The Importance of Muscular Strength: Considerations for Athletic Performance

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Objectives

Define muscular strength and power

Review commonly prescribed resistance training methods

Discuss relevant literature to identify best training methods for athletes with different abilities

Practical examples of how to implement various training methods

◦ What methods to use
◦ How multiple methods can be integrated
The Mentalities We Fight

“It’s all natural work that we do in the gym. Nobody does weights. I’ve never seen a player with a weight on the pitch.” - Maurizio Sarri (Chelsea FC Manager)

- The most decisive actions (short sprints, jumps, tackles, and duel play) in soccer are covered by anaerobic metabolism (Stølen, 2005)

“Lifting weights is going to make me look like a body builder.”

Strength Training for Middle- and Long-Distance Performance: A Meta-Analysis
Nicolas Berryman, Inigo Mujika, Denis Arvisais, Marie Roubeix, Carl Binet, and Laurent Bosquet

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Sir Isaac Newton –
The Original Strength Coach

3 Laws of Motion
◦ Law of Inertia
◦ Law of Acceleration
◦ Law of Action / Reaction
1\textsuperscript{st} Law: Law of Inertia

A body at rest, stays at rest, or a body in motion, stays in motion unless acted upon by an external \textit{force} that causes a change in the body’s state.
The change of motion is directly proportional to the forces impressed and is made in a straight line in which the force is impressed.
3rd Law: Law of Action/Reaction

For every action, there is an equal, opposite, and simultaneous reaction

- When you apply force to something, you receive the same force against you in the opposite direction
Okay...
Muscular Strength and Power

Strength: the ability to produce force against an external resistance
- Athlete’s own bodyweight (e.g. track and field sprinters, jumpers, etc.)
- Athlete’s own bodyweight + Opponent’s bodyweight (e.g. rugby, American football)
- Athlete’s own bodyweight + Implement (e.g. softball, hockey, T&F throws, etc.)

Power: the rate at which a given amount of work is performed (F x V)
- Depending on the sport/event, the athlete who completes the work the fastest may be the winner (e.g. 100 m dash)
- Strongly related to:
  - Sprinting (Weyand et al., 2000; 2010)
  - Jumping (Cormie et al., 2010; Hori et al., 2008)
  - Change of direction performance (Nimphius et al., 2010; Spiteri et al., 2012)
  - Throwing velocity (McEvoy & Newton, 1998; Marques et al., 2011)
The Influence of Strength

- **Power**: 65% of correlations show large relationships.
- **RFD**: 75% of correlations show large relationships.
- **Injury Potential**: $<\frac{1}{3}$ number of injuries, $\frac{1}{2}$ overuse injuries.
- **Jumping**: 59% of correlations show large relationships.
- **Potentiation**: 49% of correlations show large relationships.
- **Sprinting**: 66% of correlations show large relationships.
- **COD**: 60% of correlations show large relationships.
- **Sport Performance**: 83% of correlations show large relationships.

Correlation data from Suchomel et al., 2016.
Strong vs. Weak Comparisons

Stronger individuals:

- Jump higher/farther (Barker et al., 1993; Kraska et al., 2009; Sheppard et al., 2008)
- Sprint faster (Cronin et al., 2005; Hori et al., 2008; Meckel et al., 1995; Wisløff et al., 2004)
- Perform COD tasks better (Nimphius et al., 2010; Young et al., 2015)
- Perform better in their respective sport/event
  - Standing and 3-step running throwing velocity in handball (Gorostiaga et al., 2005)
  - Faster 100 m sprint time (Meckel et al., 1995)
  - Sprint time to 1B and 2B in softball (Nimphius et al., 2010)
  - Tackling ability in rugby (Speranza et al., 2016)
  - 25 m track cycling performance (Stone et al., 2004)
Injury Prevention Potential

The effectiveness of exercise interventions to prevent sports injuries: a systematic review and meta-analysis of randomised controlled trials

Jeppe Bo Lauersen, Ditte Marie Bertelsen, Lars Bo Andersen

Original research

Can the workload–injury relationship be moderated by improved strength, speed and repeated-sprint qualities?

