

## Everything Resistance Training

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“The most successful resistance training programs are those that are designed towards target-specific training goals.” Do you want to be successful in training? “Plan for it.” Tudor Bompa, PhD  
Recommended Reading: Ratamess, N. et al. (2009). Progression models in resistance training for healthy adults. *Medicine & Science in Sports and Exercise*, 41(3), 687-708.

- I. The structure of skeletal muscle: Let’s take a visual journey through muscle (smooth, cardiac, skeletal with a comparison of skeletal and cardiac muscle physiology)
  - A. 430 muscles in 215 pairs, chemical composition (75% H<sub>2</sub>O, 20% protein, 5% other)
  - B. Epimysium (fascia), perimysium around fasciculus, endomysium around each cell and connective tissue is composed primarily of collagen (tensile strength of steel)
  - C. Muscle cell (same as muscle fiber) may contain up to a 1000 nuclei; nuclear domain
  - D. Sarcolemma (polarized membrane), muscle’s sarcoplasm has glycogen & myoglobin
  - E. Type I Fibers: low force, low ATPase, low ATP stores, low PC stores, slow contraction speeds, slow relaxation time, low glycolytic enzyme activity, high endurance, high TG stores, high myoglobin content, high aerobic enzymes, high capillary and high mitochondrial density
  - F. Type II Fibers: high force, high ATPase, high ATP stores, high PC stores, fast contraction speeds, fast relaxation time, high glycolytic enzyme activity, low endurance, low TG stores, low myoglobin content, low aerobic enzymes, low capillary and low mitochondrial density
  - G. No difference in Type I and II fibers in intramuscular glycogen stores
  - H. Discussion of sarcomere (smallest functional unit of muscle—means segment)
    1. Z disk, I band, A band, H zone, Actin protein, Myosin protein and Titin protein
    2. Type I, Type IIa, Type IIx isoforms
    3. M-line is housing for creatine phosphate; C protein for myosin, desmin—like glue
    4. New research revelations with Titin—larges protein know; 27,000 amino acids; big contributor to passive tension as it restricts passive stretch of the sarcomere
    5. How does an eccentric action develop more force than a concentric or isometric?
    6. Winding theory hypothesis of Titin (Nishikawa et al., 2011)
    7. Newest theory: Walter Herzog, PhD (Titin as a responsive spring)
- II. Sliding filament theory: Andrew Huxley and Ralph Niedergerke (Nature 1954)
  - A. The contractile process
    1. Nerve impulse arrives at neuromuscular junction; depolarization of sarcolemma
    2. Depolarization of T-tubules triggers release of calcium ions from the sarcoplasmic reticulum SR (terminal cisternae is the end housing of SR)
    3. Calcium ion is bound by troponin causing a shift of tropomyosin
    4. ATP goes through ‘hydrolysis’ to ADP and Pi and energy release
    5. Myosin attaches to actin at unblocked binding sites (on actin)
    6. ADP and Pi drop off myosin: Actin filaments move toward center of A band with a ratchet-like movement called the Power Stroke

- B. Where does ATP fit into this muscle contraction story? ATP Hydrolysis, ATPase, origin of acidosis, S1 unit independence
    1. H<sup>+</sup> (hydrogen ion) accumulation is the cause of acidosis from hydrolysis of ATP to ADP, Pi and energy release (not lactate)
    2. Serious resistance trainers: Do high intensity cardio 2-3x/week for 5 min at end of workout to buffer H<sup>+</sup> more effectively
    3. What happens to muscle as it ages? Fiber size decreases, loss of fast-twitch fibers, ability to activate motor units decreases. Good News: factors are modifiable
    4. Independence of S1 units—practical application to humans the way we move
  - C. End of muscle action: calcium ions depleted or nerve stimulus ceases: shift of tropomyosin to inhibit actin and myosin binding
  - D. Basic nerve anatomy: dendrite, nucleus, axon hillock, myelin sheath, node of ranvier
  - E. Action potential travels 225 miles/hour which is 100-120 meters/sec
  - F. Effect of MS on Myelin Sheath: Autoimmune disease breakdown and scarring
- III. Resistance training concepts: Ratamess, N. et al. (2009)
- A. Progression: “The act of moving forward or advancing toward a specific goal over time until the target goal has been achieved.” Attain by increase in exercise intensity, increase in total repetitions at a given intensity, altering the repetition tempo, shortening rest periods, and/or increasing training volume (reps x sets)
  - B. Specificity: “All training adaptations are ‘specific’ to the stimulus applied.” Specificity to muscle actions (CON, ECC, or ISOM), speed of movement, range of motion, muscle groups trained, energy systems involved, and intensity and volume of training
  - C. Maintenance: “Refers to the program’s design to maintain the current level of muscular fitness.” Note, to attain higher muscular fitness the proper manipulation of load, exercise selection, exercise order, number of reps, number of sets, and frequency of workouts is needed
  - D. Motor unit recruitment: dictated by force placed upon them (and size of motor units)
  - E. Hypertrophy satellite cell theory discussed and illustrated
- IV. EXTRA INFO: Training characteristics for strength: Traditional Guidelines-Ratamess, N. et al. 2009
- A. Novice to Intermediate: loads of 60-70% of 1RM, 8-12 reps, 1-3 sets, 2-3 min rest between multiple sets, slow to moderate contraction speeds, novice train 2-3 days/week while intermediate may train 3-4 days/week
  - B. Advanced: loads of 80-100% of 1RM, 5-6 reps, multiple sets in a periodized sequence, 1-2 min rest between multiple sets, mixed contraction speeds (slow, moderate, fast), train 3-4 days/week
  - C. Novice, Intermediate and Advanced enthusiasts should do unilateral, bilateral and multi-joint exercise selections, large muscle groups prior to small muscle groups, progressively increase load from 2-10%, CON, ECC, and ISOM actions included
- V. **Key Research Point #1 for Strength and Hypertrophy Development: Use Eccentric Exercise Methods.** Herzog, W. (2014). Mechanisms of enhanced force production in lengthening (eccentric)

