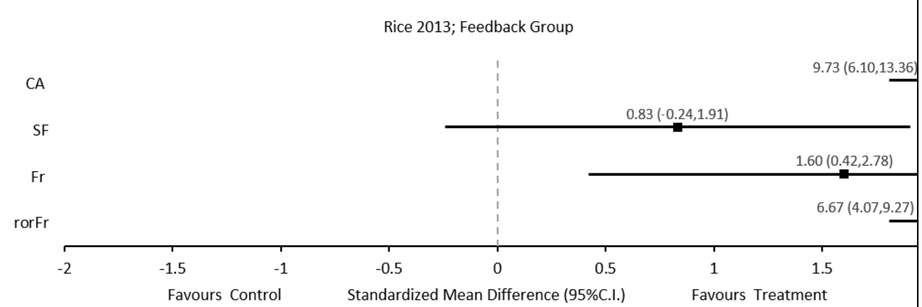
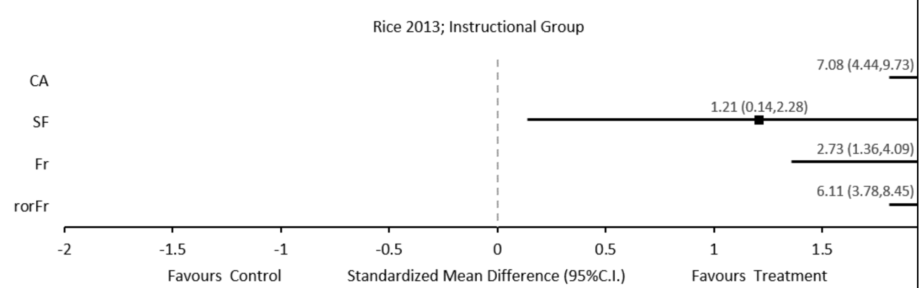
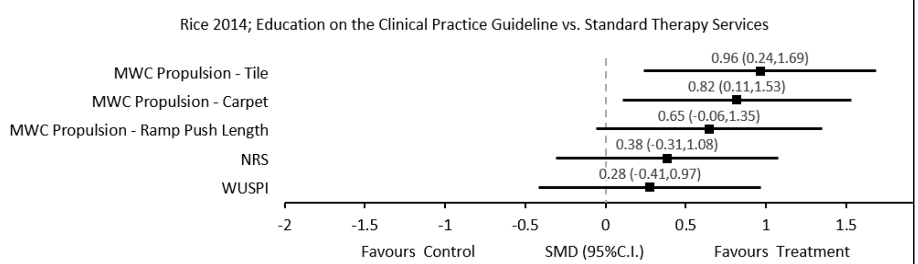
Author Year Country Research Design Score Total Sample Size	Methods	Outcome
Zwinkels et al. 2014 Netherlands Review of published articles between inception to October 2013 N=21	**Methods:** Articles published in English focused on exercise training with at least one outcome measure for wheelchair propulsion (i.e., cardio-respiratory fitness, anaerobic capacity, muscular fitness, or mechanical efficiency). **Databases:** PubMed and EMBASE. **Levels of Evidence**: *Moderate quality:* Low quality RCTS, prospective controlled trials*; Very low quality*: Case Series, case reports. **Questions/ Measures/ Hypothesis:** To review the literature on the effectiveness of training programs on improving hand-rim wheelchair propulsion capacity.	1. There was a total sample of 249 (50% SCI). 2. For all studies examining interval training (n=8), endurance wheelchair propulsion capacity was found to significantly improve in the experimental groups (ranging from 18-34% in individuals with disabilities). 3. In studies that reported sprint wheelchair propulsion (strength studies, n=2), strength training was not found to be effective in improving sprint performance. 4. Overall, Mixed Training (n=6) studies were shown to improve endurance wheelchair propulsion. 5. For the endurance studies (n=5), three studies reported significant improvement in endurance outcomes, two in peak oxygen intake, and only one study (with an able-bodied sample) showed significant improvement in mechanical efficiency.
