Beyond Barbell Research Review

TOC

Power

https://www.mdpi.com/2075-4663/9/1/5

- **Post Flywheel Squat Potentiation of Vertical and Horizontal Ground Reaction Force Parameters during Jumps and Changes of Direction**
    - Eleven male athletes performed a countermovement jump (CMJ), standing broad jump (SBJ), and "modified 505" change of direction (COD) in a control condition and 6 minutes following three sets of six repetitions of flywheel half squats at one of two inertias (0.029 kg·m2 and 0.061 kg·m2). Peak directional ground reaction force, power, and rate of force development were calculated for each test
    - Higher inertia flywheel squats were able to acutely enhance CMJ peak vertical force (Bayes Factor (BF10) = 33.5, very strong; δ = 1.66; CI: 0.67, 2.70), whereas lower inertia flywheel squats were able to acutely enhance CMJ peak vertical power (BF10 = 3.65, moderate; δ = 0.93; CI: 0.11, 1.88). The vertical squat exercise induced no PAPE effect on resultant SBJ or horizontal COD ground reaction force parameters, nor were any differences observed between the inertias.
    - Researchers and practitioners should consider the kinetic and kinematic correspondence of a pre-load stimulus to the subsequent sport-specific activity (i.e., flywheel squat to CMJ).

https://www.researchgate.net/publication/336699087_Effect_of_Volume_on_Eccentric_Overload-Induced_Postactivation_Potentiation_of_Jumps

- **Effect of Volume on Eccentric Overload–Induced Postactivation Potentiation of Jumps**
    - 13 male university soccer players participated in a crossover design study following a familiarization period. Control (no PAP) CMJ and LJ performances were recorded, and 3 experimental protocols were performed in a randomized order: 1, 2, or 3 sets of 6 repetitions of flywheel EOL half-squats (inertia = 0.029 kg·m2). Performance of CMJ and LJ was measured 3 and 6 minutes after all experimental conditions.
    - Meaningful positive PAP effects were reported for CMJ after 2 (Bayes factor [BF10] = 3.15, moderate) and 3 (BF10 = 3.25, moderate) sets but not after 1 set (BF10 = 2.10, anecdotal). Meaningful positive PAP effects were reported for LJ after 2 (BF10 = 3.05, moderate) and 3 (BF10 = 3.44, moderate) sets but not after 1 set (BF10 = 0.53, anecdotal). The 2- and 3-set protocols resulted in meaningful positive PAP effects on both CMJ and LJ after 6 minutes but not after 3 minutes
    - This study reported beneficial effects of multiset EOL exercise over a single set. A minimum of 2 sets of flywheel EOL half-squats are required to induce PAP effects on CMJ and LJ

performance of male university soccer players. Rest intervals of around 6 minutes (>3 min) are required to maximize the PAP effects via multiple sets of EOL exercise. However, further research is needed to clarify the optimal EOL protocol configurations for PAP response.

https://www.researchgate.net/publication/332343740_Effect_of_Postactivation_Potentiation_After_Medium_vs_High_Inertia_Eccentric_Overload_Exercise_on_Standing_Long_Jump_Countermovement_Jump_and_Change_of_Direction_Performance

- **Effect of Postactivation Potentiation After Medium vs. High Inertia Eccentric Overload Exercise on Standing Long Jump, Countermovement Jump, and Change of Direction Performance**
    - Twelve healthy physically active male subjects were involved in a crossover study. The subjects performed 3 sets of 6 repetitions of EOL half squats for maximal power using a flywheel ergometer.
    - Postactivation potentiation using an EOL exercise was compared between a medium (M-EOL) vs. high inertia (H-EOL) experimental condition. Long jump (LJ) was recorded at 30 seconds, 3, and 6 minutes after both EOL exercises and compared with baseline values (control). The same procedure was used to assess countermovement jump (CMJ) height and peak power and 5-m COD test (COD-5m).
    - Long jump performance reported improvements after M-EOL and H-EOL exercise (Bayes factor [BF10] = 32.7, strong; BF10 = 9.2, moderate), respectively. Countermovement jump height (BF10 = 135.6, extreme; BF10 > 200, extreme), CMJ peak power (BF10 > 200, extreme; BF10 = 56.1, very strong), and COD-5m (BF10 = 55.7, very strong; BF10 = 16.4, strong) reported improvements after M-EOL and H-EOL exercise, respectively.
    - highlight that PAP using an EOL (M-EOL and H-EOL) improves LJ, CMJ height, CMJ peak power, and COD-5m in male athletes. The optimal time window for the PAP effect was found for both EOL conditions from 3 to 6 minutes. However, M-EOL and H-EOL produce similar PAP effect on LJ, CMJ, and COD-5m tasks.