Shane Malone, Brian Hughes, Dominic A. Doran, Kieran Collins, Tim J. Gabbett

Strength training reduced sports injuries to < $\frac{1}{3}$ and overuse injuries almost $\frac{1}{2}$
Training to Improve Power

\[ F \times V \]

**Forces Emphasis**

Heavy Strength Training

\[ f \times V \]

**Velocity Emphasis**

Ballistic Exercise

\[ F \times V \]

**Combined Methods**

Both

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Modified from Haff & Nimphius, 2012
Example Training Progression

Suchomel et al., 2018; Concept from Stone et al., 1982
What training methods should we use with our athletes?
Bodyweight Exercise

Examples (e.g. squat, push-up, pull-up, lunge, etc.)

Advantages
- Closed-chain exercises
- Target multiple muscle groups
- Improve relative strength
- Versatile

Disadvantages
- Ability to provide an overload stimulus is limited
  - More repetitions → ↑ volume → ↑ fatigue & ↓ power
  - Alter how the movement is performed (e.g. push-up variations)
  - Progress from bilateral to unilateral movements
  - Gain weight
Bilateral / Unilateral Resistance Training

Examples: Back squat vs. Rear foot elevated split squat (RFESS)

Greater hamstring : quadriceps activation ratio during RFESS compared to back squat (McCurdy et al., 2010)

No difference in strength and power tests after training with either bilateral or unilateral (Makaruk et al., 2011; McCurdy et al., 2005; Speirs et al., 2015)

- Unilateral training produced greatest unilateral gains → Specificity
- Bilateral training may maintain improvements longer
- Unilateral movements may be used as alternatives to bilateral during initial training
Bilateral / Unilateral Resistance Training

Many would debate that unilateral training is more sport specific (e.g. sprinting, cutting, jumping, etc.)
◦ Should this type of training be emphasized?

Greater stability during a movement leads to greater potential to express force (Anderson & Behm, 2004; Behm & Anderson, 2006)

Unilateral exercises are less stable in nature and limit the load that can be used
◦ Lower Stability → Lower Loads → Lower Peak Power & RFD
Bilateral / Unilateral Resistance Training

Unilateral exercises should be restricted to strength-endurance and maximal strength training periods
- More volume = More fatigue → Need to emphasize most important exercises

<table>
<thead>
<tr>
<th>Day 1</th>
<th>Day 2</th>
<th>Day 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Back squat</td>
<td>Clean grip pull to knee</td>
<td>Back squat</td>
</tr>
<tr>
<td>Bench press</td>
<td>Clean grip shoulder shrug</td>
<td>Incline bench press</td>
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<tr>
<td>Barbell split squat</td>
<td>Stiff-legged deadlift</td>
<td>Barbell split squat</td>
</tr>
<tr>
<td>Military press</td>
<td>Dumbbell row</td>
<td>Military press</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Day 1</th>
<th>Day 2</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Push Press</td>
<td>Mid-thigh pull</td>
<td>Snatch pull from the floor</td>
</tr>
<tr>
<td>Back squat</td>
<td>Clean pull from floor</td>
<td>Front Squat</td>
</tr>
<tr>
<td>Bench press</td>
<td>Bent over row</td>
<td>Incline bench press</td>
</tr>
<tr>
<td>Barbell walking lunge</td>
<td>Pull-up</td>
<td>Dumbbell row</td>
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</tbody>
</table>
Kettlebell Training

Exercises that offer variety when training general strength and power characteristics (e.g. Swings, goblet squat, modified weightlifting exercises)

May improve various strength measures and vertical jump performance (Otto et al., 2012; Lake et al., 2012)

Vertical jump (Jay et al., 2013) and sprint performance (Holmstrup et al., 2016) were no different compared to control group

Similar to bodyweight training, overload stimulus is limited
- More repetitions → More volume...
- Heavier kettlebells → Handle size starts to get larger → Grip strength
Plyometric Training

Plyometric exercises: Quick, powerful movements that use a pre-stretch / countermovement that involves the stretch-shortening cycle
- E.g. Line hops, Tuck jumps, Drop jumps, Bounding, etc.

