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."

[redacted] November 2017 ➡ March 2018
~kinda crazy what eating enough & lifting heavy can do for ya 😈

International Journal of Sports Physiology and Performance, (Ahead of Print)
https://doi.org/10.1123/ijspp.2017-0032

Human Kinetics
ORIGINAL INVESTIGATION

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

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1st 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 force that causes a change in the body's state.

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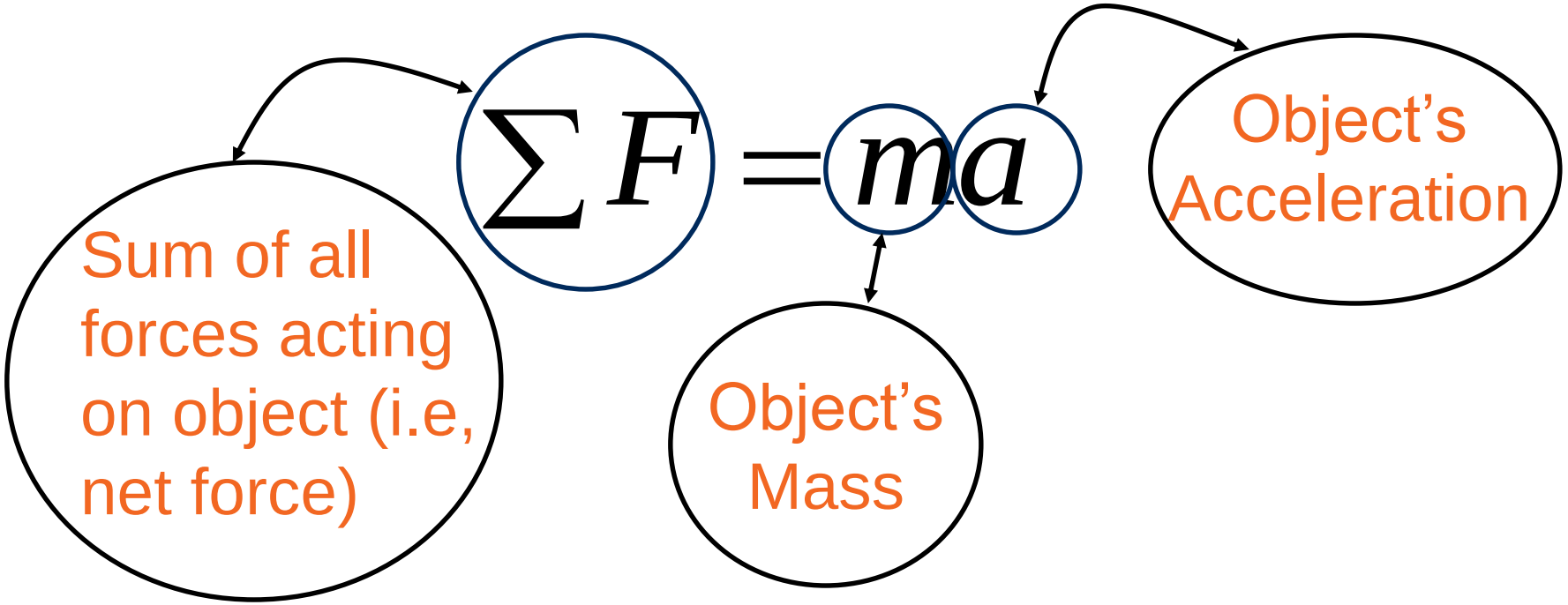
2nd law: Law of Acceleration

The change of motion is directly proportional to the forces impressed and is made in a straight line in which the force is impressed.



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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

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Okay...

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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

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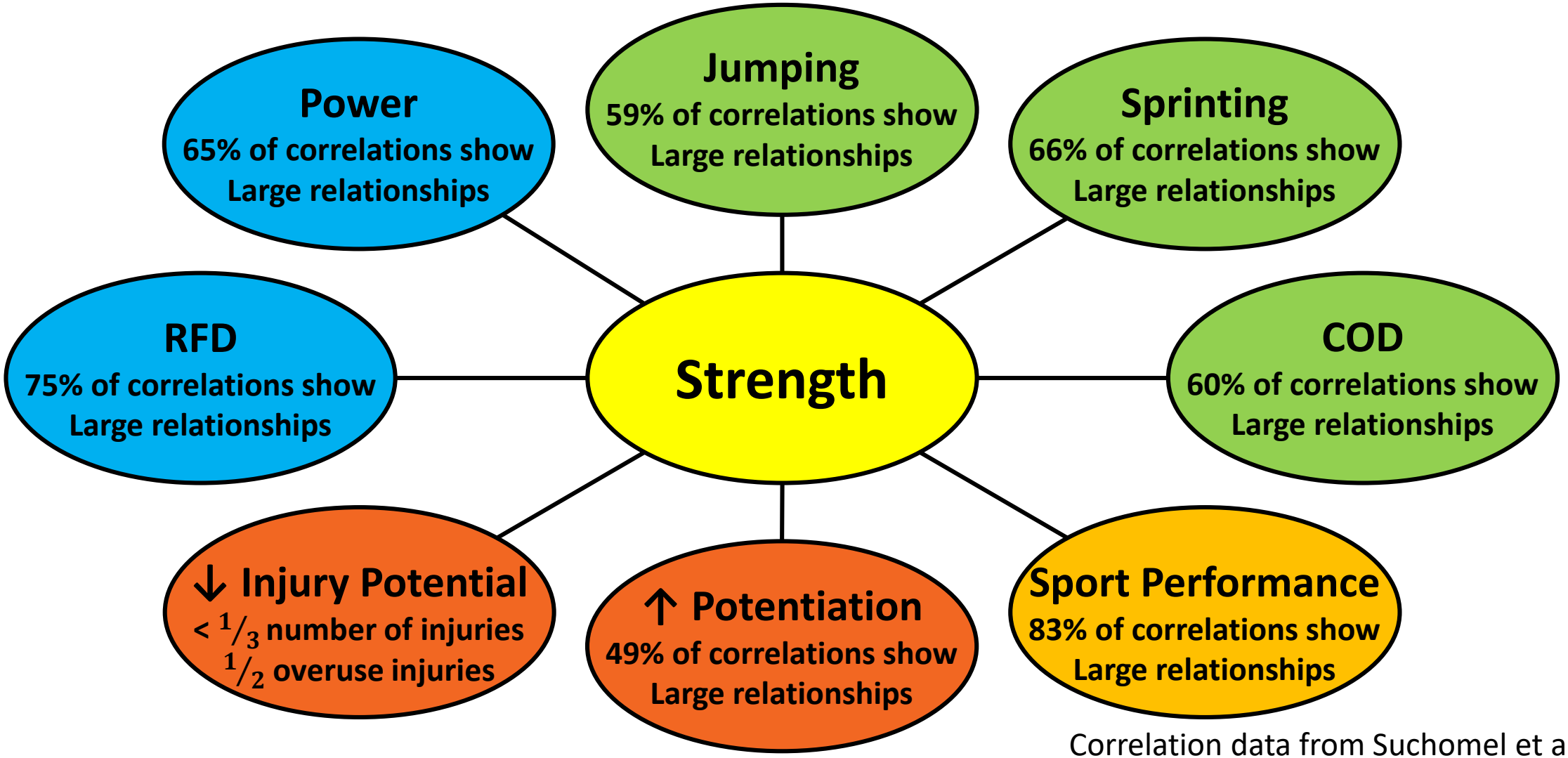