https://www.researchgate.net/publication/329444151_Effects_of_Postactivation_Potentiation_After_an_Eccentric_Overload_Bout_on_Countermovement_Jump_and_Lower-Limb_Muscle_Strength

- **Effects of Postactivation Potentiation After an Eccentric Overload Bout on Countermovement Jump and Lower-Limb Muscle Strength**
    - Eighteen active men (mean ± SD, age 20.2 ± 1.4 years, body mass 71.6 ± 8 kg, and height 178 ± 7 cm) were involved in a randomized, crossover study. The subjects performed 3 sets per 6 repetitions of EOL half squats at maximal power using a flywheel ergometer.

- Postactivation potentiation vs. control reported a meaningful difference for CMJ height after 3 minutes (effect size [ES] = 0.68, p = 0.002), 5 minutes (ES = 0.58, p = 0.008), 7 minutes (ES = 0.57, p = 0.022), and 9 minutes (ES = 0.61, p = 0.002), peak power after 1 minute (ES = 0.22, p = 0.040), 3 minutes (ES = 0.44, p = 0.009), 5 minutes (ES = 0.40, p = 0.002), 7 minutes (ES = 0.29, p = 0.011), and 9 minutes (ES = 0.30, p = 0.008), as well as quadriceps concentric, hamstrings concentric, and hamstrings eccentric peak torque (ES = 0.13, p = 0.001, ES = 0.24, p = 0.003, and ES = 0.22, p = 003, respectively) after 3-9 minutes of rest.
- present outcomes highlight that PAP using an EOL bout improves height, peak power, impulse, and peak force during CMJ, as well as quadriceps and hamstrings isokinetic strength in male athletes. Moreover, the optimal time window for the PAP was found from 3 to 9 minutes.

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7277616/

- **Eccentric-Overload Production during the Flywheel Squat Exercise in Young Soccer Players: Implications for Injury Prevention**
  - Twenty young elite soccer players (U-17) performed two sets of six repetitions of the bilateral half-squat (inertia 0.025 kg·m-2) and the lateral-squat exercise (inertia 0.010 kg·m-2) on a flywheel device. During the testing sessions, mean and peak power in concentric (MPcon) and eccentric (MPecc) phases were recorded.
  - non-dominant leg showed higher values in all power variables measured, although substantial differences were only found in MPecc (ES = 0.40, likely) and PPcon (ES = 0.36, possibly). On the other hand, for both exercises, MPcon was higher than MPecc (ES = -0.57 to -0.31, possibly/likely greater), while only PPecc was higher than PPcon in the dominant lateral-squat (ES = 0.44, likely).
  - These findings suggest that young soccer players have difficulty in reaching eccentric-overload during flywheel exercises, achieving it only with the dominant leg. Therefore, coaches should propose precise preventive programs based on flywheel devices, attending to the specific characteristics of each limb, as well as managing other variables to elicit eccentric-overload.

https://www.stuartmcnaylor.com/publication/FW_vel_power/McErlain-Naylor_Beato_2020_authorversion.pdf

- **Concentric and eccentric inertia-velocity and inertia-power relationships in the flywheel squat**

