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Strength Training Principles & Methods: Application to Orthopedic & Sports PT

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Thank You

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Objectives

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- Identify the importance of foundational principles of exercise prescription
- Define basic terminology related to strength training
- Distinguish appropriate parameters to manipulate with exercise prescription
- Summarize various modes of autoregulation
- Describe advanced training methods that one might employ in rehabilitation

Disclaimer and Context

There are rarely, if ever, any absolutes when it comes to rehabilitation & training

Other interventions are often indicated to be used in conjunction with therapeutic exercise

Is Strength & Conditioning (S&C) Research Even Applicable to PT?

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- "...it appears that resistance training guidelines, which have proven effective in a healthy population, can also be successfully applied in a rehabilitation context."
(Kristensen et al 2012)

Exercise Prescription (ExRx)

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- Applying a physical stressor to a complex system in order to elicit a response, and hopefully, a subsequent desired adaptation. (Lorenz et al 2015, Credit Henoch)

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Principles > Methods

Anchoring ExRx Principles (Credit Henoch)

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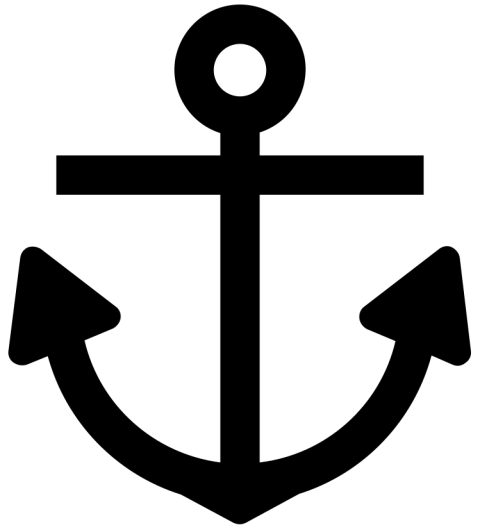
- Be objective
- Begin with the end in mind
- Address “buckets of need”
- Establish current conditions
- Identify meaningful entry point(s)
- Create a “MVP”
- Measure, learn, repeat



S&C Terminology

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- Work capacity: ability to perform exercises proficiently over time with no excessive fatigue. (Panariello et al 2017)
- Hypertrophy: enlargement of muscle fiber cross-sectional area (Haff & Triplett 2016)
- Strength: ability to exert a maximal amount of force against external resistance (Haff & Triplett 2016, Panariello et al 2017)
- Power/explosive strength: ability to exert force quickly; work/time (Panariello et al 2017)

S&C Terminology

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- Individuality: each individual is unique & will respond differently to the same training stimulus (Sands et al 2012)
- Specificity (S.A.I.D. principle): adaptations are specific to the training stimulus (Jeffreys & Moody 2016)
- Overload: the training stimulus must be greater than what the individual is accustomed to (Sands et al 2012)
- Progression: the training stimulus must gradually/constantly increase (Sands et al 2012)

S&C Terminology

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- Diminishing Returns: adaptations are related to the level of training (Sands et al 2012)

- Reversibility: individuals will see the loss of adaptation(s) in the absence of a training stimulus (Sands et al 2012)

