Systematic Review: Effects of eccentric versus concentric exercise in stimulating gains in strength, hypertrophy, or performance in healthy adults.

Presented by Gregory Kirk, Bob Maudie, Pat McKinnon, Ryan Murray, & Sarah Stewart
Introduction

- Resistance training is widely utilized by many facets of the population as a method of inducing gains in muscular strength
  - athletic performance
  - preventing injuries
  - improving functional capacity
  - maintaining a healthy lifestyle
Introduction: *Dynamic muscle activations*

- **Eccentric** = Dynamic muscle action which occurs when external resistance exceeds muscle force and the muscle lengthens while developing tension.
- **Concentric** = Dynamic muscle action which occurs when muscle shortens, and joint movement occurs as tension develops.
Introduction: *Eccentric vs. concentric activations*

- ↑’d ability to produce greater amounts of tension \[^{[3-5]}\]
- ↓’d consumption of O\(_2\) and ATP for a comparable workload \[^{[6-9]}\]
- ↓’d EMG activation (ie. recruitment of a smaller motor unit pool) for a given tension \[^{[10]}\]
- Smaller decreases in strength following repeated muscle contractions \[^{[2,11,12]}\]
- Greater cross education \[^{[13]}\]
- ↑’d muscle damage and delayed onset muscle soreness (DOMS) \[^{[14,15]}\]
Introduction: *Potential benefits of eccentric activations*

- Potential for the development of greater strength gains, because the muscle can be overloaded to a greater extent \[^{13,16,17}\]
  - Athletic performance, prevention of injuries, and a primary outcome measure
- Superior adaptations in muscular conditioning because of metabolic efficiency & decreased fatigability
  - Implications for older adults and clinical populations that have limited energy reserve
Systematic Review Question

- Is eccentric training superior to concentric training in stimulating gains in muscular strength, hypertrophy, and performance in healthy adults?
Methods
Methods: *Inclusion criteria*

- Healthy adult subjects (18 – 65 years)
- Resistance training program of at least 4 weeks in duration, minimum of 2x/week
- Testing and training completed on an isokinetic dynamometer
- Comparison of eccentric and concentric training programs
- Measurement of at least one of the following outcome measures: strength, hypertrophy, performance
- RCTs or CCTs in peer reviewed journals
Methods: *Exclusion criteria*

- Participants with any known existing pathological conditions
- Explored only one comparison variable (e.g. only eccentric training) or combined other interventions with eccentric and concentric programs
- Cross over design with insufficient washout period (≤ 6 months)
- Non-English studies
Methods: Search Strategy

- Electronic searches were performed on the following databases: SPORTDiscus, EMBASE, MEDLINE, CINAHL, PEDro, and Cochrane Controlled Trial Register.

- Grey literature searches were conducted using Proquest, PapersFirst, and ProceedingsFirst.

- Hand searches were performed for the following journals from January 1997 to April 2007: Journal of Applied Physiology, British Journal of Sports Medicine, Sports Medicine, American Journal of Sports Medicine, and the Medicine Science of Sport and Exercise.

- Reference lists of included articles were screened using the same criteria as applied to the initial citation search.
Potentially relevant publications identified and screened for retrieval. N = 1933

Publication abstracts retrieved for more detailed evaluation. N = 208

Publications (full text) articles retrieved. N = 33

Publications included in the systematic review. N = 11 FULL TEXT

Study selection

Papers excluded by title - unsuitable based on outlined criteria. N = 1726

Papers excluded by abstract - unsuitable based on outlined criteria. N = 175

Publications excluded: N = 22
- Not age appropriate: 2
- Did not meet minimum training duration/frequency: 2
- No isokinetic dynamometer: 7
- Not an appropriate comparative outcome measures: 7
- Insufficient washout period: 4
Methods: Quality and Evidence assessment

- Quality assessment
  - Modified Van Tulder ~ 11 point scale
  - Sackett’s model was used to describe the level of evidence for each included study
  - Best evidence synthesis was used to describe the overall grade of evidence
Methods: *Data extraction*

