Therapeutic Exercise: Strength, Power, and Endurance

PART I: SCIENTIFIC FOUNDATIONS

Diagram: Producing Force, Stabilization, Reducing Force
Concentric

Isometric

Eccentric

Training Stimulus

Structural Effects

Functional Effects

Motor Performance

Intermuscular Coordination

Intramuscular Coordination

Reflexive Changes

Hypertrophy

Siff & Verkhoshansky, 1999

ANATOMY
NEUROPHYSIOLOGY
MECHANICS
Key Points

- Difference between strength, power, endurance
- Different types of endurance
- Torque vs. force
- Increasing muscle force
- Fitness-Fatigue Model
- Impulse - Momentum

PART II: TECHNIQUES

PART III: PROGRAM DESIGN
Indications
- ?

Contraindications
- Pain
- Increased edema
- Surgical / physician constraints

Acute Program Variables
- Choice of exercise
- Intensity
- Tempo
- Number of Repetitions
- Number of Sets
- Volume
- Rest Intervals
- Number of Sessions
- Frequency
Choice of Exercise

- Isometric vs. Dynamic
- Open vs. Closed Chain
- Machine vs. Free Weight
- Type of Resistance
  - Manual
  - Elastic
  - Isotonic – Body weight & Free weight
  - Isokinetic

Open and Closed Chain Exercises:

Myth, Science, and Clinical Implications

Sean P. Flanagan, PhD, ATC, CSCS
Department of Kinesiology
California State University, Northridge

Presented at the Combined Sections Meeting of the APTA, 2005

“Advantages” of Closed Chain Activities

- Stimulation of proprioceptors
- Increased joint congruency & stability
- Decreased shear forces
- Enhanced dynamic stability
- More “functional”

Prentice, 1999
**Definitions**

- **Steindler, 1955**
  - Open chain - a combination in which the terminal joint is free.
  - Closed chain - one in which the terminal joint meets with some "considerable external resistance" which prohibits or restrains free movement.

**More definitions**

- Closed chain – distal end is fixed (Zatsiorsky, 1998).
- Closed chain - motion of one [segment] at one joint will produce motion at all other joints in the system in a predictable manner (Levangie & Norkin, 2001).
### Alternate Classifications?

*Dillman, Murray, & Hintermeister, J Sport Rehab, 1994*

<table>
<thead>
<tr>
<th>External Load</th>
<th>Boundary</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fixed</td>
</tr>
<tr>
<td>External Load</td>
<td>FEL</td>
</tr>
<tr>
<td>No Load</td>
<td><strong>X</strong></td>
</tr>
</tbody>
</table>

**What does EMG tell us about movement classification?**
EMG and Force

No difference in integrated EMG between similarly-loaded push-ups and bench-press

Biomechanical similarity between squat and leg press
<table>
<thead>
<tr>
<th>WEIGHT BEARING</th>
<th>Multiple Joints</th>
<th>Linear Resistance</th>
</tr>
</thead>
<tbody>
<tr>
<td>NON-WEIGHT BEARING</td>
<td>Single Joint</td>
<td>Angular Resistance</td>
</tr>
</tbody>
</table>

**No easy classification**

- Distal vs. Proximal End Moving
- Single vs. Multiple Joints
- Angular vs. Linear Resistance
- Machine vs. Free Weight
- Seated vs. Standing vs. Prone
Rationale: CC & Safety

- Decreased Shear Force
- Increased Co-contraction
- CC movements are harder to control

Shear forces a function of…

Type of loading

Lutz et al, JBJS-A, 1993
Escamilla et al, MSSE, 1998
Placement of external resistance


Amount of compressive force


What about co-contraction?
Co-Contraction

- Function of free-weights vs. machines?
- Does not affect anterior shear forces at knee
- Over-rated?
No epidemiological evidence...

- Shear forces are pathologic
- Free weights are more injurious than machines

Comparisons across studies difficult...

- Subject Population
- Intervention Duration
- Number of Exercises
- Amount and Type of Resistance
- Outcome Measures

Eight studies, no differences...

- Strength
- Pain
- Functional Performance
- Proprioception
- Joint Laxity?