Rice et al. 2013 USA RCT PEDro=6 N=27	**Population:** Mean age :40.0 yr; Gender: males=24, females=3; Level of injury range: L3-C7; Mean time since injury: 18.0 yr. **Intervention:** Compare 2 propulsion training methods (high and low tech) between experimental and control conditions to determine which system was more effective at teaching manual wheelchair users (MWUs) to increase contact angle (CA) and decrease stroke frequency (SF) during propulsion at two speeds (1.5 m/s or self-selected speed) on an overground course of 15m of level tile, of medium pile carpet and a 1.2° ramp. There were two experimental conditions: an instruction only (IO) group that received a multi-media presentation (MMP) over four sessions, and a MMP and real-time feedback (FB) group which received four sessions. The control group (CG) received no training but had three sessions where they propelled on the overground course and on the dynamometer without instruction. Participants used their own w/c throughout, with no changes in configuration. Data was collected pre-post	1. In controlling for velocity, weight, time since injury and level of injury: 1) Both intervention groups showed increased CA and decreased SF in same day and 3 mo follow up compared to the CG ($p<0.05$); 2) For SF, intervention groups decreased the identical amount but the IO group showed greater decrease at 3mo follow up ($p<0.05$); FB group showed greater percent increase in CA compared to IO group, who showed a greater percent increase than CG at both time periods ($p<0.05$); 3) Both the FB and IO groups showed significant short-term increases in peak Fr at the handrim, with a larger percent increase for the FB($p<0.05$), however long-term changes were not significantly larger than baseline; the CG showed a

	the same day (n=27) and 3mo follow up (n=22) **Outcome Measures:** CA (degrees), SF (strokes per second), peak resultant force [Fr; N/(m/s)], and rate of rise of Fr [rorFr (N/m)].	significant increase in long-term (3mo post intervention) peak Fr. 2. The FB and IO groups showed significant short- and long-term reductions in peak rorFr compared to CG (p<0.05) 3. There were no significant interactions for any of the three test groups for surface type suggesting the effects of training were not influenced by the surface type (carpet, ramp, tile). 4. There were no significant interactions across test groups for propulsion speed. 5. Results of the fixed effects analysis of CA, SF, peak force and rorF compared to demographics found: 1) older participants tend to use smaller CA (p,0.001), and more strokes (p=0.002) whereas lower level injured participants used fewer strokes (p=0.001); 2) older and heavier participants tended to use greater peak force (p=0.04) whereas lower level injured participants tended to use less peak force (p=0.001).
	Effect Sizes: Forest plot of standardized mean differences (SMD ± 95%C.I.) as calculated from pre- and post-intervention data.   	
Rice et al. 2014 USA RCT PEDro=7 N=37	**Population:** Mean age: 38.3 yr; Gender: males=28, females=9; Level of injury: paraplegia=34, tetraplegia=3; Level of severity: AIS A=20, B=4, C=8, D=2, unknown=3; Mean time since injury: acute.	1. There were no significant between-group differences or within-subject differences for: 1) wheelchair setup (rear axle position in relation to acromium or elbow flexion position at the top of the push cycle); 2) wheelchair

	Intervention: Intervention group received education on wheeled mobility and upper limb clinical practice guidelines by a physical and occupational therapist (IG); control group received standard therapy services (SCG). **Outcome measures:** Wheelchair setup, selection, propulsion biomechanics, pain, (numeric rating scale (NRS), Wheelchair Users Shoulder Pain Index (WUSPI) Satisfaction with Life Scale (SLS) and Craig Handicap Assessment and Reporting Technique scores. All measures completed at discharge, 6 mo and 1 yr.	selection although at 6mo and 1 yr 100% of IG met the recommendation of an ultra-light wheelchair; 3) pain, immediate or long term (1 yr). 2. In the SLS scores showed a trend for an increase in only the physical subsection between 6month and 1 yr (p=0.07) and the occupational subsection between 6mo and 1 yr (p=0.07). 3. For propulsion biomechanics, compared to the SCG, the intervention group had significantly lower push frequency at discharge on tile (p=0.02) a trend effect on carpet (p=0.10) and used a significantly longer push length on ramps at all time points (p=0.03).
	Effect Sizes: Forest plot of standardized mean differences (SMD ± 95%C.I.) as calculated from pre- and post-intervention data.  	