Limited in their capacity to provide a strength stimulus
- Small loads may be added, but heavier loads may increase impact forces and lengthen the time between ECC and CON actions

May produce similar improvements in vertical jump height compared to weightlifting movements (Hackett et al., 2016)
- Typically programmed for this reason (e.g. RFD and power output)

Like other resistance training methods, proper programming is necessary for the best results
- Periodized plyometric programs enhanced jumping performance (Ebben et al., 2010; 2014)
Plyometric Exercise Intensity

Approximate Highest to Lowest Intensity Plyometric Exercises

- Single leg jumps
- Depth jumps from heights that are similar to or greater than the exerciser's actual vertical jump height
- Tuck and pike jumps
- Maximum jump and reach to overhead goals
- Maximum jump and reach without overhead goals
- Weighted jumps
- Low box and depth jumps
- Squat jumps
- Sub-maximal jumps in place (tall cone hops)
- Sub-maximal jumps in place (short cone hops, ankle hops, split squat jumps)

Ebben et al., 2008; 2011; Jensen & Ebben, 2007
Weightlifting (WL) Movements

Training with WL movements produced greater strength-power benefits compared to:

- Jump training (Teo et al., 2016; Tricoli et al., 2005)
- Traditional resistance training (Chaouachi et al., 2014; Hoffman et al., 2004)
- Kettlebell training (Otto III et al., 2012)

<table>
<thead>
<tr>
<th>Exercise</th>
<th>Relative Power Outputs; Male (W·kg⁻¹)</th>
<th>Force-velocity Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clean</td>
<td>33-80</td>
<td>High Force and High Velocity Movements</td>
</tr>
<tr>
<td>Hang power clean</td>
<td>22-47</td>
<td>High Force and High Velocity Movements</td>
</tr>
<tr>
<td>Jerk</td>
<td>44-80</td>
<td>Moderate – High Force and Moderate – High Velocity Movements</td>
</tr>
<tr>
<td>Jerk drive</td>
<td>28-56</td>
<td>High Force and Low Velocity Movements</td>
</tr>
<tr>
<td>Power clean</td>
<td>25-80</td>
<td>High Force and High Velocity Movements</td>
</tr>
<tr>
<td>Snatch</td>
<td>34-80</td>
<td>High Force and High Velocity Movements</td>
</tr>
<tr>
<td>Clean pull from floor</td>
<td>33-80</td>
<td>High Force and High Velocity Movements</td>
</tr>
<tr>
<td>Hang high pull</td>
<td>47-54</td>
<td>Moderate – High Force and Moderate – High Velocity Movements</td>
</tr>
<tr>
<td>Jump shrug</td>
<td>57-70</td>
<td>Moderate – High Force and Moderate – High Velocity Movements</td>
</tr>
<tr>
<td>Mid-thigh clean pull from dead stop</td>
<td>35-67</td>
<td>High Force and High Velocity Movements</td>
</tr>
<tr>
<td>Mid-thigh snatch pull from dead stop</td>
<td>35-48</td>
<td>High Force and High Velocity Movements</td>
</tr>
<tr>
<td>Snatch pull from floor</td>
<td>30-80</td>
<td>Low Force and High Velocity Movements</td>
</tr>
<tr>
<td>Countermovement jump squat</td>
<td>64-75</td>
<td>High Force and Low Velocity Movements</td>
</tr>
<tr>
<td>Static jump squat</td>
<td>58-69</td>
<td>High Force and Low Velocity Movements</td>
</tr>
<tr>
<td>Bench press</td>
<td>0.3-8.3</td>
<td>High Force and Low Velocity Movements</td>
</tr>
<tr>
<td>Deadlift</td>
<td>11-13</td>
<td>High Force and Low Velocity Movements</td>
</tr>
<tr>
<td>Squat</td>
<td>11-30</td>
<td>High Force and Low Velocity Movements</td>
</tr>
</tbody>
</table>
WL Catching Derivatives

Most commonly prescribed derivatives (e.g. power clean, hang power snatch, etc.)

