

# ***THE ANAEROBIC ASPECTS OF RESISTANCE TRAINING***

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## INTRODUCTION

Resistance training has become the common term to describe exercise involving any form of resistance, be it free weights, machines, elastic bands, pulley systems, or body weight as used in some exercise equipment. The lifting of weights comes under this broad umbrella and can be separated into a variety of categories (11) but most weight exercises can be performed for a variety of sets and repetitions and resistances, with somewhat different outcomes. There are some basic differences between training for strength and hypertrophy (muscle size) compared to training for power (explosive strength) which is a major component of most sports. However, all forms of resistance training rely on anaerobic metabolism for their energy needs. The purpose of this brief review is to explain how anaerobic metabolism supplies that energy and how these forms of training differ in their usage.

## MUSCLE TRANSITION

Strength is based on the ability to produce force, and the amount generated is dependent on the motor unit (neuron and muscle fibers it innervates) recruitment pattern that is established. Newton's second law of physics defines force as  $F = ma$ , with  $m$  representing mass and  $a$  standing for acceleration. Mass is represented by the workload or the amount of weight moved, and acceleration involves the speed at which the weight is moved. These two components of force set the neural recruitment pattern by determining the type and number of motor units to be used, and their rate of activation.

The neurons of motor units stimulate either type I or type II muscle fibers. Type I fibers (slow twitch) contain numerous mitochondria, require oxygen to function, produce low to moderate amounts of force, and are fatigue resistant. These characteristics make them ideal for supplying the bulk of the energy when not much force is required, but must be maintained for long periods of time, such as when standing. Type II fibers (fast twitch) on the other hand, have fewer mitochondria, are more anaerobic in nature, and produce more force than type I fibers. However, they do fatigue more rapidly than type I, and come in two varieties; IIa and IIx (formally termed IIb) (2,15). The IIa form of these fast twitch fibers have the ability to use oxygen to make Adenosine Tri-phosphate (ATP) but have a high dependency on anaerobic forms of metabolism, such as glycogen breakdown which produces lactic acid. Prolonged bouts of high intensity anaerobic training can therefore produce significant amounts of lactic acid (7) in type IIa muscle fibers. The accumulation of lactic acid within the type IIa muscle fibers causes the pH to drop, and leads to fiber fatigue (1). Type IIx fibers are almost purely anaerobic in nature and fatigue even quicker than IIa fibers but become the primary fiber of choice during maximal force production and when IIa fibers become fatigued (2,15). Several studies have shown that repeated bouts of resistance exercise can transform IIx fibers into IIa fibers (10, 13,16,). The transition of IIx fibers into IIa fibers is an important part of the adaptation that resistance training produces and is discussed in more detail in the subsequent sections.

## STRENGTH AND HYPERTROPHY ADAPTATIONS

In training to optimize hypertrophy, sets are typically performed at 60-75% of the 1RM (8-12 repetitions), and have a shorter work to rest ratio (1-1.5 min). Optimizing strength involves training at higher loads (80-90% 1RM) with fewer reps (4 to 6) and a longer work:rest ratio (2-3 min) (14). Although not obvious by the set and rep combinations, there is a lot of overlap between the physiological adaptations to hypertrophy and strength training, such that one still increases strength somewhat with hypertrophy-focused training and one still increases size somewhat with strength-focused training. The overall effect of these forms of training is that they push the muscles to the point of fatigue. Fatigue is defined as the inability to maintain force, and as indicated above can increase type IIa fiber numbers. The work of several investigators (10,

13,16) has shown that muscles of untrained individuals contain hybrid muscle fiber types in addition to the type I, type IIa, and type IIx fibers, the hybrids being muscle fibers that are going through a transition from type IIa to I (9) or from type IIx to IIa (10,13,16). The muscles of highly trained athletes, on the other hand, contain few hybrid fibers (2). The increase in IIa fiber number induced by strength and hypertrophy training enhances the anaerobic capacity of muscles by forcing them to adapt to repeated bouts of exercise that depend on anaerobic metabolism (6,12).