Hierarchy of Athletic Development

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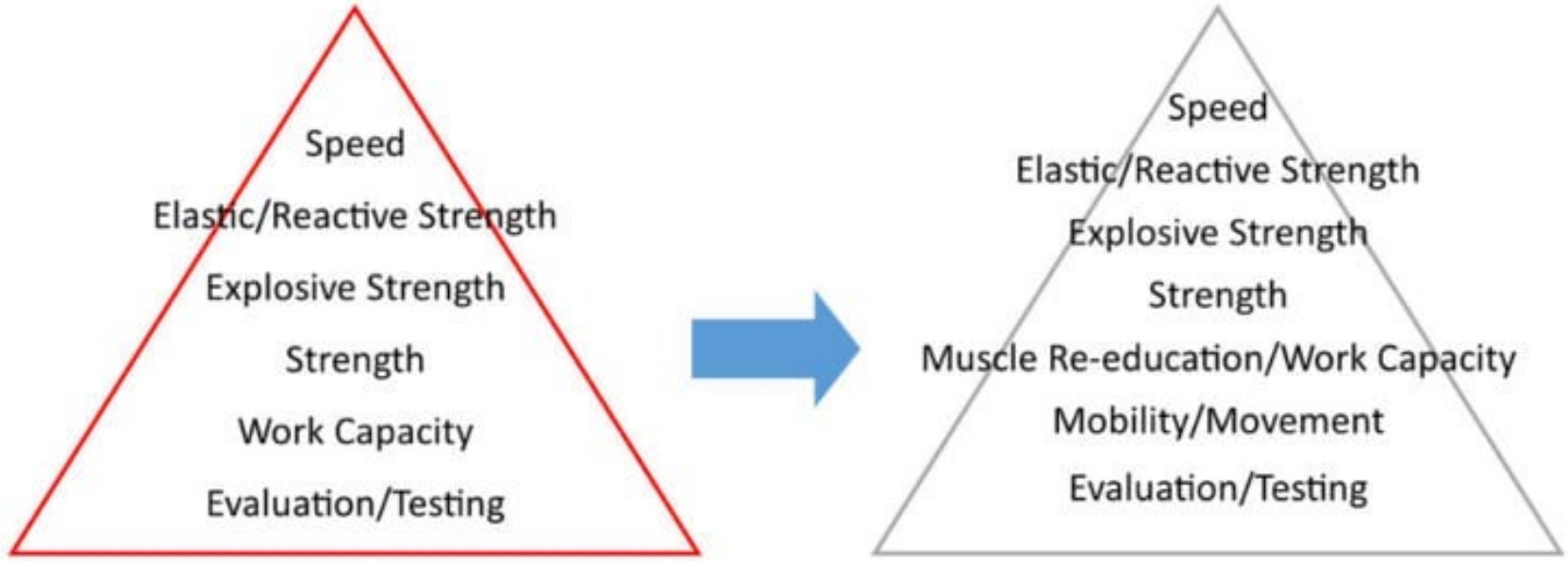
Hall of Fame S&C Coach Al Vermeil's Hierarchy of Athletic Development



Vermeil's Hierarchy of Athletic Development

Each physical quality is dependent upon it's predecessor

Rehabilitation Modified

Panariello et al *Oper Tech Sports Med* 2016

Panariello et al *Oper Tech Sports Med* 2017

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Enough on theory. How do we apply this?

Exercise Order

Within session:

- Exercises with the greatest demand **OR** focused on the "individual needs or movement patterns in greatest need of improvement" should be performed first (Simao et al 2012)

Frequency – How Often?

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- *No statistically significant difference* between low frequency (1-2 times/week) and high frequency (3-4 times/week) for hypertrophy and strength *when volume is equal* (Kessinger et al 2020; Candow and Burke 2007; Faigenbaum et al 2007; Taaffe et al 1999)

Exercise Dosing

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Training Goal	Rep Range	Volume	Rest Period
Power	1-5	Low	5-10 min
Strength	2-8	Moderate	2-3 min
Hypertrophy	8-15+	Moderate-High	45-60 sec
Endurance	>15-20	High	30 sec or less

Lorenz and Morrison 2015

Exercise Dosing Volume

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Weekly Exercise Volume	Maximum Repetitions in a Daily Exercise Category	Repetitions Per Set
Low 150 - 175 Reps	Strength 35 Reps in an exercise i.e. Back Squat, Bench Press	8 - 12 Reps/Set– More hypertrophy less strength enhancement
Medium 250 – 275 Reps	Power 25 Reps in an exercise I.e. Power clean, Snatch	5-7 Reps/Set Good hypertrophy good strength enhancement
High 350 – 375 Reps		2 – 4 Reps/Set Best strength and power enhancement least affect on hypertrophy

Lorenz et al 2019

How Many Sets Are Needed for Improving Strength?

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- *8 sets per muscle group* for improving strength in athletes (Peterson et al 2005)
- *4 sets per muscle group* for improving strength in those who are less trained (Peterson et al 2005)

- *3-4 sets per exercise* for athletes (Peterson et al 2005)
- *2-3 sets per exercise* for older adults (Borde et al 2015)
- *1-2 sets per exercise* for less trained (Peterson et al 2005)

What is the “Minimum Effective Dose” for Improving Strength?

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- 1 set of 6-12 reps at 70-85% 1RM ***to failure*** (demonstrates high intensity of effort) 2-3 times/week for 8-12 weeks (Androulakis-Korakakis et al 2019)

How Many Sets Are Needed for Improving Power?

