Adaptations to Resistance Training
Measuring Muscular Performance

**Strength** is the maximal force a muscle or muscle group can generate.

**Power** is the product of strength and the speed of movement.

**Muscular endurance** is the capacity to sustain repeated muscle actions.
One-Repetition Maximum (1RM)

The maximal weight an individual can lift just once.
Power

- The functional application of strength and speed
- The key component of many athletic performances
- Power = (force × distance)/time
Muscular Endurance

• Can be evaluated by noting the number of repetitions you can perform at a given percentage of your 1RM
• Is increased through gains in muscular strength
• Is increased through changes in local metabolic and circulatory function
Key Points

Terminology

• Muscular strength is the maximal amount of force a muscle or group of muscles can generate.
• Muscular power is the product of strength and speed of the movement.
• Consider two individuals who can lift the same amount of weight: if one can lift it faster, she is generating more power than the other.
• Muscular endurance is the ability of a muscle to sustain repeated muscle actions or a single static action.
Did You Know . . . ?

Resistance training programs can produce a 25% to 100% improvement in strength within 3 to 6 months.
Possible Neural Factors of Strength Gains

- Recruitment of additional motor units for greater force production
- Counteraction of autogenic inhibition, allowing greater force production
- Reduction of coactivation of agonist and antagonist muscles
- Changes in the discharge rates of motor units
- Changes in the neuromuscular junction
VARIABLE-RESISTANCE TRAINING
Muscle Size

• **Hypertrophy** refers to increases in muscle size.
• **Atrophy** refers to decreases in muscle size.
• Muscular strength involves more than just muscle size.
Muscle Hypertrophy

Transient hypertrophy is the pumping up of muscle during a single exercise bout due to fluid accumulation from the blood plasma into the interstitial spaces of the muscle.

Chronic hypertrophy is the increase of muscle size after long-term resistance training due to changes in number of muscle fibers (fiber hyperplasia) or size of muscle fibers (fiber hypertrophy).
Microscopic Views of Muscle Cross Sections Before and After Training

Photos courtesy of Dr. Michael Deschene's laboratory.
Fiber Hypertrophy

- The numbers of myofibrils and actin and myosin filaments increase, resulting in more cross-bridges.
- Muscle protein synthesis increases during the postexercise period.
- Testosterone plays a role in promoting muscle growth.
- Training at higher intensities appears to cause greater fiber hypertrophy than training at lower intensities.
Fiber Hyperplasia

- Muscle fibers split in half with intense weight training.
- Each half then increases to the size of the parent fiber.
- Satellite cells may also be involved in the generation of skeletal muscle fiber.
- It has been clearly shown to occur in animal models; only a few studies show this occurs in humans too.
Heavy Resistance Training in Cats
Neural Activation and Fiber Hypertrophy

• Early gains in strength appear to be more influenced by neural factors.
• Long-term strength increases are largely the result of muscle fiber hypertrophy.
Results of Resistance Training

- It increases muscle size (hypertrophy).
- It alters neural control of trained muscles.
- Studies show strength gains can be achieved without changes in muscle size, but not without neural adaptations.
Neural and muscular adaptation during resistance training.
Planning the Periods

– Major Mesocycles of Training (Matveyev)
  • Preparatory
  • First Transition (added later)
  • Competition
  • Second Transition (Active Rest)
Effects of Muscular Inactivity

- Muscular atrophy (decrease in muscle size)
- Decrease in muscle protein synthesis
- Rapid strength loss
Changes in Muscle Strength With Resistance Training in Women

Did You Know . . . ?

Once your goals for strength development have been achieved, you can reduce training frequency, intensity, or duration and still prevent losses in strength gained for at least 12 weeks. However, you must continue training with a resistance maintenance program that still provides sufficient stress to the muscles.
Key Points

Resistance Training

- Neural adaptations always accompany strength gains from resistance training; hypertrophy may or may not be present.
- Transient hypertrophy results from short-term increases in muscle size due to fluid in the muscles.
- Chronic muscle hypertrophy results from long-term training and is caused by structural changes in the muscle.

