Training and the Musculoskeletal System

Pages 267-270 and 431-439
ADAPTATIONS

Total Strength Gains

Figure 13.17
ADAPTATIONS

Total Strength Gains

1. Neural factors with “carry over” or “transfer”

Figure 13.17
ADAPTATIONS

Total Strength Gains

1. Neural factors with “carry over” or “transfer”

2. Muscular factors

Figure 13.17

2. Muscular factors

Figure 13.17
1. Neural Adaptations
1. Neural Adaptations

1. Recruitment of additional MU (IIb or Fast Twitch B)
1. Neural Adaptations

1. Recruitment of **additional MU** (IIb or Fast Twitch B)

2. Enhance **synchronization** of MU firing
1. Neural Adaptations

1. Recruitment of **additional MU** (IIb or Fast Twitch B)

2. Enhance **synchronization** of MU firing

3. **Neural dis-inhibition** (ignoring GTO)
Neural dis-inhibition
Neural dis-inhibition

Golgi tendon organs inhibit muscle contraction
Neural dis-inhibition

Golgi tendon organs inhibit muscle contraction

Training effects
2. Muscle Adaptations

- Whole Muscle hypertrophy
Hypertrophy v Hyperplasia
Hypertrophy v Hyperplasia

WHOLE MUSCLE HYPERTROPHY
1. Fiber Hypertrophy
2. Fiber Hyperplasia

95-100% of whole muscle hypertrophy due to fiber hypertrophy
Whole Muscle Hypertrophy

- Fiber hypertrophy and hyperplasia
  - Increase in protein (actin and myosin)
- Increase in water
- Increase in connective tissue
Milo of Crotona
Milo of Crotona, Greek athlete, lived about the end of the 6th century B.C. He was six times crowned at the Olympic Games and six times at the Pythian for wrestling, and was famous throughout the civilized world for his feats of strength - such as carrying an ox on his shoulders through the stadium at Olympia. In his native city he was much honored, and he commanded the army which defeated the people of Sybaris in 511.
Milo of Crotona, Greek athlete, lived about the end of the 6th century B.C. He was six times crowned at the Olympic Games and six times at the Pythian for wrestling, and was famous throughout the civilized world for his feats of strength - such as carrying an ox on his shoulders through the stadium at Olympia. In his native city he was much honored, and he commanded the army which defeated the people of Sybaris in 511.

The traditional account of his death is often used to point a moral: he found a tree which some woodcutters had partially split with a wedge, and attempted to rend it asunder; but the wedge fell out and the tree closed on his hand, imprisoning him until wolves came and devoured him. His name became proverbial for personal strength.
Milo of Crotona, Greek athlete, lived about the end of the 6th century B.C. He was six times crowned at the Olympic Games and six times at the Pythian for wrestling, and was famous throughout the civilized world for his feats of strength - such as carrying an ox on his shoulders through the stadium at Olympia. In his native city he was much honored, and he commanded the army which defeated the people of Sybaris in 511.

The traditional account of his death is often used to point a moral: he found a tree which some woodcutters had partially split with a wedge, and attempted to rend it asunder; but the wedge fell out and the tree closed on his hand, imprisoning him until wolves came and devoured him. His name became proverbial for personal strength.

