The Degree of variation in Muscle Mass and Fiber Type Composition of Mouse Skeletal Muscles as a Function of Diet and Exercise

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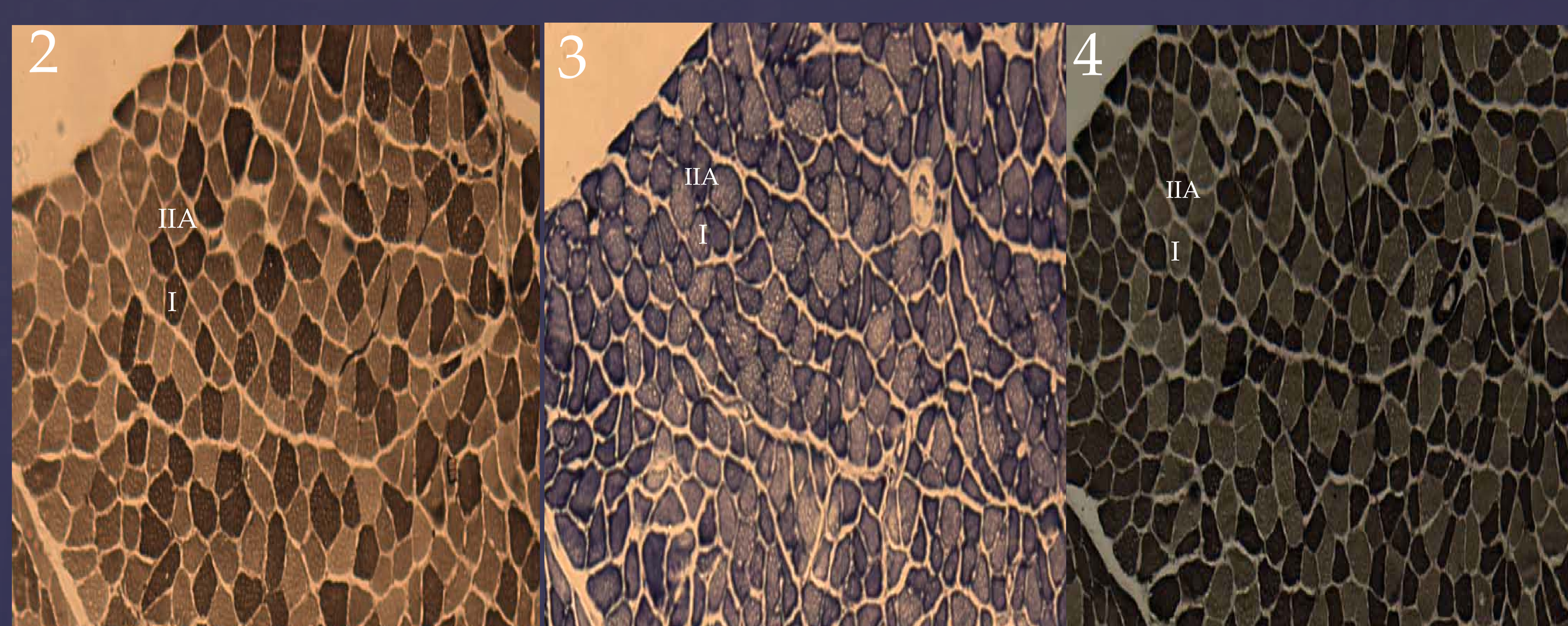
Abstract

Skeletal muscles are capable of adapting to physical demands by modifying their basic structural and physiological properties. These adaptations serve to optimize the efficiency with which individual muscles carry out their role in specific physical activities. Modifications involved in these processes have been confirmed with various laboratory techniques and include changes in muscle mass, fiber diameter, and even to the basic fiber type composition of the muscles. In this study, the changes in these characteristics were compared between two groups, one group which were sedentary and another who ran 5 days per week for up to 10 weeks. This was done to broaden our knowledge on this phenomenon and to potentially shed light on current therapeutic approaches to treating various muscle pathologies in humans. Current analysis of the data has revealed significant changes in the hind limb muscles of mice as a function of training duration. Plantaris mass significantly increases with respect to physical activity, also oxidative capacity increases as a function of training duration, while the relative proportion of different fiber types was about equal. Though the latter two were not as significant, we were able to find differences in fiber type proportions between exercise and non-exercise. Together, these data provide understanding into functional adaptations that occur under environmental response.