(continued)
Resistance Training

- Muscle hypertrophy is most clearly due to increases in fiber size, but it also may be due to increases in the number of fibers.
- Muscle atrophy occurs when muscles are inactive; however, a planned reduction in training can maintain muscle size and strength for a period of time.
- A muscle fiber type can take on characteristics of the opposite type in response to training. Cross-innervation or chronic stimulation of fibers may convert one fiber type to another fiber type.
Acute Muscle Soreness

• Results from an accumulation of the end products of exercise in the muscles
• Usually disappears within minutes or hours after exercise
Delayed-Onset Muscle Soreness (DOMS)

- Results primarily from eccentric action
- Is associated with damage or injury within muscle
- May be caused by inflammatory reaction inside damaged muscles
- May be due to edema (accumulation of fluid) inside muscle compartment
- Is felt 12 to 48 hours after a strenuous bout of exercise
DOMS and Performance

- DOMS causes a reduction in the force-generating capacity of muscles.
- Maximal force-generating capacity returns after days or weeks.
- Muscle glycogen synthesis is impaired with DOMS.
MUSCLE FIBERS AFTER A MARATHON
MUSCLE BEFORE AND AFTER A MARATHON
Muscle Soreness

- Acute muscle soreness occurs late during or immediately after an exercise bout.
- Delayed-onset muscle soreness (DOMS) occurs 12 to 48 hours after exercise (especially eccentric exercise).
- DOMS may include structural damage to muscle cells or inflammatory reactions within the muscles.
- Muscle soreness may be an important part of maximizing the resistance training response.
Reducing Muscle Soreness

• Reduce eccentric component of muscle action during early training.
• Start training at a low intensity, increasing gradually.
• Begin with a high-intensity, exhaustive bout of eccentric-action exercise to cause much soreness initially but decrease future pain.
Did You Know . . . ?

Resistance training can benefit almost everyone, regardless of sex, age, level of athletic involvement, or sport.
Key Points

Resistance Training Programs

• Resistance training can use static or dynamic actions.
• A needs analysis is necessary for designing a program for a specific athlete’s needs.
• Low-repetition, high-intensity training improves muscle strength while high-repetition, low-intensity training improves endurance training.

(continued)
Key Points (continued)

Resistance Training Programs

• Periodization prevents overtraining by varying the volume and intensity of training.
• Typically volume is gradually decreased while intensity is gradually increased.
• Strength gains are specific to the speed of training and the movement patterns used in training.
### Table 18.1

**Example of Classifying Resistance Training Status**

<table>
<thead>
<tr>
<th>Training status</th>
<th>Current program</th>
<th>Resistance training background</th>
<th>Technique experience/skill</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beginner (untrained)</td>
<td>Not training or just began training</td>
<td>&lt; 2 mo</td>
<td>None or minimal</td>
</tr>
<tr>
<td>Intermediate (moderately trained)</td>
<td>Currently training</td>
<td>2-6 mo</td>
<td>Medium</td>
</tr>
<tr>
<td>Advanced (well trained)</td>
<td>Currently training</td>
<td>1+ yr</td>
<td>High</td>
</tr>
</tbody>
</table>

*In this example, “training stress” describes the degree of physical demand or stimulus of the resistance training program.*
Sports Specific Exercises

- Specificity
- See p. 400

<table>
<thead>
<tr>
<th>Movement pattern</th>
<th>Related exercises</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ball dribbling and passing</td>
<td>Triceps pushdown, reverse curl, close-grip bench press</td>
</tr>
<tr>
<td>Ball kicking</td>
<td>Unilateral hip adduction/abduction, leg (knee) extension, leg raise</td>
</tr>
<tr>
<td>Freestyle swimming</td>
<td>Lat pulldown, lateral raise, lunge</td>
</tr>
<tr>
<td>Jumping</td>
<td>Power clean, push jerk, back squat</td>
</tr>
<tr>
<td>Racket stroke</td>
<td>Dumbbell fly, bent-over lateral raise, wrist curl/extension</td>
</tr>
<tr>
<td>Rowing</td>
<td>Bent-over row, seated row, hip sled</td>
</tr>
<tr>
<td>Running/sprinting</td>
<td>Lunge, step-up, toe raise (dorsiflexion)</td>
</tr>
<tr>
<td>Throwing/pitching</td>
<td>Pullover, overhead triceps extension, shoulder internal/external rotation</td>
</tr>
</tbody>
</table>
Alternated Upper & Lower Body Exercises

• Good for untrained individuals.
• Use the rest period to work the opposing muscle group.
• Decreases overall training time.
• Also considered circuit training if the exercises are performed with minimal rest periods.
Alternated Push & Pull Exercises

• Insures that the same muscle groups will not be used for two exercises in a row thereby reducing fatigue of the muscle.