muscle contractions, *Journal of Applied Physiology*, 116, 1407-1417. 'Eccentric exercises produce the greatest force production of any type of contraction.'

**Is there a BEST way to do eccentric exercises?** Best eccentric exercise practices include the following: Thorough full-body warm-up (5-10 min); Appropriate muscle/joint preparation; One traditional warm-up set at 50% of what the client normally lifts. TWO METHODS Follow:  
**Eccentric emphasis training:** a) Start with the weight client normally, b) For instance, if the client normally does a 8-RM, meaning she/he does 8 reps using a weight where he/she reaches 'momentary muscular fatigue' at 8 reps, c) Have client do the concentric contraction, lifting the load in a 1 second up, d) On the eccentric contraction, lower the load in 3-4 seconds (thus emphasizing the eccentric phase of the exercise), e) Client completes 8 repetitions (as this example is an 8-RM); the personal trainer will probably need to aid with the concentric lifts as the client starts to fatigue, f) Progression options: may increase time (i.e., 5-6 sec) during the lowering, eccentric emphasis phase: and/or vary the rep zones (4-RM, 6-RM, 10-RM, 12-RM, etc.), g) Number of sets is individualized to client goals.

A. Exercise video demonstrations: single leg squat on incline leg press, dip on bench, back extension on Roman chair.

**Two up: One down eccentric training technique:** a) The two up: one down technique is used with the arms and legs, b) Initially start with 40-50% of the weight the client normally uses for the particular muscular fitness goal being trained (overload progressively), c) For instance, if the client normally does a 10-RM with 100 lbs., meaning she/he does 10 repetitions with 100 lbs then you would start with 40% or 50% of that weight or 40 lbs or 50 lbs, respectively, d) With the two up: one down eccentric technique lift the weight up concentrically with both limbs and then lower the weight with one limb; repeat the concentric phase and lower with the alternating limb, e) Try to go up (concentric) with one second and lower (eccentric) with three seconds

A. Exercise video demonstrations: leg extension, leg curl, heel raise

### **SPECIAL TOPIC WITH ECCENTRIC EXERCISE: DOMS**

VI. Exercise-induced delayed-onset muscle soreness D.O.M.S. (also abbreviated DOMS)

- A. What is D.O.M.S.? Muscle soreness and swelling that becomes evident 8-10 hrs after exercise. Soreness peaks 24-48 hrs. Especially noticed after eccentric training. Takes up to 72 hrs for body to dissipate (Balnave et al., 1993).
- B. **Minimizing DOMS from eccentric exercise. Repeated bout effect** (Proske & Allen, 2005). Eccentrically stimulate the target muscles (progressively) 1 week or more prior to a higher intensity eccentric bout.
- C. Repeated bout effect sequence/mechanism: 1<sup>st</sup> (lighter) eccentric exercise workout, DOMS, adaptation occurs (neural theory—increases in motor unit activity; connective tissue theory—increases in connective tissue, cellular theory—addition of sarcomeres), repeat SAME bout of exercise (at higher intensity) ≥ 1 week later, less DOMS (major adaptation: sarcomeres)

D. How does repeated bout effect help? One major adaptation is muscle adds sarcomeres

### **VII. Key Research Point # 2 for Strength and Hypertrophy Development: Train to Failure.**

Morton et al. (2016). Neither load nor systemic hormones determine resistance training-mediated hypertrophy or strength gains in resistance-trained young men, *J of Appl Phys*, 121, 129-138.

