Author Year Country Score Research Design Total Sample Size	Methods	Outcome
	Muscle Morphology	
Carvalho et al. 2008 Brazil Downs & Black score=21 Prospective Controlled Trial N=15	**Population:** Traumatic SCI: Mean age: 31.95±8.01 yrs; Gender: 15 males; Mean body mass: 63.52±9.41 kg; Mean height: 176.28±5.28 cm:; Mean time post-injury: 66.43±48.23 mo **Treatment:** Gait group (n=8): Treadmill gait training at 0.5 km/h (increased according to individual's capacity) with partial body weight support (BWS) and neuromuscular electrical stimulation (NMES) delivered by a custom built four-channel stimulator (200V at 25Hz with 300ms duration). Training was performed over 6 mo, 2d/wk, for 20 min each session. Control group (n=7) : individuals performed only conventional physiotherapy 2d/wk for 6 mo without using NMES. **Outcome Measures:** MRI of bilateral thighs was performed in all participants, to determine the average cross sectional area (CSA) of quadriceps and mean value of gray scale. Outcomes were obtained at baseline and at the end of treatment (6 mo).	1. At moment of inclusion in this study, the average CSA values for the gait group and control group did not differ significantly. 2. After 6 months, a significant increase of 15% quadriceps CSA occurred in the gait group. 3. A 7.7% increase in gray scale value was also observed but was not statistically significant. 4. In the control group, no significant change in CSA or gray scale value was found after 6 months, but there was a noteworthy decrease in gray scale value of 11.4% .
Scremin et al. 1999 USA Downs & Black score=21 Pre-Post N=13	**Population:** Age (range): 24-46 yrs; Gender: 13 males; Level of injury (range): C5-L1; Severity of Injury: ASIA A (100%); Time post-injury (range): 2-19 yrs **Treatment:** 3 phase, FES induced, ergometry exercise program. Phase 1: quadriceps strengthening; Phase 2: progressive sequential stimulation to achieve a rhythmic pedaling motion; Phase 3: FES induced cycling for 30 min **Outcome Measures:** Muscle cross-sectional area and proportion of muscle and adipose tissue measured at baseline, at the first follow-up (mean 65.4 wks), and at second follow-up (mean 98.2 wks)	1. The cross sectional area of the rectus femoris increased by 31% ($p<0.001$), the sartorius increased by 22% ($p<0.025$), the adductor magnus- hamstrings increased by 26% ($p<0.001$), the vastus lateralis increased by 39% ($p=0.001$), and the vastus medialis-intermedius increased by 31% ($p=0.025$). 2. The cross-sectional area of the adductor longus and gracilis muscles did not change. The ratio of muscle to adipose tissue increased significantly in thighs and calves.
Sabatier et al. 2006 USA Downs & Black score=21 Pre-Post N=5	**Population:** Mean age: 35.6 yrs; Gender: 5 males; Severity of injury: AISA A (100%); Mean time post-injury: 13.47±6.5 yrs **Treatment:** Patients underwent 18 wks of home-based neuromuscular electrical stimulation (NMES) resistance training on the quadricpes muscle group 2d/wk with 4 sets of 10 dynamic knee extensions against resistance while in a seated position **Outcome Measures:** Femoral arterial diameter resting blood flow, blood velocity, and neuromuscular fatigue. All measurements were made before training and after 8, 12, and 18 wks of training.	1. Training resulted in significant increases in weight lifted and muscle mass and a 60% reduction in muscle fatigue ($p=0.001$). 2. Femoral arterial diameter did not increase ($p=0.70$). Resting, reactive hypermic, and exercise blood flow did not appear to change with training. 3. Quadriceps femoris muscle CSA was increased in both thighs after 18 weeks. 4. The mean QF CSA of the right thigh was significantly increased from 32.6 to 44.0 cm² ($p<0.05$), and the left QF was increased from 34.6 to 47.9 cm² ($p<0.05$) which is a 35% and 39% increase in CSA respectively.
Kern et al. 2010 Austria Downs & Black score=19	**Population:** Complete conus cauda syndrome: Age (range): 20-55 yrs; Gender:	1. Similar increase in muscle excitability and contractility in both legs.