• Can also be constructed in a circuit training format.

• Is appropriate for beginning and returning exercisers.
Supersets & Compound Sets

- **Superset** – involves 2 exercises that stress 2 opposing muscles.
- **Compound set** – involves performing 2 exercises for the same muscle sequentially.
- Very demanding
- May not be appropriate for beginners
<table>
<thead>
<tr>
<th>Training goal</th>
<th>Load (%1RM)</th>
<th>Goal repetitions</th>
</tr>
</thead>
<tbody>
<tr>
<td>*Strength</td>
<td>≥ 85</td>
<td>≤ 6</td>
</tr>
<tr>
<td>*Power: single-effort event</td>
<td>80-90</td>
<td>1-2</td>
</tr>
<tr>
<td>multiple-effort event</td>
<td>75-85</td>
<td>3-5</td>
</tr>
<tr>
<td>Hypertrophy</td>
<td>67-85</td>
<td>6-12</td>
</tr>
<tr>
<td>Muscular endurance</td>
<td>≤ 67</td>
<td>≥ 12</td>
</tr>
</tbody>
</table>

*These RM loading assignments for muscular strength training only apply to core exercises; assistance exercises should be limited to loads not heavier than an 8RM (6).

*The load and repetition assignments shown for power in this table are **not consistent** with the %1RM-repetition relationship. On average, loads equaling about 80% of the 1RM apply to the 2-5 repetition range. Refer to the “Assigning Percentages of the 1RM for Power Training” discussion on page 412 for further explanation.

Data from references 11, 25, 26, 29, 41, 43, 57, 64, 77, 98, 104, 105, and 106.
Table 18.11
Volume Assignments Based on the Training Goal

<table>
<thead>
<tr>
<th>Training goal</th>
<th>Goal repetitions</th>
<th>Sets*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strength</td>
<td>≤ 6</td>
<td>2-6</td>
</tr>
<tr>
<td>#Power: single-effort event</td>
<td>1-2</td>
<td>3-5</td>
</tr>
<tr>
<td></td>
<td>multiple-effort event</td>
<td>3-5</td>
</tr>
<tr>
<td>Hypertrophy</td>
<td>6-12</td>
<td>3-6</td>
</tr>
<tr>
<td>Muscular endurance</td>
<td>≥ 12</td>
<td>2-3</td>
</tr>
</tbody>
</table>

*These assignments do not include warm-up sets and typically apply to core exercises only (6, 57).

#The repetition assignments shown for power in this table are not consistent with the %1RM-repetition relationship. On average, loads equaling about 80% of the 1RM apply to the 2-5 repetition range. Refer to the “Assigning Percentages of the 1RM for Power Training” discussion on page 412 for a further explanation.

Data from references 11, 26, 27, 29, 41, 64, 77, 98, 104, 105, and 106.
Step 7 - Rest Periods

- Rest period – the time dedicated to recovery between sets & exercises.
- Dependent on the goal of training, load lifted and person’s training status.
- General guideline is:
  - 2-5 minutes rest for power and strength.
  - 30 s – 1.5 min for hypertrophy and endurance.

### Table 18.12

<table>
<thead>
<tr>
<th>Training goal*</th>
<th>Rest period length</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strength</td>
<td>2-5 min</td>
</tr>
<tr>
<td>Power: single-effort event</td>
<td>2-5 min</td>
</tr>
<tr>
<td></td>
<td>multiple-effort event</td>
</tr>
<tr>
<td>Hypertrophy</td>
<td>30 s - 1.5 min</td>
</tr>
<tr>
<td>Muscular endurance</td>
<td>≤ 30 s</td>
</tr>
</tbody>
</table>

*Because there are occasions when the prescribed percentage of the 1RM for assistance exercises falls outside the range associated with the training goal (e.g., ≥ 8RM loads are recommended for assistance exercises as part of a muscular strength training program [6]), the strength and conditioning professional should examine the loads used for each exercise when assigning rest periods rather than generally applying the guidelines for a training goal.

Data from references 26, 59, 62, 64, 96, 98, 111, and 113.