### **STUDY DESIGN**

49 resistance-trained males (23yrs)

10RM and 1RM on incline press, bench press, knee extension and shoulder press

HIGH rep group: 3 sets of 20-25 reps/set to FAILURE

LOW rep group: 3 sets of 8-12 reps/set to FAILURE

Mon/Thur Training Program

Incline leg press with seated row (super set with 60 sec rest): 3x

Bench press with cable hamstring curl (super set with 60 sec rest): 3x

Tue/Fri Training Program

Shoulder press with biceps curls (super set with 60 sec rest): 3x

Lat pull down with triceps extension (super set with 60 sec rest): 3x

3 sets of knee extensions

Participants consumed 30 g of whey protein twice per day: immediately following RT on training days and 1-2 hours prior to sleep. On non-training days, participants consumed the first dose in the morning and the second dose 1-2 hours prior to sleep.

**RESULTS:** The HIGH rep and LOW rep groups were equally effective in stimulating hypertrophy (muscle biopsy techniques). The HIGH rep and LOW rep groups were equally effective in stimulating muscular strength. Researchers suggest HIGH and LOW rep training programs (such as done with periodization) for optimal benefits in strength!

**VIII. Key Research Point #3 for Strength and Hypertrophy Development: Use Periodization**

Periodization for Strength: "Periodization programs have been consistently shown in research to be the superior training programs." Ratamess et al. 2009.

**Classic Strength Study: Periodization Study: Linear vs. Reverse Linear for Strength (12-week mesocycle) from Brazilian research team**

20 females in 12-week total body training workout 3 days/week

Tests for 1RM of bench press, lat pull-down, arm curl, and leg extension

Weeks 1-3 Rep zones: 10-12 reps, 8-10 reps, 6-8 reps

Week 4: High Volume Training Week; 12 RM for all exercises

Weeks 5-7 Rep zones: 8-10 reps, 6-8 reps, 4-6 reps

Week 8: High Volume Training Week; 12 RM for all exercises

Weeks 9-11 Rep zones: 6-8 reps, 4-6 reps, 2-4 reps

Week 12: High Volume Training Week; 12 RM for all exercises

**Training Exercises:** Alternate 'A' & 'B' Workouts: 'A' (bench press, incline fly, dumbbell shoulder press, lateral raise, standing arm curl, biceps preacher curl, triceps extension, close-grip bench press); 'B' (back squat, leg extension, leg curl, glute kickbacks, hip abduction, hip adduction, standing heel raise, lat pull-down, seated row). Example of training: On one week the subjects did Training 'A' on Mon. & Fri. and Training 'B' on Wed. The next week subjects did Training 'A' on Wed. and Training 'B' on Mon. & Fri.

**Rest Intervals between sets:** 60 seconds between 10-12 repetitions; 80 seconds between 8-10 repetitions; 100 seconds between 6 to 8 repetitions; 120 seconds between 4-6 reps

**Results: Linear periodization superior for strength development**

**IX. Key Research Point #4: Training for Overall Conditioning: Circuit High Intensity Exercise from Italian Research Team.** Paoli et al. (2010). Effects of three distinct protocols of fitness training on body composition, strength and blood lactate, *J. Sports Med & Phys Fit*, 50, 43-51  
 40 males, aged 50-65 doing very little exercise; no cardiovascular disease, T2 diabetes or arthritis  
 3 times a week of workouts for 12 weeks (control group just worked up to a 40min run)

5-min warm-up and 5-min cool-down

**Circuit Group**

**Circuit High Intensity Group**

Exercise	Sets	Reps	Recovery	Exercise	Sets	Reps	Recovery
Treadmill	8min	65% Steady		Treadmill	8min	1 to 3 work	
Lat Pulls	3	15	60sec	Lat Pulls	3	RP	60sec
Crunch	1	20	0sec	Crunch	1	20	0sec
Chest Press	3	15	60sec	Chest	3	RP	60sec
Crunch	1	20	0sec	Crunch	1	20	0sec
Lat. Arm raise	3	15	60sec	Lat. Arm raise	3	RP	60sec
Crunch	1	20	0sec	Crunch	1	20	0sec
Leg Press	3	15	60sec	Leg Press	3	RP	60sec

**RP=Rest Pause technique: Weight at a 6RM-rest 20 sec—(2 to 3 reps)—rest 20 sec (1-2 reps)**

Control group did endurance training only; 12-week study; exercised 3 times a week

**Results:** Circuit High Intensity Group showed the greatest reductions in body weight, lower percent fat loss, and greater improvement in leg press and underhand cable pulldowns strength

**X. Key Research Point 5: Training for Overall Conditioning: Reciprocal Super Setting**

Review of a different types of super sets (1 set performed and immediately perform 2nd set of a different exercise). Agonist/antagonist, opposite action, upper body/lower body, lower body only, upper body only

**Introducing Reciprocal Super Setting:** Biceps curl/triceps extension REST 1 min REPEAT up to 4 times. Kelleher, A.R. et al. (2010). The metabolic costs of reciprocal supersets vs. traditional resistance exercise in young recreationally active adults. *Journal of Strength and Conditioning Research*. 24(4), 1043-1051. Study results showed reciprocal super setting elicits a significantly higher EPOC (exercise afterburn) than tradition resistance training.