Correlation data from Suchomel et al., 2016

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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)

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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,[1] Ditte Marie Bertelsen,[2] Lars Bo Andersen[3,4]

Contents lists available at ScienceDirect

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journal homepage: www.elsevier.com/locate/jsams

Original research

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

Shane Malone[a,b,*], Brian Hughes[b], Dominic A. Doran[a], Kieran Collins[a], Tim J. Gabbett[c,d]

[a] The Tom Reilly Building, Research Institute for Sport and Exercise Sciences, Liverpool John Moores University, UK
[b] Gaelic Sport Research Centre, Department of Science, Institute of Technology Tallaght Dublin, Ireland
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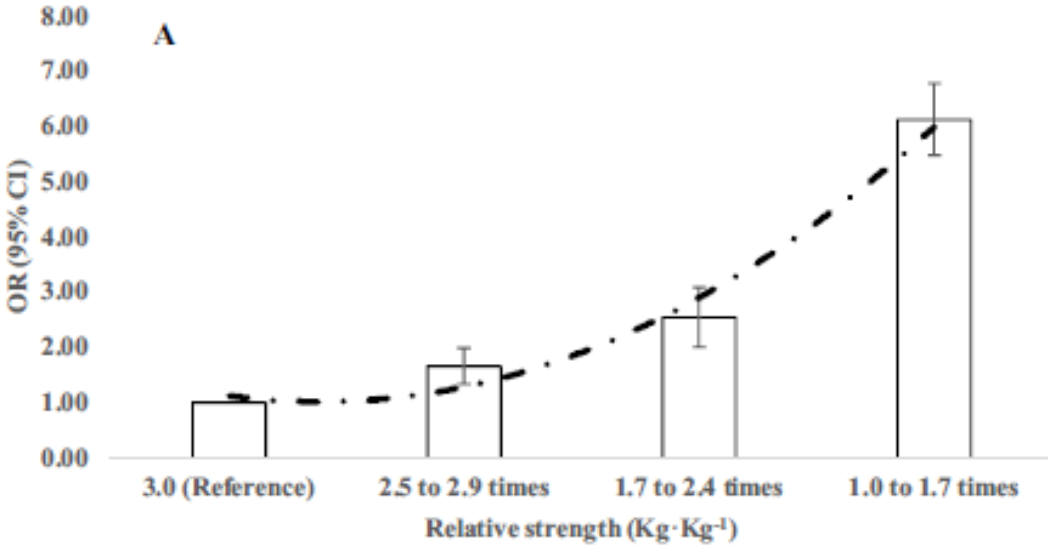
[d] Institute for Resilient Regions, University of Southern Queensland, Australia

- Strength training reduced sports injuries to < $^1/_3$ and overuse injuries almost $^1/_2$



Training to Improve Power

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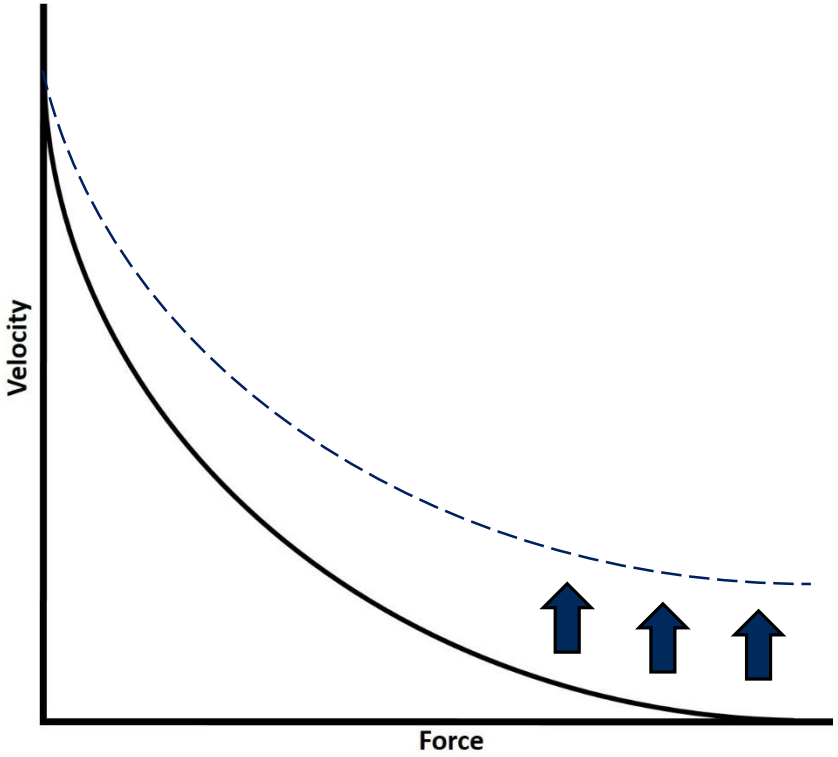
F x v

