



# Neuromuscular Physiology of Strength

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[www.ualberta.ca/~loren1/nmrp.htm](http://www.ualberta.ca/~loren1/nmrp.htm)



## Questions

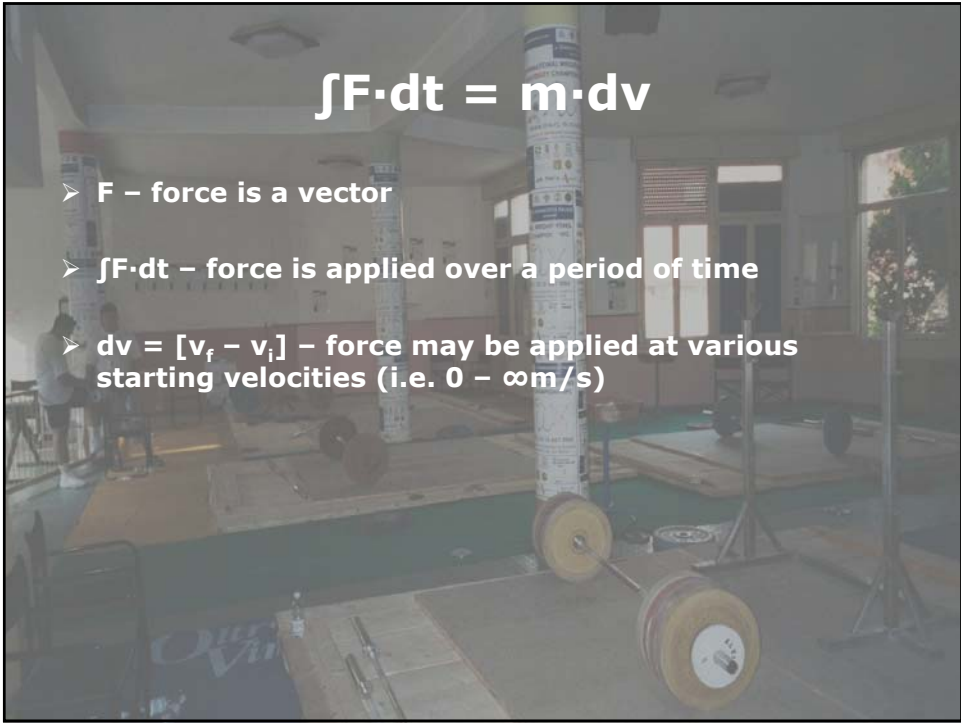
- Why is strength important?
- Why is strength training necessary for athletes?
- How do we train for strength?

# Overview

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

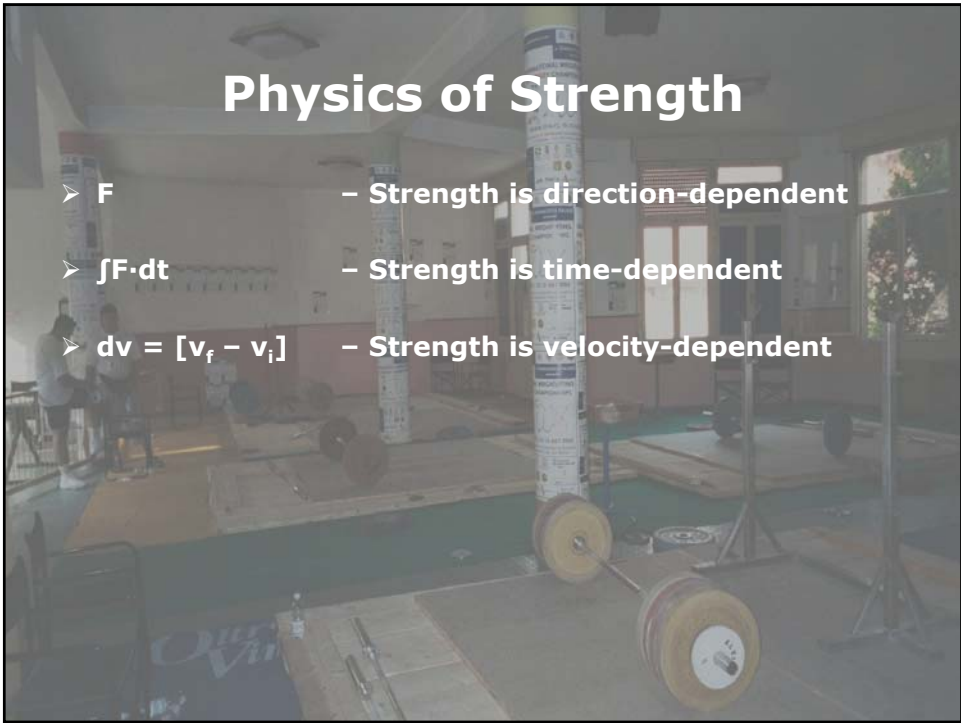
# What is Strength?

- Ability to generate force  
 $F = m \cdot a$
- Ability to generate impulse  
 $\int F \cdot dt = m \cdot dv$