- Fifteen healthy physically active males performed 6 maximal effort flywheel half-squats at each of 0.029, 0.061, 0.089, and 0.121 kg·m2, with velocity recorded via 3D motion capture and power recorded via inbuilt transducer. Peak concentric velocity (χ^2 = 37.9; p < 0.001), peak eccentric velocity (χ^2 = 24.9; p < 0.001), mean concentric velocity (F(3) = 52.7; p < 0.001), and mean eccentric velocity (χ^2 = 16.8; p <0.001) all tended to decrease with increases in flywheel inertia, whereas the ratio of peak eccentric to peak concentric power (F(3) = 4.26; p = 0.010) tended to increase
- The best fit subject-specific inertia-velocity relationships were reported for peak concentric velocity (median linear R2 = 0.95, median logarithmic R2 = 0.97). The results suggest that velocity, rather than power, should be used to prescribe and monitor flywheel squat exercise intensities, and that individualized linear relationships between inertia and peak concentric velocity can be used for this purpose.
- Similar to the observed decreases in peak concentric back squat vertical velocity with increases in barbell mass (Pérez-Castilla et al., 2020; Weakley, Mann, et al., 2020; Zink et al., 2006), peak (Carroll et al., 2019) and mean (Carroll et al., 2019; Worcester et al., 2020) concentric vertical velocities tend to decrease with each progressive increase in flywheel inertia up to 0.100 kg·m2 . Although velocity-based prescription in traditional resistance training typically uses linear load-velocity relationships (Banyard, Nosaka, & Haff, 2017; Weakley, Mann, et al., 2020), linear relationships between flywheel inertia and peak (R2 = 0.60) or mean (R2 = 0.66) concentric vertical velocity have not achieved good fits at the group level (Carroll et al., 2019) and are yet to be explored at the level of individual subjects
- In contrast with the a priori hypothesis, flywheel inertia had no significant effect on peak concentric or eccentric power. The best fit linear and non-linear inertia-velocity relationships were reported for peak concentric velocity. These findings offer innovative insights for prescription and monitoring of flywheel resistance exercise.
- Low inertias may be well suited to stimulating a training-induced rightward shift of the force-velocity curve, whereas higher inertias may be better suited to stimulating an upward shift. Training at higher inertias will likely therefore be more beneficial for individuals with a ‘force-deficit’, whilst lower inertias are more suitable for addressing ‘velocity-deficits’
- The observed subject-specific relationships suggest that velocity, rather than power, should be used to prescribe and monitor flywheel squat exercise intensities. The monitoring of velocity may represent a key step forward for practitioners and should be implemented into the current acute and chronic training recommendations

https://pubmed.ncbi.nlm.nih.gov/18976996/

- **Neuromuscular and balance responses to flywheel inertial versus weight training in older persons**
    - age-matched older individuals (69.9+/-1.3 years) were randomly assigned to flywheel (n=12), or weight-lifting (n=12) groups, training the knee extensors thrice weekly for 12 weeks.
    - knee extensors peak isokinetic power increased by 28% (P<0.01) in the flywheel group with no change in the weight-lifting group.
    - The gastrocnemius characteristic with the highest response to training was tendon stiffness, with increases of 54% and 136% in the weight-lifting and flywheel groups, respectively (P<0.01).
    - The larger increase in tendon stiffness in the flywheel group was associated with an improvement in postural balance (P<0.01).
    - Quadriceps flywheel loading not only produces a greater increase in power than weight training but its physiological benefits also transfer/overspill to the plantarflexor muscle-tendon unit resulting in a significantly improved balance.

https://pubmed.ncbi.nlm.nih.gov/26349042/

- **Neuromuscular Fatigue and Physiological Responses After Five Dynamic Squat Exercise Protocols**
    - In a randomized and counterbalanced order, 15 male resistance-trained athletes (mean ± SD; age: 23.1 ± 1.9 years, body mass: 77.4 ± 8.0 kg) completed traditional multiple sets (MS: 4 × 6, 85% 1 repetition maximum [RM]), drop sets (DS: 1 × 6, 85% 1RM + 3 drop sets), eccentric overload (EO: 4 × 6, 70% 1RM concentric, 100% 1RM eccentric), flywheel YoYo squat (FW: 4 × 6, all-out), and a plyometric jump protocol (PJ: 4 × 15, all-out).
    - lood lactate (La), ratings of perceived exertion (RPE), counter movement jump height (CMJ), multiple rebound jump (MRJ) performance, maximal voluntary isometric contraction force, serum creatine kinase (CK) and delayed onset muscle soreness were measured. Immediately post exercise, La was significantly ($p < 0.001$) higher in FW (mean ± 95% confidence limit; 12.2 ± 0.9 mmol·L) and lower in PJ (3.0 ± 0.8 mmol·L) compared with MS (7.7 ± 1.5 mmol·L), DS (8.5 ± 0.6 mmol·L), and EO (8.2 ± 1.6 mmol·L), accompanied by similar RPE responses.
    - Neuromuscular performance (CMJ, MRJ) significantly remained decreased ($p < 0.001$) from 0.5 to 48 hours post exercise in all protocols.
    - There was a significant time × protocol interaction ($p \leq 0.05$) in MRJ with a significant lower performance in DS, EO, and FW compared with PJ (0.5 hours post exercise), and in EO compared with all other protocols (24 hours post exercise).