- **Data extraction**
  - A data extraction form was developed to improve standardization and ease of the extraction process.
  - Data extraction was completed by 2 reviewers independently for each full text publication.
  - Disagreements were resolved during a consensus meeting.
Methods: *Data analysis*

- Data was analyzed qualitatively for the following comparisons:
  1. Effectiveness of eccentric versus concentric training on eccentric, concentric, and isometric strength
  2. Effectiveness of eccentric versus concentric training on selected hypertrophy measures
  3. Effectiveness of eccentric versus concentric training on selected performance measures
## Results: Study description

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Results: Study participants

- **Training status:** Untrained (8), Moderately trained (1), Trained tennis players (2)
- **Sex:** Female only (3), Male only (5), Male and female (3)
- **Age:** Mean age = 24.0 years; Range 19.6 – 33 years
- **Dropout rate:** Reported by 7 studies
  ~ Mean = 1.4 subjects; Range 0 – 6 subjects
Results: *Training intervention*

- **Exercise:** Knee extension (7); Knee flexion and extension (1); Shoulder internal and external rotation (2); Elbow flexion (1)
- **Frequency:** Ranged from 2 – 4 days/week
- **Duration:** Ranged from 4 – 20 weeks, with 8/11 studies lasting between 6 – 10 weeks in length
- **Volume:** Ranged from 12 – 60 total exercise sessions; 1 – 8 sets of 6 – 12 repetitions (6 – 72 contractions per session)
- **Intensity:** Absolute (8) ~ MVC for both ETG and CTG; Relative (2) ~ ETG exercised at the same relative load as the CTG (90 – 100 % of the concentric MVC); “Submaximal” (1) ~ intensity not specified
- **Progression:** Periodization design (3), Constant number of sets and repetitions (8)
- **Contraction speed:** Varied from 60 – 210 deg/s; Single speed for all contractions (9); Pyramid of speed (2)
Strength
Results

Effectiveness of eccentric and concentric training on eccentric, concentric, and isometric strength
Results: Strength

- **Eccentric strength** ~ 10/11 studies measured eccentric strength in ETG and CTG
  - 9/10 studies found significant ↑’s with ET
  - 8/10 studies found significant ↑’s with CT
  - Of the 7 studies that compared the significance of the ET vs CT in producing gains in eccentric strength, all 7 found that ET improved eccentric strength significantly more than CT.
Results: *Strength*

- **Concentric strength** ~ 10/11 studies measured concentric strength in ETG and CTG
  - 6/10 studies found significant ↑’s with ET
  - 9/10 studies found significant ↑’s with CT
  - Of the 7 studies that compared the significance of the ET vs CT in producing gains in concentric strength, 2 found that CT improved concentric strength significantly more than ET. No studies found that the ET was significantly more effective than the CT in ↑’ing gains in concentric strength.
Results: Strength

- **Isometric strength** ~ 4/11 studies measured isometric strength in the ETG and CTGs
  - 2 studies found that isometric strength ↑‘d significant with ET; 1 study found that isometric strength ↑’d significant with CT
  - 2/4 studies did not report significance levels
  - 3 studies compared the significance of the ET vs CT in producing gains in isometric strength; mixed results were reported
Results: *Strength*

- **Total strength** ~ 2/11 studies calculated total strength gains by the ETG and CTG, averaging over all contraction types and velocities
  - No significant differences were reported
  - Three studies reported that the ETG ↑’d eccentric strength more than the CTG ↑’d concentric strength
Discussion

Effectiveness of eccentric and concentric training on eccentric, concentric, and isometric strength
Discussion: *Strength*

- *Eccentric strength*
  - Strong evidence that both ET and CT programs can produce gains in eccentric strength
  - Strong evidence that ET is superior to CT in developing eccentric strength
    - Suggests a strong mode specific relationship between ET and eccentric strength development
Discussion: Strength

Concentric strength

- Strong evidence that CT and ET programs are effective in producing gains in concentric strength
- No evidence that CT is superior to ET in promoting concentric strength gains
Discussion: *Strength*