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- Dose-response relationship seems to be less clear in the literature

- *Possibly* **3-4 sets per exercise** (Lesinski et al 2016; Slimani et al 2018)
  - Note: the 2 referenced systematic reviews included youth athletes

Strategies to Measure Intensity

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- Rate of Perceived Exertion (RPE)
- Reps In Reserve (RIR)
- “Zone” Training
- Autoregulatory Progressive Resistive Exercise (APRE)
- Daily Adjustable Progressive Resistive Exercise (DAPRE)
- Velocity Based Training (VBT)

Rate of Perceived Exertion (RPE)

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- Modified Borg RPE, or OMNI-Resistance Exercise Scale (OMNI-RES) (Lea et al 2022; Lagally and Robertson 2006)
- Patient reported measure of intensity
- Ideally at 7-9/10 RPE for strength training (Helms et al 2018)
- No significant difference based on age, sex, & training history (Lea et al 2022)

Rating of Perceived Exertion (RPE Scale)	
10	Maximal
9	Really, Really, Hard
8	Really Hard
7	
6	Hard
5	Challenging
4	Moderate
3	Easy
2	Really Easy
1	Rest

Reps In Reserve (RIR)

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- Patient reported measure of how many additional reps they feel like they could perform
- Ideally 1-4 RIR for strength training
- *Potentially* appropriate for untrained individuals (Lovegrove et al 2022)
- May work best after individual knows what failure feels like

RPE SCALE BASED ON REPS IN RESERVE		
RPE	RIR	DESCRIPTION
10	0	Could not do more reps or lift more weight
9.5		Could not do more reps, but could lift slightly more weight
9	1	Could do 1 more rep
8.5		Could definitely do 1 more rep, possibly 2
8	2	Could do 2 more reps
7.5		Could definitely do 2 more reps, possibly 3
7	3	Could do 3 more reps
5-6	4-5	Could do 4-to-5 more reps
1-4	6+	Very light to light effort
0		Complete rest

“Zone” Training

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- Load based off 1RM
- Predicted 1RM equations: Brzycki or Epley (Reynolds et al 2006; Whisenant et al 2003; Knutzen et al 1999; LeSuer et al 1997)
- Training goal determines load
- May be more suitable for compound/multi-joint exercises

Table 1
Zones of Intensity for Strength and Power Training

	Type and/or Goal of Training of Each Intensity Zone	
	Strength	**Power**
Zone 1: <50%	General muscle and technical	General neural and technical (<25% 1RM)
Zone 2: 50–75%	Hypertrophy training	Ballistic speed training (25–37.5 % 1RM)
Zone 3: 75–90%	Basic strength training	Basic power training (37.5–45 % 1RM)
Zone 4: 90–100%	Maximal strength training	Maximal power training (45–55 % 1RM)

Baker & Newton 2005

Predicted 1RM Equations

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- Brzycki: 1RM = weight / [102.78 – 2.8 (reps)]
- Epley: 1RM = [0.033 x (reps)] x (weight) + weight

Autoregulatory Progressive Resistive Exercise (APRE) (Mann 2011)

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- Adjusted to individual's performance/readiness
- 3 different loading methods:
  - APRE10 - hypertrophy, requires 10RM
  - APRE6 – hypertrophy & strength, requires 6RM
  - APRE3 – strength & power, requires 3RM
- 4 sets are performed
- Load for last set determined by # of reps performed on 3rd set
- Last set is to failure
- Effectively produces strength gains (Zhang et al 2021; Horschig et al 2014; Mann et al 2010; McNamara et al 2010)

APRE Protocol (Mann 2011)

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Set	APRE10	APRE6	APRE3
1	12 repetitions at 50% 10RM	10 repetitions at 50% 6RM	6 repetitions at 50% 3RM
2	10 repetitions at 75% 10RM	6 repetitions at 75% 6RM	3 repetitions at 75% 3RM
3	Repetitions to failure at 10RM	Repetitions to failure at 6RM	Repetitions to failure at 3RM
4	Repetitions to failure at adjusted load	Repetitions to failure at adjusted load	Repetitions to failure at adjusted load

APRE Protocol 4th Set Load Adjustment (Mann 2011)

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APRE10	
3rd set reps	Load adjustment
4-6	↓ 2.5-5 kg
7-8	↓ 0-2.5 kg
9-11	Maintain load
12-16	↑ 2.5-5 kg
17+	↑ 5-7.5 kg

