Evidence-based Practice Initiative – Eccentron

Eccentron specific references:


ABSTRACT: Skeletal muscle is a dynamic tissue that responds adaptively to both the nature and intensity of muscle use. This phenotypic plasticity ensures that muscle structure is linked to patterns of muscle use throughout the lifetime of an animal. The cascade of events that result in muscle restructuring – for example, in response to resistance exercise training – is often thought to be initiated by muscle damage. We designed this study to test the hypothesis that symptomatic (i.e. detectable) damage is a necessary precursor for muscle remodeling. Subjects were divided into two experimental populations: pre-trained (PT) and naïve (NA). Demonstrable muscle damage was avoided in the PT group by a three-week gradual ‘ramp-up’ protocol. By contrast, the NA group was subjected to an initial damaging bout of exercise. Both groups participated in an eight-week high-force eccentric-cycle ergometry program (20 min, three times per week) designed to equate the total work done during training between the groups. The NA group experienced signs of damage, absent in the PT group, as indicated by greater than five times higher levels of plasma creatine kinase (CK) and self-reporting of initial perceived soreness and exertion, yet muscle size and strength gains were not different for the two groups. RT-PCR analysis revealed similar increases in levels of the growth factor IGF-1Ea mRNA in both groups. Likewise, the significant (P<0.01) increases in mean cross-sectional area (and total muscle volume) were equal in both groups. Finally, strength increases were identical for both groups (PT=25% and NA=26% improvement). The results of this study suggest that muscle rebuilding – for example, hypertrophy – can be initiated independent of any discernible damage to the muscle.


ABSTRACT:
Background: Resistance exercise programs with high compliance are needed to counter impaired muscle and mobility in older cancer survivors. To date outcomes have focused on older prostate cancer survivors, though more heterogeneous groups of older survivors are in-need. The purpose of this exploratory pilot study is to examine whether resistance exercise via negative eccentrically-induced work (RENEW) improves muscle and mobility in a diverse sample of older cancer survivors.
Methods: A total of 40 individuals (25 female, 15 male) with a mean age of 74 (± 6) years who have survived (8.4 ± 8 years) since their cancer diagnosis (breast, prostate, colorectal and lymphoma) were assigned to a RENEW group or a non-exercise Usual-care group. RENEW
was performed for 12 weeks and measures of muscle size, strength, power and mobility were made pre and post training.

**Results:** RENEW induced increases in quadriceps lean tissue average cross sectional area (Pre: 43.2 ± 10.8 cm²; Post: 44.9 ± 10.9 cm²), knee extension peak strength (Pre: 248.3 ± 10.8 N; Post: 275.4 ± 10.9 N), leg extension muscle power (Pre: 198.2 ± 74.7 W; Post 255.5 ± 87.3 W), six minute walk distance (Pre: 417.2 ± 127.1 m; Post 466.9 ± 125.1 m) and a decrease on the time to safely descend stairs (Pre: 6.8 ± 4.5 s; Post 5.4 ± 2.5 s). A significant (P < 0.05) group x time interaction was noted for the muscle size and mobility improvements.

**Conclusions:** This exploration of RENEW in a heterogeneous cohort of older cancer survivors demonstrates increases in muscle size, strength and power along with improved mobility. The efficacy of a high-force, low perceived exertion exercise suggests RENEW may be suited to older individuals who are survivors of cancer.

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ABSTRACT: Rehabilitation services are less-studied aspects of the management following total knee arthroplasty (TKA) despite long-term suboptimal physical functioning and chronic deficits in muscle function. This paper describes the preliminary findings of a six-week (12 session) eccentrically-biased rehabilitation program targeted at deficits in physical function and muscle function, initiated one month following surgery. A quasi-experimental, one group, pretest-posttest study with thirteen individuals (6 female, 7 male; mean age 57 ± 7 years) examined the effectiveness of an eccentrically-biased rehabilitation program. The program resulted in improvements in the primary physical function endpoints (SF-36 physical component summary and the six-minute walk test) with increases of 59% and 47%, respectively. Muscle function endpoints (knee extension strength and power) also increased 107% and 93%, respectively. Eccentrically-biased exercise used as an addition to rehabilitation may help amplify and accelerate physical function following TKA surgery.

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ABSTRACT:

**Introduction:** Older individuals who have survived cancer, and the commensurate treatment, often experience a reduced quality of life in part due to their impaired muscular abilities and deficits in mobility. The purpose of this preliminary study was to determine the feasibility and preliminary efficacy of resistance exercise via negative, eccentrically-induced work (RENEW) with older cancer survivors.

**Methods:** Older cancer survivors with a perception of moderate muscle weakness and fatigue
participated in 12 weeks of RENEW. Measures of feasibility included: 1) the participant’s ability to progress the total amount of work of RENEW; 2) whether peak knee extension torque production became impaired; and 3) whether RENEW induced leg muscle pain as measured on a visual analog scale. The preliminary measure of efficacy included: the performance of a timed up and go mobility test.

**Results:** The participants significantly increased the total average work per week over the 12 weeks of RENEW. Participants increased (p<0.001) their work ~3-fold from week 3 (7.6± 5.1 kJ) to week 12 (22.1±14.8kJ) without muscle pain over the 12 week RENEW training period. Knee extension peak torque production improved (11%) significantly (p=0.02) (pretest: 248 ±92 N; posttest: 275±99 N) after 12 weeks of RENEW. The time to perform the TUG test improved (14%) significantly (p<0.001) (pretest: 8.4±2.7; posttest: 7.2±2.3 s) after 12 weeks of RENEW, suggesting preliminary efficacy.

**Conclusion:** Collectively, RENEW appears feasible and potentially efficacious for older, weak and fatigued cancer survivors. 

**Implications for Cancer Survivors:** The use of eccentric muscle exercise may be ideally suited for older cancer survivors due to its high force and low energetic cost capabilities.