Encyclopaedia Britannica
SUMMARY

American College of Sports Medicine Position Stand on Progression Models in Resistance Training for Healthy Adults. Med. Sci. Sports Exerc. Vol. 34, No. 2, 2002, pp. 364–380. In order to stimulate further adaptation toward a specific training goal(s), progression in the type of resistance training protocol used is necessary. The optimal characteristics of strength-specific programs include the use of both concentric and eccentric muscle actions and the performance of both single- and multiple-joint exercises. It is also recommended that the strength program sequence exercises to optimize the quality of the exercise intensity (large before small muscle group exercises, multiple-joint exercises before single-joint exercises, and higher intensity before lower intensity exercises). For initial resistances, it is recommended that loads corresponding to 8–12 repetition maximum (RM) be used in novice training. For intermediate to advanced training, it is recommended that individuals use a wider loading range, from 1–12 RM in a periodized fashion, with eventual emphasis on heavy loading (1–6 RM) using at least 3-min rest periods between sets performed at a moderate contraction velocity (1–2 s concentric, 1–2 s eccentric). When training at a specific RM load, it is recommended that 2–10% increase in load be applied when the individual can perform the current workload for one to two repetitions over the desired number. The recommendation for training frequency is 2–3 d·wk⁻¹ for novice and intermediate training and 4–5 d·wk⁻¹ for advanced training. Similar program designs are recommended for hypertrophy training with respect to exercise selection and frequency. For loading, it is recommended that loads corresponding to 1–12 RM be used in periodized fashion, with emphasis on the 6–12 RM zone using 1- to 2-min rest periods between sets at a moderate velocity. Higher volume, multiple-set programs are recommended for maximizing hypertrophy. Progression in power training entails two general loading strategies: 1) strength training, and 2) use of light loads (30–60% of 1 RM) performed at a fast contraction velocity with 2–3 min of rest between sets for multiple sets per exercise. It is also recommended that emphasis be placed on multiple-joint exercises, especially those involving the total body. For local muscular endurance training, it is recommended that light to moderate loads (40–60% of 1 RM) be performed for high repetitions (> 15) using short rest periods (< 90 s). In the interpretation of this position stand, as with prior ones, the recommendations should be viewed in context of the individual’s target goals, physical capacity, and training status.
4. Resistance Training Programs
4. Resistance Training Program Design
4. Resistance Training Program Design

- Intensity
- resistance
- force
4. Resistance Training Program Design

- **Intensity**
  - resistance
  - force

- **Volume**
  - reps
  - sets
4. Resistance Training Program Design

- Intensity
  - resistance
  - force
- Volume
  - reps
  - sets
- Rest
4. Resistance Training Program Design

- Intensity
  - resistance
  - force
- Volume
  - reps
  - sets
- Rest
Resistance Training Programs

- Untrained/Novice
  - Faster gains
  - Any “program” effective
  - As little as 1 set at 67-80% (8-12 reps)
Resistance Training Programs

Moderate to Highly Trained Individuals

- Strength
- Power
- Hypertrophy
- Endurance
Strength Program
Strength Program

- Resistance: high (≥ 85%)
Strength Program

- Resistance: high (≥ 85%)
- Repetitions: few (≤ 6)
Strength Program

- Resistance: high ($\geq 85\%$)
- Repetitions: few ($\leq 6$)
- Sets: few (3-5)
Strength Program

- Resistance: high ($\geq 85\%$)
- Repetitions: few ($\leq 6$)
- Sets: few (3-5)
- Rest periods: moderate to long rest periods (2-5 min)
Strength Program

- Resistance: high (≥ 85%)
- Repetitions: few (≤ 6)
- Sets: few (3-5)
- Rest periods: moderate to long rest periods (2-5 min)
Strength Program

- Resistance: high ($\geq 85\%$)
- Repetitions: few ($\leq 6$)
- Sets: few (3-5)
- Rest periods: moderate to long rest periods (2-5 min)

Why the longer time period between sets?
Power Program
Power Program

- **Emphasis: speed**
  - increases neural stimulation
  - minimizes the slowing effects of strength
Power Program

- **Emphasis:** speed
  - increases neural stimulation
  - minimizes the slowing effects of strength

- **Resistance:** less than for strength (~75-85%)
  - Why less than strength?
Power Program

- **Emphasis:** speed
  - increases neural stimulation
  - minimizes the slowing effects of strength
- **Resistance:** less than for strength (~75-85%)
  - Why less than strength?
- **Repetitions:** few (~3-5)
Power Program

- **Emphasis:** speed
  - increases neural stimulation
  - minimizes the slowing effects of strength
- **Resistance:** less than for strength (~75-85%)
  - Why less than strength?
- **Repetitions:** few (~3-5)
- **Sets:** 3-5
Power Program