Force Emphasis

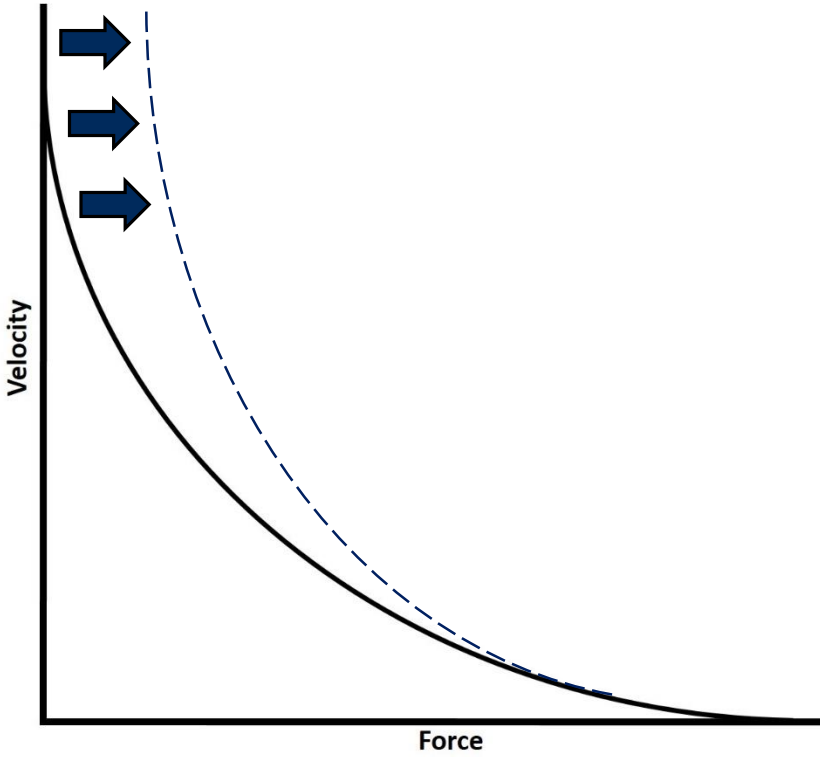
Heavy Strength Training



f x V

Velocity Emphasis

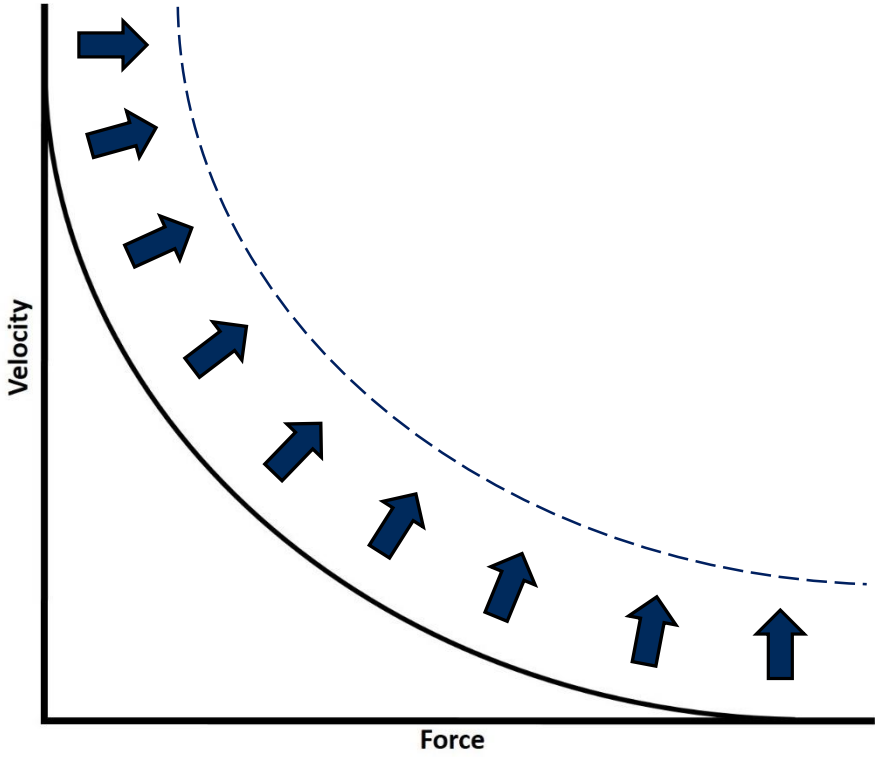
Ballistic Exercise



F x V

Combined Methods

Both



Modified from Haff & Nimphius, 2012

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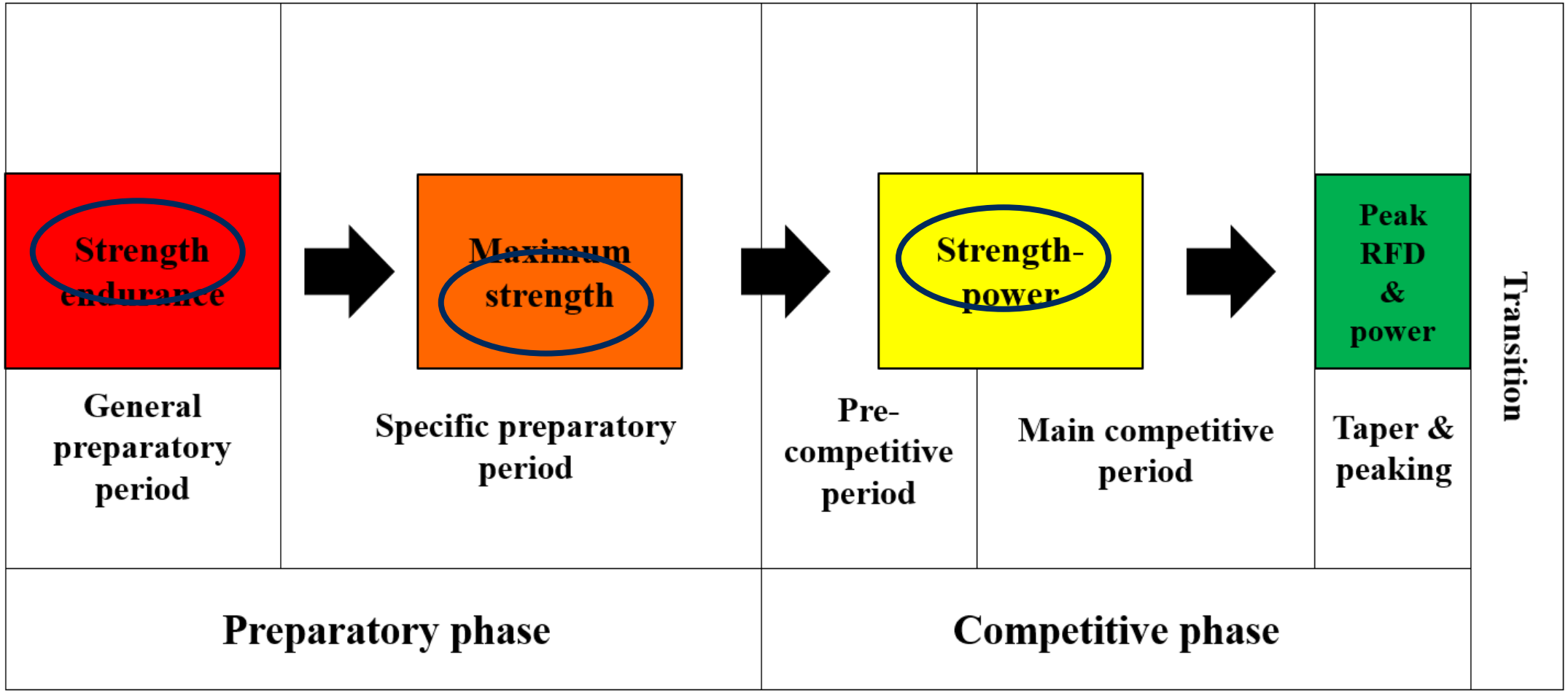
Example Training Progression



Suchomel et al., 2018; Concept from Stone et al., 1982

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What training methods should we use with our athletes?

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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

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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

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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

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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

Day 1	Day 2	Day 3
Back squat	Clean grip pull to knee	Back squat
Bench press	Clean grip shoulder shrug	Incline bench press
Barbell split squat	Stiff-legged deadlift	Barbell split squat
Military press	Dumbbell row	Military press

Day 1	Day 2	Day 3
Push Press	Mid-thigh pull	Snatch pull from the floor
Back squat	Clean pull from floor	Front Squat
Bench press	Bent over row	Incline bench press
Barbell walking lunge	Pull-up	Dumbbell row

