Skeletal Muscle Mass and Function with Increased Use or Disuse: Lessons from space to benefit sports performance and health promotion

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Since the early era of the manned spaceflight program in 1960’s it has become evident that space crew suffer from muscle atrophy and deteriorated musculoskeletal function. Hence, numerous studies of real or simulated weightlessness ranging from a few weeks to several months duration, have reported marked decreases in maximal voluntary force mainly due to muscle loss. Weight-bearing muscles are more affected than non-weight bearing muscles. The rate of e.g., triceps surae or quadriceps muscle atrophy during the course of one to six weeks of simulated spaceflight may exceed 2% per week. Decreases in isometric, concentric and eccentric strength are even greater.

Regardless of which mechanism(s) are responsible for the loss of skeletal muscle mass, countermeasures to this effect are imperative on the International Space Station (ISS) and other future long-term orbital missions. The most attractive solution to this problem seems to be the implementation of some kind of in-flight exercise program alone or combined with other countermeasures e.g., pharmacological interventions or artificial gravity. Collectively, the results from a myriad of human studies show that resistance type, but not aerobic endurance exercise, promotes increased muscle size and strength. It therefore seems logical that resistance exercise would offer an important stimulus to maintain muscle mass and strength in weightlessness.

Designing resistance exercise programs for use in a weightlessness environment is challenging. First, there are several physiological aspects to consider. Any exercise task effective in promoting muscle hypertrophy should comprise both concentric and eccentric muscle actions, and in any particular exercise should muscle tension be near maximal. Moreover, in an environment where there is a shortage of food, water and oxygen, energy
expenditure must be kept low. Also, there are certain technical aspects that must be taken into account when designing exercise equipment to be used in space. In the absence of gravity, barbells or dumb-bells for example, cannot be used. It is therefore imperative that the gravitational pull from a lifted weight must be replaced by an alternative force or power source. This paper will discuss how findings from recent space related muscle research has been employed for terrestrial use. More specifically, molecular and global skeletal muscle adaptations to weightlessness or unloading with or without resistance training will be covered. Further, the use of resistance exercise paradigms, designed for space travellers to combat muscle atrophy, to optimize athletic performance and benefit in health promotion will be discussed.