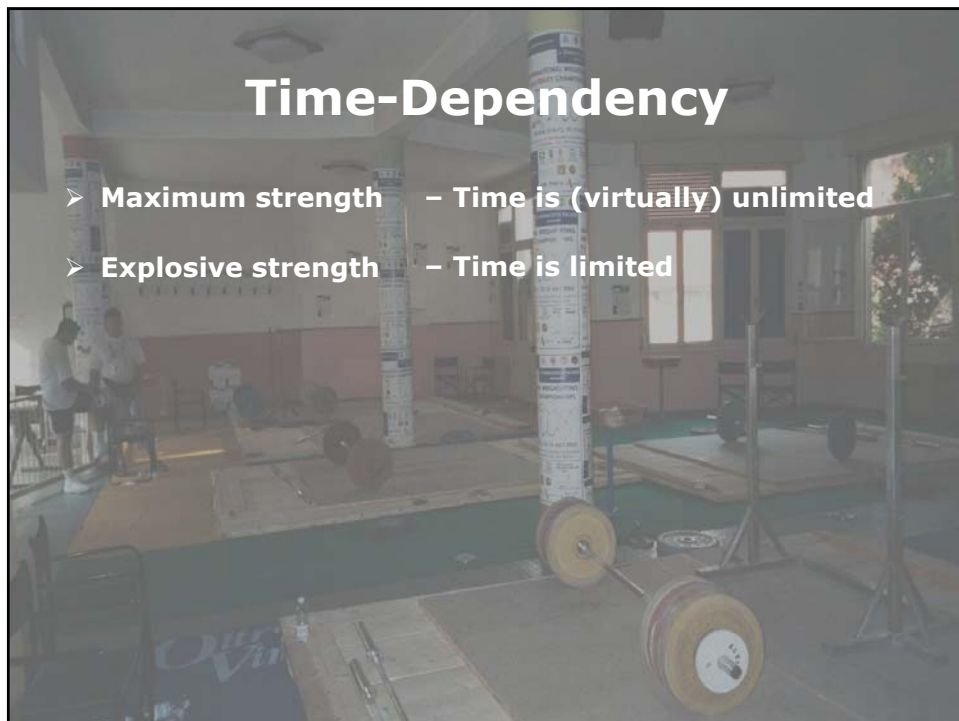
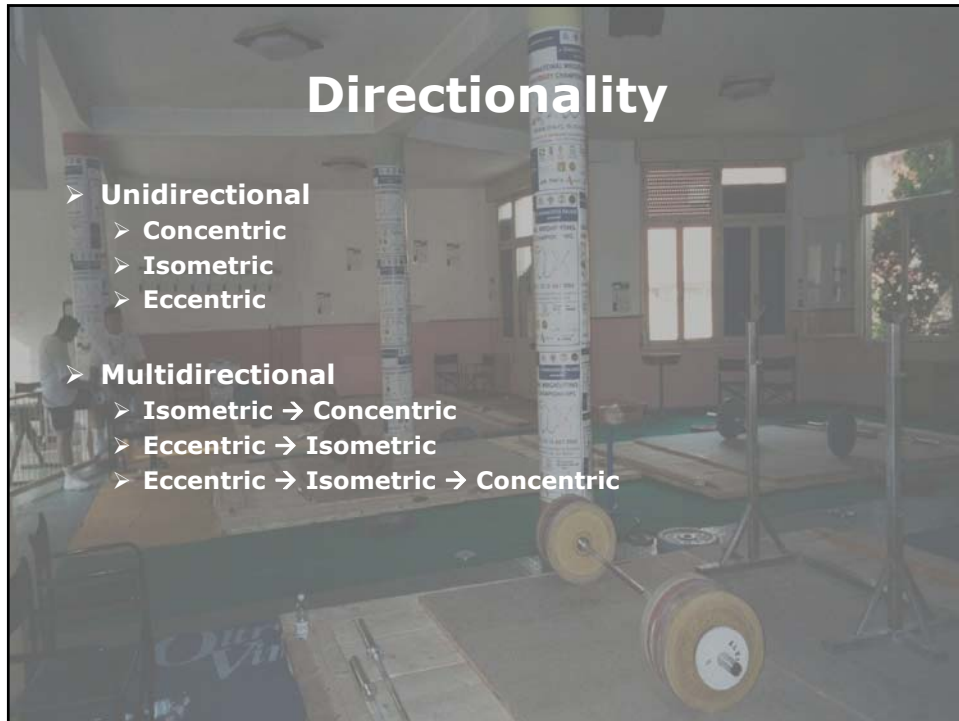
**$\int F \cdot dt = m \cdot dv$**

- **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



## Velocity-Dependency

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

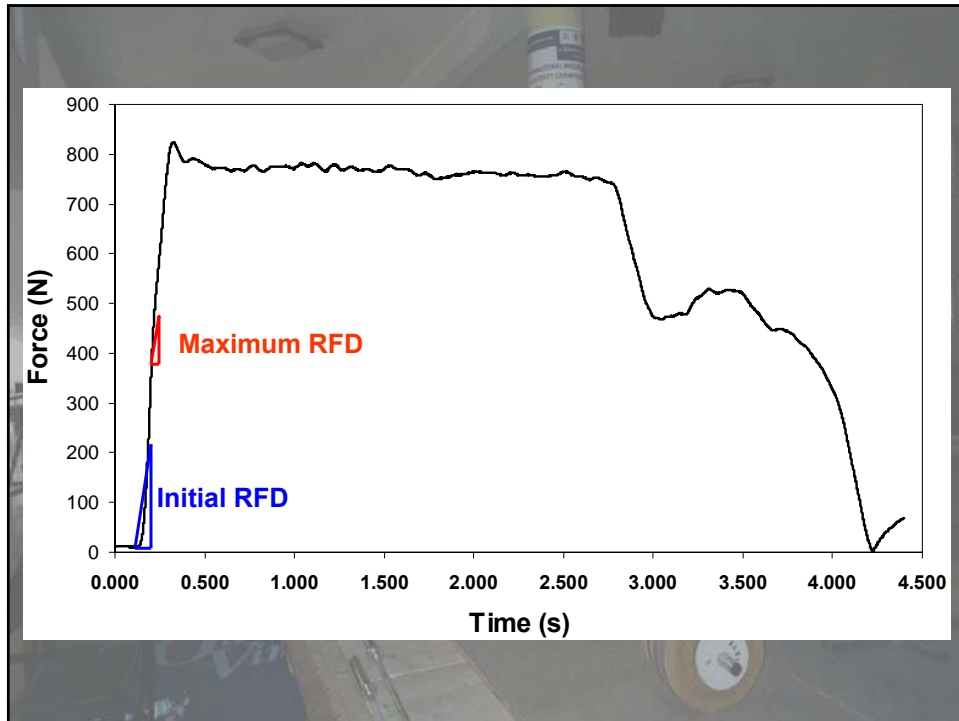
## Maximum Strength

- Ability to generate maximum force/impulse
- $\int F \cdot dt = m \cdot dv$ 
  - $\int F \cdot dt$  – large impulse  
Time =  $> \sim 300\text{ms}$
  - $m \cdot dv$  – 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)