- A significant main time effect with peak values 24 hours post exercise was observed in CK serum concentrations ($p < 0.001$), but there was no time × protocol interaction.
- In conclusion, (a) metabolic and perceptual demands were higher in FW and EO compared with MS, DS and PJ, (b) neuromuscular fatigue was consistent up to 48 hours post exercise in all protocols, and(c) EO induced the greatest neuromuscular fatigue.

https://pubmed.ncbi.nlm.nih.gov/28385560/

- **Skeletal muscle functional and structural adaptations after eccentric overload flywheel resistance training: a systematic review and meta-analysis**
  - Outcomes were analyzed as continuous outcomes using a random effects model to calculate a standardized mean difference (SMD) and 95% CI. A total of 9 studies with 276 subjects and 92 effect sizes met the inclusion criteria and were included in the statistical analyses.
  - The overall pooled estimate from the main effects analysis was 0.63 (95% CI 0.49-0.76) with a significant ($p<0.001$) Z overall effect of 9.17. No significant heterogeneity (p value=0.78) was found. The meta-analysis showed significant differences between FW-EOT vs. conventional resistance training in concentric and eccentric strength, muscle power, muscle hypertrophy, vertical jump height and running speed, favoring FW-EOT.
  - This meta-analysis provides evidence supporting the superiority of FW-EOT, compared with traditional weight-stack exercise, to promote skeletal muscle adaptations in terms of strength, power and size in healthy subjects and athletes.

https://pubmed.ncbi.nlm.nih.gov/28538317/

- **Effects of Inertial Setting on Power, Force, Work, and Eccentric Overload During Flywheel Resistance Exercise in Women and Men**
  - study examined power, work, force, and eccentric overload produced during flywheel resistance exercise with different inertial settings in men and women. Twenty-two women ($n = 11$) and men ($n = 11$) performed unilateral (in both legs) isolated concentric (CON) and coupled CON and eccentric (ECC) exercise in a flywheel knee extension device employing 6 inertias (0.0125, 0.025, 0.0375, 0.05, 0.075, 0.1 kg·m).
  - Power decreased as higher inertias were used, with men showing greater ($p \leq 0.05$) decrements than women (-36 vs. -29% from lowest to highest inertia). In contrast, work increased as higher inertias were employed, independent of sex ($p \leq 0.05$; ~48% from lowest to highest inertia). Women increased CON and ECC mean force (46-55%, respectively) more ($p \leq 0.05$) than men (34-50%, respectively) from the lowest to the

highest inertia evaluated, although the opposite was found for peak force data (i.e., peak force increased more in men than in women as inertia was increased).
    - Men, but not women, increased ECC overload from inertia 0.0125 to 0.0375 kg·m2. Although estimated stretch-shorting cycle use during flywheel exercise was higher ($p \leq 0.05$) in men (6.6%) than women (4.9%), values were greater for both sexes when using low-to-medium inertias.

https://pubmed.ncbi.nlm.nih.gov/27967273/

- **Eccentric-Overload Training in Team-Sport Functional Performance: Constant Bilateral Vertical Versus Variable Unilateral Multidirectional Movements**
    - Forty-eight amateur or semiprofessional team-sport players were randomly assigned to an EOT program including either the same bilateral vertical (CBV, n = 24) movement (squat) or different unilateral multidirectional (VUMD, n = 24) movements.
    - Training programs consisted of 6 sets of 1 exercise (CBV) or 1 set of 6 exercises (VUMD) × 6-10 repetitions with 3 min of passive recovery between sets and exercises, biweekly for 8 wk.
    - VUMD showing more robust adaptations in pooled COD tests and lateral/horizontal jumping, whereas the opposite occurred in CBV respecting linear sprinting and vertical jumping.
    - Eight weeks of EOT induced substantial improvements in functional-performance tests, although the force-vector application may play a key role to develop different and specific functional adaptations.

https://pubmed.ncbi.nlm.nih.gov/24519446/

- **Muscle damage responses and adaptations to eccentric-overload resistance exercise in men and women**
    - Dynamic strength (1 RM), jump performance, maximal power at different percentages of 1 RM, and muscle mass in three different portions of the thigh were assessed in 16 men and 16 women before and after 6 weeks (15 sessions) of flywheel supine squat RE training.
    - After training, increases in 1 RM were somewhat greater (interaction $P < 0.001$) in men (25 %) than in women (20 %). Squat and drop jump height and power performance at 50, 60, 70 and 80 % of 1 RM increased after training in both sexes ($P < 0.05$). Power improvement at 80 % of 1 RM was greater (interaction $P < 0.02$) in men than women. Muscle mass increased ~5 % in both groups ($P < 0.05$). CK increased in men after the first training session ($P < 0.001$), whereas the response in women was unaltered. In both sexes, LDH

concentration was greater after the first training session compared with basal values ($P < 0.05$). After the last session, CK and LDH remained at baseline in both groups.
    - eccentric-overload RE training induces comparable and favorable gains in strength, power, and muscle mass in both men and women.