Can benefit explosive triple extension movement and load absorption (Moolyk et al., 2013)

May be limited in their capacity to provide a force overload stimulus
- Cannot prescribe loads greater than 1RM
- Low loads decrease the effort needed to complete the movement

Athletes may short the triple extension movement to drop under the bar
- ↓ knee joint work performed (Daehlin et al., 2018) = ↓ training stimulus
- Reduces bar height and may put athletes in a compromised position
WL Pulling Derivatives

May be used to teach catching derivatives

Can benefit athlete during triple extension and load absorption to a similar or greater extent compared to WL catching derivatives, depending on the loads used

- Comfort et al., 2011a; 2011b; 2017; 2018
- Kipp et al., 2018
- Suchomel et al., 2014; 2017; 2018; In progress; Suchomel & Sole, 2016; 2017

Potential to overload both force and velocity to a greater extent

- May use loads > 1RM catching movement (Comfort et al., 2012; 2015; Haff et al., 2003)
- More ballistic movements in nature (e.g. jump shrug) → Faster velocities (Suchomel et al., 2014)
WL Derivative
Force-Velocity Characteristics

Modified from
Suchomel et al., 2017
2.5 m/s
1.0 m/s

Jump Shrug
Hang High Pull
Countermovement Power Clean
Mid-Thigh Power Clean
Power Clean From Knee
Power Clean From Floor
Clean Pull From Floor
Clean Pull from the Knee
Mid-Thigh Pull
Countermovement Shrug & Hang Clean Pull

Suchomel et al., 2013
Suchomel et al., 2015
Suchomel et al., 2014
Comfort et al., 2013
Comfort et al., 2012
Cormie et al., 2007
Haff et al., 2003

#NSCA 2017
Comfort et al., 2012, 2015
Meechan et al., In Review

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Modified from Suchomel et al., 2017
Potentiation Complexes

Postactivation potentiation (PAP): an acute enhancement of muscle performance as a result of contractile history (Robbins, 2005)

- Several underpinning mechanisms that may contribute to performance

Typically pair a strength-based movement (e.g. squat) with a biomechanically similar explosive movement (e.g. CMJ)

- Some mixed results in literature due to poor protocol design and weak participants

Individuals increased the magnitude of potentiation following resistance training (Miyamoto et al., 2013)

Stronger participants potentiated earlier and to a greater extent (Seitz et al., 2014; Suchomel et al., 2015)

- Participants squatted ≥ 2x their body mass
Variable Resistance Training (VRT)

Traditional exercises use the same load throughout the entire movement
- May be limited at specific joint angles due to mechanical disadvantages (Abelbeck, 2002)
- May lead to “sticking” points or regions during the movement (van den Tillaar, et al. 2014)

VRT in contrast modifies external resistance throughout the movement to maximize force production properties (Fleck & Kraemer, 2014)
- Chains or bands alter force, velocity, and power characteristics by creating greater force during early ECC phase and later CON phase (Israetel et al., 2010)

VRT produced greater back squat (Soria-Gila et al., 2015) and bench press (Ataee et al., 2014) strength gains compared to traditional resistance training

VRT produced benefits as part of potentiation complexes (Mina et al., 2014; 2016)
VRT Back Squat Example
Accentuated Eccentric Loading (AEL)

Prescribing ECC loads in excess of the CON portion of ECC/CON movements with minimal disruption of natural exercise mechanics

Greater increases in strength and explosive performance compared to traditional loading (Friedmann-Bette, et al., 2010; Walker et al., 2016)

Advanced training strategy that requires a baseline level of strength before benefits can be maximized (e.g. potentiation within set)
# Resistance Training Method Potential