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**ABSTRACT:**

**Background:** Novel interventions that can safely and effectively overload muscle early following anterior cruciate ligament reconstruction are needed to minimize atrophy and weakness that often becomes longstanding.

**Evidence Acquisition:** Eccentrically induced forces can be safely applied during the early stages of rehabilitation following surgery and serve as a potent stimulus for increasing muscle size and strength.

**Results:** Compared to a standard rehabilitation program, adding an early 12-week eccentric resistance-training program 3 weeks after anterior cruciate ligament reconstruction induces improvement in quadriceps and gluteus maximus volume at 15 weeks and at 1 year after surgery. Likewise, those who performed an eccentrically biased rehabilitation program also achieved greater improvements in quadriceps strength and hopping ability measured at 15 weeks and at 1 year after surgery.

**Clinical relevance:** There is potential to safely and feasibly perform eccentric contractions as part of a formal rehabilitation program following anterior cruciate ligament reconstruction.

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ABSTRACT: Muscle and mobility deficits can persist for years after a total knee arthroplasty (TKA). The purposes of this study were (1) to determine if 12 weeks of rehabilitation with resistance exercise induces increases in muscle size, strength, and mobility in individuals 1 to 4 years after a TKA; and (2) to compare the muscle and mobility outcomes of a traditional resistance exercise rehabilitation program with a rehabilitation program focused on eccentric resistance exercise. Seventeen individuals (13 women, four men; mean age, 68 years; age range, 55–80 years) with either a unilateral or bilateral TKA (total of 24 knees) were included in this matched and randomized repeated-measures rehabilitation pilot trial. Increases in quadriceps muscle volume and knee extension strength followed 12 weeks of eccentric exercise. Improvements were also noted in four mobility tests. Similar improvements were noted in the traditional group in two mobility tests. An increase in muscle size and strength and an improvement in levels of mobility can occur after 12 weeks of resistance exercise in older individuals 1 to 4 years after TKA. When the exercise mode focuses on eccentric resistance, the muscle growth response is greater as is the improvement in important mobility tasks. Level of Evidence: Level II, therapeutic study.


ABSTRACT:
Background: Menopause is associated with both a loss of muscle mass and a worsening of insulin sensitivity (IS). Although eccentric resistance exercise (ECC) can effectively improve muscle mass over time, a single bout of ECC can worsen IS. This study assessed the effect of repeated ECC on IS, muscle mass, and function in postmenopausal women with impaired glucose tolerance (IGT).
Methods: Sixteen PM women (aged 56 years ± 6.4) with IGT were randomly assigned to a 12-week, knee extensor ECC program (n = 10) or a non-exercise control group (CON) (n = 6). Participants underwent hyperinsulinemic-euglycemic clamps, dual-energy x-ray (DEXA) absorptiometry, quadriceps strength assessment, 6-minute walk (6MW) tests, and an assessment of steps taken per day before and after training.
Results: ECC participants experienced greater increases in leg lean soft tissue mass (ECC, 0.41 kg; CON, -0.53 kg; p = 0.03), quadriceps strength (ECC, 9.3 kg force; CON, -2.9 kg force; p = 0.02), and 6MW distance (ECC, 56.4 meters; CON, 3.3 meters; p = 0.03) than CON participants and demonstrated a trend toward more steps taken per day post-training (ECC, +1747 steps; CON, +339 steps; p = 0.10). IS was unchanged.
Conclusions: This novel exercise improves muscle mass and function without worsening IS in postmenopausal women with IGT. Because it can be performed at low levels of exertion and improves muscle mass and function without impairing IS, ECC should be used to ameliorate muscle loss in physically inactive postmenopausal women. The impact of longer-term ECC on IS should be investigated. Demonstrating that ECC does not worsen IS in this population is significant because it has promise to combat the muscle-mediated impairments common in...

ABSTRACT:
Background and Purpose: The purpose of this study was to compare the outcomes between a diabetes exercise training program using combined aerobic and high-force eccentric resistance exercise and a program of aerobic exercise only.

Subjects and Methods: Fifteen participants with type 2 diabetes mellitus (T2DM) participated in a 16-week supervised exercise training program: 7 (mean age=50.7 years, SD=6.9) in a combined aerobic and eccentric resistance exercise program (AE/RE group) and 8 (mean age=58.5 years, SD=6.2) in a program of aerobic exercise only (AE group). Outcome measures included thigh lean tissue and intramuscular fat (IMF), glycosylated hemoglobin, body mass index (BMI), and 6-minute walk distance.

Results: Both groups experienced decreases in mean glycosylated hemoglobin after training (AE/RE group: -0.59% [95% confidence interval (CI)=-1.5 to 0.28]; AE group: -0.31% [95% CI=-0.60 to -0.03]), with no significant between-group differences. There was an interaction between group and time with respect to change in thigh lean tissue cross-sectional area, with the AE/RE group gaining more lean tissue (AE/RE group: 15.1 cm² [95% CI=7.6 to 22.5]; AE group: -5.6 cm² [95% CI=-10.4 to 0.76]). Both groups experienced decreases in mean thigh IMF cross-sectional area (AE/RE group: -1.2 cm² [95% CI=-2.6 to 0.26]; AE group: -2.2 cm² [95% CI=-3.5 to -0.84]) and increases in 6-minute walk distance (AE/RE group: 45.5 m [95% CI=7.5 to 83.6]; AE group: 29.9 m [95% CI=-7.7 to 67.5]) after training, with no between-group differences. There was an interaction between group and time with respect to change in BMI, with the AE/RE group experiencing a greater decrease in BMI.

Discussion and Conclusion: Significant improvements in long-term glycemic control, thigh composition, and physical performance were demonstrated in both groups after participating in a 16-week exercise program. Subjects in the AE/RE group demonstrated additional improvements in thigh lean tissue and BMI. Improvements in thigh lean tissue may be important in this population as a means to increase resting metabolic rate, protein reserve, exercise tolerance, and functional mobility.