Author Year Country Score Research Design Total Sample Size	**Methods**	**Outcome**
Pre-Post N=25	20 males, 5 females; Time post-injury (range): 0.7-8.7 yrs; **Treatment:** Muscles of patients were electrically stimulated at home by large surface area electrodes and a custom designed stimulator. **Outcome Measures:** Force induced by electrical stimulation, isometric knee extension torque, force measurements, area and density of quadriceps muscle and hamstring, tissue type distribution recorded before, at 1 yr, and after the 2 yrs of training	2. Improved feasibility to elicit tetanic contractions with about ten times improvement. 3. Myofiber size increased by 94% after 2 years of FES. 4. Functional class improved to a level 4 for 20% of the subjects. 5. After 2 years of home-based FES, the degenerative phase of LMN denervation was delayed or reverted.
Griffin et al. 2009 USA Downs & Black score=19 Pre-Post N=18	**Population:** Traumatic SCI: Mean age: 40±2.4 yrs; Gender: 13 males, 5 females; Time post-injury: 11±3.1 yrs **Treatment:** FES cycling performed on an Ergys2 automated recumbent bicycle 2–3 d/wk for 10 wks **Outcome Measures:** Total body mass, lean muscle mass	1. Training week had a statistically significant effect on the ride time without manually assisted pedaling. Ride times during training weeks 5–10 were statistically greater than during week 1. 2. Total body mass (3%) and lean muscle mass (4%) significantly increased, while, there was no significant difference in bone or adipose tissue following the 10 weeks of training 3.
Carvalho et al. 2009 Brazil Downs & Black score=19 Cohort N=7	**Population:** Traumatic SCI: Mean age: 32.8±3.5 yrs; Gender: 7 males; Mean body mass: 65.5±10.6 kg; Mean height: 176.8±8.4 cm; Mean time post-injury: 55.3± 10.6 mo **Treatment:** Individuals performed conventional physiotherapy, 2d/ wk without using NMES for 6 mo. After 6 mo, the CG was provided an additional 6 mo of gait training without NMES. **Outcome Measures:** MRI of bilateral thighs was performed on all participants, to determine the average cross sectional area (CSA) of quadriceps. Outcomes were measured 6 months post intervention.	1. 1 year post Carvalho et al. (2008) intervention no significant changes were observed in the quadriceps CSA in individuals receiving conventional physiotherapy.
Giangregorio et al. 2006 Canada Downs & Black score=18 Pre-Post N=14	**Population:** Chronic Incomplete SCI: Mean age: 29 yrs; Gender: 11 males, 3 females; Level of injury: Tetraplegia (11), Paraplegia (3); Severity of injury: ASIA C (86%); ASIA B (14%); Mean time post-injury: 7.7 yrs **Treatment:** Body weight supported treadmill training (BWSTT) program - 144 sessions, 3 d/wk. **Outcome Measures:** Lean body mass; Muscle cross sectional area (CSAs).	1. BWSTT training ↑ whole body lean mass ($p<0.003$). 2. ↑ muscle CSAs in the thigh (4.9%) and lower leg (8.2%).
Willoughby et al. 2000 USA Downs & Black score=17 Pre-Post N=10	**Population:** Age (range): 16-50 yrs; Gender: 5 males, 3 females; Level of injury (range): C4-T12; Severity of injury: AISA A and C; Time post- injury(range):1-9.4yrs **Treatment:** 12 wk exercise program using the Psycle ergometer. Training 2 d/wk at 75% of each subject's maximum heart rate. **Outcome Measures:** Thigh girth, body weight, and body mass index measured before and after training.	1. mRNA expression had a significant increase in expression of MHC types IIa and Iix, and significant decreases in the expression for UBI, E2, and 20S. 2. The overall mean decrease for body weight and BMI from pre-training to post-training decreased for all eight subjects1.82±4.4% and 1.40±1.3%, respectively.

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		3. There was also an increase of 63.08%, 49.47%, and 61.39% that were significantly different for α-actin (t(7)=2.61 (p=0.0413), MHC type II a (t(7)=3.04 (p=0.0188), and MHC type II x (t(7)=2.51 (p=0.0405) respectively.