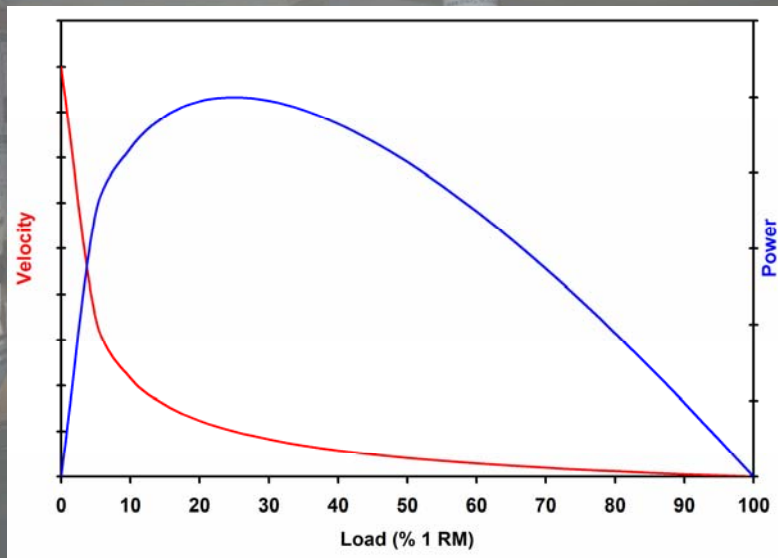
## Rate of Force Development

- RFD is required when initial movement velocity is zero
- Examples
  - Sprinting - start
  - Squat/countermovement jump

# Power

- $P = dW/dt$ 
  - 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

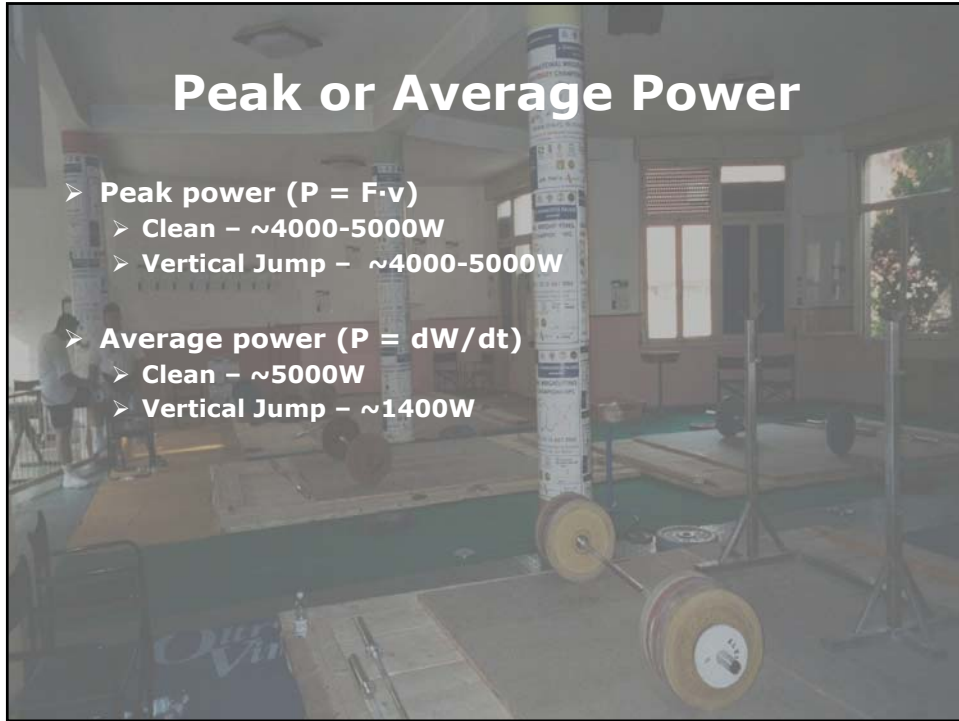
# Load-Dependent



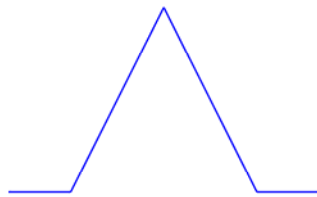


## Peak or Average Power

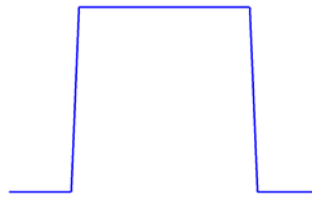
- Peak power ( $P = F \cdot v$ )
  - Clean – ~4000-5000W
  - Vertical Jump – ~4000-5000W
- Average power ( $P = dW/dt$ )
  - Clean – ~5000W
  - Vertical Jump – ~1400W