APRE6	
3rd set reps	Load adjustment
0-2	↓ 2.5-5 kg
3-4	↓ 0-2.5 kg
5-7	Maintain load
8-12	↑ 2.5-5 kg
13+	↑ 5-7.5 kg

APRE3	
3rd set reps	Load adjustment
1-2	↓ 2.5-5 kg
3-4	Maintain load
5-6	↑ 2.5-5 kg
7+	↑ 5-10 kg

Daily Adjustable Progressive Resistive Exercise (DAPRE) (Knight 1979 & 1985; Lorenz & Morrison 2015)

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- Similar to APRE, adjusted to individual's performance
- 4 sets are performed
- Select desired training zone
- Estimate "working weight"

DAPRE Protocol (Knight 1979; Table from Wilson 2008)

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Table 1
The DAPRE system

Set	Weight	Number of Repetitions
1	50% working weight	10
2	75% working weight	6
3	Full working weight	Maximum*
4	Adjusted working weight*	Maximum†

*Number of repetitions performed in the 3rd set is used to determine the weight of the 4th set according to the algorithm in Table 2.

†Number of repetitions performed in the 4th set is used to determine the working weight for the 3rd set at the next session according to the algorithm in Table 2.

DAPRE Protocol (Knight 1979; Table from Wilson 2008)

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Table 2
Guidelines for modification of working weight in DAPRE system

Number of repetitions performed during set	Fourth set	Next session
0–2	Decrease 5–10 lb	Decrease 5–10 lb
3–4	Decrease 0–5 lb	Keep the same
5–6	Keep the same	Increase 5–10 lb
7–10	Increase 5–10 lb	Increase 5–15 lb
≥11	Increase 10–15 lb	Increase 10–20 lb

Velocity Based Training (VBT)

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- Immediate, objective feedback while measuring repetition velocity
  - Requires specific technology
- Many possible applications for training (Jovanović & Flanagan 2014)
- Premise: monitor velocity and adjust as needed to remain within desired ”zone” or intensity
- More suitable for athletic population & foundational multi-joint exercises

Velocity Based Training (VBT)

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Table 5. The Strength-Velocity Continuum and associated velocity ranges from various exercises.

Percentage of 1-RM (%)										
0	10	20	30	40	50	60	70	80	90	100
None	Starting Strength		Speed-Strength		Strength-Speed		Accelerative Strength		Absolute Strength	
Original and arbitrary velocity ranges (m/s; [40])										
	>1.3		1.3-1		1-0.75		0.75-0.5		<0.5	
Research Supported Velocity Ranges (m/s)										
Back Squat [26]	-		-		-		-		<0.54	
Bench Press [10, 41]	>1.3		1.3-0.9		0.95-0.63		0.63-0.32		<0.32	
Prone Pull [41]	>1.52		1.52-1.23		1.23-0.94		0.94-0.67		<0.67	

Walker 2017

Resources for Velocity Based Training (VBT)

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- https://www.scienceforsport.com/velocity-based-training/

- Weakley, Jonathon; Mann, Bryan; Banyard, Harry; McLaren, Shaun; Scott, Tannath; Garcia-Ramos, Amador. Velocity-Based Training: From Theory to Application. Strength and Conditioning Journal 43(2):p 31-49, April 2021.

Advanced Training Methods

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- Eccentric Training
- Cluster Sets
- Myo-reps
- Supersets
- Drop Sets
- Complex Training
- Contrast Training

Eccentric Training

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- Effective at developing strength (Douglas et al 2017)
- Can enhance power and elastic strength (Stretch-Shortening Cycle) (Douglas et al 2017)
- Loads greater than max concentric strength lead to greater adaptations (Douglas et al 2017)
- Potential strategies
  - Active eccentric/passively move through concentric
  - Active eccentric/active assisted concentric
  - Deliberate/tempo eccentric/active concentric
  - Unilateral eccentric/bilateral concentric
  - Loaded eccentric/unloaded concentric

Cluster Sets (Roll 1987)

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- Effective for developing hypertrophy, strength, or power (Davies et al 2021)
- Involves intra-set rest periods (in addition to inter-set rest periods)
  - Reduces fatigue during sets & RPE (Haff et al 2003; Tufano et al 2017)
  - Able to maintain velocity & power output (Tufano et al 2017)
- Many ways to alter set structure
  - One popular “rest-pause” method: perform single reps of near maximal load with short rest period for 4-6 reps (Verkhoshansky & Siff)