https://pubmed.ncbi.nlm.nih.gov/24910951/

- **Effects of a 10-week in-season eccentric-overload training program on muscle-injury prevention and performance in junior elite soccer players**
    - Thirty-six young players (U-17 to U-19) were recruited and assigned to an experimental (EXP) or control group (CON). The training program consisted of 1 or 2 sessions/wk (3-6 sets with 6 repetitions) during 10 wk
    - Regarding muscle performance, a substantial better improvement (likely to very likely) was found in 20-m sprint time (ES: 0.37), 10-m flying-sprint time (ES: 0.77), and CMJ (ES: 0.79) for EXP than for CON.
    - Conversely, substantial improvements were obtained in CMJ (ES: 0.58), 20-m sprint time (ES: 0.32), 10-m flying-sprint time (ES: 0.95), and injury severity (ES: 0.59) in EXP.
    - The eccentric-based program led to a reduction in muscle-injury incidence and severity and showed improvements in common soccer tasks such as jumping ability and linear-sprinting speed.

https://pubmed.ncbi.nlm.nih.gov/26670989/

- **Effects of In-Season Inertial Resistance Training With Eccentric Overload in a Sports Population at Risk for Patellar Tendinopathy**
    - Players of 8 (4 basketball and 4 volleyball) teams (38 women and 43 men) were randomly assigned to either the intervention (IG) or control (CG) group. Although IG and CG maintained scheduled in-season training routines over 24 weeks, IG, in addition, performed 1 weekly session of eccentric overload by 4 sets of 8 repetitions of the squat using flywheel inertial resistance
    - Countermovement jump scores significantly ($p \leq 0.05$) differed between groups in favor of the IG. Both Squat-Con and Squat-Ecc mean scores from the IG were significantly ($p < 0.01$) higher than the CG.
    - Adding a weekly eccentric overload squat training bout to a regular basketball and volleyball exercise routine enhances lower limb muscle power without triggering patellar tendon complaints

https://journals.lww.com/nsca-jscr/fulltext/2019/05000/criterion_validity_of_force_and_power_outputs_for.2.aspx

- **Criterion Validity of Force and Power Outputs for a Commonly Used Flywheel Resistance Training Device and Bluetooth App**
    - Eleven subjects volunteered to take part in this study, with subjects completing between 5 and 35 repetitions of the harness squat with 0.05, 0.10, 0.15 $kg \cdot m^{-2}$ isoinertial load.
    - A synchronized dual force plate and tricamera optoelectronic setup was used as the criterion measure to calculate force and power output, while the kMeter app was used as the practical measure. Very large to nearly perfect relationships were observed between the 2 measures, with trivial to moderate bias reported.
    - These findings suggest that the kMeter app, when used in conjunction with the kBox flywheel device, demonstrates acceptable levels of validity.
    - kMeter app is an acceptable method of monitoring flywheel resistance training. Furthermore, it is advised that practitioners use mean power rather than mean force.

https://pubmed.ncbi.nlm.nih.gov/31743092/

- **Current Evidence and Practical Applications of Flywheel Eccentric Overload Exercises as Postactivation Potentiation Protocols: A Brief Review**
    - 7 eligible studies were identified based on the following results: First, practitioners can use different inertia intensities
    - EOL exercise can be used to stimulate PAP responses to obtain performance advantages in various sports

Strength

https://pubmed.ncbi.nlm.nih.gov/30547232/

- **Effects of Flywheel Training on Strength-Related Variables: a Meta-analysis**
    - meta-analysis includes 20 experimental studies that met the inclusion criteria.
    - Flywheel training for a period of 4-24 weeks shows statistically significant increases in all strength aspects.
    - Effect sizes were for
        - hypertrophy, CSA 0.59; volume/mass 0.59;
        - maximum strength 1.33; power 1.19;
        - horizontal 1.01 and vertical movement 0.85.
    - The evidence is particularly strong for beneficial effects from flywheel training in the development of maximal strength and power in trained younger individuals, and utilization of this training modality in shorter more intensive blocks.
    - Flywheel training is an effective method for improving several aspects of strength and power with importance for sports performance.

