Lecture 6: Skeletal Muscle Plasticity (Adaptations of Skeletal Muscle to Strength/Resistance and Endurance Training

Learning Objectives
- Compare and contrast the adaptations of skeletal muscle to:
  - Endurance training
  - Resistance/strength training
- Understand concepts of:
  - Overload
  - Specificity

Limitations to Exercise Adaptation
- Muscles will adapt optimally to exercise that moderately exceeds their capacity.
  - Muscles are really resistant to change.
- Requires a gradual progression in training load in order to maximize performance.
- Limits to the physiological and anatomical development that can be achieved.
- When we force the muscle to do things it's not used to, theres an alarm phase, then a resistance phase when it's adapting, and then an exhaustion phase if overworked. (GAS, see diagram →)

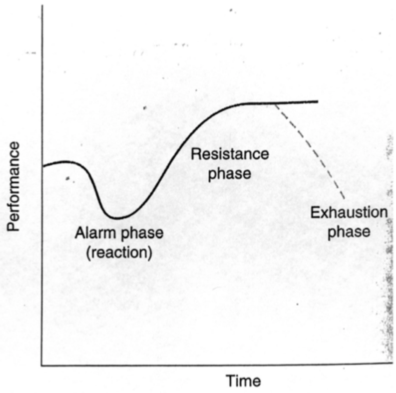


Figure 22.1 The General Adaptation Syndrome (GAS).

Limitations to Exercise Adaptation
- Genetics
- Different adaptive potential for exercise.
- Hence why athletes that exercise under identical conditions often showed different levels of improvement.

Muscle Plasticity Through Electrical Stimulation
- Electrical stimulation gives us clues for how the muscle will react when exercised.

Electrical Stimulation vs. Exercise Training
During Voluntary Muscle Contractions
1. Muscle tension can be varied over a wide range of varying number of active motor units to produce fine or smooth movements. (Through Heinemann size principal)
2. Motor units are activated according to size principle.
3. During sustained contractions motor units activate asynchronously (as one becomes active the other ceases its activity – for submaximal tasks).

During Electrical Stimulation
- All of these activation patterns are abolished.
- Activates all motor units synchronously and with the same impulse pattern.

Advantages of Electrical Stimulation
- Standardised model – Adaptive responses occur in a reproducible, well- defined manner.
- Elicits maximal adaptive potential of muscle.
- Adaptations occur in a shorter period compared with voluntary activity.
- Adaptations restricted to target muscle; therefore, minimise systemic effects.
- Does not induce muscle damage in rodents, allowing for 'clean' investigative model.

Principles of Training (1)
Overload (Progressive overload)
- A system or tissue must be challenged with an intensity, duration, or frequency of exercise to which it is unaccustomed.
- Over time the tissue or system adapts to this load.

Principles of Training (2)
Specificity
- The training effect is limited to the muscle fibres involved in the activity.
- The muscle fibre adapts specifically to the type of activity (S.A.I.D)
- Mitochondrial and capillary adaptations to endurance training.
- Contractile protein adaptations to resistance exercise training.

Adaptations of Skeletal Muscle to Endurance Training
- Changes to central and peripheral circulation.
- CO, muscle blood flow.
- Muscle metabolism; Muscle respiratory capacity.

Fibre Composition
- Little/no change in fibre size of fibre proportions.
  - i.e. no fast to slow twitch fibre conversion.
  - Subtle changes among fast fibre subtypes: IIB → IIA or intermediates.
- Chronic training may recruit IIB (glycolytic) fibres in a manner normally expected of the IIA fibres. More oxidative.

Endurance Training
Oxygen Delivery
- Capillarisation.
- 15% *increase* in # of capillaries after 8 weeks training.
- Greater exchange of gases and fuels between blood and working muscles.

Energy Production
- Mitochondrial capacity to produce ATP is *increased*.
- Number, size and efficiency of mitochondria.
- Oxidative enzyme activity: SDH, CS.
- Release of FFA, shift to a reliance on fat for ATP release.

- The greater the max uptake of oxygen, the more muscle activity. (e.g. SDH enzyme)
- Aerobic enzymes (E.g. SDH, MDH) are higher in endurance exercise, and anaerobic (CPK, MK etc.) is higher in sprint training.
- Different types of exercise will increase the proportion of type I or II fibres. Normal non-exercise produces 50-50 split.

