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Exercise and Skeletal muscles: A love story

Abstract

The following paper explains the findings on the role of *Muscles*, which are complex hard-working underrated organs. There are 3 types of muscles: *skeletal*, cardiac, and smooth muscles (National Cancer Institute, n.d.). They are formed by thousands of *muscle fibers* that break down to smaller components. We can find 2 types of muscle fibers mainly *aerobic* or *anaerobic*, that can be subcategorized into 4 subtypes. The difference between muscle fibers causes them to have distinct responsibilities and uses. This contrast also shows in the *metabolic adaptations* that muscles undergo during *exercise*, which attributes their important functions in regulating *homeostasis* and affect different organs. Overall, this review highlights the anatomy, physiology, and biochemistry of muscles during exercise, which aim to support the healthy function of the human body.

Keywords: muscles, skeletal, muscle fibers, aerobic, anaerobic, metabolic adaptations, exercise, homeostasis.

I. Introduction

The human body is a complex machine formed and sustained by multiple sets of mechanisms that work by both positive and negative feedback that together allow homeostasis, the process that keeps this machine functioning properly (OpenStaxCollege, 2013). Every organ/system has specific roles to play in this fine balance system; for instance, the nervous and endocrine system work in the "communication department" (Villa-forte, 2022), while the pulmonary supplies oxygen with the help of the cardiovascular system that circulates blood, which includes muscles too (Villa-forte, 2022). Muscles are underrated organs; people link them only to exercise and movement, yet they have many important functions in the body. Muscles are also very adaptive and have the ability to change due to a process that we all know as exercising, which affects mostly skeletal muscles. In this essay we will be explaining the effect of exercise on skeletal muscles.

II. Types of muscles

First, we can find three types of muscles, smooth (non-striated, surround organs mainly in the digestive system, responsible for peristalsis, involuntary) (Hafen et al., 2023), cardiac (striated of rectangular shape, strong forming the muscle of the heart which contracts to create heartbeat, involuntary) (Saxton et al., 2023), and skeletal (striated, connected to bones, allows movement, voluntary) (Dave et al., 2023).

III. Skeletal muscle morphology

Skeletal muscles are the most abundant, constituting 1/3 of the total body weight of a person; they form an important combinatory system which is the musculoskeletal system that is responsible for movement. Skeletal muscles vary in size and shape, but they share a common structure, striations, which are formed by groups of muscle fibers. Each muscle fiber is made of myofibrils and each myofibril contains myofilaments with the most important structure, the sarcomere. The latter is the contractile part of the muscle. The sarcomere is formed by actin and myosin filaments which due to a nervous impulse, ATP and other factors will allow the gliding motion of the filaments that will cause the shortening of the sarcomere thus inducing muscle contraction (Dave et al., 2023). Other than movement, skeletal muscles are also responsible for body posture, protection of viscera, body temperature regulation, blood pressure regulation, nutrient storage, and glucose and lipid levels regulation (Gash et al., 2023).

IV. Types of skeletal muscle fibers

Although muscles might appear to be all similar, we can find differences in structure on the level of their fibers. We can find 2 types of muscle fibers: type 1 and type 2. Type 1 muscle fibers are called slow oxidative fibers and use an aerobic respiration pathway (in the presence of O_2). This type of muscle fiber is used for slow and steady needs. They have a slow contractile speed, are the most vascularized, are low in power, and have high amounts of myoglobin which means they are very red in color and are rich in O_2 and nutrients. Plus, they have high amounts of mitochondria which means that they can generate more energy. All of these criteria make this type of muscle fiber more resistant to fatigue and allow it to last for longer periods of exercise. For example, running or riding a bike is done in long periods of times and steadily (Scott et al., 2001).

Type 2 muscle fibers are divided into 2: Type 2A Fast oxidative muscle fibers use aerobic partially and mostly anaerobic respiration (without the presence of O_2). This type of muscle has fast contractile speed, moderate levels of power, a moderate level of vascularization and myoglobin which makes it less rich in color and O2 than type 1. It also has a moderate number of mitochondria, which makes it have less energy than Type 1, and it gets quickly fatigued. For example, when sprinting, we start with a quick sprint and slowly start losing power due to fatigue and less oxygen levels. Type 2B Fast glycolytic muscle fibers use anaerobic respiration. They have a very fast contractile speed and generates high power. They are the least vascularized and have the least amount of myoglobin which makes them relatively lighter in color and less oxygenated than the rest. They also contain little amounts of mitochondria meaning that they get very quickly fatigued. For example, heavy weightlifting needs maximum energy but is not steady or long in duration. We can also find hybrid fibers made of Type 1 and Type 2a fibers (1/2a hybrid) and Type 2a plus Type 2b hybrid (2a/2b hybrid) (Scott et al., 2001). Another thing about muscles is that we also have 3 types of muscle contraction: Isometric where there is no movement, Concentric where the muscle shortens, and Eccentric where the muscle elongates (Gash et al., 2023).

V. Metabolic adaptations and biochemistry

Having different types of fibers is not a coincidence. While exercising muscles go through metabolic adaptations and these adaptations cause many changes in the entire muscle. The adaptations are related to the muscle fiber type that is being used and is induced by exercising. Two types of adaptations happen: aerobic and anaerobic.

Aerobic adaptations are categorized into the following: fiber type and size changes, blood supply changes, myoglobin level changes, mitochondrial changes, biochemical changes.