Heesterbeek et al. 2005 The Netherlands Downs & Black score=16 Pre-post N=10	**Population:** Chronic Paraplegia; Mean age: 39.3 yrs; Gender: 9 males, 1 female; Severity of injury: ASIA A (90%), ASIA C (10%); Mean time post-injury: 10.5 yrs **Treatment**: Exercise program – 4 wks, 8-12 total sessions. Each session consisted of a 5min warm-up, 30min hybrid (voluntary arm and FES-assisted leg) cycling & a 5min cool-down. **Outcome Measures:** Leg Volume; Graded Hybrid Exercise Test (GHT) - peak power output (PO_{peak}); Power of the legs (defined by delta power); all @ baseline & 4 wks.	1. Leg Volume: • Upper left leg: 8.3% ↑ (p=0.018) • Upper right leg: 8.5% ↑ (p=0.047) • Lower legs did not change. 2. $PO_{peak:}$ ↑ 9.3% (p=0.015). 3. Power of legs: did not change
Chilibeck et al. 1999 Canada Downs & Black score=14 Pre-post N=6	**Population:** Chronic SCI: Age (range): 31-50 yrs Gender: 5 males, 1 female;; Time post-injury (range): 3-25 yrs **Treatment:** FES training with a leg cycle ergometer- 30 min, 3 d/wk for 8 wks **Outcome Measures:** Work rate, duration & total work output/exercise per session; Muscle fibre composition & area; Capillarization.	1. Mean fibre area: ↑ 23% after training (p<0.05) 2. Capillarization: capillary-to-fibre ratio ↑ 39% (p<0.05) & capillaries contacted with each fibre ↑ 29% (p<0.05). 3. Mean work rate: ↑ from 0 to 5.1 watts (p<0.05) from baseline to 8 wks. 4. Mean duration: continuously pedal without assistance ↑ from 4.3 min to 21.2±5.6 min after training (p<0.05). 5. Mean total work output: ↑ from 0 to 9.2 KJ at 8 wks (p<0.05).
Crameri et al. 2002 **Denmark** **Downs & Black score=14** **Pre-post** **N=6**	**Population:** Chronic complete paraplegia: Age (range): 28-43 yrs; Gender: 5 males, 1 female; Time post-injury (range): 8-36 yrs **Treatment:** FES leg cycle ergometry training- 30min/d, 3d/wk, for 10 wks **Outcome Measures**: Incremental exercise leg test to muscle fatigue (total work output); Histological assessment; Myosin heavy chain (MHC); Citrate synthase and hexokinase.	1. Paralysed vastus lateralis muscle was altered with ↑ type IIA fibres, ↓ type IIX fibres ↓ MHC IIx and ↑ MHC IIa (p<0.05). 2. Total mean fibre cross-sectional area ↑ 129%, ↑ cross-sectional area of type IIa and IIx fibres (p<0.05). 3. Number of capillaries surrounding each fibre ↑ (p<0.05). 4. Citrate synthase and hexokinase activity ↑ (p<0.05). 5. Total work performed: ↑ after training (p<0.05)
Mohr et al. 1997 Denmark Downs & Black score=14 Pre-post N=10	**Population:** Chronic Complete SCI: Age range: 27-45 yrs; Gender: 8 males, 2 females; Level of injury: Tetraplegia (6), Paraplegia (4); Time post-injury (range): 3-23 yrs **Treatment:** 1 yr exercise training using an FES cycle ergometer (30 min/d, 3 d/wk) **Outcome Measures:** Total work output; Muscle properties; @ baseline & 1 yr	1. 12% ↑ in thigh muscle mass over 1 yr. 2. Muscle atrophy found @ baseline partially improved by 1 yr. 3. 4 fold ↑ in total work output.
Sloan et al. 1994 Australia	**Population:** Age range: 15-54 yrs; Gender: 7 males, 5 females; Severity of injury: complete (1), incomplete (11); Time post-injury (range): 2 -138 mo	1. Muscle size: • ↑ Quadriceps CSA (p<0.05) • ↑ Total thigh CSA (p<0.05)

Author Year Country Score Research Design Total Sample Size	Methods	Outcome
Downs & Black score=14 Pre-post Initial N=12; Final N=9	**Treatment:** Electrical stimulation induced cycling programme: 3d/wk for 3 mo, all programmes were individualized & gradually progressed to 30 min each. **Outcome Measures:** Quadriceps muscle area & Thigh muscle area – cross sectional analysis (CSA); Neurological muscle charts; @ baseline & 3 mo	2. Muscle strength: • ↑ Voluntary isometric strength ($p<0.05$) • ↑ Stimulated isometric strength ($p<0.05$) ↑ Stimulated quadriceps endurance ($p<0.05$) • ↑ Quadriceps & biceps femoris grading ($p<0.05$). 3. Cycling improvement: • 9/9 ↑ cycling time by a mean of 11.7 min • 8/9 ↑ cycling load by a mean of 30N. • Speed=constant
Giangregorio et al. 2005 Canada Downs & Black score=13 Pre-post N=5	**Population:** Tetraplegia; Age range: 19-40 yrs; Gender: 2 males, 3 females; Severity of injury: ASIA B (4), ASIA C (1); Time post-injury (range): 66-170 d **Treatment:** Body-weight supported treadmill training (BWSTT). Initial session started at 5min, ↑ gradually to 10-15min in all but 1 participant during 2d/wk training over a period of 6-8 mo **Outcome measures:** Muscle cross-sectional area (CSA) done pre & post treatment; Average adherence.	1. ↑ muscle CSAs were seen in all patients. 2. Total body lean mass and fat mass ↑. 3. Partial reversal of muscle atrophy was seen. 4. Average adherence = 78%.
