Busting muscle myths

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Skeletal muscle is the most abundant tissue in the human body. Known for its primary role in movement, muscle also plays important roles in regulating metabolism, maintaining body temperature and providing large stores of protein, carbohydrates and fats. Muscle cells (known as 'muscle fibres') can rapidly adapt to exercise or disuse by changing size and function. Many myths and misconceptions have proliferated through the years related to skeletal muscle, exercise training and human performance. Some of these myths have spanned centuries, but more recent research has passed doubt on these stories. In this article, we address common misconceptions, including the 'go big or go home' and 'if you don't use it, you lose it' approaches to training. Clarification of these myths could positively impact individual exercise programs/therapies and their outcomes.

Introduction

Human skeletal muscle is made up of specialized cylindrical muscle cells called muscle fibres that have many nuclei, referred to as myonuclei. As one of the most adaptable tissues in the human body, skeletal muscle can change quickly in response to resistance and endurance exercise or inactivity. Possible cellular adaptations include an increase or decrease in size (known as hypertrophy and atrophy,) the addition of more myonuclei in tandem with hypertrophy and the creation of additional mitochondria, which improves muscular endurance. These exercise-induced adaptations are generally accepted in humans and other mammals, but there are lingering misconceptions regarding the biological explanations and prevalence of these processes. This article shares insights into several pervasive myths about how muscle responds to different stimuli and questions how long some of those adaptations last if exercise cessation occurs. Three common myths include:

1. Muscle mass can only be gained by lifting heavy weights (Figure 1a).
2. A long layoff from exercise means starting from scratch (Figure 1b).
3. Muscle fibre 'type' is genetically pre-determined and cannot shift with exercise training (Figure 1c).

We will address the veracity of these claims by providing recent perspectives from the scientific literature.

Myth #1: Muscle mass can only be gained by lifting heavy weights

It is intuitive that progressively lifting heavier and heavier weight is the most effective strategy to make a muscle larger and stronger. This knowledge has been passed down since the time of antiquity. According to legend, the ancient Greek wrestler Milo of Croton (sixth century BC) carried a young bull on his shoulders every day until he was an adult. As the bull got heavier, Milo's muscles became larger until he finally became one of the biggest and strongest men of his time. This story is perhaps one of the oldest examples of 'progressive overload' during resistance training, and at the heart of the story is the effectiveness of lifting heavy weight for muscle hypertrophy. This belief has been pervasive until recently. About a decade ago, a group of researchers in Canada sought to rigorously test whether lifting heavy weights was a prerequisite for maximal muscle hypertrophy in young untrained men. To the surprise of many, lifting lighter loads was equally as effective at increasing muscle mass as lifting heavy loads, so long as the light load lifting was performed with very high intensity and effort. Over the last decade, researchers have sought to understand how training with lighter loads could elicit the same muscle growth as heavy lifting. The potential mechanisms are not yet fully detailed, but it is becoming evident that lighter load with high exertion is effective for producing maximal hypertrophy, but perhaps not maximal strength (see Figure 1a). The hypertrophic potential of training with lighter loads for increasing muscle mass could have implications for athletes recovering after injury, when lifting very heavy loads is generally not recommended or feasible. Overall, challenging the commonly held belief of 'go big or go home' with respect to weight training illustrates the need for deeper investigation into how muscle mass is regulated and how best to structure training regimes to optimize muscle hypertrophy and strength.

Myth #2: A long layoff from exercise means starting from scratch

When a muscle fibre gets larger with resistance training, the number of myonuclei also increases (i.e. nuclei inside the multinuclear muscle fibre, see Figure 1a,b). It is believed that myonuclei cannot divide to increase in number. New myonuclei must therefore be acquired