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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

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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)

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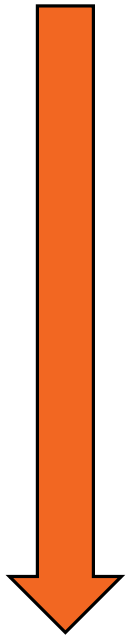
Plyometric Exercise Intensity

High



Low

Approximate Highest to Lowest Intensity Plyometric Exercises

- Single leg jumps
- Depth jumps from heights that are similar to or greater than the exercisers 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

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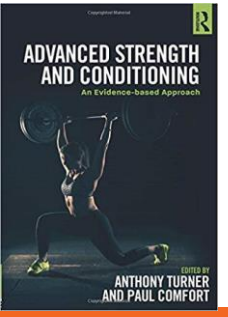
Weightlifting (WL) Movements

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)

Catching derivatives

Pulling derivatives



Suchomel et al., 2018

Exercise	Relative Power Outputs; Male ($W \cdot kg^{-1}$)	Force-velocity Characteristics
Clean	33-80	High Force and High Velocity Movements
Hang power clean	22-47	
Jerk	44-80	
Jerk drive	28-56	
Power clean	25-80	
Snatch	34-80	
Clean pull from floor	33-80	Moderate – High Force and Moderate – High Velocity Movements
Hang high pull	47-54	
Jump shrug	57-70	
Mid-thigh clean pull from dead stop	35-67	
Mid-thigh snatch pull from dead stop	35-48	
Snatch pull from floor	30-80	
Countermovement jump squat	64-75	Low Force and High Velocity Movements
Static jump squat	58-69	
Bench press	0.3-8.3	High Force and Low Velocity Movements
Deadlift	11-13	
Squat	11-30	