ABSTRACT:

STUDY DESIGN: Randomized, matched design.

BACKGROUND: Optimal rehabilitation following anterior cruciate ligament reconstruction (ACLR) requires safe and effective interventions. Negative work exercise (via eccentric muscle activity) has the potential to be highly effective at producing large quadriceps size and strength gains early after ACL-R. The purpose of this investigation was to evaluate the short-term safety and efficacy of adding a progressive negative work exercise program via eccentric (ECC) ergometry early after ACL-R.

METHODS AND MEASURES: Beginning 3 weeks after ACL-R, 32 participants were randomly assigned into either a 12-week traditional (TRAD) or ECC exercise program. Safety was assessed by measuring knee pain, thigh pain, knee effusion, and knee stability prior to surgery and at 3, 15, and 26 weeks after surgery. Efficacy was assessed by measuring negative work output during the 12-week training program and by measuring functional ability (ie, quadriceps peak torque, hopping distance, self-reported functional ability and activity level scales) prior to surgery and 26 weeks after ACL-R.

RESULTS: There were no significant differences between groups in measures of knee and thigh pain, effusion, or stability at any period after surgery. Negative work output increased systematically throughout training, while knee and thigh pain remained at relatively low levels. A significant group-by-time interaction was observed for quadriceps peak torque, hopping distance, and activity level ($P < .02$). Quadriceps strength and hopping distance of the involved limb improved by a significantly greater amount in the ECC group compared to the TRAD group ($P < .01$). Activity level decreased to a lesser extent in the ECC group compared to the TRAD group ($P = .02$).

CONCLUSIONS: Negative work via an ECC intervention was implemented safely after ACLR. The addition of negative work exercise also induced superior short-term results in strength, performance, and activity level after surgery.


ABSTRACT:

Background: Thigh muscle atrophy is a major impairment that occurs early after reconstruction of the anterior cruciate ligament and persists for several years. Eccentric resistance training has the potential to induce considerable gains in muscle size and strength that could prove beneficial during postoperative rehabilitation. The purpose of this study was to evaluate the effects of progressive eccentric exercise on thigh muscle structure following reconstruction of the anterior cruciate ligament.

Methods: Beginning three weeks after reconstruction of the anterior cruciate ligament, forty patients were randomly assigned to a program involving either twelve weeks of eccentric exercises or a standard rehabilitation protocol. Patients were matched by surgical procedure, sex, and age. The final series consisted of two cohorts of twenty patients each who had been treated with one of two types of graft (semitendinosus-gracilis or bone-patellar tendon-bone), with ten patients treated with each of the two rehabilitation protocols in each graft cohort. To
evaluate changes in muscle structure, magnetic resonance images of the involved and uninvolved thighs were acquired before and after training. The volume and peak cross-sectional area of the quadriceps, hamstrings, and gracilis and the distal portion of the gluteus maximus were calculated from these images.

**Results:** The volume and peak cross-sectional area of the quadriceps and gluteus maximus, in both the involved and the uninvolved thighs and in the patients treated with each type of graft, improved significantly more in the eccentric exercise group (p < 0.001). The magnitude of the volume change was more than twofold greater in that group. No significant differences in any hamstring or gracilis structural measurements were observed between the rehabilitation groups. However, the volume and peak cross-sectional area of the gracilis were markedly reduced, compared with the pretraining values, in the patients who had undergone reconstruction with the semitendinosus-gracilis graft.

**Conclusions:** Eccentric resistance training implemented three weeks after reconstruction of the anterior cruciate ligament can induce structural changes in the quadriceps and gluteus maximus that greatly exceed those achieved with a standard rehabilitation protocol. The success of this intervention can be attributed to the gradual and progressive exposure to negative work through eccentric exercise, ultimately leading to production of high muscle force.

**Level of Evidence:** Therapeutic Level I.


ABSTRACT:
**Background and Purpose:** Elderly individuals participate in resistance exercise to induce an anabolic response and grow muscle to help overcome functional deficits. It is thought that a muscle damage and inflammatory response to resistance exercise is a necessary prerequisite for an anabolic and muscle growth response.

**Methods:** This is a descriptive study of 11 elderly individuals in rehabilitation who underwent a 2-3x/week high force resistance exercise that used eccentric contractions. Serum measures of muscle damage, inflammation, and an anabolic response are reported along with changes in muscle mass as measured with dual energy X-ray absorptiometry.

**Results:** Negative work increased >3-fold during the 11 weeks of resistance exercise. There were no significant changes in the damage measure of serum creatine kinase (pretraining: 18.5 ± 1.2 Sigma units/ml; post-training: 19.2 ± 1.1 Sigma units/ml). Proinflammatory tumor necrosis factor-α values remained within normal range (<4.0 pg/ml) throughout the 11 weeks of training. A nonsignificant trend for an anabolic increase (65%) in insulin like growth factor-α was noted along with a significant increase (6%) in thigh muscle mass.

**Conclusions:** Neither damage, nor inflammation appear to be prerequisites for inducing anabolic and muscle growth responses in elderly individuals undergoing a high force resistance exercise with eccentric contractions.

**ABSTRACT:**

**Objective:** To examine the effect of high-force eccentric resistance exercise on measures of muscle damage and injury in persons with mild to moderate Parkinson’s disease (PD).

**Design:** Before-after trial.

**Setting:** Tertiary care center clinical laboratory.

**Participants:** Ten persons with PD (Hoehn and Yahr Staging Scale, stage 1–3).

**Intervention:** Participants trained 3 days a week for 12 weeks on an eccentric ergometer, performing high-force eccentric resistance exercise with bilateral lower extremities.

**Main Outcome Measures:** Serum creatine kinase (CK) concentrations, muscle pain scores, and isometric force production were measured before, during, and after training.

**Results:** Mean CK levels did not differ and did not exceed the threshold of muscle damage at any time point ($P=.17$). Muscle visual analog scale scores were low and only differed at week 2 ($P=.04$). Participants were highly compliant, whereas total negative work and isometric force increased over time ($P=.02$, $P=.006$, respectively).