- **Isometric strength**
  - Indicative findings that both ET and CT are effective in producing gains in isometric strength
  - No evidence that either contraction type is superior
Discussion: *Strength*

- **Total Strength**
  - No evidence that either contraction type is superior in producing gains in total average strength.
  - Strong evidence that ET increases eccentric strength more than CT increases concentric strength.
Discussion: Strength

- **Eccentric vs Concentric**
  - Results clearly show that eccentric and concentric training are both effective methods of inducing strength gains in the healthy adult population.
  - However, eccentric training appears to elicit a more substantial effect on mode specific strengthening.
    - All studies that reported a statistical comparison of the ETG and CTG found that the ETG produced superior eccentric gains with respect to the CTG, but only two out of seven found that the CTG produced superior concentric gains in comparison to the ETG.
Eccentric vs Concentric Cont.

- **Eccentric vs Concentric**
  - The distinct outcomes generated by the eccentric and concentric training groups suggest that different mechanisms are responsible for increases in strength
    - Eccentric muscle actions have been shown to generate significantly higher levels of maximal tension \(^{[3-5]}\), it is possible that the greater increases in strength are due to the higher absolute loads
    - Two studies included addressed this issue by having the ETG and CTG exercise at equal absolute loads; the results were mixed
Eccentric vs Concentric Cont.

- Further research necessary, but results suggest that ET is potentially able to produce significantly greater eccentric gains than CT when exercising at equalized loads.
- Suggests other adaptive mechanisms:
  - Combination of neurological factors and hypertrophy [2,32-34,38,42-45]
Hypertrophy
Results

Effectiveness of eccentric versus concentric training on selected hypertrophy measures
Results: *Hypertrophy*

- 5/11 studies included a hypertrophy outcome measure
- 3 of which used measures of CSA
  - Duncan et al. reported no significant change in girth for eccentric or concentric training using a thigh circumference measure.
  - Komi et al. found a significant ↑ in upper arm circumference in the trained arm of the ETG compared to pre-test values and the CTG.
  - Higbie et al., using MRI showed a significant ↑ in CSA in both ETG and CTGs with a significantly greater ↑ in the ETG compared to the CTG.
Results: *Hypertrophy*

- Two studies used muscle biopsies to explore changes in fibre type and area.
  - Hortobagyi et al. showed no significant change in the percentage of type I fibres, a significant ↓ in type IIb fibres, and a significant ↑ in type IIa fibres in both the ETG and CTGs. They also showed a significant ten times greater ↑ in type IIa fibre area when comparing ETG to CTG.
  - Mayhew et al. showed no significant change in type I or type II fibres pre/post, but a significant ↑ in type II fibre area in the CTG compared to the ETG.
Discussion

Effectiveness of eccentric versus concentric training on selected hypertrophy measures
Discussion: Hypertrophy

- Moderate evidence that eccentric muscle training ↑’s skeletal muscle hypertrophy more than concentric training by measure of CSA
- Moderate evidence that eccentric training ↑’s type II fibre area greater than concentric training
Results

Effectiveness of eccentric versus concentric training on selected performance measures
Results: *Performance*

- 3/11 studies included performance measures
  - Two studies explored the effect of ET and CT on serve velocity.
    - Ellenbecker et al. → CT significantly ↑’d serve velocity compared to pre-test values. No significant change was seen in the ETG.
    - Mont et al. → ET and CT significantly ↑’d serve velocity compared to the CG.
  ~ Also explored % drop off of serve velocity → both training groups maintained serve velocity better than the CG. No difference between ETG and CTG.
Results: *Performance*

- Miller et al. included 2 performance measures:
  - **Acceleration time**
    - The CTG improved acceleration time, compared to pre-test values, for *concentric* knee extension only.
    - ETG had significant improvements in acceleration time for *concentric and eccentric* movements compared to the pre-test values. Improvements in acceleration time with eccentric movements were greater in the ETG compared to the CTG.
  