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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

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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)

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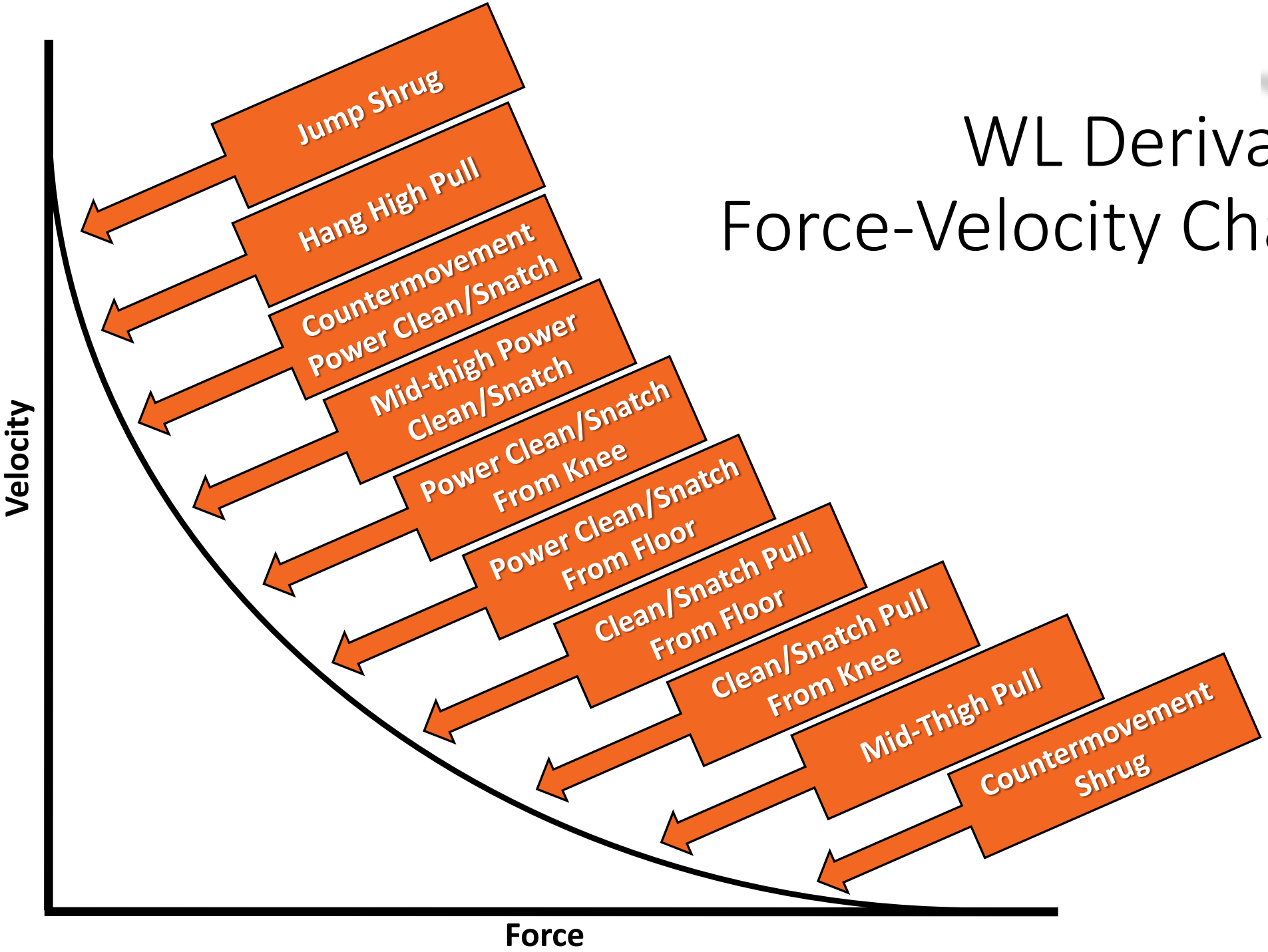
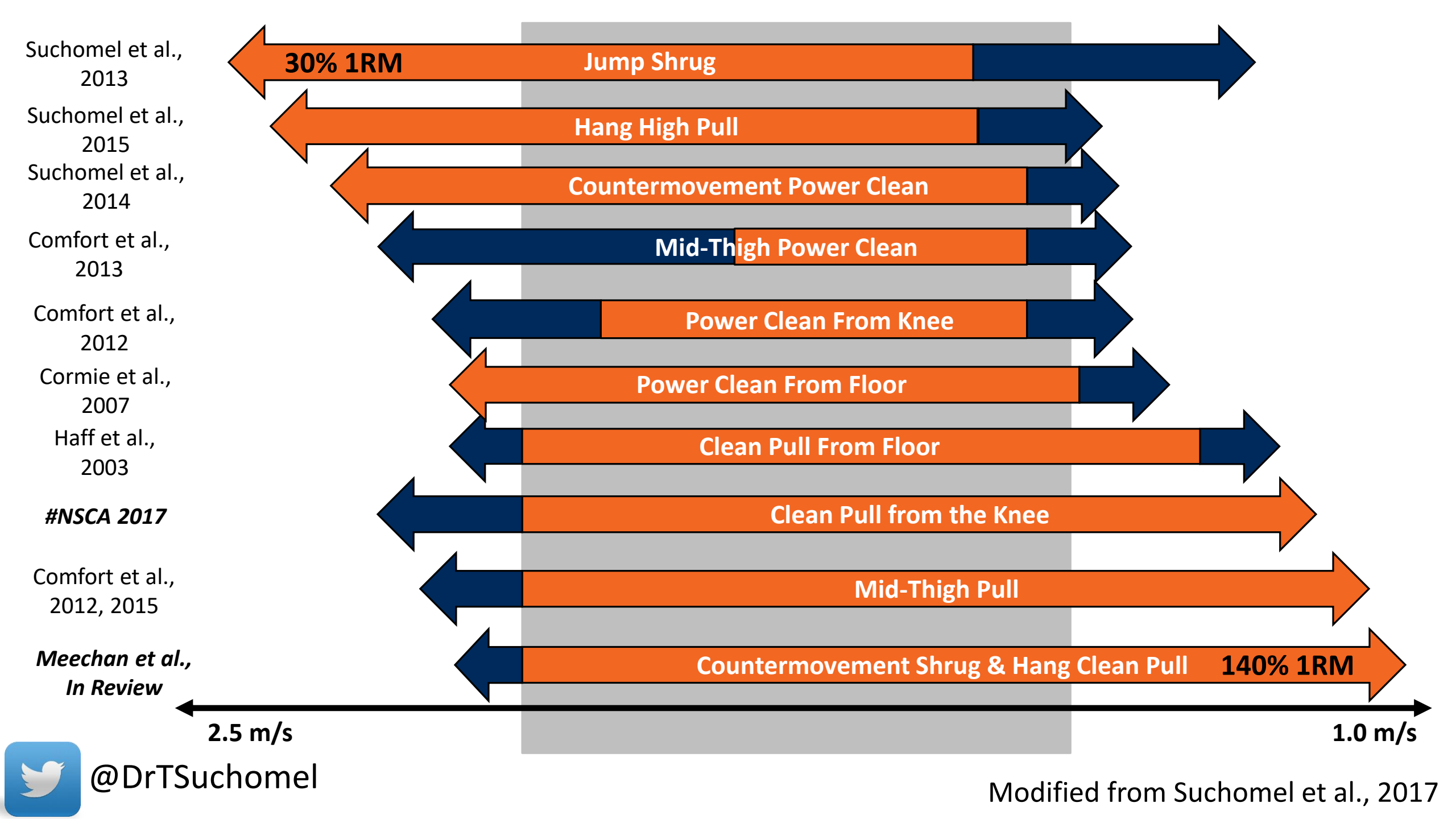
WL Derivative Force-Velocity Characteristics