Crameri et al. 2004 Denmark Downs & Black score=22 Prospective controlled trial N=6	**Population:** Chronic complete paraplegia; Age range: 26-54 yrs; Time post-injury (range): 3-21 yrs **Treatment:** FES training 45 min/d, 3 d/wk, for 10 wks. One leg: dynamic cycle ergometry involving bilateral quadriceps and hamstring stimulation; Contralateral leg: isometric contractions. **Outcome Measures:** Muscle biopsies; Capillary-to-fibre ratio; Muscle proteins; Oxygenation.	1. The isometric-trained leg showed significantly larger mean improvements force, type 1 fibres, fibre cross-sectional area, capillary-to-fibre ratio, citrate synthase activity & relative oxygenation after static training, in comparison to baseline & the dynamically trained leg. 2. These changes reflect the importance of load in the amount of adaptation to FES.
Hjeltnes et al. 1997 Norway Downs & Black score=12 Pre-post N=5	**Population:** Chronic Complete Tetraplegia; Mean age: 35 yrs; Gender: 5 males; Mean time post-injury: 10.2 yrs **Treatment:** 8 wks of FES leg cycling, 7d/wk **Outcome Measures:** Cross sectional area (CSA) of multiple muscles.	1. 21.3% ↑ from 267cm^2 to 324cm^2 in muscle cross-sectional area for hamstrings, quadriceps, gluteus maximus & gluteus medius muscles ($p<0.05$).
Mahoney et al. 2005 USA Downs & Black score=11 Pre-post N=10	**Population:** Chronic SCI; Mean age: 35.6 yrs; Gender: 5 males, 5 females; Mean time post-injury:13.4 yrs **Treatment:** Residence-based, resistance exercise training (RET) for thighs for 12 wks, 2d/wk for 4 sets of 10 unilateral, dynamic knee extensions. RET induced extensions via neuromuscular electric stimulation. **Outcome Measures:** Muscle cross sectional area (CSA) - quadriceps femoris; @ baseline & 12 wks.	1. Muscle CSA: 35% ↑ in right quadriceps femoris (32.6cm^2 @ baseline to 44.0cm^2 @ 12 wks) 39%↑ in left quadriceps femoris (34.6cm^2 @ baseline to 47.9cm^2 @ 12 wks) ($p<0.05$).
	Population: Incomplete SCI; Gender: 8	1. Muscle biopsy:

Author Year Country Score Research Design Total Sample Size	Methods	Outcome
Stewart et al. 2004 Canada Downs & Black score=10 Pre-post N=9	males, 1 female; Mean time post-injury: 8.1 yrs **Treatment:** Body weight-supported treadmill training, 3 d/wk for 6 mo **Outcome Measures:** Treadmill performance; Muscle biopsy – Fibre type & Myosin heavy chain (MHC) analysis.	• ↑ mean muscle-fibre area of type I & IIa fibres ($p<0.001$) • ↓ in mean type IIax/IIx fibres ($p<0.05$) • ↓ IIx myosin heavy chain ($p<0.05$) • ↑ mean type IIa fibres ($p<0.01$) 2. Treadmill performance: • 135% ↑ treadmill velocity ($p<0.05$) • 55%, ↑ in session length ($p<0.05$) • amount of externally supported weight ↓ as the result of training ($p<0.05$)
Strength		
Needham-Shropshire et al. 1997 **USA/CA** PEDro=8 RCT Initial N=43; Final N=32	**Population:** Chronic Tetraplegia; Mean age: 18-45yrs; Gender: 31 males, 3 females; Mean time post-injury: 3yrs **Treatment**: Subjects randomly assigned to one of three groups: **Group 1** – received 8 wks of neuromuscular stimulation (NMS) assisted arm ergometry exercise. **Group 2** – received 4 wks of NMS assisted exercise, and then 4 wks of voluntary arm crank exercise. **Group 3 (control group)** – voluntary exercise for 8 wks without the application on NMS. **Outcome Measures:** Manual muscle test.	1. No significant difference was found at the 4-week evaluation between Groups 1 and 2 or between Groups 2 and 3. 2. Subjects in Group 1 had a higher proportion of muscles improving one or more muscle grades after 4 weeks of NMS cycling compared with Group 3 ($p<0.003$). 3. Following the second 4 weeks of training, a significant difference was found between Groups 1 and 3 ($p<0.0005$) and between Groups 2 and 3 ($p<0.03$). 4. No statistical difference was found between Groups1 and 2.