1. Ten mice running on a treadmill (15 degree incline) for 30 minutes 3-5 days per week. The other nine were sedentary 2-4. Cross sections of a single male mouse stained for oxidative characteristic, fiber type proportions, and fast and slow fiber types respectively. (Type I and Type IIA fibers are labeled in each figure in their corresponding locations)



Introduction

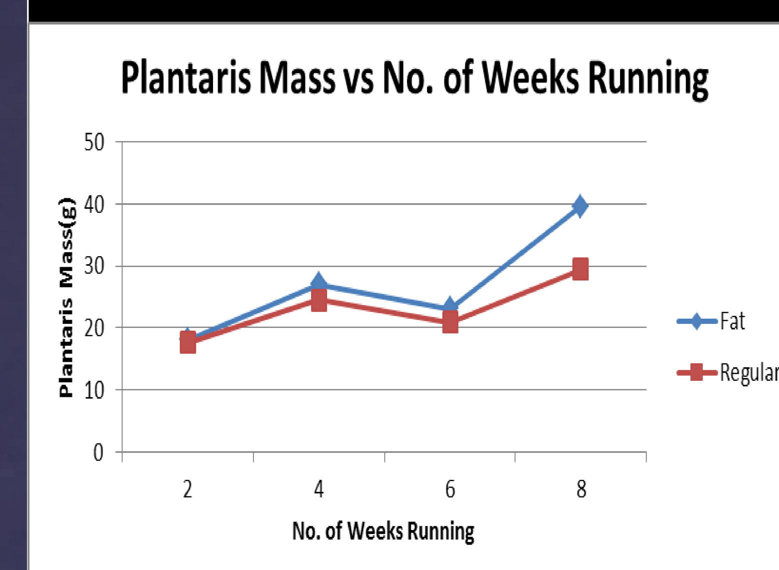
Muscle fibers of mice have been studied extensively over the past decade. Examination of these muscle tissue fibers can offer a better understanding of the underlying mechanisms involved in the remodeling process of muscles as a function of exercise, and possibly shed light on current healing approaches to treating various muscle diseases. There are varying proportions of different types of muscle fibers that each has distinctive physiological properties. The slow fibers possess specific combination of myosin proteins, which is the result for its slower speed of contraction and lower force; they also tend to be most resistant to fatigue. Slow fibers are characterized as type I. Unlike slow fibers, fast fibers are characterized as type II which are further broken down into type IIA, IIX and IIB fibers. These fibers are classified as being more anaerobic as well as more prone to becoming fatigue quickly; it has also been seen that these fibers possess fewer amounts of capillaries around each fiber. Skeletal muscles are varied and possess the capability to adapt efficiently to the demands under exercise training. Many studies have shown through different types of activities, such as functional overload, endurance exercise, and resistance training, that muscle fibers possess the cellular and molecular potential for dramatic shifts in fiber phenotype. Collectively, studies show that these fibers, Type I and Type IIB fibers represent two extreme ends of the spectrum with intermediate fibers, such as Type IIA/IIX or even IIB/IIX hybrids, share similar physiological features from both sides in variable degrees. Classified as one of the superficial muscles, the plantaris mainly acts with the gastrocnemius; this muscle was monitored in males and females with diet and running exercise taken into account, to look for changes in fiber diameter, capillary density and fiber type compositions of the muscle. These changes could be detected using ATPase and NADH diaphorase histochemical staining techniques. My initial hypothesis for this study was that an increase in running exercise intensity under regular diet would increase in the size of fiber diameter as well as the amount of capillary density which would lead to a shift of fiber type proportions towards fatigue resistant fibers in the plantaris muscle (a leftward shift on the Type I←→ Type IIA←→Type IIX ←→ Type IIB). The plantaris is mainly made up of type IIA fibers so it will probably lead to an increase in proportions of type I fibers relative to type IIA fibers in response to exercise. This hypothesis was based on the aerobic nature of the current proposed exercise; with continuous running exercise, constant supply of oxygen would be needed for the muscles and therefore, larger proportions of fatigue-resistant fibers (Type I) are required in order to withstand it.

