a muscle's cross-sectional area [1]. However, recent research have indicated that training can convert type IIX fibers to IIA and vice versa [5]. Although these two types of muscle fibers both fall under the category of type II fibers, type IIA fiber's contraction speed is between that of slow-twitch fibers and fast-twitch fibers because they contain more mitochondria and oxidative enzymes, which allow them to produce energy supply for a longer time and sustain prolonged exercise. IIA muscle fibers also have a certain level of endurance and adaptability, making them suitable for light to moderate intensity long-term exercise.

Strength gain after resistance training is largely attributed to the increase in physiological cross-sectional area (PCSA) of skeletal muscle, which is a result of two main mechanisms: hypertrophy of muscle fibers and sarcoplasmic hypertrophy [8]. Resistance training can cause micro-damage to the architecture of the muscle, and stimulates proliferation of satellite cells. Satellite cells can facilitate the synthesis of contractile proteins through contributing their nuclei to a myofibril [2]. What's more, satellite cells may also combine existing cells to each other and create new myofibrils [12].

As for sarcoplasmic hypertrophy, the noncontractile components may be the key to muscle building, as different strategies of resistance training would lead to changes in these components, thus different muscle bulk and power. For example, 6 to 12 repetitions per set with training loads ranging from 67 to 85 percent of one's 1-repetition max (RM) lift are the recommended training volumes and loads for bodybuilding, whereas 1 to 3 repetitions performed at 75 percent or higher of one's 1-RM are for power enhancement [12]. Recent study has pointed out that a greater time under load might contribute to greater hypertrophic effects in type I muscle fibers [13]. Another research has pointed out in order to achieve better hypertrophic stimulus, one should carry out either high-load training or low-load resistance training to muscular failure [14]. What's more, it appears that compared to concentric contractions, eccentric contractions may provide additional advantages for contractile adaptations, muscle fiber recruitment, and hypertrophy response [11]. For injured athletes who cannot life heavy loads, it is advisable for them to utilize blood flow restriction technique [15]. It is significant for coaches athletes to be aware of their training goals and adopt suitable training plans accordingly.

5 Conclusion

This article discusses muscle fiber composition in humans. There are two popular methods for classifying muscle fibers: twitch-speed typing system and myosin ATPase typing system. The former divides muscle fibers into fast and slow twitch based on their twitch speed, while the latter is based on the fact that the isoforms of myosin ATPase vary in different types of skeletal muscle fibers. Muscle fiber compositions are a crucial determinant for athletic success. Athletes who compete in sports that demand the most aerobic and endurance capacity have slow twitch fiber percentages as high as 90-95%, while those who compete in sports that demand the most anaerobic capacity, strength, and power have fast twitch fiber percentages ranging from 60 to 80%. Research has shown type I and type II fibers can shift to each other as a result of resistance training. High-load training, low-load resistance training to muscular failure, and eccentric training have more advantages on contractile adaptations, muscle fiber recruitment, and hypertrophy. The article suggests future research focus on optimizing resistance training program design in order to achieve specific goals, such as increasing power or endurance.

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