  - **Time to peak torque**
    - The CTG improved time to peak torque in *concentric* knee flexion and knee extension compared to pre-test values.
    - The ETG showed significant improvements for *concentric and eccentric* movements compared to the pre-test and also showed significant improvements in eccentric movements compared to the CTG.
Discussion

Effectiveness of eccentric versus concentric training on selected performance measures
Discussion: *Performance*

- **Serve velocity and endurance**
  - Limited evidence that both ET and CT improved serve velocity
  - Limited evidence that the ET and CT groups tended to maintain their serve velocity to a significantly greater extent than the CG
  - ET and CT → equally beneficial in improving serve velocity and endurance compared to a training regimen that does not include strength training
Discussion: Performance

- **Acceleration time**
  - Indicative finding → CT improved acceleration time, compared to pre-test values, for *concentric* knee extension only
  - Indicative finding → ET resulted in significant improvements in acceleration time for *concentric and eccentric* movements compared to the pre-test values

- **Time to peak torque**
  - Indicative finding → CT significantly improved time to peak torque in *concentric* knee flexion and extension compared to pre-test values
  - Indicative finding → ET resulted in significant improvements in *concentric and eccentric* movements compared to the pre-test and showed significant improvements in eccentric movements compared to the CTG

- Based on this single study, concentric training appears to be more mode specific compared to eccentric training in regards to these selected performance measures
Conclusion
Conclusion

- Eccentric and concentric strength training are effective means of producing gains in muscular strength in a population of healthy adults.

- **Eccentric training:**
  - More effective than concentric strength training in stimulating gains in eccentric strength.
  - ↑’s eccentric strength to a greater degree than concentric training ↑’s concentric strength.

- **Concentric training:**
  - No evidence to support the superiority of concentric training in stimulating gains in concentric strength.
Conclusion

- **Hypertrophy:**
  - Eccentric training ↑’d muscle fiber CSA more than concentric training and induced greater ↑’s in type II fiber area.

- **Performance:**
  - No significance difference in serve velocity
  - Indicative findings that both ET and CT improved acceleration time and concentric time to peak torque
  - Indicative evidence that ET was more effective at improving eccentric time to peak torque
Clinical implications

- Specificity: Target a specific muscle action to prevent injury of an athlete and enhance performance
  - Eccentric: Nordic hamstring curls in the training program of a sprinter
- Both modes should be considered when performance and injury prevention is the primary goal
- Eccentric training with energetically compromised populations may be warranted
Strengths

- Review limited to RCTs and CCTs
- Homogenous populations
- All training and testing completed on isokinetic dynamometers
Limitations

○ Reviewers were not blinded to authors or journal publication
○ Methodological weaknesses
  ● Six studies of low quality (<5 mod VanTulder)
  ● Four studies failed to report dropout rate
  ● No allocation concealment or assessor blinding
○ Restricted to studies written in English
○ Main outcome measure focused on body structure and function level of ICF, minimal involvement on an activity or participation level
○ Population of healthy adults: lacks external validity to the clinical population
○ Isokinetic dynamometer not commonly used in clinical rehabilitation
Future Recommendations

- **Reviews**
  - Comparison of eccentric and concentric training at the same absolute load
  - Differences with fatigue and activation patterns using EMG between ETG and CTG
  - Isotonic actions as this contraction type relates more to the general population
  - Examining the effect of the combination of modes versus a single mode is warranted

- **Research**
  - More primary research is needed on the effects of resistance training and its application to performance
Acknowledgements

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  - Darlene Reid: Supervisor
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Final cost of systematic review...

- 8 credits (RSPT 526, 532, and 572) $5920.00
- Transportation to meetings $376.05
- Phone calls $478.12
- Photocopying $126.56
- Printing $267.89
- Cutting edge Filing Device $11.02
- Surprise $400 x 5
Completion of a Systematic Review ........
PRICELESS!
References

32. Duncan PW, Chandler JM, Cavanaugh DK, Johnson KR, Buehler AG. Mode and speed specificity of eccentric and concentric exercise training. JOSPT 1989; 11(2) 70-75
47. Folland JP, Williams AG. The adaptations to strength training: morphological and neurological contributions to increased strength. Sports Med 2007; 37(2): 145-68
Search strategy: **EMBASE**

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