Theoretical “V”  
Curve



Theoretical “U”  
Curve



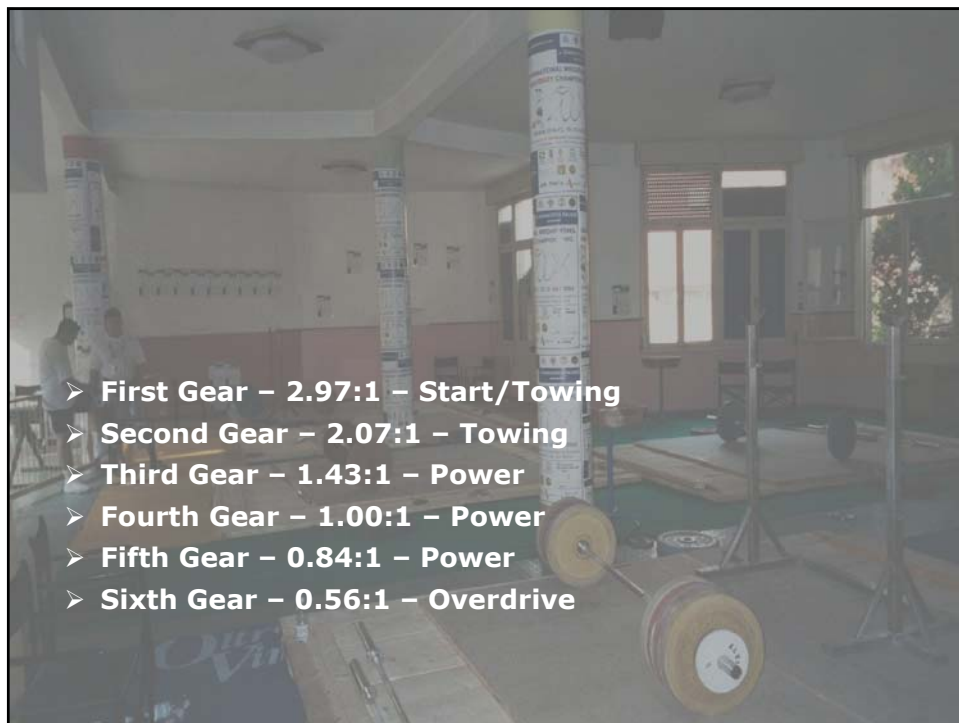
Adapted from Garhammer & Gregor 1992

# 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

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2. Physiology of Strength

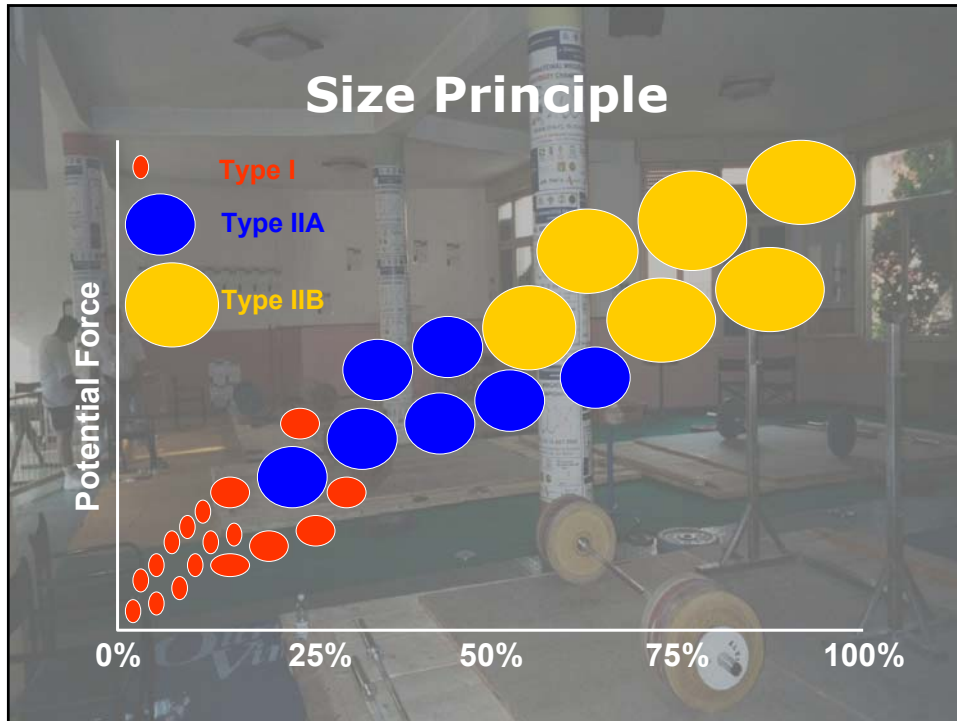


## Motor Unit

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

## Motor Unit Types

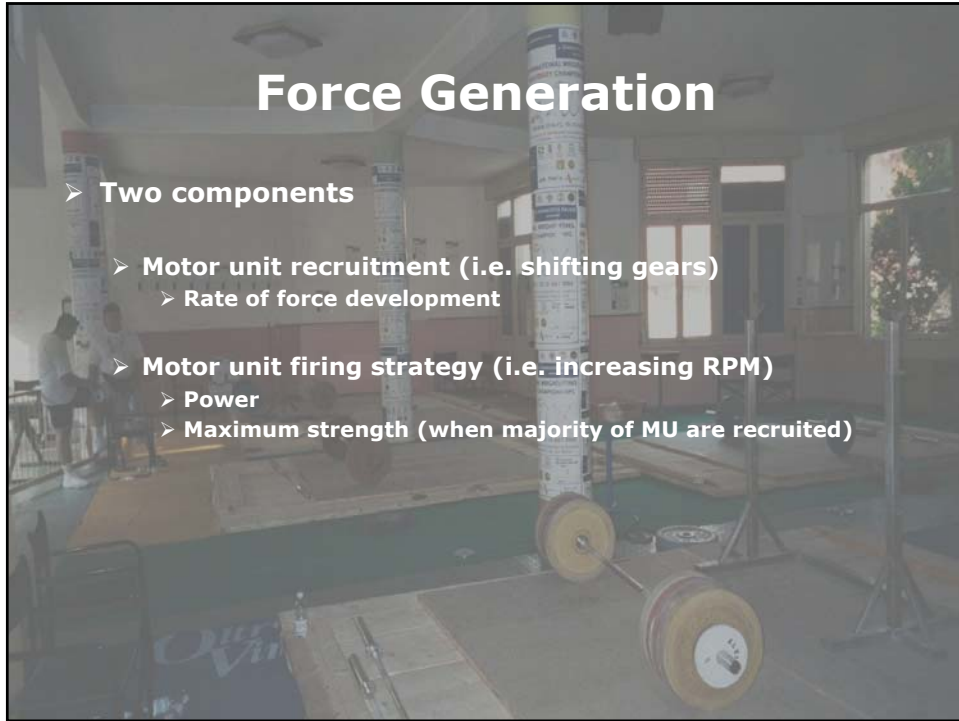
	Size	Speed	Fatigue
I	Small	Slow	Fatigue Resistant
IIA	Large	Fast	Fatigable
IIB	Large	Fastest	Fast Fatigable