Myo-reps (Fagerli)

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- Enhances muscle hypertrophy & endurance (Prestes et al 2019)
- Specific form of “rest-pause” method
- Begin with “activation set”
  - Load that can be performed 9-20 repetitions
    - Start with 30% 1RM beginners; 40% 1RM intermediate; 50% 1RM elite athletes (Fagerli)
  - Set taken to failure or until rep speed slows considerably
- Rest 3-5 deep breaths
- Keep going for 3-5 sets of 3-5 reps with same load
- Stop when unable to match # of reps performed on 2nd set

Supersets

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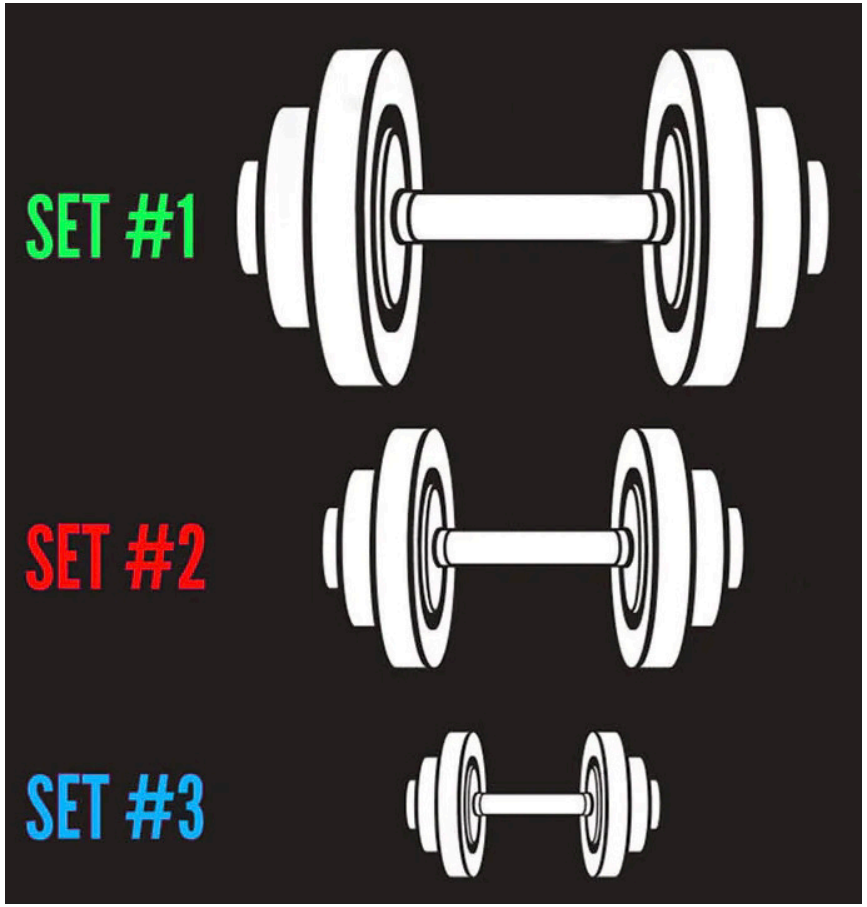
- Two different exercises done back-to-back before a rest period
- Promotes positive training adaptations while decreasing exercise session duration (Realzola et al 2022)
- Types of supersets:
  - Upper/lower body
  - Agonist/antagonist (example: leg extensions/leg curls)
  - Same muscle group

Drop Sets

- Enhances muscle hypertrophy (Schoenfeld & Grgic 2018)
  - Induces motor unit fatigue & metabolic stress
- Perform 1-3 sets to failure, decreasing load 20-25% for each set (Schoenfeld & Grgic 2018)
- More practical for single-joint exercises



Complex Training

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- Enhances strength, power, & speed qualities (Cormier et al 2020)
- Perform one set of a higher load exercise then one set of a lower load/bodyweight plyometric exercise
- Biomechanically similar movements
  - Example = one set of squats then one set of box jumps, repeat
- More practical/suitable for athletes

Contrast Training

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- Similar to complex training
- Enhances strength, power, & speed qualities (Cormier et al 2020)
- Perform all sets of heavy load exercises then all sets of lower load/bodyweight plyometric exercises
  - Example: 4 sets of squats then 4 sets of box jumps
- More practical/suitable for athletes

Questions?

- Please feel free to reach out to me!
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