**Conclusions:** Persons with mild to moderate PD can safely and feasibly participate in high-force eccentric resistance training. The data we present provide a basis for future investigations of the efficacy of this type of training on muscle size, strength, and mobility in persons with PD.

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**ABSTRACT:** Strength deficits in persons with Parkinson’s disease (PD) have been identified as a contributor to bradykinesia. However, there is little research that examines the effect of resistance training on muscle size, muscle force production, and mobility in persons with PD. The purpose of this exploratory study was to examine, in persons with PD, the changes in quadriceps muscle volume, muscle force production, and mobility as a result of a 12-week high-force eccentric resistance training program and to compare the effects to a standard-care control. Nineteen individuals with idiopathic PD were recruited and consented to participate. Matched assignment for age and disease severity resulted in 10 participants in the eccentric group and 9 participants in the control group. All participants were tested prior to and following a 12-week intervention period with testing and training conducted at standardized times in their medication cycle. The eccentric group performed high-force quadriceps contractions on an eccentric ergometer 3 days a week for 12 weeks. The standard-care group exercise program encompassed standard exercise management of PD. The outcome variables were quadriceps muscle volume, muscle force, and mobility measures (6-minute walk, stair ascent/descent time). Each outcome variable was tested using separate one-way analyses of covariance on the difference scores. Muscle volume, muscle force, and functional status improvements occurred in persons with PD as a result of high-force eccentric resistance training. The eccentric group
demonstrated significantly greater difference scores for muscle structure, stair descent, and 6-minute walk \((P < 0.05)\). Magnitude of effect size estimators for the eccentric group consistently exceeded those in the standard-care group for all variables. To our knowledge, this is the first clinical trial to investigate and demonstrate the effects of eccentric resistance training on muscle hypertrophy, strength, and mobility in persons with PD. Additional research is needed to determine the anatomical and neurological mechanisms of the observed strength gains and mobility improvements.


ABSTRACT:

Study Design: Case report.

Objectives: To present a progressively increasing negative-work exercise program via eccentric ergometry early after anterior cruciate ligament reconstruction (ACL-R) and to suggest the potential of negative work to amplify the return of quadriceps size and strength.

Case Description: The patient was a 26-year-old highly active recreational athlete who sustained an ACL tear while skiing in January 2004 and then again while skiing in February 2005. This individual underwent an arthroscopically assisted ACL-R with a double-loop semitendinosus gracilis autograft initially, then a patellar tendon autograft following his ACL graft rupture. Beginning within 3 weeks after surgery, a progressive negative-work exercise program was initiated using an eccentric ergometer. The patient completed 31 training sessions of 5 to 30 minutes in duration over a 12-week period following the ACL-R and 33 training sessions of the same frequency and duration following the ACL revision.

Outcomes: Following ACL-R, quadriceps volume increased 28% (involved lower extremity) and 14% (uninvolved lower extremity) during the 12-week training program. Following revision, quadriceps volume returned to similar levels at the same postoperative period as those achieved after the initial surgery (2% less on the involved side and 2% greater on the uninvolved side). Quadriceps strength, 15 weeks after ACL-R, exceeded preoperative measures by an average of 20% (involved) and 14% (uninvolved). Quadriceps strength after ACL revision exceeded all previous measures.

Discussion: This case report suggests that if gradually and progressively applied, negative work via eccentric ergometry can be both safe and efficacious early after ACL-R. Eccentric exercise may mitigate the prevalent muscle size and strength deficits commonly observed after ACL-R. The results of this case suggest a need for continued research with early negative work interventions following ACL-R.

ABSTRACT: Muscles operate eccentrically to either dissipate energy for decelerating the body or to store elastic recoil energy in preparation for a shortening (concentric) contraction. The muscle forces produced during this lengthening behavior can be extremely high, despite the requisite low energetic cost. Traditionally, these high-force eccentric contractions have been associated with a muscle damage response. This clinical commentary explores the ability of the muscle-tendon system to adapt to progressively increasing eccentric muscle forces and the resultant structural and functional outcomes. Damage to the muscle-tendon is not an obligatory response. Rather, the muscle can hypertrophy and a change in the spring characteristics of muscle can enhance power; the tendon also adapts so as to tolerate higher tensions. Both basic and clinical findings are discussed. Specifically, we explore the nature of the structural changes and how these adaptations may help prevent musculoskeletal injury, improve sport performance, and overcome musculoskeletal impairments.


ABSTRACT:
Background: The objective of this study was to determine if a chronic eccentric training intervention, i.e., negative work, could limit or even reverse sarcopenia and its related impairments and functional limitations. Is high-force eccentric training tolerable by elderly people and will it result in improved muscle size, strength, balance, and fall risk?

Methods: 21 frail elderly subjects (mean age, 80 years) experienced 11 weeks of lower extremity resistance training. The experimental eccentric (ECC) group (n = 11) performed negative work while exercising on a high-force eccentric ergometer. The active “controls” performed traditional (TRAD) (n = 10) lower extremity resistance exercises (weight training). Muscle fiber cross-sectional area and strength, balance, stair descending abilities, and fall risk were assessed prior to and following this intervention.

Results: All ECC subjects who started the negative work intervention completed the study and reported the training to be relatively effortless; they experienced minimal and transient muscle soreness. Both groups experienced a significant increase in muscle fiber cross-sectional area (ECC = 60%, TRAD = 41%). Only the ECC group experienced significant improvements in strength (60%), balance (7%), and stair descent (21%) abilities. The timed up and go task improved in both groups, but only the ECC group went from a high to a low fall risk.

Conclusions: These data demonstrate that lower extremity resistance exercise can improve muscle structure and function in those with limited exercise tolerance. The greater strength increase following negative work training resulted in improved balance, stair descent, and fall risk only in the ECC group. Because low energy cost is coupled to high force production with eccentric exercise, this intervention may be useful for a number of patients that are otherwise
unable to achieve high muscle forces with traditional resistance exercise.