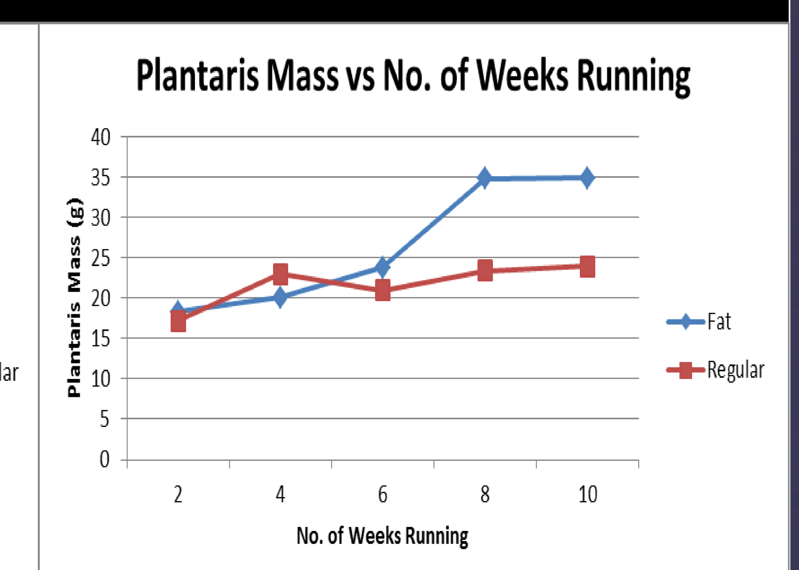
Exercise

1

Non-Exercise

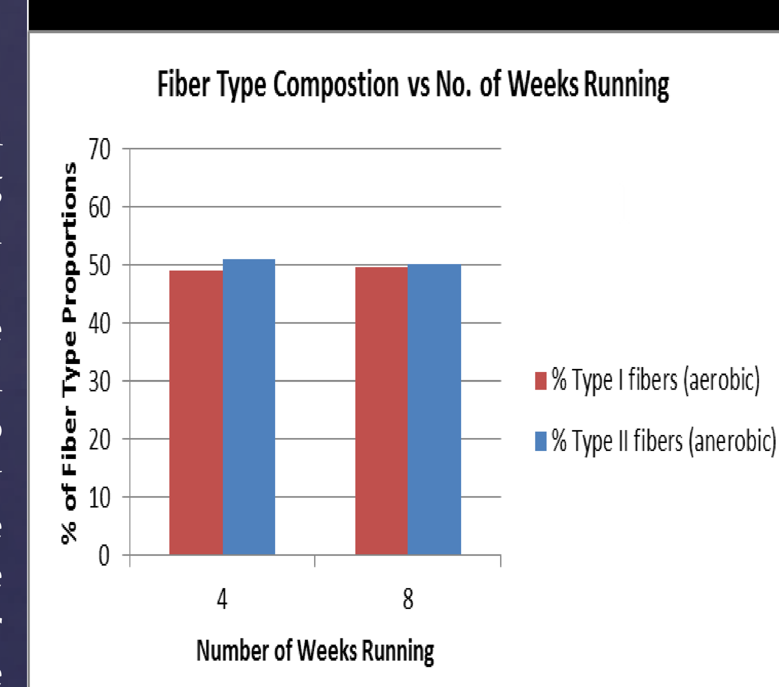
2

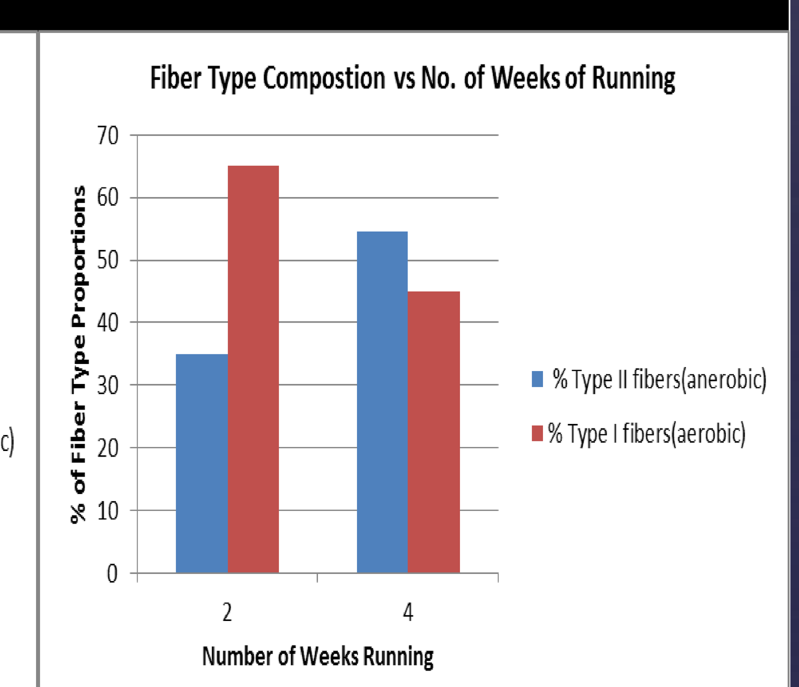




3a Males

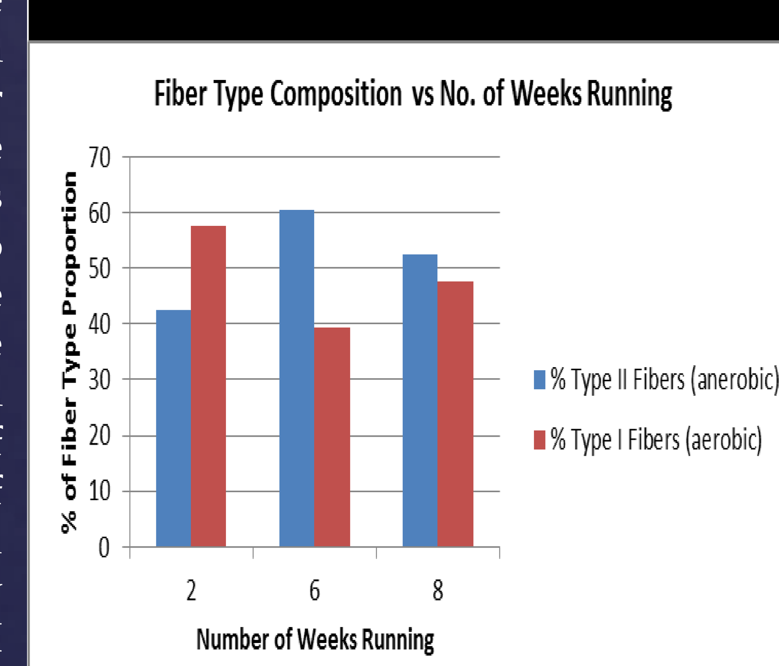
4a Males

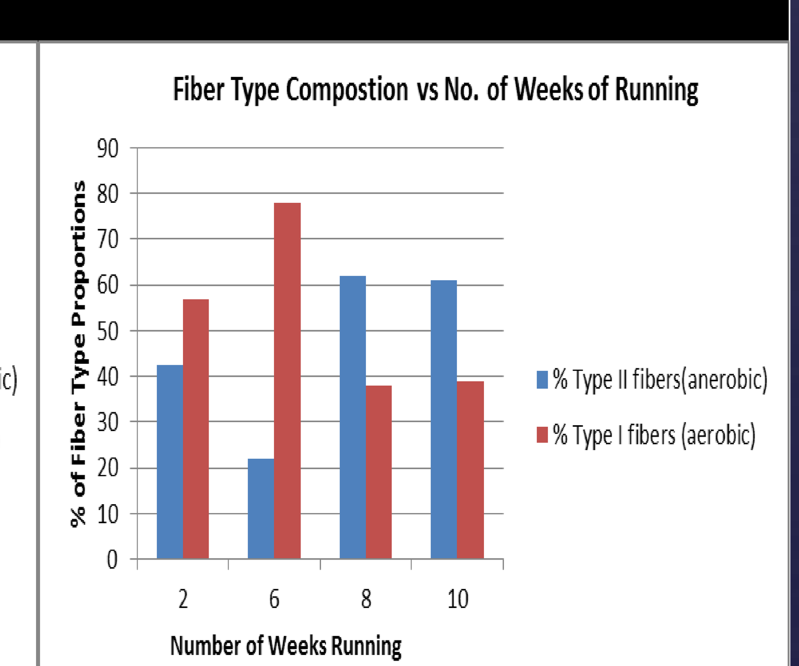




3b Females

4b Females





1-2: Males and females show a significant change in the plantaris mass of fat vs. regular diet. However, there is no significance in plantaris mass between exercise and non-exercise.
3: Males and females show no significant changes in the fiber type composition as a function of running exercise training duration
4: Males and females show no significant changes in the fiber type composition under no endurance

Methods

- Ten mice are to be run on a treadmill (15 degree incline) for 30 minutes 4-5 days per week
- Nine mice will be sedentary
- Each group are to be sacrificed at different stages of the experiment.
- Mice from each group are to be sacrificed at week 2, 4, 6, 8 and 10 of the experiment.
- The individual muscle tissues from the sacrificed mice will be isolated and frozen immediately and cooled with liquid nitrogen. These tissues will then be sectioned (8 – 10 µm) on a cryostat and transferred on to slides to be processed with different histochemical staining procedures.