https://pubmed.ncbi.nlm.nih.gov/29107539/

- **Is inertial flywheel resistance training superior to gravity-dependent resistance training in improving muscle strength? A systematic review with meta-analyses**
    - meta-analyses on randomised and non-randomised controlled trials to determine the standardized mean difference between the effects of inertial flywheel and gravity-dependent resistance training on muscle strength. A total of 76 and 71 participants were included in the primary and secondary analyses, respectively.
    - primary outcome muscle strength, the pooled results from randomised controlled trials showed no difference (SMD=-0.05; 95%CI -0.51 to 0.40; p=0.82; I2=0%). In the secondary analyses of the primary outcome, the pooled results from non-randomised controlled trials showed no difference (SMD=0.02; 95%CI -0.45 to 0.49; p=0.93; I2=0%; and SMD=0.03; 95%CI -0.43 to 0.50; p=0.88; I2=0%)
    - inertial flywheel resistance training was not superior to gravity-dependent resistance training in enhancing muscle strength.

https://pubmed.ncbi.nlm.nih.gov/18976996/

- **Neuromuscular and balance responses to flywheel inertial versus weight training in older persons**

- age-matched older individuals (69.9+/-1.3 years) were randomly assigned to flywheel (n=12), or weight-lifting (n=12) groups, training the knee extensors thrice weekly for 12 weeks.
- knee extensors peak isokinetic power increased by 28% (P<0.01) in the flywheel group with no change in the weight-lifting group.
- he gastrocnemius characteristic with the highest response to training was tendon stiffness, with increases of 54% and 136% in the weight-lifting and flywheel groups, respectively (P<0.01).
- The larger increase in tendon stiffness in the flywheel group was associated with an improvement in postural balance (P<0.01).
- Quadriceps flywheel loading not only produces a greater increase in power than weight training but its physiological benefits also transfer/overspill to the plantarflexor muscle-tendon unit resulting in a significantly improved balance.

https://journals.lww.com/nsca-jscr/abstract/2022/01000/improved_muscle_strength,_muscle_power,_and.37.aspx

- **Improved Muscle Strength, Muscle Power, and Physical Function After Flywheel Resistance Training in Healthy Older Adults: A Randomized Controlled Trial**
  - thirty-six older adults (64 ± 5 years) were randomly allocated to either a flywheel resistance exercise training group (ETG; n = 18) or a control (CON) group (n = 18). Subjects in the ETG underwent 6 weeks of resistance training on a flywheel squat device (4 sets of 9 maximal repetitions). Isokinetic concentric (60 and 240°·s^{-1}) and eccentric (120°·s^{-1}) knee extension and flexion peak torques and mean power were measured. Physical function was assessed by the 30-second Chair Sit-Stand Test (CST) and walking speed
  - within-group analyses showed significantly greater flexion torques and mean power with the dominant leg (concentric at 60°·s^{-1} and 240°·s^{-1} and eccentric at 120°·s^{-1}; all d > 0.7, p < 0.05) and improvements in CST (d > 0.8) in the ETG, while no substantial differences were found in the CON group. Significant between-group differences in knee flexion torque both concentric (at 60°·s^{-1}: η^2 = 0.168 and 240°·s^{-1}: η^2 = 0.112) and eccentric (at 120°·s^{-1}: η^2 = 0.103) with the dominant leg were also found in favor of the ETG.
  - Significantly better performance in the CST for the ETG (η^2 = 0.207). There was a significant association between changes in strength and changes in mean power in the ETG
  - flywheel resistance exercise training is an appropriate form of activity for improving strength and functional capacity of older adults.

Hypertrophy

https://pubmed.ncbi.nlm.nih.gov/17053104/

- **Early skeletal muscle hypertrophy and architectural changes in response to high-intensity resistance training**
    - Seven young healthy volunteers performed bilateral leg extension three times per week on a gravity-independent flywheel ergometer.
    - By the end of the training period, MVC and EMG activity increased by 38.9 +/- 5.7 and 34.8% +/- 4.7%, respectively. Significant increase in QF CSA (3.5 and 5.2% in the C and D regions, respectively) was observed after 20 days of training, along with a 2.4 +/- 0.7% increase in fascicle length from the 10th day of training. By the end of the 35-day training period, the total increase in QF CSA for regions C and D was 6.5 +/- 1.1 and 7.4 +/- 0.8%, respectively, and fascicle length and pennation angle increased by 9.9 +/- 1.2 and 7.7 +/- 1.3%, respectively.
    - The results show for the first time that changes in muscle size are detectable after only 3 wk of RT and that remodeling of muscle architecture precedes gains in muscle CSA. Muscle hypertrophy seems to contribute to strength gains earlier than previously reported; flywheel training seems particularly effective for inducing these early structural adaptations.