**ABSTRACT:**
**Purpose:** With lengthening (eccentric) muscle contractions, the magnitude of locomotor-muscle mass and strength increase has been demonstrated to be greater compared with shortening (concentric) muscle contractions. In healthy subjects, energy demand and heart rate responses with eccentric exercise are small relative to the amount of muscle force produced. Thus, eccentric exercise may be an attractive alternative to resistance exercise for patients with limited cardiovascular exercise tolerance.

**Methods:** We tested the cardiovascular tolerance of eccentric exercise in 13 coronary patients (ages 40–66) with preserved and/or mild reduced left ventricular function. Patients were randomly assigned to either an eccentric (ECC; \( N = 7 \)) or a concentric (CON; \( N = 6 \)) training group and trained for 8 wk. Training workload was increased progressively (from week 1 to 5) to an intensity equivalent to 60% \( \text{[latin capital V with dot above]} \text{O}_2 \text{peak} \).

**Results:** On average, maximum power output achieved with ECC was fourfold compared with CON (357 ± 96 W vs 97 ± 21 W; \( P < 0.005 \)), whereas measures of oxygen uptake and blood lactate were significantly lower (\( P < 0.05 \) each), and ratings of perceived exertion were similar for ECC and CON. During a 20-min session of ECC and CON, central hemodynamics was measured by means of right heart catheterization. During ECC, responses of mean arterial blood pressure, systemic vascular resistance, pulmonary capillary pressure, cardiac index, and stroke work of the left ventricle on average were in the normal range of values and similar to those observed during CON. Compared with baseline, after 8 wk of training, echocardiographic left ventricular function was unchanged.

**Conclusion:** The results indicate uncoupling of skeletal muscle load and cardiovascular stress during ECC. For low-risk patients with coronary heart disease without angina, inducible ischemia, or left ventricular dysfunction, ECC can be recommended as a safe new approach to perform high-load muscular exercise training with minimal cardiovascular stress.

Lindstedt SL, Reich TE, Keim P, LaStayo PC: **Do muscles function as adaptable locomotor springs?** J Experiment Biol. 2002;205:2211-2216

**ABSTRACT:** During normal animal movements, the forces produced by the locomotor muscles may be greater than, equal to or less than the forces acting on those muscles, the consequences of which significantly affect both the maximum force produced and the energy consumed by the muscles. Lengthening (eccentric) contractions result in the greatest muscle forces at the lowest relative energetic costs. Eccentric contractions play a key role in storing
elastic strain energy which, when recovered in subsequent contractions, has been shown to result in enhanced force, work or power outputs. We present data that support the concept that this ability of muscle to store and recover elastic strain energy is an adaptable property of skeletal muscle. Further, we speculate that a crucial element in that muscle spring may be the protein titin. It too seems to adapt to muscle use, and its stiffness seems to be ‘tuned’ to the frequency of normal muscle use.


ABSTRACT: Lengthening (eccentric) muscle contractions are characterized by several unusual properties that may result in unique skeletal muscle adaptations. In particular, high forces are produced with very little energy demand. Eccentrically trained muscles gain strength, but the specific nature of fiber size and composition is poorly known. This study assesses the structural and functional changes that occur to normal locomotor muscle after chronic eccentric ergometry at training intensities, measured as oxygen uptake, that do not influence the muscle when exercised concentrically. Male subjects trained on either eccentric or concentric cycle ergometers for 8 wk at a training intensity starting at 54% and ending at 65% of their peak heart rates. The isometric leg strength increased significantly in the eccentrically trained group by 36%, as did the cross-sectional area of the muscle fiber by 52%, but the muscle ultrastructure remained unchanged. There were no changes in either fiber size, composition, or isometric strength in the concentrically trained group. The responses of muscle to eccentric training appear to be similar to resistance training.

LaStayo PC, Reich TE, Urquhart M, Hoppeler H, Lindstedt SL: **Chronic eccentric exercise: improvements in muscle strength can occur with little demand for oxygen.** Am J Physiol Regulatory Integrative Comp Physiol. 1999;45:R611-R615

ABSTRACT: Eccentric contractions, the lengthening of muscle while producing force, are a common part of our everyday movements. This study presents a challenge to the accepted notion that eccentric work causes obligatory muscle injury while demonstrating that an increase in muscle strength, via eccentric work, can occur with little demand for oxygen. Nine healthy subjects, ages 18–34, were randomly placed in either an eccentric or a concentric training group. Both groups trained for 6 wk while progressively increasing training frequency and duration. Significant gains in isometric leg strength were seen in the eccentrically trained subjects only. While training, the oxygen consumption required to do the eccentric work was equal to or less than that required to do the concentric work. The results demonstrate that by progressively increasing the eccentric work rate, significant isometric strength gains can be
made without muscle injury and with minimal increase in metabolic demand for oxygen. The potential clinical implications of an eccentric training program that uncouples skeletal muscle strength improvements from the demand for oxygen are alluring.

Supporting Evidence:


ABSTRACT:
Background: Physical therapists treat older individuals, characterized as both a needy and expanding population. Frailty, a predisability condition with links to chronic inflammatory conditions, is estimated to affect 7% of individuals older than 60 years and 40% of people older than 80 years. Chronic inflammation is one of the most important physiologic correlates of the frailty syndrome and high levels of proinflammatory cytokines, related to both aging and increasing adiposity in older individuals are related to an increased risk of mortality, sarcopenia, reduced muscle strength and decreased mobility.

Purpose: The purpose of this narrative review is to inform the physical therapist of the effects of aging and increasing adiposity on chronic inflammation and the association of inflammation with muscle loss, strength, and mobility impairments in older adults; and to review the current evidence to provide clinical recommendations on physical activity and exercise regimes that may mitigate chronic inflammation in older adults.