Glinsky et al. 2008 Australia PEDro=8 RCT Initial N= 32 **Final N= 29**	**Population:** Intervention group: Mean age: 37±16 yrs; Gender: 12 males, 3 females; Control group: Mean age: 47±20 yrs; Gender: 15 males, 1 female **Treatment:** The intervention group carried out a progressive resistance exercise program on one wrist 3 d/wk for 8 wks. It consisted of three sets of 10 repetitions (maximum) of one wrist muscle group, which was increased if the participant could do more than 10 repetitions and decreased if 10 repetitions were not achieved. Control group received routine physiotherapy and occupational therapy with no progressive resistance exercise program for the wrist. **Outcome Measures:** Strength measured as maximal voluntary isometric torque in Nm, muscle endurance measured as fatigue resistance and participants' perceptions about use of their hands using the Canadian Occupational Performance Measure (COPM). Measurements were taken at the beginning of the program and at end of 8 wks.	1. No statistically significant evidence was found to suggest that progressive resistance exercise does or does not increase strength and/or endurance. Although, an 11% increase in mean initial muscle endurance and an 8% increase in mean initial strength was noted in the experimental group compared to the control group 2. The activities of daily living most frequently selected by participants as part of COPM assessment were using cutlery and lifting objects such as bottles and cups. The mean effects of progressive resistance exercise on these activities were –0.3 for participants' perceptions of performance and –0.3 for participants' satisfaction. This indicates that the experimental group did not perceive that progressive resistance exercise improved performance of or satisfaction with their activities of daily living compared with the control group.
Alexeeva et al. 2011 USA PEDro=7 RCT	**Population:** Fixed Track Group: Mean age: 37.3± 13 yrs ; Gender: 12 males, 2 females; Level	1. The mean change in muscle strength increased by 6-9% across all groups.

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N=35	of injury: ASIA C (17%), ASIA D (83%); Cause of injury: traumatic (100%) Treadmill Group: Mean age: 36.4±12.9 yrs ; Gender: 8 males, 1 female; Level of injury: ASIA C (36%), ASIA D (64%); Cause of injury: traumatic (100%) Physical Therapy Group: Mean age: 43.3±15.8 yrs ; Gender: 10 males, 2 females; Level of injury: ASIA C (11%), ASIA D (89%); Cause of injury: traumatic (75%), non-traumatic (25%) **Treatment:** Patients participated in a body weight supported training program (Fixed Track or Treadmill) or comprehensive physical therapy for 1hr/d, 3 d/wk for 13 wks. **Outcome Measures:** ASIA International Standard (AIS) manual muscle test (MMT)	2. There was a significant increase in strength across all groups ($p<0.01$), but no difference between groups.
Mulroy et al. 2011 USA PEDro=7 RCT N=80	**Population:** Exercise/Movement Optimization group: Mean age: 47±9 yrs; Gender: 31 males, 9 females; Level of injury: ASIA A (62%), ASIA B (23%), ASIA C (8%), ASIA D (2%), Unknown (5%) Control Group: Mean age: 47±12 yrs; Gender: 26 males, 14 females; Level of injury: ASIA A (62%), ASIA B (13%), ASIA C (13%), ASIA D (2%), UNKNOWN (10%) **Treatment:** Patients received a shoulder home exercise program 3d/wk for 12 wks. Stretching, warm-up, and resistive shoulder exercises were included. **Outcome Measures:** Shoulder muscle force production using a handheld dynamometer	1. Strength gains were significantly greater in the exercise/movement optimization group compared with the control group in all 4 motions tested ($p<0.01$). 2. All muscle groups demonstrated a statistically significant increase in maximal torque production following the intervention in the exercise/movement optimization group ($p<0.05$).
