Neuromuscular Physiology of Strength

Loren Z.F. Chiu, Ph.D., CSCS
Faculty of Physical Education and Recreation
University of Alberta
Loren.Chiu@ualberta.ca
www.ualberta.ca/~loren1/nmrp.htm

Questions

- Why is strength important?
- Why is strength training necessary for athletes?
- How do we train for strength?
Overview

1. Types of Strength
2. Physiology of Strength
3. Training for Strength
   1. Acute Programming Variables
   2. Program Development

What is Strength?

- Ability to generate force
  \[ F = m \cdot a \]

- Ability to generate impulse
  \[ \int F \cdot dt = m \cdot dv \]
\[ \int F \cdot dt = m \cdot dv \]

- \( F \) – force is a vector
- \( \int F \cdot dt \) – force is applied over a period of time
- \( dv = [v_f - v_i] \) – force may be applied at various starting velocities (i.e. 0 – \( \infty \) m/s)

**Physics of Strength**

- \( F \) – Strength is direction-dependent
- \( \int F \cdot dt \) – Strength is time-dependent
- \( dv = [v_f - v_i] \) – Strength is velocity-dependent
Directionality

- Unidirectional
  - Concentric
  - Isometric
  - Eccentric

- Multidirectional
  - Isometric → Concentric
  - Eccentric → Isometric
  - Eccentric → Isometric → Concentric

Time-Dependency

- Maximum strength
  - Time is (virtually) unlimited

- Explosive strength
  - Time is limited
Velocity-Dependency

- Maximum strength - Velocity is low
- Explosive strength
- Rate of Force Development - Velocity = 0
- Power - Velocity is high

Maximum Strength

- Ability to generate maximum force/impulse
  - \[ \int F \cdot dt = m \cdot dv \]
  - \[ \int F \cdot dt \] - large impulse
    - Time = >~300ms
  - \[ m \cdot dv \] - move a large mass at low velocity
Rate of Force Development

- RFD = dF/dt
- Ability to generate maximum force in minimum time
- Vertical jump ~ 200-250ms
- Sprint (start) ~ 150ms

Areas of interest
- Initial RFD (0-25% maximum force)
- Maximum RFD (~50% maximum force)
Rate of Force Development

- RFD is required when initial movement velocity is zero

- Examples
  - Sprinting - start
  - Squat/countermovement jump
Power

- $P = \frac{dW}{dt}$
  - Ability to perform a large amount of work in a short period of time
- $W = F \cdot d$
- $P = F \cdot v$
  - Ability to generate force at a high velocity

Load-Dependent
Peak or Average Power

- Peak power ($P = F \cdot v$)
  - Clean – ~4000-5000W
  - Vertical Jump – ~4000-5000W

- Average power ($P = \frac{dW}{dt}$)
  - Clean – ~5000W
  - Vertical Jump – ~1400W

Adapted from Garhammer & Gregor 1992
Power

- Power is required when movement velocity is not zero
  1. Muscles are already contracting
  2. Body is already moving (muscles playing "catch up")

- Examples
  - Sprinting – acceleration phase
  - Running jumps
    - Long jump, high jump

Overview

1. Types of Strength
2. Physiology of Strength
- First Gear – 2.97:1 – Start/Towing
- Second Gear – 2.07:1 – Towing
- Third Gear – 1.43:1 – Power
- Fourth Gear – 1.00:1 – Power
- Fifth Gear – 0.84:1 – Power
- Sixth Gear – 0.56:1 – Overdrive
Motor Unit

- Action potential traveling down sarcolemma
- Acetylcholine release at neuromuscular junction
- Actin-myosin binding
- ATP hydrolysis

Motor Unit Types

<table>
<thead>
<tr>
<th></th>
<th>Size</th>
<th>Speed</th>
<th>Fatigue</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Small</td>
<td>Slow</td>
<td>Fatigue Resistant</td>
</tr>
<tr>
<td>IIA</td>
<td>Large</td>
<td>Fast</td>
<td>Fatigable</td>
</tr>
<tr>
<td>IIB</td>
<td>Large</td>
<td>Fastest</td>
<td>Fast Fatigable</td>
</tr>
</tbody>
</table>
Size Principle

- Type I
- Type IIA
- Type IIB

MU Activation

- Recruitment
- Threshold for activation
- Synchronization
- Firing strategy
- Frequency
- Recycling
Force Generation

- Two components
  - Motor unit recruitment (i.e. shifting gears)
  - Rate of force development
  - Motor unit firing strategy (i.e. increasing RPM)
    - Power
    - Maximum strength (when majority of MU are recruited)

Low Load

- RFD
- MU recruitment
**Moderate Load**

- RFD
- Power
- Conditions

- MU recruitment
- MU firing rate

1. $v_i \neq 0$
   - MU recruitment occurs prior to loading

   and/or

2. Time is available

**High Load**

- RFD
- Maximum strength

- MU recruitment
- MU firing rate
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Training Principles

- Overload
  - ↑ volume and/or
  - ↑ intensity and/or
  - ↑ frequency

- Specific adaptations to imposed demands (SAID)
SAID Principle

- Adaptations are specific to the overload provided by the exercise
- Adaptations transfer to some aspect of a sport skill
- Exercise selection affects the type of strength trained

Training for RFD

1. Exercises where initial movement velocity = 0
2. Exercises where peak force/torque is generated near start of movement
   - Near-maximal/maximal loads
     - >90% maximum force
     - Intent to contract rapidly
CLEAN DEADLIFT/PULL

-600 -500 -400 -300 -200 -100 0 100 200

0 0.2 0.4 0.6 0.8 1 1.2

Hip
Knee
Ankle
Training for Power

1. Exercises where peak force is generated when velocity > 0

2. Exercises where peak force occurs late in the movement (i.e. muscles are already contracting)
   - Moderate loads
     - 30-70% maximum force
   - Intent to contract rapidly
Jerk
Hang Clean

Weightlifting

- Weightlifting exercises train both RFD and power
- Snatch
  - Snatch, Power Snatch
- Clean
  - Clean, Power Clean
Snatch
Training for Maximum Strength

- Large range of motion
- Increases force/torque requirements
- Moderate to heavy loads
- 70-90% maximum force
- Static/isometric holds

BACK SQUAT VIDEO
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Program Development

- Training = curriculum
  - Long-term process
  - Sequential
  - Cyclical
- The training program must be fitted to the athlete
- All aspects of training must be considered simultaneously
  - Sport
  - Strength & conditioning
  - Other
Adaptation

- **Short-term adaptations**
  - Elicited 1-4 weeks of training
  - Persist for 1 week to few months
  - May be positive or negative

- **Long-term adaptations**
  - Elicited following a period of training (at least 12 weeks)
  - Non-linear
  - Cumulative
  - Semi-permanent
  - Should be positive

Non-Linear

- Not all physical qualities develop simultaneously

- Performance adaptations do not occur in a linear fashion

- Adaptations to an effective training period may not be observed immediately

- Adaptations to an effective training period may be conditional to successive training periods
Priorities

- Overemphasis on short-term adaptations
- Short-term performance decrements should be expected
  - S&C may temporarily impair sport performance
- Consider how each training session benefits long-term development
Summary

- Training for strength = Engineering an athlete
- Types of strength
- Physiology of strength
- Adaptations to training

- Training is a curriculum
- Long-term process
- Adaptations are non-linear
- Adaptations are cumulative