Discussion: As physical therapists help manage and treat an increasingly older population, understanding how the inflammatory milieu changes with aging and increasing adiposity and how these changes can be impacted by physical therapists via exercise and physical activity is critical.

Conclusion: Exercise is a potent preventive intervention strategy and countermeasure for chronic inflammation and adiposity. Exercise can also benefit the frail older individual by combating the negative effects of chronic inflammation and optimally balancing the production of pro and anti-inflammatory cytokines. In addition to providing an anti-inflammatory environment within muscle to mitigate the effects of chronic inflammation, exercise has the added benefit of improving muscle mass and function and decreasing adiposity in older adults.


ABSTRACT: This study investigated whether low-intensity eccentric contractions of the knee extensors would attenuate the magnitude of muscle damage induced by maximal eccentric
exercise of the same muscle performed 7 days later using elderly individuals. Healthy older men (66.4 ± 4.6 years) were assigned to control or experimental (Exp) group (n = 13 per group). The control group performed six sets of ten maximal eccentric contractions (MaxECC) of the knee extensors of non-dominant leg. The Exp group performed six sets of ten low-intensity eccentric contractions of the knee extensors on a leg extension machine by lowering a weight of 10 % maximal voluntary isometric knee extension strength (10 %ECC) 7 days prior to MaxECC. Changes in maximal voluntary isokinetic concentric torque (MVC-CON), angle at peak torque, range of motion (ROM), upper thigh circumference, muscle soreness, plasma creatine kinase activity and myoglobin (Mb) concentration and B-mode ultrasound echo-intensity before and for 5 days after MaxECC were compared between groups by a mixed factor ANOVA. No significant changes in any variables were observed following 10 %ECC. Following MaxECC, all variables changed significantly, and changes in all variables except for angle at peak torque were significantly different between groups. MVC-CON and ROM decreased smaller and recovered faster (P<0.05) for Exp than control group, and changes in other variables were smaller (P<0.05) for Exp group compared with control group. These results suggest that pre-conditioning knee extensor muscles with low-intensity eccentric contractions was effective for attenuating muscle damage induced by subsequent MaxECC of the knee extensors for elderly individuals.


ABSTRACT: The aim of this study was to analyze the responses of women to the repeated bout effect (RBE) and to a short eccentric training program. Twenty-four young females were randomly assigned to a training group (TG, n = 14) or a control group (CG, n = 10). They performed two identical acute eccentric bouts (120 repetitions at 70% of 1RM) in a leg-press device in an 8 weeks interval. TG followed a 4-week-eccentric-training program between the bouts. Maximal isometric contraction, range of motion, peak power and quadriceps muscle soreness were compared between and within groups before and after the two acute eccentric bouts. TG and CG presented significant losses of isometric strength and peak power, and an increment in soreness after the first bout. Isometric strength and peak power were recovered faster in CG after the second bout (p < 0.05) compared with TG, which showed a similar recovery of these parameters after the second bout compared with the first one. A decrease in soreness and a faster recovery of range of motion were found in TG (p < 0.05) following the second bout compared with the first one, but not in CG. Data indicate that a 4-week eccentric training program may prevent the RBE over those adaptations related with muscle damage (e.g. strength loss), but it may increase RBE impact on inflammatory processes (e.g. soreness).

ABSTRACT: The benefits and proposed physiological mechanisms of eccentric exercise have previously been elucidated and eccentric exercise has been used for well over seventy years. Traditionally, eccentric exercise has been used as a regular component of strength training. However, in recent years, eccentric exercise has been used in rehabilitation to manage a host of conditions. Of note, there is evidence in the literature supporting eccentric exercise for the rehabilitation of tendinopathies, muscle strains, and in anterior cruciate ligament (ACL) rehabilitation. The purpose of this Clinical Commentary is to discuss the physiologic mechanism of eccentric exercise as well as to review the literature regarding the utilization of eccentric training during rehabilitation. A secondary purpose of this commentary is to provide the reader with a framework for the implementation of eccentric training during rehabilitation of tendinopathies, muscle strains, and after ACL reconstruction.


ABSTRACT: There is a paucity of information concerning the cardiovascular responses and adaptations to strength training. Limited evidence suggest that which particular type of resistance exercise could be more tolerable as well as potentially safer for people with cardiac diseases or impairments. So, the aim of study was to determine and compare the effect of concentric and eccentric loading on cardiovascular variables and ECG. 20 Young healthy students (mean age 20 ± 4 years) participated and were randomly divided into two groups - Experimental & Control. Pre & Post training readings were taken for following Parameters – Heart Rate, Blood Pressure, Mean Arterial Pressure, Rate Pressure Product and ECG. At first testing bout, participants performed concentric exercises (at 75% of 10 RM). Participants returned 10 days after the first session to perform exercises using the eccentric contraction type. Related ‘t’ test and one way ANOVA was applied for statistical analysis between groups. Cardiovascular measures collected from subjects were significantly lower during eccentric than during concentric bouts in all subjects (p<0.01) and ECG showed no significant changes after both training protocols (p>0.05). So, it can be concluded that since eccentric exercise produces less cardiopulmonary demands so are more suitable for persons with low exercise tolerance, who are at the risk of adverse cardiopulmonary events and for improving and maintaining cardiac fitness.

ABSTRACT:

Clinical Problem: Falls are the leading cause of nonfatal injuries and injurious death among older adults; the aftermath of a fall stresses the health care system and places financial and psychological burdens on the patient and family. Because of this, fall prevention/risk reduction is a primary focus of numerous health care agendas. Over the last 2 decades, clinical research has provided clinicians with a variety of screening tools to quantify risk factors for falls. The majority of these measures focus on single domain intraindividual (eg, balance, strength, vision) or extraindividual (eg, home safety) falls risk factors. Some of these single domain instruments are easily introduced and administered by community lay leaders. When a more comprehensive assessment across multiple domains is required, the assessment cannot easily be administered by community program leaders. A physical therapist must determine which instrument, or combination of instruments, best targets risk of falling for a given older adult.