- ## MU Activation
- Recruitment
    - Threshold for activation
    - Synchronization
  - Firing strategy
    - Frequency
    - Recycling

## Force Generation

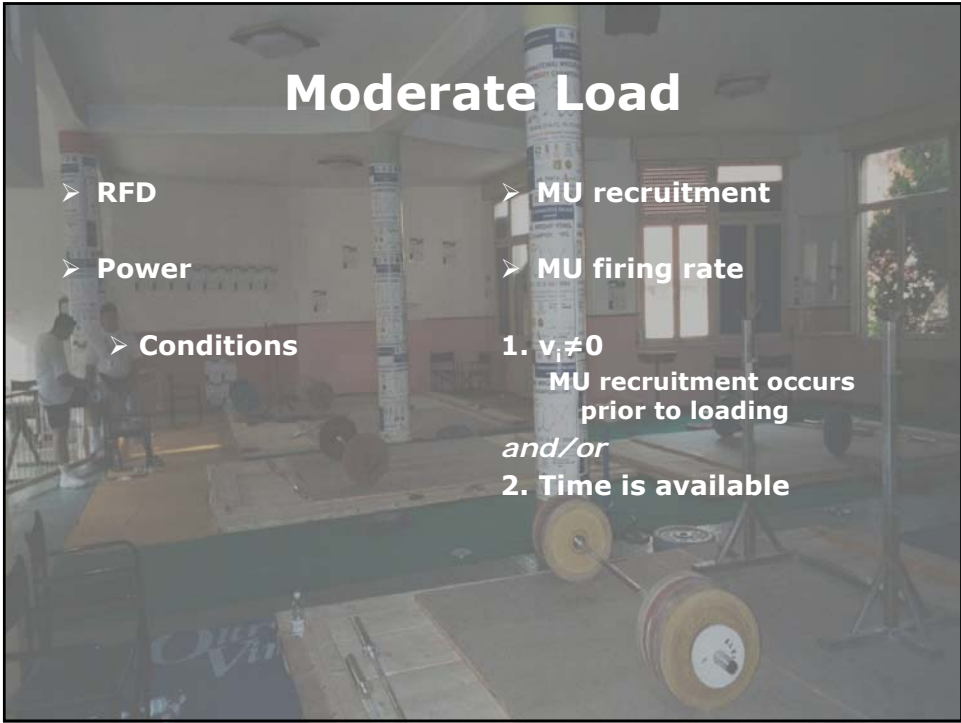
- Two components
  - Motor unit recruitment (i.e. shifting gears)
    - Rate of force development
  - Motor unit firing strategy (i.e. increasing RPM)
    - Power
    - Maximum strength (when majority of MU are recruited)



## Low Load

- RFD
- MU recruitment

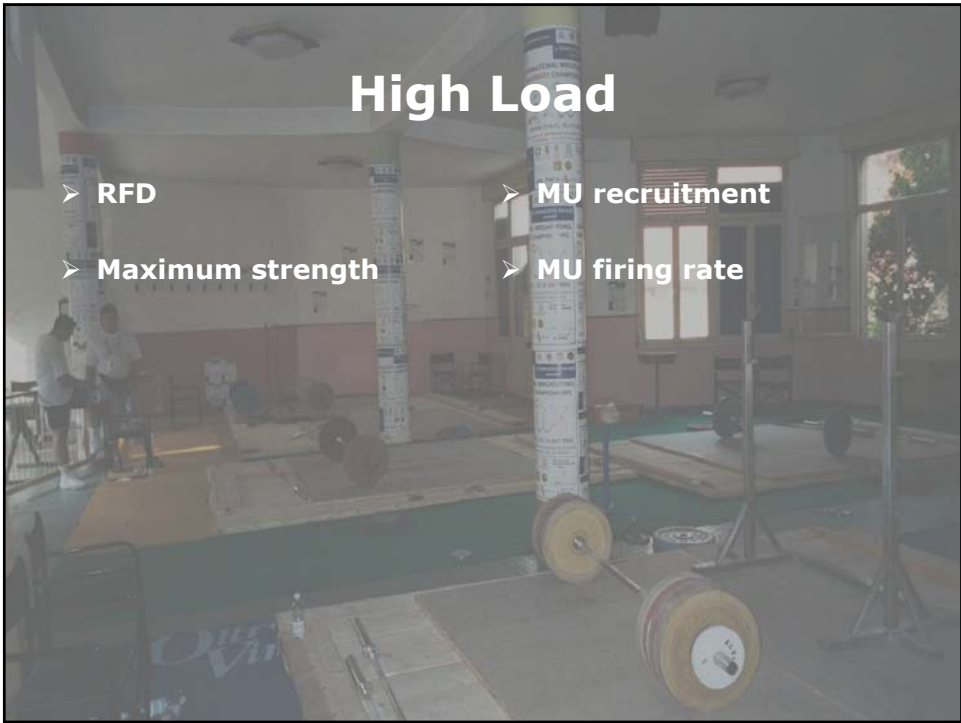




## Moderate Load

- 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

# Overview

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  1. Acute Programming Variables

# Training Principles

- **Overload**
  - ↑ volume and/or
  - ↑ intensity and/or
  - ↑ frequency
- **Specific adaptations to imposed demands (SAID)**