Modified from
Suchomel et al., 2017



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Modified from Suchomel et al., 2017

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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

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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)

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VRT Back Squat Example

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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)

Sports Med (2017) 47:2473–2495
DOI 10.1007/s40279-017-0755-6

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REVIEW ARTICLE

Accentuated Eccentric Loading for Training and Performance: A Review

John P. Wagle[1] · Christopher B. Taber[2] · Aaron J. Cunanan[1] · Garett E. Bingham[1] · Kevin M. Carroll[1] · Brad H. DeWeese[1] · Kimitake Sato[1] · Michael H. Stone[1]

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Resistance Training Method Potential

Resistance Training Method	Hypertrophy	Strength	Power
Bodyweight exercise	+	+	++
Machine-based exercise	++	++	++
Weightlifting derivatives	+++	+++	+++++
Plyometrics	+	++	++++
Eccentric training	+++++	+++++	++++
Potentiation complexes	?	+++	+++++
Unilateral exercise	+++	++	+++
Bilateral exercise	++++	++++	+++
Variable resistance	+++++	++++	++++
Kettlebell training	++	++	+++
Ballistic training	++	+++	+++++

Suchomel et al., 2018

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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

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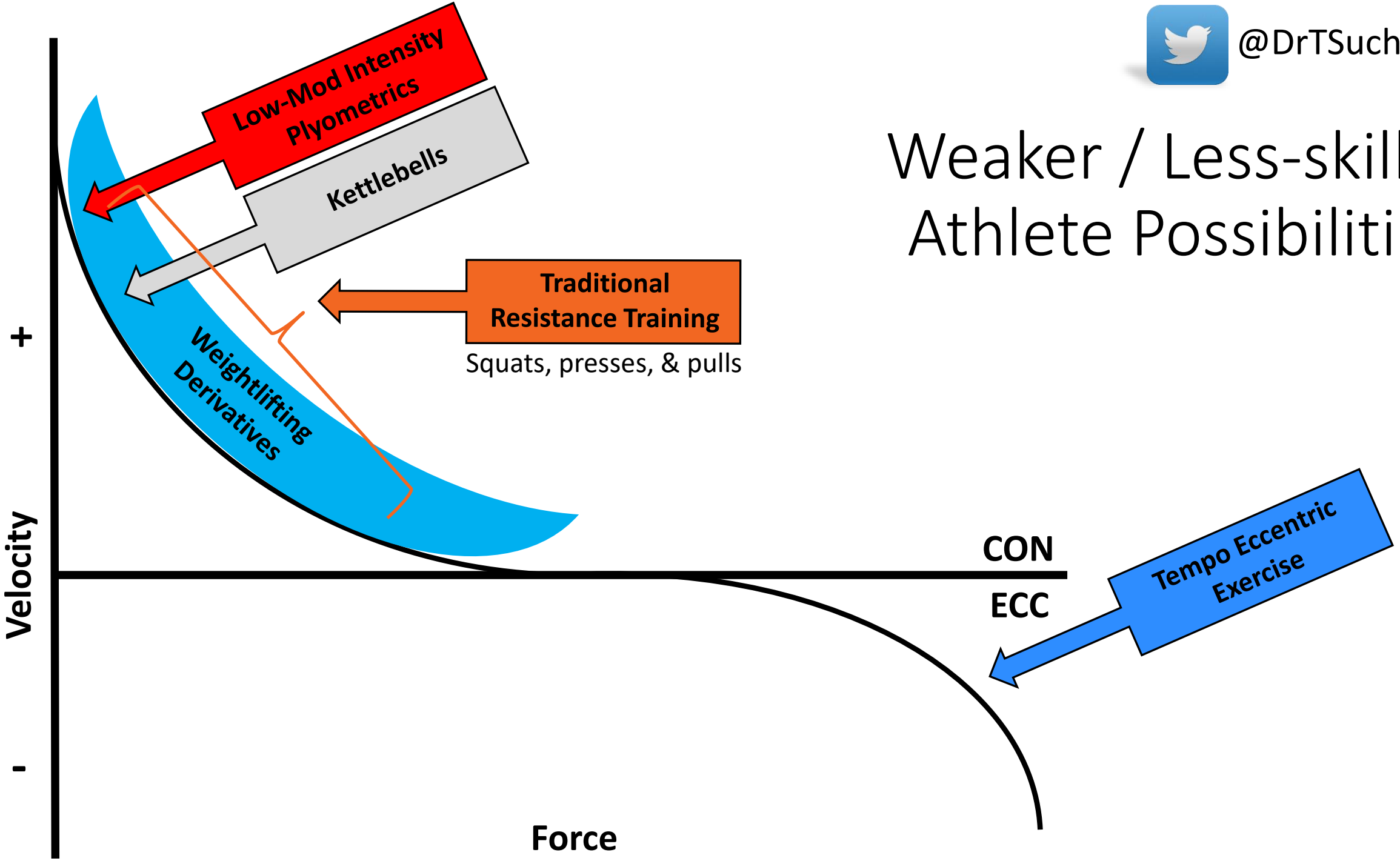
Weaker / Less-skilled Athlete Possibilities