While exercising steadily and frequently and with the presence of good oxygen levels, the favored type of fiber is Type 1 and somewhat Type 2a with some hybrid 1/2a fibers, which will cause the growth of this fiber in size, and it will be more activated and formed. For example, a recent study has shown that during aerobic training, Type 1 fibers of the participants increased from 42.6% to 48.6% (Plotkin et al., 2021). Muscles have a constant blood supply; the amount of blood that they receive increases while exercising and a phenomenon called angiogenesis which is the formation of new capillaries happens inside the muscle. This was shown in a study where interval-sprint training increased the numbers of capillaries by 20% (Laughlin & Roseguini, 2008). Another thing that we can note is that exercising also increases myoglobin levels in muscles. Myoglobin is a protein that carries oxygen and iron to muscles. When myoglobin levels increase, the muscle gets a boost in oxygen and iron levels (Roxin et al., 1986). When we are exercising, we need to mention that the energy needed is provided by the hydrolysis of ATP. But to hydrolyze ATP, we need to form it first. ATP is formed in the mitochondria, and since we are in need of more energy, mitochondrial activity will increase, and to compensate, their size and number will increase too (Porter et al., 2015).

Muscles also experience some important biochemical changes. The first thing that we can notice is an increase in VO2 max; it's the maximum amount of oxygen that our muscles, heart and lungs use to achieve a maximum level of training capabilities. So, the higher the VO2 max, the better we train and the stronger our body can get while working with oxygen. As we mentioned earlier, blood supply increases, new capillaries are formed and myoglobin levels increase, we will gain more surface area and oxygen which can allow our VO2 max to increase (Scribbans et al., 2016). Second thing we can notice is a myostatin activity decrease during aerobic training. Myostatin is a protein that limits the growth of muscles through negative feedback loops. Mutations in myostatin can cause an abnormal growth of muscles known as myostatin-related muscle hypertrophy. A study showed that aerobic exercising decreases myostatin activity thus allowing the growth of muscles (Hittel et al., 2010). Exercising can also cause an increase in insulin sensitivity, which means that cells will need much less insulin to regulate glucose levels (Venkatasamy et al., 2013). And finally, the most important biochemical alterations are glucose and lipid level regulations due to aerobic cellular respiration pathways. We mentioned earlier that we need ATP to have energy, which is formed through a complex process called the Krebs cycle in an anaerobic pathway. First, we have the process called glycolysis that happens anaerobically before the citric acid cycle. Glycolysis takes two glucose molecules, turns them into pyruvate and releases 2 ATP. Then, this pyruvate goes through the Krebs cycle in the mitochondria and generates ATP with the help of Acetyl-CoA and other reductive agents. Acetyl-CoA is made of triglycerides and the entire process needs glucose. This is how muscles generate energy and cause a regulation of glucose and lipid levels which increase during exercise (Wasserman, 1994).

Anaerobic adaptations are categorized into the following: muscle fiber type and size changes, cytoplasmic change, biochemical changes. Just like aerobic adaptations, muscle fiber type and size change in an anaerobic situation. Since we do not have O2, we will be exclusively using Type 2a, 2b and 2a/2b hybrids. Their size will increase, and they will be more recruited. For instance, a study has shown that after 8 weeks of sprint training, the participants had an increase muscle fiber Type 2a from 35% to 52% (Plotkin et al., 2021). Now for cytoplasmic changes, we mentioned earlier that muscles get energy from mitochondria due to the Krebs cycle; since we do not have oxygen in anaerobic training, energy formation will happen by anaerobic pathways. These pathways of energy formation happen in the cytoplasm; this will cause an increase of cytoplasmic density in muscle cells. And finally, muscles go through biochemical changes in anaerobic states too. Since we do not have oxygen, we need another pathway other than the Krebs cycle to form energy. In an anaerobic state, energy is provided either by glycolysis or the ATP-phosphocreatine system (ATP-Pcr). Glycolysis takes a glucose molecule and releases 2 pyruvate and 2 ATP. But since the Krebs cycle won't be using the formed pyruvates, the lactic acid fermentation pathway takes over. The 2 pyruvate molecules will turn into 2 lactic acid molecules. Then, the lactate molecules will be absorbed into the blood and go to the liver, where they will turn back into pyruvate and will form glucose through the process called gluconeogenesis. The problem with this pathway is that it can cause lactic acid accumulation in the muscle which will decrease the normal pH of the muscle, leading to muscle fatigue and painful cramps (Pfizer, 2017;Spurway, 1992). The second pathway is the ATP-Pcr system. This pathway uses a phosphocreatine molecule where the phosphate is broken, and it attaches to an ADP molecule turning it into ATP. This pathway is very fast, but the downside is that it needs 2-3 minutes to recover. Usually, the first provider of energy is ATP-Pcr during sudden anaerobic movements (Guimarães-Ferreira, 2014).

In conclusion, exercising has many benefits on many different levels in the human body. It can regulate hormones, blood glucose levels, and lipid levels, help with the heart and skeletal muscle strength, blood pressure and temperature regulations, and most importantly has great benefits on the mental well-being of a person. And when it comes to training, skeletal muscles are highly adaptive; they can easily change to conform to better conditions and to have better outcomes. But something important to note is that too much or too little of something can hurt you both ways. So little exercise will cause muscle atrophy which means muscle loss, while very harsh or intense training will cause the same problem and will especially cause damage to the bones and mental health (Kreher & Schwartz, 2012).

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