*Combined OC/CC appears superior to either one separately!*
LE Kinetics Following ACL Surgery

Case Study: Bilateral Comparisons following ACL Surgery

Three Variations of the Step Exercise

Flanagan, Kessans, & Salem, J Sport Rehabil, 2006
Intensity

- Dictates all other variables
- RM Continuum

Tempo

- Important to remember your biomechanics:
  - Force – velocity
  - Impulse – momentum

Bandy et al., Phys Ther, 1997
**Speed Repetitions**

Remember, impulse must be zero…

<table>
<thead>
<tr>
<th>% RM</th>
<th>Movement</th>
<th>Deceleration</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>50%</td>
<td>Squat</td>
<td>35%</td>
<td>Flanagan &amp; Salem*</td>
</tr>
<tr>
<td>45%</td>
<td>Bench Press</td>
<td>40%</td>
<td>Newton et al, 1996</td>
</tr>
<tr>
<td>25%</td>
<td>Squat</td>
<td>45%</td>
<td>Flanagan &amp; Salem*</td>
</tr>
</tbody>
</table>

* Preliminary unpublished data

---

**Number of Reps / Sets**

- DeLorme (DeLorme & Watkins)
- Oxford
- Aggressive Resistance Training Program
- DAPRE
- Performance-Based Periodization
### DeLorme (DeLorme & Watkins, 1945)

<table>
<thead>
<tr>
<th>Set</th>
<th>Load</th>
<th>Reps</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>50% of 10 RM</td>
<td>10</td>
</tr>
<tr>
<td>2</td>
<td>75% of 10 RM</td>
<td>10</td>
</tr>
<tr>
<td>3</td>
<td>100% of 10 RM</td>
<td>10</td>
</tr>
</tbody>
</table>

### Oxford (Zinovieff, 1951)

<table>
<thead>
<tr>
<th>Set</th>
<th>Load</th>
<th>Reps</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100% of 10 RM</td>
<td>10</td>
</tr>
<tr>
<td>2</td>
<td>75% of 10 RM</td>
<td>10</td>
</tr>
<tr>
<td>3</td>
<td>50% of 10 RM</td>
<td>10</td>
</tr>
</tbody>
</table>

### Aggressive Resistance Training Program (Stone and Kroll, 1982)

<table>
<thead>
<tr>
<th>Set</th>
<th>Load</th>
<th>Reps</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>50% of 4 RM</td>
<td>8</td>
</tr>
<tr>
<td>2</td>
<td>80% of 4 RM</td>
<td>8</td>
</tr>
<tr>
<td>3</td>
<td>90% of 4 RM</td>
<td>6</td>
</tr>
<tr>
<td>4</td>
<td>95% of 4 RM</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td>100% of 4 RM</td>
<td>4</td>
</tr>
</tbody>
</table>
DAPRE (Knight, 1985)

<table>
<thead>
<tr>
<th>Set</th>
<th>Load</th>
<th>Reps</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>50% of Working</td>
<td>10</td>
</tr>
<tr>
<td>2</td>
<td>75% of Working</td>
<td>6</td>
</tr>
<tr>
<td>3</td>
<td>100% of Working</td>
<td>Max</td>
</tr>
<tr>
<td>4</td>
<td>Adjusted Working</td>
<td>Max</td>
</tr>
</tbody>
</table>

DAPRE Adjustments

<table>
<thead>
<tr>
<th>Number of Reps / Set</th>
<th>Adjustments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4th Set</td>
</tr>
<tr>
<td>0-2</td>
<td>↓ 5-10 lbs</td>
</tr>
<tr>
<td>3-4</td>
<td>↓ 0-5 lbs</td>
</tr>
<tr>
<td>5-7</td>
<td>Keep same</td>
</tr>
<tr>
<td>8-12</td>
<td>↑ 5-10 lbs</td>
</tr>
<tr>
<td>13+</td>
<td>↑ 10-15 lbs</td>
</tr>
</tbody>
</table>

Performance-Based Periodization (Flanagan, 2001)

- Planned variables: load and rest periods
- Target: volume
- Performance variables: reps and sets
- Adjustments
Rest Intervals

- 90 sec?

Frequency

- 2 – 3 times per week?

LE Kinetics Following ACL Surgery
Case Study: Bilateral Comparisons following ACL Surgery