Hicks et al. 2003 Canada Downs & Black score=20 PEDro=5 RCT Initial N=34; Final N=24	**Population:** Chronic SCI; Age (range): 19-65 yrs; Level of injury: C4-L1; Time post-injury (range):1-24 yrs **Treatment:** Intervention group participated in progressive arm ergometry exercise training and progressive resistance training in several upper body muscle groups twice weekly for 9 mo-each session offered on alternative days lasing 90-120 min. **Outcome Measures:** Muscle strength	1. Following training, EX group had 81% ↑ sub maximal arm ergometry power output ($p<0.05$) & 1-35% ↑ in upper body muscle strength ($p<0.05$). 2. Overall 11 in the EX group (exercise adherence 82.5%) and 13 in the control group completed the study.
Jacobs et al. 2009 USA PEDro=5 RCT N=18	**Population:** Traumatic SCI: RT Group: Mean age: 33.7±8.0 yrs; Gender: 6 males, 3 females; Mean body mass: 72.3±18.3 kg: ET group: Mean age: 29.0±9.9 yrs; Gender: 6 males, 3 females; Mean body mass: 83.7±8.9 kg **Treatment:** Subjects participated in a series of testing sessions before and after a 12wk training period. Patients were randomly assigned to two groups. The endurance training (ET) group performed 30 min of arm cranking exercise using a Saratoga arm crank device during each session at 70%–85% of	1. Significant effects of both modes of training (RT and ET) in the physiological responses to peak GXT were observed. 2. Muscular strength significantly increased for all exercise maneuvers in the RT group with no changes detected in the ET group 3. VO_{2peak} values were significantly greater after RT (15.1%) and ET (11.8%). 4. Both RT and ET study groups displayed significant increases in P_{peak} and P_{mean} .

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	HR_{peak}. The resistance training (RT) group performed three sets of 10 repetitions at six Hammer Strength MTS exercise stations (including horizontal press, horizontal row, overhead press, overhead pull, seated dips, and arm curls) with an intensity ranging from 60% to 70% of 1 rep max (1RM). **Outcome Measures:** VO_{2peak}, Graded exercise test (GXT); assessed at baseline and at end of treatment (12 wks)	5. Mean power increased 8% and 5% for the RT and ET groups, respectively, with no statistically significant differences apparent between groups. RT produced significantly greater gains in P_{peak} (15.6%) compared with ET (2.6%). 6. The RT group displayed significantly increased strength values ranging from 34% to 55% for the six exercise maneuvers. In contrast, the ET group did not display increases in muscular strength for any of the six exercises after 12 wks of training.
Harness et al 2008 USA Prospective Controlled Trial Initial N=31, Final N=29	**Population:** Intense Exercise Group: Mean age: 37.8±3.6 yrs; Gender: 18 males, 3 females; Severity of Injury: ASIA A or B (12), ASIA C or D (9) Control: Mean age: 34.5±2.9 yrs; Gender: 8 males **Treatment:** Treatment group - multi-modal intense exercise program; Control group - self-regulated exercise. **Outcome Measures:** Medical Research Council scale (muscle strength)	1. At least one muscle increased in strength over 6 months in 15/21 treatment participants compared to 0/8 control participants ($p<0.0001$); in these 15, the mean number of muscles showing a change was 4.1 (3.2 in lower extremities).
Bjerkefors et al. 2006 Sweden Downs & Black score=20 Pre-Post N=20	**Population:** Traumatic SCI: SCI Group: Mean age: 38±12 yrs; Gender: 14 males, 6 females: Mean body mass: 70.8±13.9 kg: Reference Group: Mean age: 35±10 yrs; Gender: 7 males, 3 females; Mean body mass: 76.5±12.7 kg **Treatment:** 10-wk period of kayak ergometer training using commercially available kayak ergometer (Dansprint, I Bergmann A/S, DK). Every week subjects completed 3x60 min training sessions of kayak ergometer training. **Outcome Measures:** Shoulder muscle strength	1. There was a main effect of kayak ergometer training with increased shoulder muscle strength (in the beginning and middle positions and independent of shoulder movement) after training in persons with SCI. 2. There was no interaction between training, movement and angular position or between training and movement, but an interaction was observed between training and angular position. 3. The SCI group had less shoulder muscle strength compared to the reference group but the difference was not statistically significant to draw conclusions.