- NADH Diaphorase staining will be used to determine the changes in oxidative capacity of the muscles, and myofibrillar ATPase staining will be used to determine the changes in fiber type composition of the muscle fibers.
- When staining for fiber types, ATPase will be used with an acid; pH value of 4.6 will be used.
- Micrographs of stained sections will be taken in the microscopy room and analyzed using features of Adobe Photoshop 7.0
- Plantaris Mass for each mice will be weighed using an analytical balance.

Results

The collected data has somewhat confirmed my initial hypothesis of how the mouse plantaris muscle would respond to the running exercise training duration. While there was no significant change observed in the fiber type diameter and fiber type proportions of the muscle after the 10 week training period in both male and female mice, there was a significant increase in the plantaris mass from regular to fat diet, this may have no avail towards my hypothesis, but I noticed that with exercise, plantaris muscle overall had a higher mass than the non-exercised which would agree with the idea that with training, one could increase the plantaris mass mostly that of muscle weight which as a result would tend to increase in slow fibers relative to fast fibers. Moreover, this part helped piece together my understandings of the fiber diameter that Type IIA fibers tend to have larger diameters than Type I, due to their densely packed myofibrils, large glycogen reserves, and relatively few mitochondria. With regards to fiber type composition, there was an increase shift of Type I fibers in exercise and an increase in Type IIA in the non-exercise, this led me to believe that the mammalian muscle's adaptation mechanism to the demands are indeed influenced by physical activity. One other interesting observation that was made was the obvious physical activity effect in the fiber type proportions that make up the plantaris muscle. Exercise male and female plantaris muscle had on average 50% type I fibers and 50% type IIA fibers, while non-exercise male and female soleus muscle had approximately 45% and 55% of type I and type IIA fibers respectively. This could explain how under no physical activity, the muscle fiber would tend to be under fast fibers in order to stimulate quickly and use large ATP for short movement; while under physical activity, you would have more Type I fibers for longer duration activities as we had seen in our experiment . It could be possible that the mice in this study have not reached that similar threshold to cause the expected changes. Future studies should aim to increase the running exercise intensity so as to confirm this possibility.

Acknowledgement

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