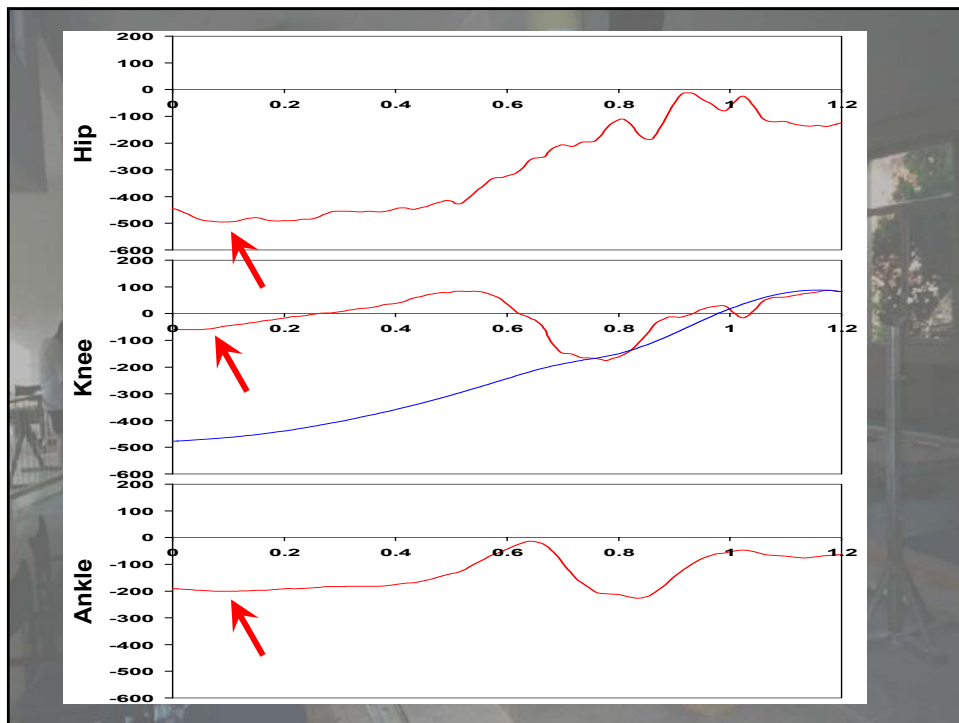


## SAID Principle

- 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 Pull

CLEAN PULL VIDEO



## Quarter Squat

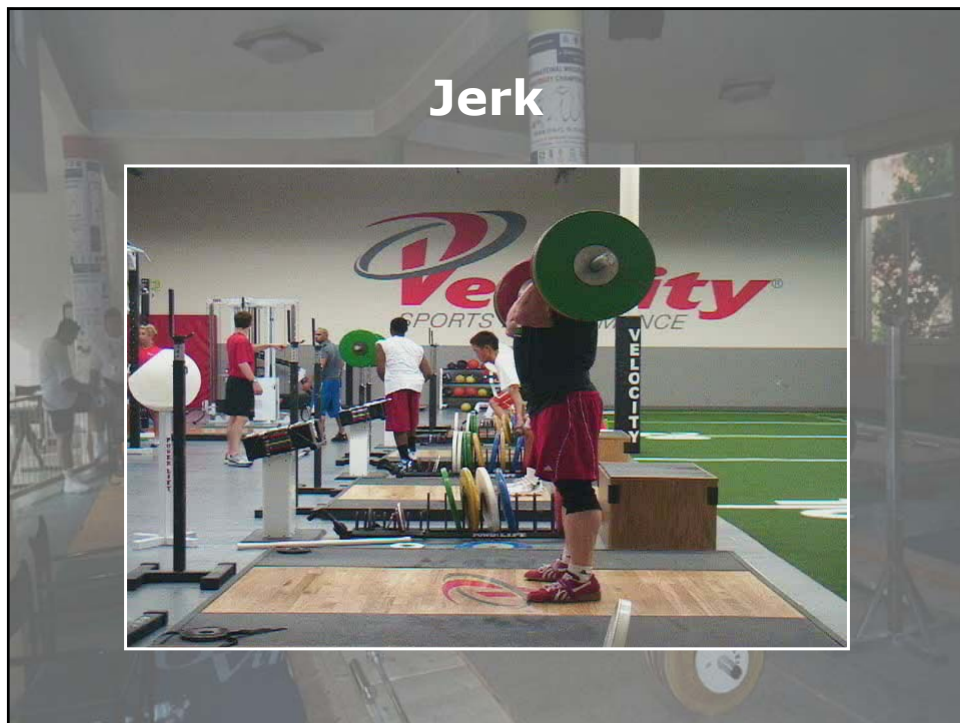
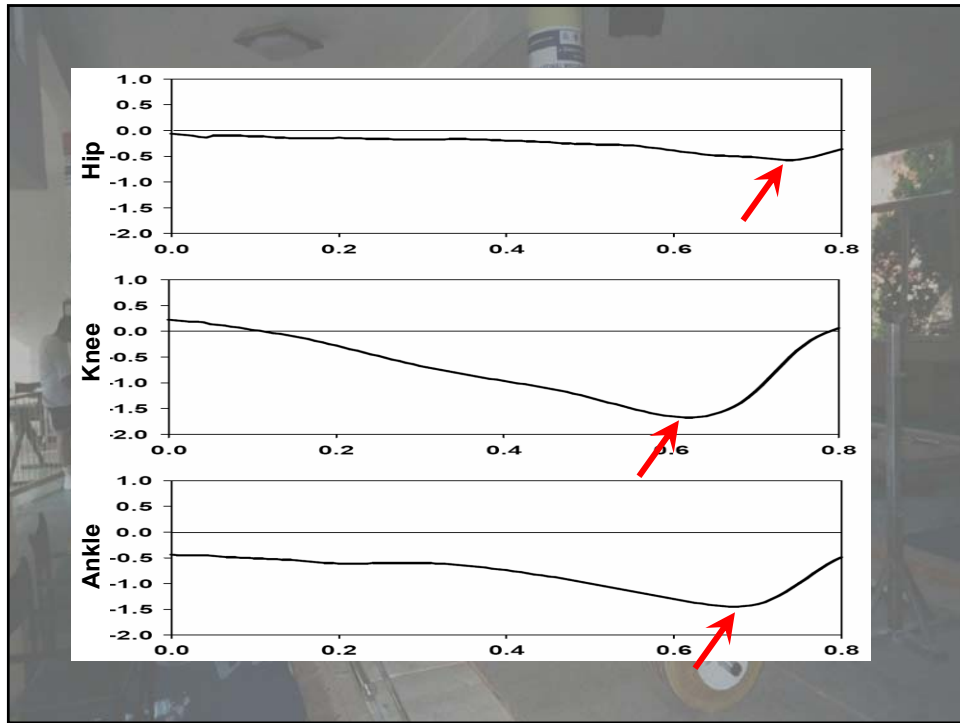
QUARTER SQUAT VIDEO