Purpose: This integrative review of the literature will provide clinicians and researchers a concise examination of falls risks factors and a compendium of falls risk screening and assessment instruments.

Methods: Searchable databases, such as Medline and CINAHL were used to identify articles about strategies used for fall risk assessment. Information about measurement properties and characteristics were extracted and are presented in table format.

Conclusion: Comparison of recently developed multidimensional and comprehensive screening algorithms for falls risk identification may aid in lowering the rates of false negatives associated with using very specific instruments that screen or assess in only 1 falls risk factor domain.


ABSTRACT: Persons with Parkinson disease (PD) often demonstrate bradykinesia during mobility tasks. Bradykinesia combined with other PD-related movement deficits may contribute to self-reported reductions in quality of life. At this time, no studies have examined the effects of resistance exercise as an intervention to reduce bradykinesia and improve self-reported quality of life. Therefore, we examined changes in muscle force production, clinical measures of bradykinesia, and quality of life following 12 weeks of a high intensity eccentric resistance exercise program in persons with mild to moderate PD. Twenty individuals with idiopathic PD were matched into an experimental or an active control group. All participants were tested prior to and following a 12-week intervention period. The experimental group performed high intensity quadriceps contractions on an eccentric ergometer 3 days a week for 12 weeks. The active control group participated in an evidence based exercise program of PD. The outcome variables were quadriceps muscle force, clinical bradykinesia measures (gait speed, timed up and go) and disease specific quality of life (Parkinson’s disease questionnaire-39 [PDQ-39]). Data was analyzed using separate 2 (group) x 2 (time period) ANOVAs. Results demonstrated significant time by group interaction effects for gait speed, timed up and go, and the composite PDQ-39
score (p < 0.05). Muscle force, bradykinesia, and QOL were improved to a greater degree in those that performed high intensity eccentric resistance training compared to an active control group. Additional research is needed to determine if this type of training has long-term impact and if it results in an alteration of the natural history of mobility and QOL decline in persons with PD.


ABSTRACT:
Background and Purpose: Parkinson’s disease is a progressive neurodegenerative disorder that affects neurophysiologic function, movement abilities, and quality of life (QOL). Research examining the effects of exercise has suggested benefits related to a variety of outcomes; however, no reviews have synthesized research findings across the spectrum of disability. This project sought to systematically review studies that examined the impact of exercise interventions on balance outcomes for people with Parkinson’s disease, within the categories defined by the World Health Organization in the International Classification of Functioning, Disability, and Health (ICF) model.

Methods: A systematic review of medical literature databases was performed using keywords Parkinson’s disease and exercise. Studies were eligible if the intervention included exercise and examined variables within one of the three ICF categories. Following the ICF model, outcomes regarding Body Structure and Function, Activity, and Participation were measured, respectively, in terms of postural instability, balance task performance, and QOL and fall events.

Results: Within the Body Structure and Function category, there was moderate evidence that exercise resulted in improvements in postural instability. Within the Activity category, there was moderate evidence that exercise was effective for improving balance task performance. In contrast, within the Participation category, there was limited evidence that exercise resulted in improvements in QOL measures or fall events.

Discussion and Conclusions: Regardless of the strength of the evidence, the studies reviewed all report that exercise resulted in improvements in postural stability and balance task performance. Despite these improvements, the number and quality of the studies and the outcomes used were limited. There is a need for longer term follow-up to establish trajectory of change and to determine if any gains are retained long term. The optimal delivery and content of exercise interventions (dosing, component exercises) at different stages of the disease are not clear.

Gerber JP, Marcus RL, Dibble LE, Greis PE, Burks RT, LaStayo PC: Effects of early progressive eccentric exercise on muscle size and function after anterior cruciate
ligament reconstruction: a 1-year follow-up study of a randomized clinical trial. 
Phys Ther J. 2009;89:51-59

ABSTRACT:

Background and Purpose: The authors previously reported that focused eccentric resistance training during the first 15 weeks following anterior cruciate ligament reconstruction (ACL-R) induced greater short-term increases in muscle volume, strength, and measures of function relative to standard rehabilitation. The purpose of this study was to evaluate the effects of early progressive eccentric exercise on muscle volume and function at 1 year after ACL-R.

Participants and Methods: Forty patients who had undergone an ACL-R were randomly assigned to 1 of 2 groups: a group that received early progressive eccentric exercise (n=20) and a group that received standard rehabilitation (n=20). Seventeen participants in the eccentric exercise group and 15 participants in the standard rehabilitation group completed a 1-year follow-up. Magnetic resonance images of the thighs were acquired 1 year after ACL-R and compared with images acquired 3 weeks after surgery. Likewise, routine knee examinations, self-report assessments, and strength and functional testing were completed 1 year after surgery and compared with previous evaluations. A 2-factor analysis of variance for repeated measures (group x time) was used to analyze the data.

Results: Compared with the standard rehabilitation group, improvements in quadriceps femoris and gluteus maximus muscle volume in the involved lower extremity from 3 weeks to 1 year following ACL-R were significantly greater in the eccentric exercise group. Improvements in quadriceps femoris and gluteus maximus muscle volume were 23.3% (SD=14.1%) and 20.6% (SD=12.9%), respectively, in the eccentric exercise group and 13.4% (SD=10.3%) and 11.6% (SD=10.4%), respectively, in the standard rehabilitation group. Improvements in quadriceps femoris muscle strength and hopping distance also were significantly greater in the eccentric exercise group 1 year post-surgery.

Discussion and Conclusions: A 12-week focused eccentric resistance training program, implemented 3 weeks after ACL-R, resulted in greater increases in quadriceps femoris and gluteus maximus muscle volume and function compared with standard rehabilitation at 1 year following ACL-R.