Hartkopp et al. 2003 Denmark Downs & Black score=20 Prospective controlled trial N=18	**Population:** HR: Age (range): 29-55yrs; Gender: 8 males, 4 females; Level of injury: C-5/6; Time post-injury (range): 5-38 yrs; LR: Age (range): 32-44yrs; Time post-injury (range): 4-27yrs **Treatment:** Wrist extensor muscles were stimulated (30min/d, 5 d/wk for 12 wks) using either a high-resistance (HR group) or low-resistance (LR group) protocol. **Outcome Measures:** strength and endurance of contractile properties, muscle metabolism, fatigue resistance measured at baseline and 12wks	1. Maximum voluntary torque increased in the Hr group ($p<0.05$), but not the Lr group. 2. For the Hr group the electrically stimulated peak tetanic torque increased only at 15Hz ($p<0.1$), and the Lr group remained unchanged. 3. Resistance to fatigue increased ($p<0.05$) in both the Hr (42%) and Lr (41%). 4. For the Hr group, the cost of contraction decreased by 38% ($p<0.05$) and the half-time of phosphocreatine recovery was shortened by 52% ($p<0.05$). 5. Electrical stimulation of the wrist increases fatigue resistance independent of the training pattern, but only in the Hr group does increased muscle strength improve aerobic metabolism after training.

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Griffin et al. 2009 USA Downs & Black score=19 Pre-Post N=18	**Population:** Traumatic SCI: Mean age: 40±2.4 yrs; Gender: 13 males, 5 females; Mean time post-injury: 11±3.1 yrs **Treatment:** FES cycling performed on an Ergys2 automated recumbent bicycle 2–3 d/wk for 10 wks **Outcome Measures:** AIS scores	1. Training week had a statistically significant effect on the ride time without manually assisted pedaling. Ride times during training weeks 5–10 were statistically greater than during week 1. 2. Lower extremity total AIS scores and the motor and sensory components of the AIS test were all significantly higher following training 3.
Durán et al.2001 Colombia Downs & Black score=16 Pre-post N=13	**Population:** Paraplegia; Age (range): 17-38yrs; Gender: 12 males. 1 female; Severity of injury: ASIA A (85%), ASIA B (7.5%), ASIA C (7.5%); Time post-injury (range): 2-120 mo **Treatment:** 16 wk exercise program (4 wks adaptation, 1 wk enhancement, 11 wks specific program (3d/wk, 120 min/session) including mobility, coordination, strength, aerobic resistance and relaxation exercises. **Outcome Measures:** Max. strength of upper limbs: max. weight mobilized in one trial or number of reps in 30 sec; Progressive resistance arm crank test: 3 min warm up @ 0 watts, resistance ↑ every 2 min; done pre & post program.	1. Weight lifted pre-program vs. post-program: • Bench press - 46% ↑, 42.7 vs. 62.5 (p=0.0001) • Military press - 14% ↑, 60.0 vs. 68.3 (p=0.0002) • Butterfly press- 23% ↑, 52.3 vs. 64.2 (p=0.0001). 2. Repetitions pre-program vs. post-program: • Biceps (dumbbell) - 10%↑, 26.7 vs. 29.4 (p=0.0001) • Triceps (dumbbell) - 18% ↑, 35.8 vs. 42.4 (p=0.0001) • Shoulder abductors- 61% ↑, 8.8 vs. 14.2 (p=0.0001) • Abdominal in 1' - 33% ↑, 47.0 vs. 62.4 (p=0.009) • Curl back neck - 19% ↑, 112.3 vs. 134.0 (p=0.0001) 3. Arm Crank Test: • Max. resistance ↑ from 90 watts to 110 watts post-program (p<0.001).