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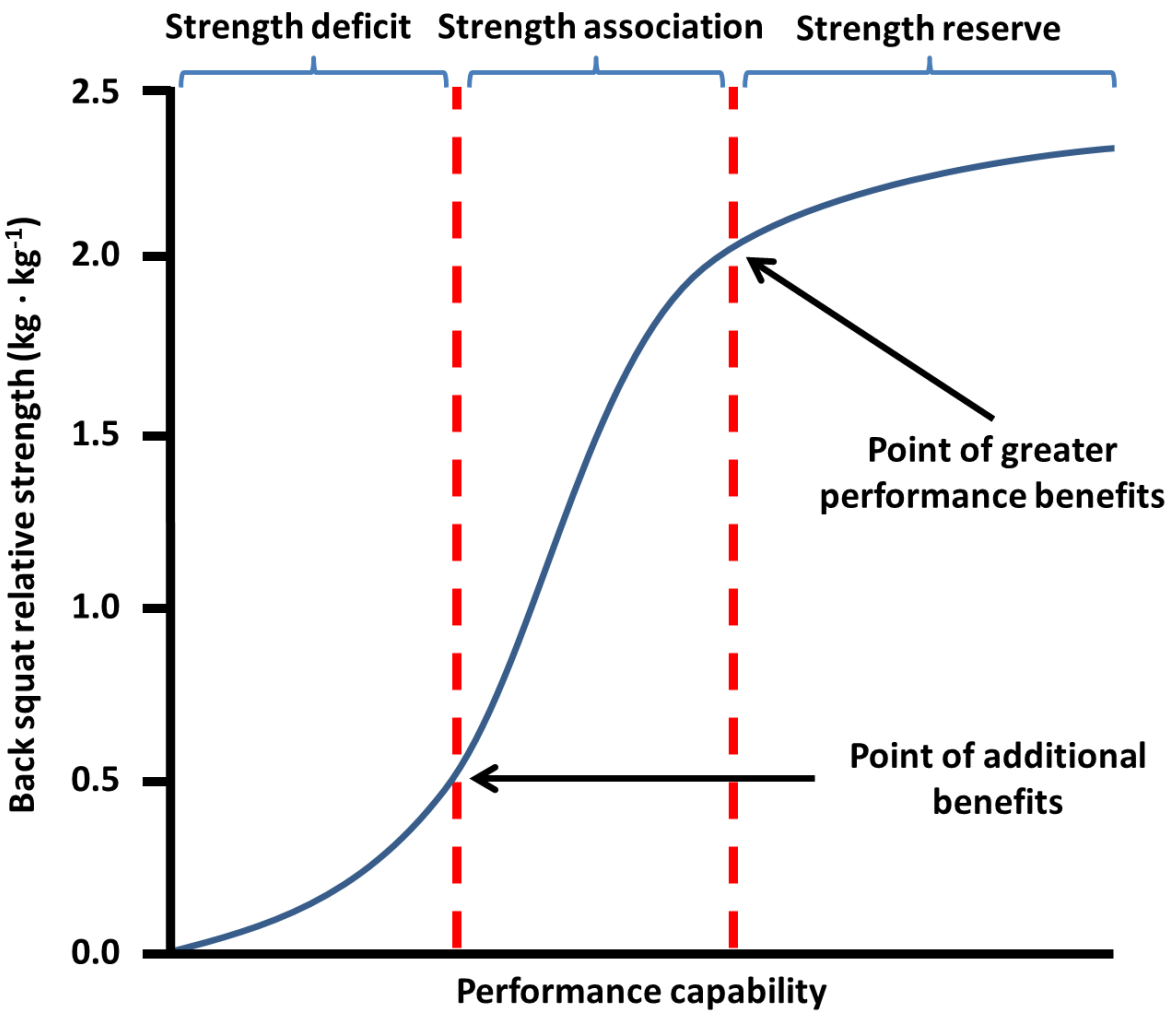
Relative Strength and Performance



- 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

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Stronger / More-skilled Athletes