Although there are no definitive studies that have measured the enzymatic alterations that resistance training induces, the work of MacDougall et al. (8) does indicate the type of change that can occur. The subjects in this investigation underwent 7 weeks of sprint training on a cycle ergometer. Training started with four 30 sec maximal exercise bouts (Wingate protocol) with 2-4 min recovery between them, and the subjects trained three days per week. By the end of the 7 weeks they completed ten 30 sec rides three times per week. They found that the subjects' peak power, total work and VO<sub>2</sub>max was significantly increased by training, and attributed it to the significant increases in both aerobic (malate dehydrogenase, succinate dehydrogenase, and citrate synthase) and anaerobic (phosphofructokinase and hexokinase) enzyme activity. It might seem odd that the training improved both forms of metabolism until the accumulation of lactic acid and its ability to induce fatigue is taken into account. The primary effect of the muscle fiber transition is that IIx fibers, that are almost entirely anaerobic in nature, become IIa fibers that can use both aerobic and anaerobic metabolism. Therefore, the stress represented by repeated bouts of high intensity exercise converts the enzymatic composition of the IIx fibers to a IIa form of metabolism, and increases both oxidative and non-oxidative capability of the muscle. This enables the muscle to use a greater amount of glucose and/or glycogen with less build-up of lactic acid. This was demonstrated in a resistance training study conducted by Keeler (6).

## POWER ADAPTATIONS

Power forms of lifting are more explosive in nature than strength and hypertrophy training. Although the sets and repetitions and rest periods are similar to that of strength-focused training, the amount of weight lifted can be as low as only body weight, up to about 40% of the 1RM, except in the case of the Olympic lifts, which are performed at 70-80% 1RM. The lifter is required to exert maximal power to get the weight moving, and the only way that can be done is by training the nervous system to recruit as many type IIa fibers as possible. However, before an individual can train explosively they have to build a strength base.

Acceleration enables the establishment of movement velocity (speed) but is directly related to the rate of force development (RFD) generated with the initiation of movement. In strength and hypertrophy the lifter concentrates on the movement patterns of concentric and eccentric phase of the lift and tries to maintain a steady rhythm. The lift can even be performed slowly to maximize the fatiguing aspects of the exercise (3). Explosive lifts, on the other hand, are dependent on the neural recruitment of large numbers of type IIa muscle fibers to get the weight moving as quickly as possible. Therefore, any improvement in the RFD is a very important aspect of training.

Hakkinen et al. (4) demonstrated that strength and hypertrophy training can enhance peak strength but it does not affect the RFD, whereas power training does significantly improve the RFD. Although the anaerobic breakdown of glycogen (7) is used to some degree during an explosive lift, the primary energy source is ATP and the regeneration of ATP via the breakdown of creatine phosphate (CP). It is what gives the lifter the ability to explode and is why the rest period between lifts is longer. The extra time is needed to re-establish the ATP and CP stores of the muscle fibers. To date no one has examined

the ATP and CP turnover in power forms of lifting but these factors have been examined with sprint training.

Harmer et al. (5) sprint trained athletes for 7 weeks using a protocol that was similar to that used by MacDougal et al. (8) and found that the rate of anaerobic ATP usage following training was approximately half of what it was before training, whereas CP turnover was the same. They did not address this issue in their discussion but the data implies that the biomechanical improvements (better neural recruitment) might be responsible for the decline in ATP usage.

Anaerobic metabolism is dependent on the percentage of type IIa muscle fibers within the body. That percentage can be altered with training. Untrained individuals have a higher percentage of undifferentiated fibers (hybrids) than highly trained athletes. Resistance training is an effective way to enhance the muscle profile and increases the number of fast twitch fibers (type IIa) it contains. Although type I muscle fibers can increase in diameter with training it is the type IIa fibers that undergo the greatest hypertrophy with resistance training and are the basis for the increase in strength that is achieved from this form of training (2,15). The added benefit is that the anaerobic capacity also increases due to an enzymatic conversion that occurs with muscle fiber transition. Although power training depends more on ATP and CP than glycogen for energy needs it still requires a high percentage of type IIa muscle fibers. Once this fiber type is established with resistance training, power forms of training will enable an athlete to maximize the neural recruitment of type IIa fibers.

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