Nash et al. 2007 USA Downs & Black score=16 Pre-post N=7	**Population:** Chronic Complete Paraplegia; Age (range): 39-58 yrs; Gender: 7 males; Mean time post-injury: 13.1 yrs **Treatment:** Circuit resistance training (CRT), 45/min, 3d/wk on non-consecutive days for 16 wks. Training consisted of low-intensity endurance activities, circuit resistance training, military press, horizontal rows, pectoralis (horizontal row), preacher curls, wide-grip latissimus dorsi pull-downs, and seated dips. **Outcome Measures:** Wingate Anaerobic test (power assessment); Strength testing; all @ baseline & 16 wks.	1. Anaerobic power: • 6% ↑ in peak power (p=0.005) • 8.6% ↑ average power (p=0.001). 2. Strength: • ↑ on all maneuvers from 38.6% to 59.7% (p<0.001).
Jacobs et al. 2001 USA Downs & Black score=15 Pre-post N=10	**Population:** Chronic Paraplegia; Mean age: 39.4 yrs; Gender: 10 males; Mean time post-injury: 7.3 yrs **Treatment:** 12wk training program – 40-45 min/session, 3d/wk on non-consecutive days. Sessions included resistance training (weight lifting) and endurance training (arm cranking).	1. 16.1% ↑ peak power output (p<0.05). 2. Isoinertial strength: • Mean 21,1% ↑ after 12 wks (p<0.01) • Improvements noted every month. 3. Isokinetic strength: • ↑ after 12 wks for the shoulder joint internal rotation, extension,

Author Year Country Score Research Design Total Sample Size	Methods	Outcome
	Outcome Measures: Isoinertial strength testing; Isokinetic strength testing; @ baseline 4, 8 & 12 wks.	abduction, adduction & horizontal adduction (p<0.05).
Petrofsky et al. 2000 USA Downs & Black score=13 Prospective controlled trial N=90 (9/group)	**Population:** Paraplegia; Mean age: 24.9 yrs; Gender: 90 males **Treatment:** 10 wk training period – consisted of electrical stimulation of quad muscles with 10 groups examining different variations of session length, frequency of sessions and length of flexion-extension cycle used in exercise program. **Outcome Measures:** Isometric strength; 3 experiments were designed looking at: 1) the effect of the length of the training session on performance; 2) the number of days of training/wk on performance; 3) the effect of the length of the extension-flexion cycle on training	1. Length of training session: • Greatest ↑ in work capacity in group training for 30min/day vs. 5 or 15 min/day (p<0.01). • 30 min/day group: rate ↑ of training was more rapid. • Quad muscle strength was greater in 30 min/day group than others 2. Number of days training/wk: • Working out 3 days/wk benefitted more than those that worked out for 1 day/wk or 5 days/ wk. • Those that worked out 3 & 5 days/wk were significantly more improved (p<0.01). • 3 days/wk had greater isometric strength in the quads. 3. Length of extension-flexion cycle: • ↑ training effect was assessing training by total work which would be done over the 30 min pd.
Gregory et al. 2007 USA Downs & Black score=11 Pre-post N=3	**Population:** Chronic SCI: Age (range): 22-61 yrs; Gender: 3 males; Level of injury: tetraplegia (2), paraplegia (1) Severity of injury: ASIA D (100%); Time post-injury (range): 17-27 yrs **Treatment:** 12 wks of lower extremity resistance training in combination with plyometric training (RPT) (2-3 d/wk for 30 sessions) **Outcome Measures:** Muscle max cross-sectional area (max-CSA) of knee extensor (KE) & plantar flexor (PF) - MRI; Peak isometric torque, time to peak torque (T20–80), torque developed in initial 220 ms of contraction (torque 220) & mean rate of torque development (ARTD) -Dynamometry; Voluntary activation deficits.	1. Peak torque production improved following RPT in KE (M=28.9%) & PF (M=35%). 2. ↓ T (20-80), ↑ torque (220) & ↑ mean rate of torque development in both muscle groups. 3. PF & KE voluntary activation deficits ↓ following RPT.
Cameron et al. 1998 USA Downs & Black score=9 Pre-post N=11	**Population:** Chronic SCI: Age (range): 18-45 yrs; Gender: 10 males, 1 female; Level of injury: C4-C7 **Treatment:** Testing of hybrid device, 8 wks of neuromuscular stimulation-assisted exercise with training sessions 3d/wk. **Outcome Measures:** Manual muscle test scores biceps, triceps, wrist flexors and extensors.	1. All subjects showed improvement in one or more of their manual muscle scores, with the most dramatic occurring in the triceps (mean ↑ 1.1 for L triceps, 0.7 for R triceps) 2. Results show neuromuscular stimulation in combination with resistive exercise can be used safely and assists in the strengthening of voluntary contractions