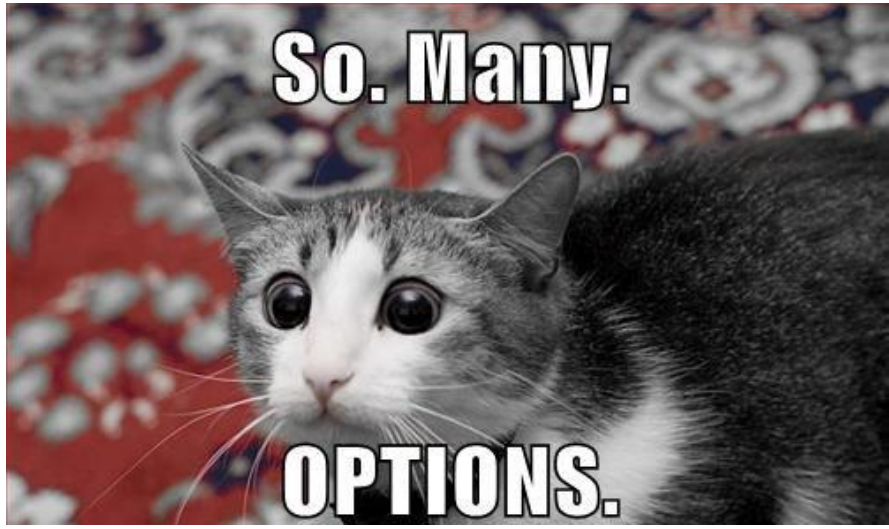
Training emphasis should be maintaining / increasing strength and shifting focus to power / ballistic training

- 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



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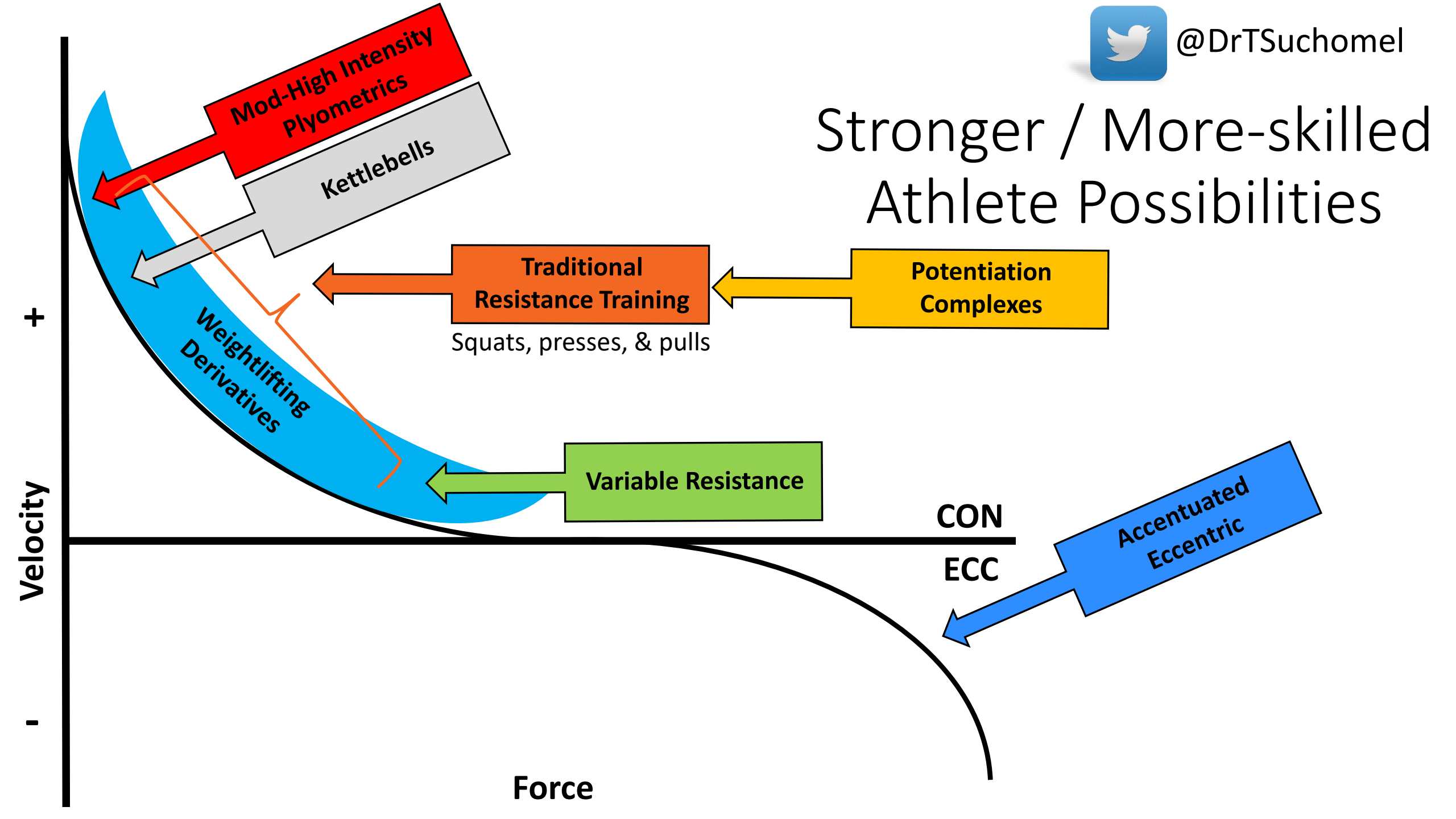
Stronger / More-skilled Athlete Possibilities



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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)

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Thank you!

Co-investigators:

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Dr Paul Comfort
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REVIEW ARTICLE

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