ABSTRACT:

Background: Novel interventions that can safely and effectively overload muscle early following anterior cruciate ligament reconstruction are needed to minimize atrophy and weakness that often becomes longstanding.

Evidence Acquisition: Eccentrically induced forces can be safely applied during the early stages of rehabilitation following surgery and serve as a potent stimulus for increasing muscle size and strength.

Results: Compared to a standard rehabilitation program, adding an early 12-week eccentric
resistance-training program 3 weeks after anterior cruciate ligament reconstruction induces improvement in quadriceps and gluteus maximus volume at 15 weeks and at 1 year after surgery. Likewise, those who performed an eccentrically biased rehabilitation program also achieved greater improvements in quadriceps strength and hopping ability measured at 15 weeks and at 1 year after surgery.

**Clinical Relevance:** There is potential to safely and feasibly perform eccentric contractions as part of a formal rehabilitation program following anterior cruciate ligament reconstruction.


ABSTRACT: Sarcopenia is the age-related loss of muscle mass and strength and has been associated with an increased risk of falling and the development of metabolic diseases. Various training protocols, nutritional and hormonal interventions have been proposed to prevent sarcopenia. This study explores the potential of continuous eccentric exercise to retard age-related loss of muscle mass and function. Elderly men and women (80.6 ± 3.5 years) were randomized to one of three training interventions demanding a training effort of two sessions weekly for 12 weeks: cognitive training (CT; n = 16), conventional resistance training (RET; n = 23) and eccentric ergometer training (EET; n = 23). Subjects were tested for functional parameters and body composition. Biopsies were collected from M. vastus lateralis before and after the intervention for the assessment of fiber size and composition. Maximal isometric leg extension strength (MEL: +8.4 ± 1.7%) and eccentric muscle coordination (COORD: -43 ± 4%) were significantly improved with EET but not with RET (MEL: +2.3 ± 2.0%; COORD: -13 ± 3%) and CT (MEL: -2.3 ± 2.5%; COORD: -12 ± 5%), respectively. We observed a loss of body fat (-5.0 ± 1.1%) and thigh fat (-6.9 ± 1.5%) in EET subjects only. Relative thigh lean mass increased with EET (+2.5 ± 0.6%) and RET (+2.0 ± 0.3%) and correlated negatively with type IIX/type II muscle fiber ratios. It was concluded that both RET and EET are beneficial for the elderly with regard to muscle functional and structural improvements but differ in their spectrum of effects. A training frequency of only two sessions per week seems to be the lower limit for a training stimulus to reveal measurable benefits.


ABSTRACT:

**Synopsis:** The number of total knee arthroplasty (TKA) surgeries performed each year is predicted to steadily increase. Following TKA surgery, self-reported pain and function improve, though individuals are often plagued with quadriceps muscle impairments and functional
limitations. Postoperative rehabilitation approaches either are not incorporated or incompletely address the muscular and functional deficits that persist following surgery. While the reason for quadriceps weakness is not well understood in this patient population, it has been suggested that a combination of muscle atrophy and neuromuscular activation deficits contribute to residual strength impairments. Failure to adequately address the chronic muscle impairments has the potential to limit the long-term functional gains that may be possible following TKA.

Postoperative rehabilitation addressing quadriceps strength should mitigate these impairments and ultimately result in improved functional outcomes. The purpose of this paper is to describe these quadriceps muscle impairments and to discuss how these impairments can contribute to the related functional limitations following TKA. We will also describe the current concepts in TKA rehabilitation and provide recommendations and clinical guidelines based on the current available evidence.

**Level of Evidence:** Therapy, level 5.

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**ABSTRACT:**

**Purpose/Hypothesis:** Bradykinesia associated with Parkinson’s Disease (PD) is considered a strong contributor to disability and strength deficits have been implicated as a contributor to PD bradykinesia. Despite clear discussions of the rationale for strength training in PD, and the dramatic improvements in strength and function seen in healthy and frail elders exposed to strength training, research that examines the effect of resistance training on bradykinesia or overall quality of life is sparse. The purpose of this study was to examine, in persons with PD, the changes in bradykinesia, balance, and self-reported quality of life as a result of participation in a 12 week high intensity strength training program. NUMBER OF SUBJECTS: Eight individuals with idiopathic PD (mean age = 61; mean Hoehn and Yahr on medication= 2.5) participated.

**Materials/Methods:** The focus of the exercise program was performing high intensity negative work on an eccentric ergometer 3 days a week for 12 weeks. Participants were tested prior to and following a 12 week intervention period with testing and training conducted at standardized times in their medication cycle. Clinical bradykinesia and balance measures (10 meter walk, TUG, BBS, and FR), and a self-report quality of life measure (PDQ-39) were utilized as outcomes. Pre to post intervention differences were tested using separate Wilcoxon matched pairs tests with an alpha level set at .05. To determine strength of effect, percent improvement and Cohen’s effect sizes were also calculated.

**Results:** Significant improvements (% change) were seen in gait speed (14%), balance test performance (TUG 20%; FR 16%) and physical components of perceived quality of life (ADL 15%; bodily discomfort 31%) (p<.05). The range of effect sizes was .35-2.13.

**Conclusions:** Persons with PD demonstrate reduced bradykinesia and improvements in their balance function and physical components of quality of life as a result of high intensity lower extremity negative work. This research supports the hypothesis that peripheral muscle force limitations affect movement abilities in persons with PD and that these limitations are subject to
Clinical Relevance: Lower extremity resistance training may be a critical component of PD rehabilitation and this research provides effect sizes to assist in the design of larger trials to examine this topic more thoroughly. The neurologic, hormonal, and structural adaptations that contribute to the observed improvements are the subject of further research in our laboratory.


No abstract.


ABSTRACT: When the force applied to a muscle exceeds the force produced by the muscle it will lengthen, absorbing mechanical energy. These eccentric contractions, which result in both braking and storing elastic recoil energy in normal locomotion, require very little metabolic energy, yet they are characterized by high force production.