Morgan et al. 2017 USA Prospective controlled trial N=6	**Population:** Mean age= 38±17.5 yr; Gender: males=4, females=2 ; Level of injury range: C6-L2. **Intervention:** Manual wheelchairs (MWC) users participated in nine 90-min wheelchair training sessions 2-3 times per week, using motor learning principleswith a repetition-based approach; participants acted as their own control The aim of the training was to increase the push angle and efficiency, use a semicircular push pattern and, decrease push force Two baseline measures were taken three weeks apart , and the psot-test immediately after the intervention **Outcome Measures:** Wheelchair push forces (WMS): Average force, Peak force, Slope of the force; Wheelchair Skills Test (WST), Kinematic Variables: Area of the push loop, hand-axle relationship, push angle; Wheelchair performance test (WPT): contact, recovery, speed, push effectiveness, push frequency.	1. Area of the push loop significantly increased from pre to post test (p=0.05), as well as hand-axel relationship (p=0.03). 2. A positive, but not statistically significant improvement was found for push angle pre- and post- intervention (p=0.07). 3. No significant improvement was found for the WST 4. Three items on the WPT improved significantly pre and post intervention: recovery (p<0.01), speed (p<0.01), push effectiveness (p=0.04). 5. Slope of the force was the only factor that improved significantly on the WMS (p=0.03).
Blouin et al. 2015 Canada	**Population:** Mean age: 42.1 yr; Gender: males=16, females=2; Mean weight: 77.4	1. On average, participants increased mean MEF by up to

Pre-Post N=18	kg; Mean time since injury: 14.8 yr; Level of injury: C7 or LI; Severity of injury: AIS A, B or C. **Intervention:** Patients participated in a training session in a standard manual wheelchair on a stimulator with haptic biofeedback (HB) in order to modify patient's mechanical effective force (MEF) along push phase to achieve more effective MEF pattern. Two pre- and two post training trials were completed without hepatic feedback, each for 1 min. Training was in five 3-min blocks with a 2min rest between; heptic feedback was provided at five different, randomized levels. Visual feedback on the linear velocity was also provided. **Outcome Measures:** Raw force measured using forces sensors on the wheels and simulator base and moment data measured using the SmartWheel, MEF (%push) patterns, mean wheelchair linear velocity, Mean biofeedback moments and mean power output.	15.7% on right side and 12.4% on left side from pre-training to post-training. 2. Power output was significantly higher during the training blocks compared to the pre-and post-training ($p \leq .007$). 3. Mean wheelchair velocities remained equivalent or slightly decreased during the training. 4. No significant differences in ΔMEF_{rms} scores were found neither between the pre-training and the training, nor between any pairs of training blocks ($p>0.1$). 5. Biofeedback level had significant impact on mean MEF in both Q_2 and Q_3 quartiles and on both sides ($p>0.02$). 6. Significant increases in mean MEF were found between the pre-training trial and training blocks BL3, BL4, and BL5 on the right side ($p \leq 0.001$). 7. On the left side, mean MEF was significantly higher during training block BL5 in quartile Q_2, and demonstrated a tendency to increase between the pre-training trial and training blocks BL3, BL4, and BL5 in quartile Q_3 ($p \leq 0.06$). 8. Mean MEF decreased slight during post-training compared to pre-training on left side, remained equivalent on right side, led to non-significant increase in ΔMEF_{rms}.
DeGroot et al. 2009 USA Pre-Post N=9	**Population:** Mean age: 37 yr; Gender: males=6, females=3; Injury etiology: tetraplegia=2, paraplegia=4, cerebral palsy=1, spinal muscular atrophy=1, multiple sclerosis=1; Mean during of w/c use: 10 yr. **Intervention:** Participants were trained on a wheelchair treadmill with verbal instruction (in-depth explanation of Boninger et al. propulsion principles – using a semicircular pattern, using long and smooth strokes and reducing push frequency) and visual instruction and feedback (1) video of an experienced wheelchair user demonstrating the four propulsion patterns – arc, single-loop-over, double-loop-over, and semicircular and 2) visual feedback of performance during propulsion)Training continued until trainer and trainee felt sufficient training and practice had occurred. 10 sec of data were	1. Push length increased ($p<0.05$) pre-to post training. 2. Push frequency decreased ($p<0.01$) pre-to post training. 3. Peak ($p<0.05$) and average ($p<0.01$) forces increased pre-to post training. 4. Average speed did not change. 5. Graphic representations showed differences in propulsion characteristics between one participant with paraplegia and one participant with tetraplegia. • Tetraplegia participant propelled at slower speed than paraplegia participant. • Participant with tetraplegia had, on average, a lower push frequency than the participant with paraplegia. • Push force comparisons did not show clear patterns.

	collected immediately following training/practice. **Outcome Measures:** push frequency, push length, peak push force, average push force, peak push force and average speed using a SMART [wheel] attached to the participants' own MWC. Propulsion was on a wheelchair treadmill.	