https://pubmed.ncbi.nlm.nih.gov/20676897/

- **Flywheel resistance training calls for greater eccentric muscle activation than weight training**
    - Subjects, assigned to either weight stack (grp WS; n = 8) or iso-inertial "eccentric overload" flywheel (grp FW; n = 9) knee extensor resistance training, completed 12 sessions of four sets of seven concentric-eccentric actions.
    - Grp FW showed greater ($p < 0.05$) overall normalized angle-specific EMG(ECC) of vastii muscles compared with grp WS. Grp FW showed near maximal normalized EMG(CON) both pre- and post-training. EMG(CON) for Grp WS was near maximal only post-training.
    - We believe the higher EMG(ECC) activity noted with FW exercise compared to standard weight lifting could be attributed to its unique iso-inertial loading features. Hence, the resulting greater mechanical stress may explain the robust muscle hypertrophy reported earlier in response to flywheel resistance training.

https://pubmed.ncbi.nlm.nih.gov/21235100/

- **Quadriceps muscle use in the flywheel and barbell squat**
    - The subjects were 10 strength-trained men who performed 5 sets of 10 repetitions using the barbell squat (BS; 10 repetition maximum) or flywheel squat (FS; each repetition maximal), respectively.
    - The quadriceps muscle group showed greater exercise-induced T2 increase following FS compared with BS. Among individual muscles, the rectus femoris displayed greater T2 increase with FS (+24 +/- 14%) than BS (+8 +/- 4%). Normalized quadriceps EMG showed no difference across exercise modes.
    - the results of this study suggest that quadriceps muscle use in the squat is comparable, if not greater, with flywheel compared with free weight resistance exercise. Data appear to provide support for use of flywheel squat resistance exercise as a countermeasures adjunct during spaceflight.

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5495834/

- **Skeletal Muscle Remodeling in Response to Eccentric vs. Concentric Loading: Morphological, Molecular, and Metabolic Adaptations**
    - Flywheel training has shown to lead to very early hypertrophic and architectural adaptations (visible by MRI-assessed ACSA and ultrasound-derived fascicle length from 21 days after the start of the protocol; Seynnes et al., 2007). Although it is not within the scope of this manuscript to further present mixed CON/ECC loading strategies, it is intriguing to acknowledge that differences exist between muscular adaptations to ECC only or CON only and the combination of both types of contractions (with or without ECC overload) in training regimes.
    - ECC RT has been usually associated to greater increases in muscle mass compared to CON RT, the present review clearly illustrated that the findings presented in the literature are too varied to clearly affirm which training mode leads to greater long-term muscle growth.
        - distinct contraction-specific adaptations in muscle architecture are found. In addition, different molecular and myogenic mechanisms have found distinctly activated after ECC vs. CON exercise bouts, suggesting that these responses could be underlying the structural remodeling patterns previously described:
        - preferential addition of sarcomeres in-series (usually occurring after ECC RT)
        - he preferential addition of either sarcomeres in-series or in-parallel (dependent on the contraction mode used)
        - eccentric-only RT induces greater increase in Fassicle Length
    - greater than normal joint range of motion may explain the similar structural remodeling in response to the two loading modes

https://pubmed.ncbi.nlm.nih.gov/17926060/

- **Resistance training using eccentric overload induces early adaptations in skeletal muscle size**
    - Fifteen healthy men performed a 5-week training program comprising four sets of seven unilateral, coupled concentric-eccentric knee extensions 2-3 times weekly. While eight men were assigned to training using a weight stack (WS) machine, seven men trained using a flywheel (FW) device, which inherently provides variable resistance and allows for eccentric overload.
    - Average work showed a non-significant 8.7% increase in flywheel
    - Although the more than twofold greater hypertrophy evident in FW (6.2%) was not statistically greater than that shown in WS (3.0%), all four individual quadriceps muscles of FW showed increased ($P < 0.025$) volume whereas in WS only m. rectus femoris was increased ($P < 0.025$)..
    - Collectively the results of this study suggest more robust muscular adaptations following flywheel than weight stack resistance exercise supporting the idea that eccentric overload offers a potent stimuli essential to optimize the benefits of resistance exercise.

https://www.frontiersin.org/journals/physiology/articles/10.3389/fphys.2018.01265/full

- **Early Functional and Morphological Muscle Adaptations During Short-Term Inertial-Squat Training**
    - Ten young RT-naive volunteers (age 23.4 ± 4.1 years) underwent 10 training sessions (2–3 per week) consisting of five sets of 10 flywheel squats (moment of inertia 900 $kg \cdot cm^2$).
    - Significant quadriceps hypertrophy was detected during (IN: 5.5% ± 1.9%) and after (POST: 8.6% ± 3.6%) the training program.
    - Increases in squat force (CON: 32% ± 15%, ECC: 31 ± 15%) and power (CON: 51% ± 30%, ECC: 48% ± 27%) were observed over the training program.
    - Knee extensor MVIC significantly increased 28% ± 17% after training, but no changes were seen in knee flexor MVIC. No correlation was found between regional muscular activation in the first session and the % of increase in regional CSAs ($r = -0.043$, $P = 0.164$).
    - This study reports the earliest onset of whole-muscle hypertrophy documented to date. The process initiates early and continues in response to RT, contributing to initial increases in force.