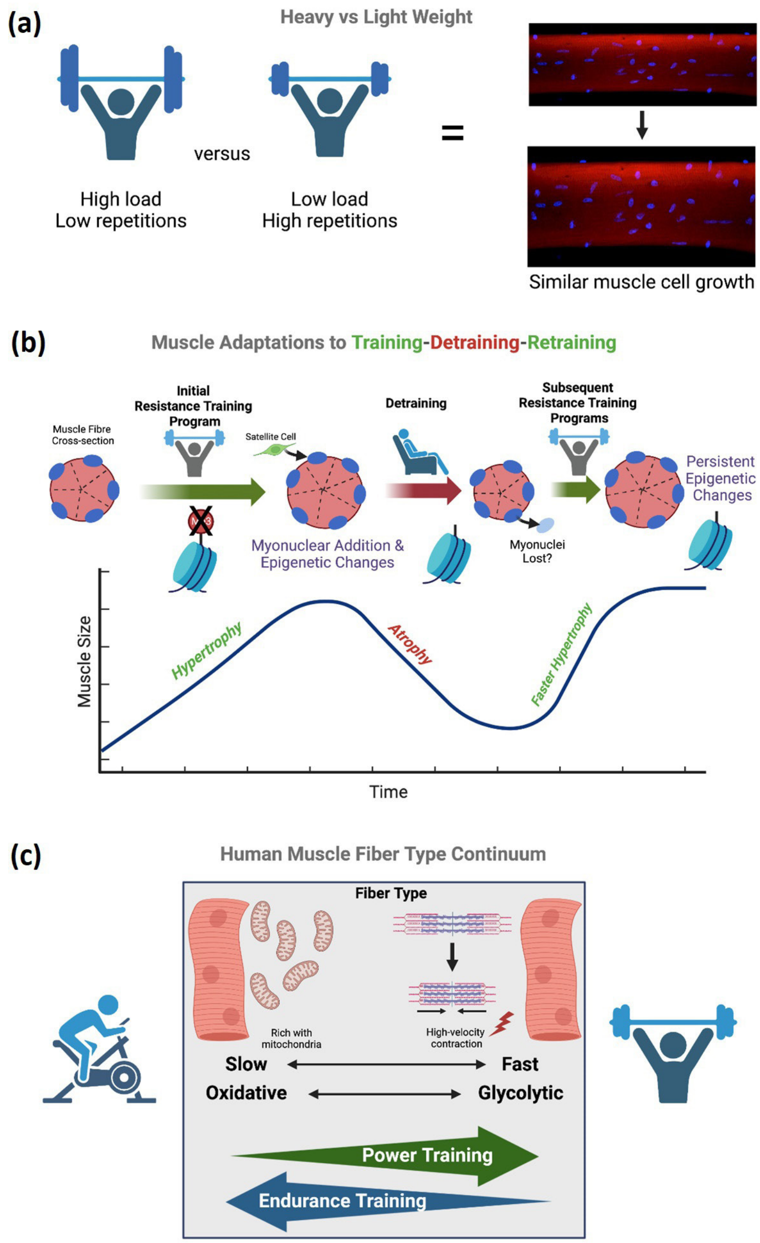

Figure 1. Muscle fibres can rapidly adapt to exercise by changing size and function. (a) Muscle growth can occur with high or low load weight training. (b) Muscle growth with exercise training is accompanied by epigenetic changes to myonuclei that persist, providing a type of molecular 'muscle memory' that may facilitate more rapid re-growth. (c) Muscle fibre types exist on a functional continuum (slow/oxidative to fast/glycolytic) and can shift depending on the type of exercise training (slow-to-fast with power/speed training; fast-to-slow with endurance training).

from muscle stem cells (satellite cells). A long-standing belief was that the myonuclei that are gained through the process of resistance training are not lost when the muscle fibre becomes smaller during detraining. Maintaining a high number of myonuclei in a muscle fibre after training has ceased and adaptation is lost could confer the benefit of more rapid growth when training resumes. While this may be true in the short term, longer-term studies in mice and humans have questioned whether the myonuclei gained during muscle growth are indeed permanent.

Is the saying 'if you don't use it, you lose it' true when pertaining to myonuclei? Perhaps, in some cases, but recent research suggests it is more complicated than just maintaining myonuclear number. Recent evidence in humans and mice is beginning to suggest that molecular 'epigenetic changes' to the DNA within the myonuclei may have a 'memory' of previously being trained may have a 'memory' of previously being trained (see Figure 1b). Epigenetics is a relatively new field that studies changes in how genes are accessed – usually caused by the environment – without altering the DNA sequence. When people undergo a period of inactivity after being previously resistance trained, they can gain muscle mass faster than if they had not had any previous resistance training exposure. In general, these epigenetic changes in muscle fibres increase the activity of genes involved in muscle growth and muscle cells therefore 'remember' how to grow. This intrinsic molecular 'muscle memory' may have a significant role in facilitating more rapid training-induced adaptations if having been trained previously. More recently, the ability of myonuclei to replicate their own DNA has recently been challenged, adding yet another layer of complexity with exercise adaptation for muscle biologists to unravel. Understanding how muscle becomes more trainable has implications for enhancing muscle health when muscle adaptability to exercise declines, such as during aging.