# 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



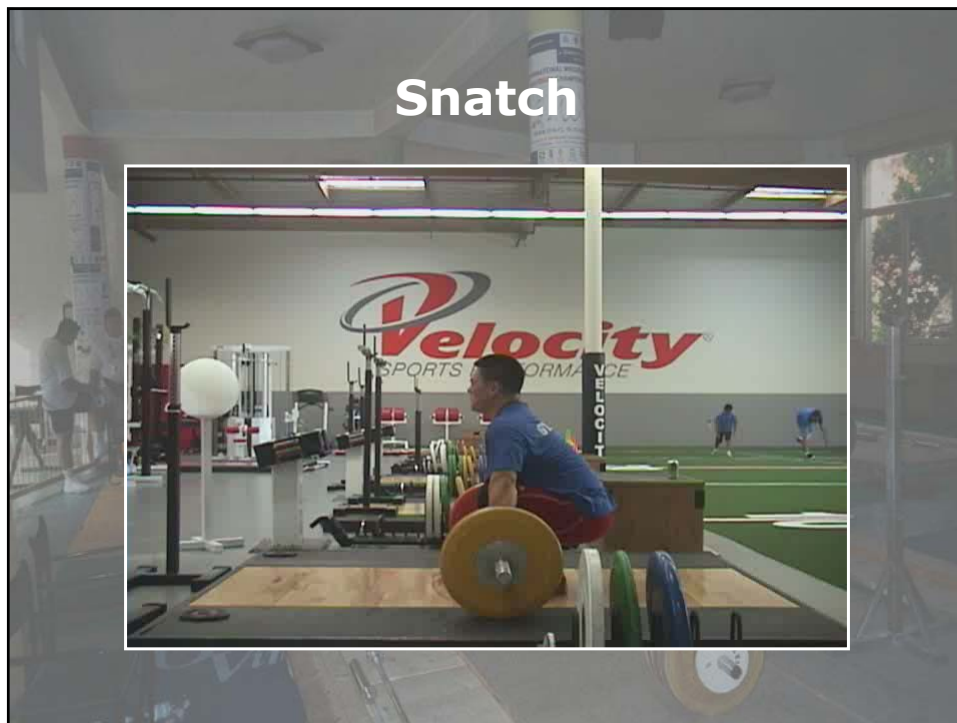
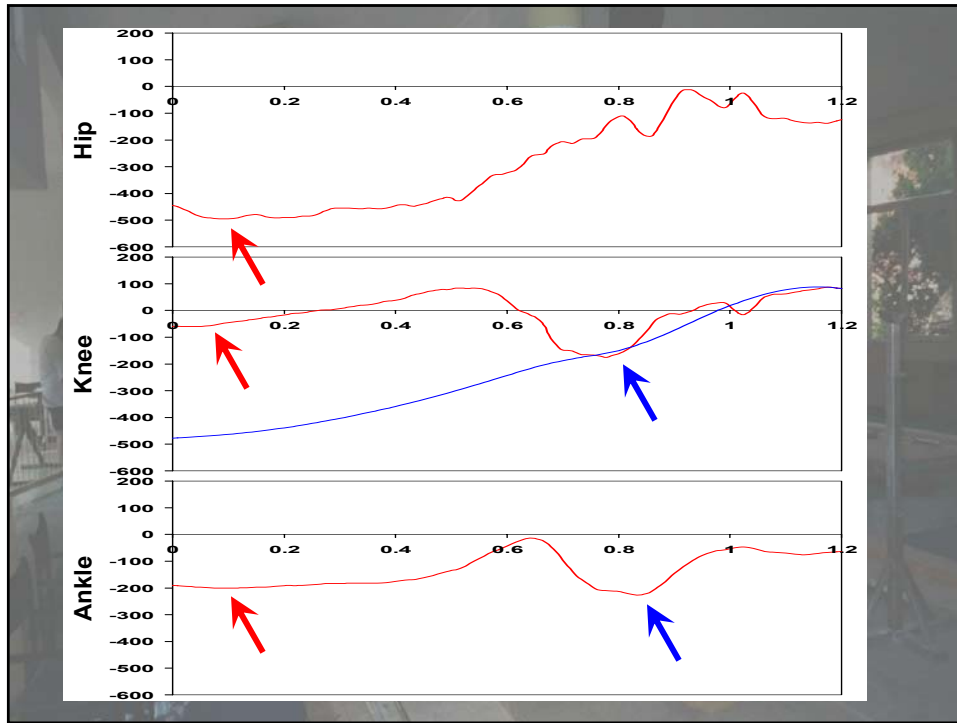


## Hang Clean



## Weightlifting

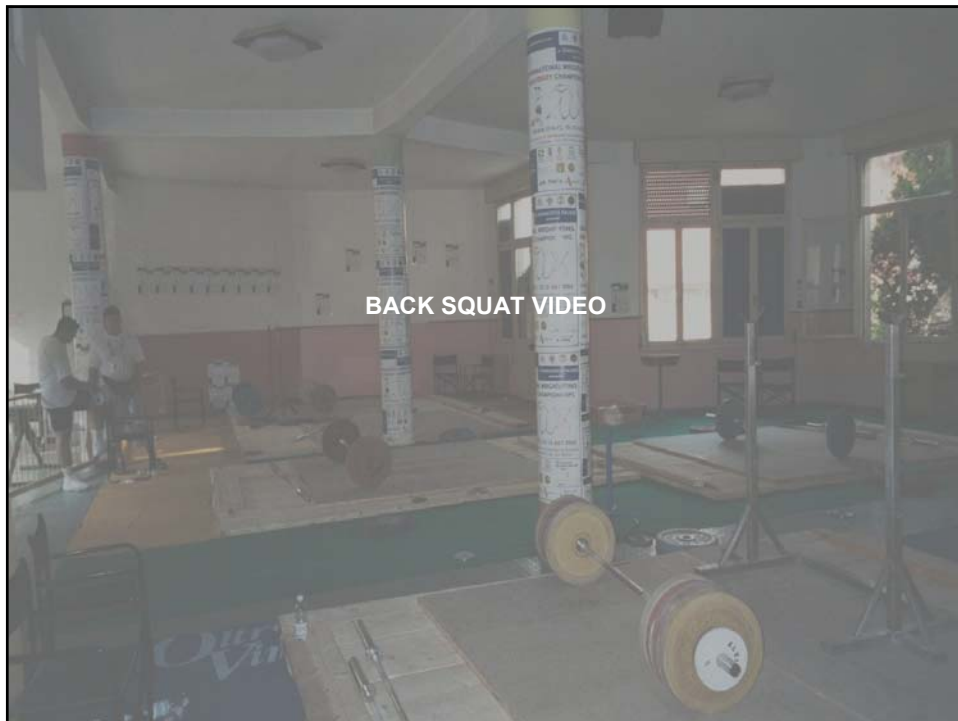
- Weightlifting exercises train both RFD and power
- Snatch
  - Snatch, Power Snatch
- Clean
  - Clean, Power Clean