Adaptations of Skeletal Muscle to Resistance Training

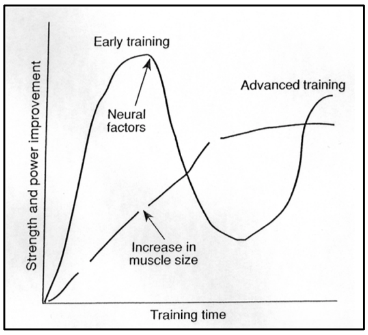
- Hypertrophy - ↑ in size of muscle (fibre)
- Atrophy - ↓ in size of muscle (fibre)
- Muscle size generally correlated with strength.
- Is it a simple cause-effect relationship though?
- ↑ in size of individual fibres or ↑ in muscle fibre number? (Hypertrophy vs. hyperplasia)
- Fibre number is fixed at birth, but the # of myofibrils and/or filaments or connective tissue could ↑.

Specificity of Training Response

- Greatest change accompanying strength training seen in the exercise itself rather than objective assessments of strength/size.
- Improvement in exercise performance through familiarity.
- 'Task specificity'

Changes in Strength with Training

- First changes in muscle strength during training are result of altered neural drive.
- Large, fast motor units are only recruited at higher forces.
- Training can facilitate recruitment of largest and fast motor units.
- Changes in pattern of motor unit stimulation or synchronization of motor unit firing.
- Neural pathways in learning are complex.
- Even though many tasks seem to require little skill, we have acquired many skills unconsciously.



Interplay between neural and muscle tissue factors →

- Muscle can get to a plateau phase.
- To get past this, the exercise has to be adjusted, and the neural factors come into play, and hence results in further muscle changes.
- Pharmacological enhancements can change the environment which can lead to muscle growth promotion (e.g. steroids)

Stimulus for Increase in Strength

- Which training protocol is best?
- Generally, high forces have to be employed before new growth occurs.
- Is it the high force or the fact that all motor units are recruited?
- Protein synthesis → protein degradation (net protein accretion)
- Stimulation for hypertrophic response.
- Increase in muscle fibre size.

Adaptations to Heavy Resistance Training

- All muscle fibres get bigger because they are all recruited in consecutive order to produce high levels of force.
- In advanced lifters, the CNS might adapt to allow these athletes to recruit some motor units not in consecutive order.
  - i.e. recruiting larger ones first with greater production power or speed.

Hypertrophy vs. Hyperplasia

- Can fibre hyperplasia occur in muscle as a consequence of strength training?
- 2 possibilities for hyperplasic response:
  - splitting of hypertrophied fibres in two or more daughter fibres.
  - Satellite cell proliferation following muscle damage
- When muscles grow to a particular size, are they so large and aren't viable?
- Does the muscle die?
- Solution may be to split the cell into 2, instead of becoming anoxic.
- E.g. In the Japanese quail, more and more weight is added to their wings, and this leads to increased muscle fibres. This reflects hypertrophy and hyperplasia due to resistance training.

Key Concepts of Physiological Adaptations to Exercise Training

- Each person responds differently to each training program.
- An individualised training program is needed to address an athlete's specific needs and response.
- Magnitude of physiological or performance gain is related to size of athlete's adaptation window
  - i.e. genetic ceiling for change.
- Degree of physiological adaptation depends on the effectiveness of exercise prescriptions used in the training program.
- Exercise training programs need to change and provide variation to keep exercise stimulus effective in eliciting positive changes or maintaining sport fitness.
- Training for peak athlete's performance is different from training for optimal health and fitness.
  - Training for athletes requires higher intensity, frequencies and volume.
- In a total conditioning program one needs to integrate and balance the different types of training.
- There is a psychological component to training.
- Each individual responds differently psychologically to a given physical stress.

Adaptations to Heavy Resistance Training

Five acute program variables of a resistance exercise protocol:

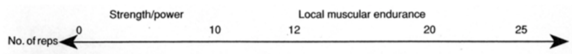


Figure 8.2 Repetition maximum continuum for training effects.

- Choice of exercise
- Order of exercise
- Resistance or intensity used
- Number of sets
- Length of rest period between sets and exercises.
- We use the "Repetition maximum continuum for training efforts" to measure changes. (See above)