Myth #3: Muscle fibre 'type' is genetically pre-determined and cannot shift with exercise training

Muscle fibres come in different 'types' categorized by their speed of contraction (slow↔fast) and metabolism (oxidative↔glycolytic) contraction (slow↔fast) and metabolism(oxidative↔glycolytic) (see Figure 1c). Muscle contraction occurs when myosin, a large motor protein, 'grabs' a smaller protein actin and pulls it, thus causing muscle shortening. There is a wide continuum of fibre types in humans based on *my*osin *h*eavy *c*hain (MyHC) types, with MyHC I being slow-twitch and MyHC IIa and MyHC IIx being fast-twitch. Faster fibre types usually contract with more velocity but are quick to fatigue, the inverse being true of slower types. In fact, MyHC IIa fibres produce five to six times more power than MyHC I, while MyHC IIx fibres produce ~20× more power than MyHC I fibres.

In humans, skeletal muscles (e.g., the quadriceps muscles of the thighs) may be composed of ~40% 'slow-twitch', ~40% 'fast-twitch' and ~20% 'hybrid' slow/fast muscle fibres. Textbooks still convey that the distribution of fibre type – the proportion of slow-twitch (endurance oriented) vs fast-twitch (power producing) – is genetically pre-determined and cannot change appreciably with exercise training. The inability to 'switch' fibre types in muscle could mean that athletic performance is largely pre-determined. Slow-twitch vs fast-twitch predominance could influence muscle endurance and sprinting ability, respectively. In 2006, it was reported that 16 weeks of marathon run training in young healthy humans could increase slow-twitch fibre type proportion by ~10%. These findings hinted that fibre-type proportion can transform based on the type of exercise being performed. Along with many other corroborating findings, it is now well accepted that fibre type can change based on exercise training modality. A recent case study further illustrated the magnitude to which fibre type can change with training. Genetically identical twins with divergent lifestyles were recruited to have thigh muscle biopsies taken. One twin was inactive and sedentary for his whole life, while the other was a sub-elite triathlete that engaged in heavy endurance training for most of his life (both were 52 years old at the time of study). The inactive twin had <40% slow-twitch muscle fibres in his thigh, whereas the triathlete had >90% slow-twitch fibres. The molecular mechanism of fibre-type transformation with exercise is still under investigation, but the current evidence is clear: exercise can change your fibre type. Since muscle is the largest tissue in the body, shifting fibre types with exercise has important implications for overall metabolic health and whole-body function.

Conclusions

Skeletal muscle is a fascinating tissue with the ability to profoundly adapt to exercise training. Research in the last decade has taught us that (1) muscle can grow substantially with low-load weight lifting, (2) muscle may have an epigenetic 'muscle memory' of previous exercise training that could facilitate future adaptability and (3) muscle fibre types can transform to a significant degree with exercise training. Muscle researchers and clinicians face many challenges ahead, but understanding the mechanisms of how healthy muscle adapts to exercise may inform therapies for improving muscle health during aging, disuse and disease. ■

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Additional articles on skeletal muscle related to the work from the authors

- *New York Times* article about "muscle memory": https://www.nytimes.com/2022/01/05/well/move/muscle-memory-exercise.html;
- *Men's Health* article about muscle fiber type: https://www.menshealth.com/fitness/a27559880/muscle-cell-fiber-research-mentality/;
- 25 Min Physiology of Muscle Hypertrophy by Dr. Andy Galpin (YouTube, 2/28/2021): https://youtu.be/QMk88IswzMQ
- Andrew J. Galpin, Nathan Serrano, & Kara Lazauskas article about fiber type transitioning (Renaissance Periodization Strength Article, 11/2017): https://rpstrength.com/muscle-fiber-types-change-training-end-unfounded-debate/
- Irene Tobias, PhD and Andy Galpin, PhD scholarly review on muscle fiber type (*J Appl Physiology*, 05/11/2020): https://journals.physiology.org/doi/full/10.1152/ajpcell.00107.2020