<table>
<thead>
<tr>
<th>Resistance Training Method</th>
<th>Hypertrophy</th>
<th>Strength</th>
<th>Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bodyweight exercise</td>
<td>+</td>
<td>+</td>
<td>++</td>
</tr>
<tr>
<td>Machine-based exercise</td>
<td>++</td>
<td>++</td>
<td>++</td>
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<tr>
<td>Weightlifting derivatives</td>
<td>+++</td>
<td>+++</td>
<td>++++</td>
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<tr>
<td>Plyometrics</td>
<td>+</td>
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<tr>
<td>Eccentric training</td>
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<tr>
<td>Potentiation complexes</td>
<td>?</td>
<td>+++</td>
<td>++++</td>
</tr>
<tr>
<td>Unilateral exercise</td>
<td>+++</td>
<td>++</td>
<td>+++</td>
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<tr>
<td>Bilateral exercise</td>
<td>++++</td>
<td>++++</td>
<td>+++</td>
</tr>
<tr>
<td>Variable resistance</td>
<td>++++</td>
<td>++++</td>
<td>++++</td>
</tr>
<tr>
<td>Kettlebell training</td>
<td>++</td>
<td>++</td>
<td>+++</td>
</tr>
<tr>
<td>Ballistic training</td>
<td>++</td>
<td>+++</td>
<td>++++</td>
</tr>
</tbody>
</table>

Suchomel et al., 2018
Based on what we know, how can we improve power by exploiting both force & velocity?
Weaker / Less-skilled Athletes

Training emphasis should be increasing maximal strength
  ◦ Will lay the foundation for future gains in RFD, velocity, and power (Stone et al., 1982; Minetti, 2002; Zamparo et al., 2002; Cormie et al., 2010)

Youth benefit more from resistance training prior to completing power-type training (Behm et al., 2017)

Suggested training methods → TECHNIQUE!
  ◦ Bodyweight exercise
  ◦ Bilateral → Bilateral & Unilateral
  ◦ Kettlebells
  ◦ Weightlifting derivatives – Pulls to start → Pulls & Catches if desired
  ◦ Low-moderate intensity plyometrics → Higher intensity
Weaker / Less-skilled Athlete Possibilities

- Low-Mod Intensity Plyometrics
  - Kettlebells
- Traditional Resistance Training
  - Squats, presses, & pulls
- Tempo Eccentric Exercise

Velocity

Force

CON

ECC
Relative Strength and Performance

- Improvements in performance can directly be related to increases in muscular strength (Strength Association).

- The window of adaptation for improved performance resulting from increased strength becomes smaller (Strength Reserve).

- Thus, novel stimuli must be introduced to allow for continued adaptation.

Figure from Suchomel et al., 2016
Stronger / More-skilled Athletes

Training emphasis should be maintaining / increasing strength and shifting focus to power / ballistic training
- Squat ≥ 2x their body mass

Previously discussed training methods serve as the foundation for advanced methods

Greater power emphasis / additional training methods:
- Moderate-High intensity plyometrics
- Ballistic training
- Weightlifting derivatives
- Potentiation complexes
- Variable resistance training
- Accentuated eccentric training
Force
Velocity

Stronger / More-skilled Athlete Possibilities

Mod-High Intensity Plyometrics
Kettlebells

Traditional Resistance Training
Squats, presses, & pulls

Potentiation Complexes

Variable Resistance

Accentuated Eccentric

Weightlifting Derivatives

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Take Aways

Get stronger.

- Strength lays the foundation for other general and specific sport skills
- Weaker/Less-skilled athletes should prioritize gaining strength before focusing more on power-type training

There are many methods of increasing strength and power, but choosing those that are the most effective for your athletes is key

- Some training methods require greater baseline levels of strength before the greater benefits can be realized (e.g. PAP complexes, VRT, and AEL)

A variety of training methods can be used to train both the force and velocity aspects of power

- Heavy & light sets of the same exercise
- Multiple exercises that load differently (e.g. mid-thigh pull and jump shrug)
- Combined training methods (e.g. heavy strength training and plyometrics)
Thank you!

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