Endurance

https://pubmed.ncbi.nlm.nih.gov/20145569/

- **Blood lactate and hormonal responses to prototype flywheel ergometer workouts**
    - Comprised of 10 repetition sets, the workouts entailed 3 sets of concentric and eccentric (CE3) actions, or concentric-only actions done for 3 (CO3) or 6 (CO6) sets.
    - Think it increases Blood Lactate Levels compared to regular training

https://www.frontiersin.org/journals/physiology/articles/10.3389/fphys.2019.01260/full

- **Effects of High-Intensity Interval Training and Isoinertial Training on Leg Extensors Muscle Function, Structure, and Intermuscular Adipose Tissue in Older Adults**
    - Twelve healthy men (69.3 ± 4.2 years; 77.8 ± 10.4 kg; 1.72 ± 0.05 m) were exposed to 8 weeks of HIT (7 × 2-min cycling repetitions at 90% of $\dot{V}O_{2peak}$, 3 times/week) and, after 4 months (detraining), to IRT (4 × 7 maximal concentric–eccentric knee extensions, 3 times/week).
    - IRT was able to elicit a greater increase of ACSA than HIT; Vol increases similarly and significantly after HIT and IRT (P = 0.003–0.001); IMAT at 50% of femur length decreased after both HIT and IRT (P = 0.001–0.003); physiological cross-sectional area (PCSA) was larger after IRT than before (P = 0.025); specific torque did not change throughout the study (45.5 N cm^{-2} ± 12.0); %Act of the quadriceps was significantly affected only by IRT (P = 0.011). Both HIT and IRT are able to elicit beneficial modifications of muscular mass, architecture, and quality (reducing IMAT) in elderly subjects in connection with an amelioration of strength.
    - The increases of functional torque seemed to be attributed to a parallel increase of %Act and muscle hypertrophy only after IRT. Data suggest that IMAT may be a prominent indicator to track metabolic-dependent activity and skeletal muscle quality.

https://www.researchgate.net/publication/307893882_The_High-Pull_Exercise_A_Comparison_Between_a_VersaPulley_Flywheel_Device_and_the_Free_Weight

- **The High-Pull Exercise: A Comparison Between a VersaPulley Flywheel Device and the Free Weight**
    - Fifteen rugby players randomly performed two training sessions of 6 sets of 6 repetitions with 20 s of recovery in between sets of the high pull exercise with the VP and the FW.

- Barbell displacement (+4.8%, small ES), peak velocity (+4.5% small ES), mean propulsive acceleration (+8.8%, small ES), and eccentric force (+26.7, large ES) were substantially higher with VP than with FW.
- blood lactate concentration was also greater after the VP exercise (End: +32.9%; 3´later: +36%; 5´later: +33.8 %, large ES).
- Maximal concentric force was substantially higher with FW than VP during the 6th set (+6.4%, small ES).
- Within the cohort and exercise investigated in the present study, VP training can be considered an efficient training device to induce an accentuated eccentric overload and augmented metabolic demands (i.e., blood lactate concentration).

General

https://www.researchgate.net/publication/354552136_Perception_and_application_of_flywheel_training_by_professional_soccer_practitioners

- **Perception and application of flywheel training by professional soccer practitioners**
    - Three general questions followed, allowing more detail about flywheel training application. A Majority of the participants reported ≥ 2 years' experience of programming flywheel training. Nearly all participants agreed that familiarisation is needed. Practitioners agree that flywheel training can improve sport performance, strength and likelihood of non-contact injury outcomes. Most practitioners prescribe 2 weekly sessions during pre- and in-season periods. Flywheel sessions mostly consist of squats but a variety of exercises (lunge, hip hinge, and open kinetic chain) are also frequently included.
    - Practitioners are mostly unsure about differences between flywheel and traditional resistance training equipment and outcomes, practicality of flywheel equipment, and evidence-based guidelines