- **Emphasis:** speed
  - increases neural stimulation
  - minimizes the slowing effects of strength
- **Resistance:** less than for strength (~75-85%)
  - Why less than strength?
- **Repetitions:** few (~3-5)
- **Sets:** 3-5
- **Rest:** moderate to long rest periods (2-5 min.)
Power Program

- Emphasis: speed
  - increases neural stimulation
  - minimizes the slowing effects of strength
- Resistance: less than for strength (~75-85%)
  - Why less than strength?
- Repetitions: few (~3-5)
- Sets: 3-5
- Rest: moderate to long rest periods (2-5 min.)
- Plyometric exercises (next...)
Power Program

- **Emphasis:** speed
  - increases neural stimulation
  - minimizes the slowing effects of strength
- **Resistance:** less than for strength (~75-85%)
  - Why less than strength?
- **Repetitions:** few (~3-5)
- **Sets:** 3-5
- **Rest:** moderate to long rest periods (2-5 min.)
- **Plyometric exercises** (next...)

![Image of a man exercising]
Power Program – Plyometrics
Power Program - Plyometrics
Plyometric Loading
Plyometric Loading

What is it?
Plyometric Loading

What is it?

What’s the physiology behind it?

- **Elastic energy:** more powerful muscle contraction

- **Stretch-shortening cycle:** greater fiber recruitment (next slide...)
Plyometric Physiology

Muscle Spindles
Plyometric Physiology

Muscle Spindles

Neutral
Plyometric Physiology

Muscle Spindles

Neutral  Stretch
Plyometric Physiology

**Stretch-Shortening Cycle**

**Muscle Spindles**

---

**Diagram**

- **Spinal Cord**
  - Gray matter
  - Dorsal root
  - Dorsal root ganglion
- **Muscle**
  - Alpha motor neuron
  - Ventral root
  - Inhibitory interneuron
  - Muscle spindle
  - Goji tendon organ
- **Extrafusal muscle fibers**

**Neutral**

**Stretch**

**Shortening**
Hypertrophy Program
Hypertrophy Program

- Greater **volume** and **number of exercises**
- **Volume** = reps * sets
Hypertrophy Program

- Greater *volume and number of exercises*
- *Volume = reps x sets*
- Resistance: moderate to high
Hypertrophy Program

- Greater **volume and number of exercises**
  - *Volume = reps x sets*
- Resistance: moderate to high
- Repetitions: moderate (~6-12)
- Why more reps and less resistance than strength?
Hypertrophy Program

- Greater **volume and number of exercises**
  - **Volume = reps x sets**
- Resistance: moderate to high
- Repetitions: moderate (~6-12)
  - Why more reps and less resistance than strength?
- Sets: moderate
Hypertrophy Program

- Greater **volume** and **number of exercises**
- **Volume = reps x sets**
- Resistance: moderate to high
- Repetitions: moderate (~6-12)
- Why more reps and less resistance than strength?
- Sets: moderate
- Less rest (less than 90 sec.)
- Why less rest?
Hypertrophy Program

- Greater **volume** and **number of exercises**
- **Volume = reps x sets**
- Resistance: moderate to high
- Repetitions: moderate (~6-12)
- Why more reps and less resistance than strength?
- Sets: moderate
- **Less rest (less than 90 sec.)**
- Why less rest?
Endurance Program

What is muscle endurance?
Endurance Program

- What is muscle endurance?
- Resistance: low ≤67%
Endurance Program

- What is muscle endurance?
- Resistance: low ≤67%
- Repetitions: high ≥12
Endurance Program

What is muscle endurance?