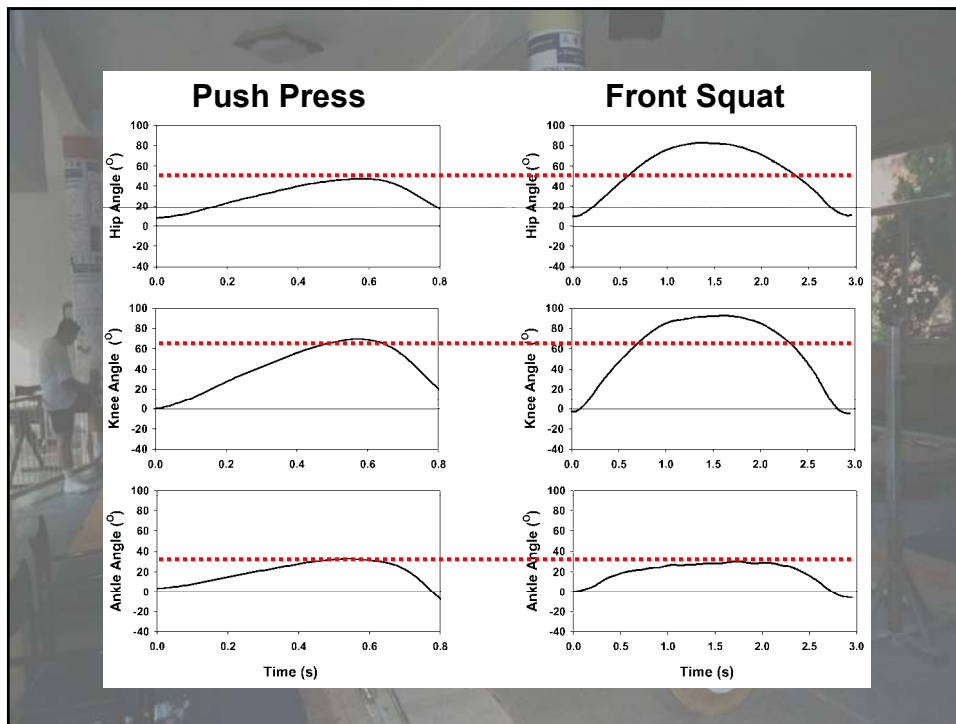
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## Training for Maximum Strength

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







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# Program Development

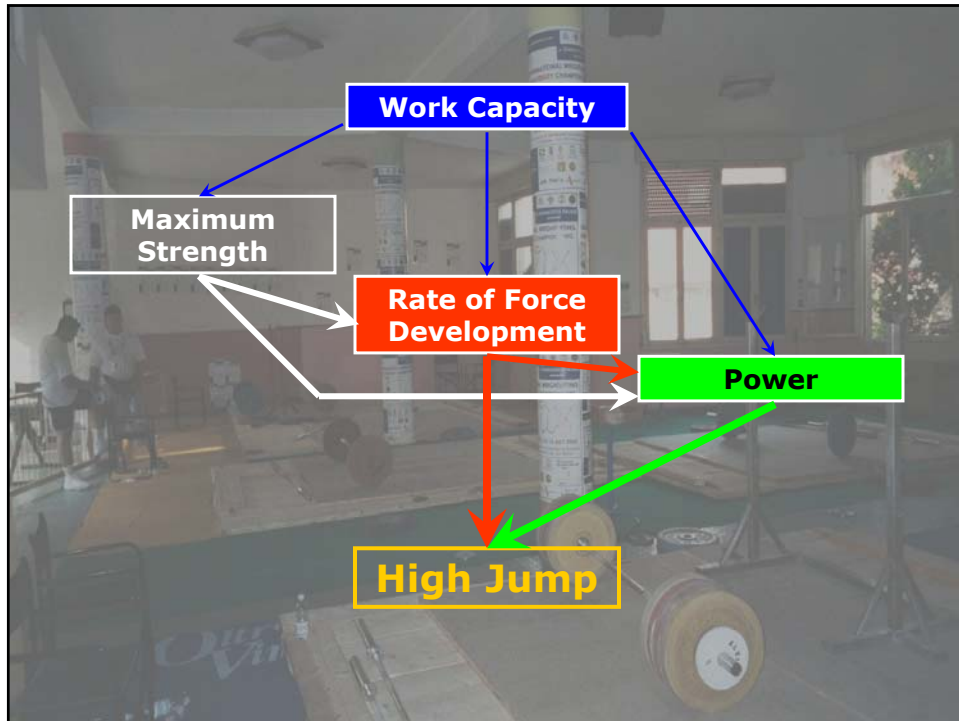
- Training = **curriculum**
  - Long-term process
  - Sequential
  - Cyclical
- The training program must be fitted to the athlete
- All aspects of training must be considered simultaneously
  - Sport
  - Strength & conditioning
  - Other

## 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