- Resistance: low ≤ 67%
- Repetitions: high ≥ 12
- Sets: 2-3
Endurance Program

- What is muscle endurance?
- Resistance: low ≤67%
- Repetitions: high ≥12
- Sets: 2-3
- Moderate rest depending on number of reps (30 sec to 3 min)
Endurance Program

- What is muscle endurance?
- Resistance: low ≤67%
- Repetitions: high ≥12
- Sets: 2-3
- Moderate rest depending on number of reps (30 sec to 3 min)
- Reasons: toning (?), core training, injury prevention, etc
## Resistance Programs

<table>
<thead>
<tr>
<th>Resistance Programs</th>
<th>Strength</th>
<th>Power</th>
<th>Hypertrophy</th>
<th>Endurance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resistance</td>
<td>≥85%</td>
<td>75–85%</td>
<td>67–85%</td>
<td>≤67%</td>
</tr>
<tr>
<td>Reps</td>
<td>≤6</td>
<td>3–5</td>
<td>6–12</td>
<td>≥12</td>
</tr>
<tr>
<td>Sets</td>
<td>2–6</td>
<td>3–5</td>
<td>3–6</td>
<td>2–3</td>
</tr>
<tr>
<td>Rest</td>
<td>2–5 min</td>
<td>2–5 min</td>
<td>0.5–1.0 min</td>
<td>≤0.5 min</td>
</tr>
</tbody>
</table>

Know the physiology
Periodization
Periodization

Example
Periodization

Example

1. Hypertrophy
   - 2-3 months with microcycles or day to day variations
Periodization

Example

1. Hypertrophy
   - 2–3 months with microcycles or day to day variations
2. Endurance
   - 2–3 weeks
Periodization

Example

1. Hypertrophy
   - 2-3 months with microcycles or day to day variations
2. Endurance
   - 2-3 weeks
3. Strength
   - 2-3 months with microcycles or day to day variations
Periodization

Example

1. Hypertrophy
   - 2-3 months with microcycles or day to day variations

2. Endurance
   - 2-3 weeks

3. Strength
   - 2-3 months with microcycles or day to day variations

4. Power
   - 1-2 Weeks
Periodization
Periodization - Changes in Volume, Intensity, and Total Training Load
Myth Busters
Myth Busters

Muscle size (hypertrophy) does not necessarily lead to inflexibility
Myth Busters

- Muscle size (hypertrophy) does not necessarily lead to inflexibility

- Endurance programs (high reps) are not effective for weight loss
Myth Busters

Muscle size (hypertrophy) does not necessarily lead to inflexibility

Endurance programs (high reps) are not effective for weight loss

Muscle tissue has only a slightly higher “metabolism” than fat tissue
5. Muscle Action
5. Muscle Action

- Isometric
5. Muscle Action

- Isometric
- Isotonic or Dynamic
5. Muscle Action

- Isometric
- Isotonic or Dynamic
- Isokinetic
Isometric Training
Isometric Training

isometric exercise

60° = 67%

100° = 100%
120° = 98%
140° = 95%
180° = 71%
Isometric Training
Isotonic Training
Isotonic Training

- Concentric and eccentric muscle contractions
Isotonic Training

- Concentric and eccentric muscle contractions
- Examples of isotonic exercises
  1. Free Weights
  2. Machines
Free Weights
Free Weights

What are the physiological advantages?
Free Weights

What are the physiological advantages?

What are the physiological disadvantages?
Eccentric Loading

Increase in length of pectoralis major as the weight is lowered
Eccentric Loading

Increase in length of pectoralis major as the weight is lowered.

120% of 1RM is used as an upper limit.
Eccentric Loading

Increase in length of pectoralis major as the weight is lowered

120% of 1RM is used as an upper limit

What are the physiological benefits?
Eccentric Loading

Increase in length of pectoralis major as the weight is lowered.

120% of 1RM is used as an upper limit.

What are the physiological benefits?

What are the physiological risks?
Machines

- What are the physiological advantages?
- What are the physiological disadvantages?
Variable Resistance

Note the shape of the cam

Easy

Hard
Variable Resistance

- What are the physiological advantages?
- What are the physiological disadvantages?
Isokinetic
Isokinetic

Accommodating resistance keeps the speed of contraction constant
## Comparison

<table>
<thead>
<tr>
<th>Program</th>
<th>Equipment</th>
<th>Advant.</th>
<th>Disadvant.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Isometric</td>
<td>Various types</td>
<td>Weak points</td>
<td>R.O.M., Valsalva</td>
</tr>
<tr>
<td>Isotonic</td>
<td>Free Weights</td>
<td>Synergist Muscles</td>
<td>Weak points</td>
</tr>
<tr>
<td></td>
<td>Machine (Universal)</td>
<td>Emphasize</td>
<td>Synergist Muscles</td>
</tr>
<tr>
<td>Variable Resistance</td>
<td>Machine (Nautilus)</td>
<td>Full ROM</td>
<td>Synergist Muscles</td>
</tr>
<tr>
<td>Isokentnic</td>
<td>Machine (Cybex)</td>
<td>Rehab</td>
<td>Non-specific</td>
</tr>
</tbody>
</table>

Table 21.3
6. Gender Differences
6. Gender Differences

Why are men generally stronger than women?
6. Gender Differences

- Why are men generally stronger than women?
- Pound for pound of muscle mass, are men stronger than women?
7. Muscle Group Specificity

Percent improvement in strength from training with squat exercise only
7. Muscle Group Specificity

Type of exercise matters even in the same muscle groups.

Percent improvement in strength from training with squat exercise only.

<table>
<thead>
<tr>
<th>Exercise</th>
<th>Force Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>SQUATS</td>
<td>Highest</td>
</tr>
<tr>
<td>LEG PRESS</td>
<td>Moderate</td>
</tr>
<tr>
<td>LEG EXTENSION</td>
<td>Least</td>
</tr>
</tbody>
</table>
8. Reversibility

Return of strength after periods of inactivity

Why is strength re-gained faster than the initial gains?
8. Reversibility

Return of strength after periods of inactivity

Why is strength re-gained faster than the initial gains?
Flexibility

Pages 318, 436, 439
Flexibility

Pages 318, 436, 439
Streching/Flexibility
Streching/Flexibility

Frequency = 3–7 days a week
Streching/Flexibility

Frequency = 3-7 days a week
Intensity = tightness
Streching/Flexibility

Frequency = 3–7 days a week

Intensity = tightness

Time = 15–60 sec., 1–3 sets

Why more than 15 sec.?
Training for Flexibility

Diagram of muscle and nerve connections illustrating the concepts of stretch and contract.
Training for Flexibility

- **Static stretching**
- Prevents **muscle spindles** from shortening the muscle
**Training for Flexibility**

- **Static stretching**
  - Prevents *muscle spindles* from shortening the muscle

- **Dynamic stretching**
  - May activate muscle spindles which produce muscle shortening
Training for Flexibility
Training for Flexibility

Proprioceptive Neuromuscular Facilitation
Training for Flexibility

Proprioceptive Neuromuscular Facilitation

Contract muscle to stimulate GTO
Proprioceptive Neuromuscular Facilitation

Contract muscle to stimulate GTO

GTO cause muscle to relax
Training for Flexibility

Proprioceptive Neuromuscular Facilitation

Contract muscle to stimulate GTO
GTO cause muscle to relax
Stretch relaxed muscle further
Flexibility

Does stretching increase flexibility?

Does stretching decrease the risk of injury?
THE IMPACT OF STRETCHING ON SPORTS INJURY RISK: A SYSTEMATIC REVIEW OF THE LITERATURE

THACKER, S. B., J. GILCHRIST, D. F. STROUP, and C. D. KIMSEY, JR.

IMPACT OF STRETCHING ON SPORTS INJURY

- Little evidence of link between flexibility and injury rate

- Lack of flexibility does not account for many muscles injuries that occur within a normal range of motion

- Imbalance in flexibility may increase injury risk

- Stretching may increase performance or it may decrease performance
There is not sufficient evidence to endorse or discontinue routine stretching before or after exercise to prevent injury among competitive or recreational athletes.

Further research, especially well-conducted randomized controlled trials, is urgently needed to determine the proper role of stretching in sports.