Author Year Country Research Design Score Sample Size	Methods	Outcome
Xiang et al. 2021; China RCT (pilot) PEDro = 8 Level 1 N = 18	**Population:** 18 patients with SCI; 15 males and 3 females; mean age 38.2 years; AIS A (n = 12), AIS B (n = 2), and AIS C (n = 4); level of injury T4-T10 (n = 9) and T11-below (n = 9); and median duration of injury 2 months. **Treatment:** The participants were divided into exoskeleton-assisted walking (EAW) group (n = 9) or conventional group (n = 9). Intensity, duration, and frequency were similar in both groups (40–60% HRmax, 50–60 min/session, 4 days/week, 4 weeks): ● EAW group: Training session included sitting, standing, walking, climbing stairs and slope. ● Conventional group: Consisted in strength training using dumbbell, aerobic exercise, such as walking training with brace as well as static and dynamic balance training. **Outcome Measures:** Pulmonary function test (FVC, predicted FEV%, FEV_1, $FEF_{25/50/75}$, PEF, and MVV), 6-MWT, HR, SpO_2, RPE, LEMS, and ASIA scores were collected and analyzed pre and post intervention.	1. There were no adverse events. 2. FVC (t = 2.224; p = 0.041), predicted FVC% (t = 2.848, p = 0.012) and FEV_1 (t = 2.779; p = 0.013) showed significant improvements for EAW group vs. conventional group. 3. EAW group had statistical improvements from pre- to post-intervention in mean change in predicted FVC% (Δ = 17.2%; t = 2.445; p = 0.040), FEV_1 (Δ = 0.8 L; t = 3.359; p = 0.010), FEF_{75} (Δ = 1.7 L/s; t = 3.268; p = 0.011), PEF (Δ = 1.8 L/s; t = 3.381; p = 0.010), and MVV (Δ = 19.3 L; t = 3.274; p = 0.017). EAW training produced no statistical improvements in distance and SpO_2 vs. conventional group during 6-MWT. 4. There was no evidence of statistical improvements from pre- to post-intervention in conventional group in FVC, predicted FVC%, FEV_1, FEF_{75}, FEF_{50}, FEF_{25}, PEF, and MVV. There were also no statistical differences for the

		conventional group in distance, HR, SpO_2, and RPE.
Vivodtzed et al. 2020a USA RCT (crossover) PEDro = 7 Level 1 N = 19	**Population:** 19 patients with SCI, wheelchair-dependent who needed FES to produce leg contractions for exercise, all had been training with FES-rowing for at least 6 months; mean (SD) age 39 (± 13) years; mean time since injury 9.05 years; level of injury ranged from C4 to T8; and AIS A (n = 8), AIS A/B (n = 1), AIS B (n = 3) and AIS C (n = 7). **Treatment:** Two hybrid FES-rowing peak exercise tests (performed with NIV or sham in random order). **Outcome Measures:** Changes in peak alveolar ventilation (VApeak) and peak oxygen consumption (VO_2peak) during the incremental FES-rowing test (n = 13 met criteria for peak exercise), oxygen uptake efficiency slope (OUES) (a nonlinear measure of the ventilatory response to exercise, as an index of cardiopulmonary reserve for patients who didn't meet criteria for peak exercise, n = 6)), changes in respiratory pattern (peak V_T] and peak breathing frequency [fb]) during exercise testing.	1. NIV significantly changed respiratory pattern. Patients breathed deeper and slower with NIV compared with the sham ($P < 0.05$). As a result, VApeak was not changed on average with NIV; the change in VApeak was related to the change in V_T (r = 0.89; $P < 0.01$) but not to the change in fB (r = 0.20; P = 0.51). 2. Average VO_2peak (n = 13) did not change with NIV vs. sham. However, there was a strong correlation between change in VApeak (NIV – sham) and change in VO_2peak (r = 0.89; $P < 0.05$). 3. OUES (n = 19) was not improved. Moreover, change in VApeak was a discriminant factor for change in OUES; those in whom NIV increased VA (6 ± 3 L; n = 12) demonstrated an approximately 50% improvement in OUES, whereas those in whom NIV did not increase VA (–6 ± 6 L; n = 7) demonstrated an approximately 5% reduction in OUES ($P < .05$). 4. Those with TSI ≤ 6 years increased OUES with

		NIV significantly more than participants with TSI > 6 years (0.89 ± 1.59 [n = 12] vs. –0.59 ± 0.84 [n = 7]; $P < 0.05$). Moreover, there was a tendency for OUES to increase in those with cervical injuries compared with those with thoracic injuries (0.79 ± 1.79 [n = 12] vs. –0.37 ± 0.39 [n = 7]; P = 0.15). 5. Lastly, those with incomplete injury tended to have greater improvements in VO_2peak than those with complete injury (P = 0.11).
Vivodtzed et al. 2020b USA RCT PEDro = 3 Level 2 N = 9	**Population:** 9 people with high-level SCI (T3-C4) who had been participating in a rehabilitation program training with whole-body hybrid FES-rowing during 4 ± 2 years, and having training adaptations plateauing for more than 6 months; mean age 38.9 years; mean time since injury 13.1 years; level C4 (n = 3), C5 (n = 1), C6 (n = 1), C7 (n = 1), T2 (n = 1), and T3 (n = 1); AIS A (n = 4), AIS B (n = 1), and AIS C (n = 4). **Treatment:** Patients had completed the study of Vivodtzed et al. 2020a (see above) and continue with whole-body hybrid FES-rowing training for 3 months with NIV (n = 6: IPAP = 20 ± 2, EPAP: 3 cmH_2O) or sham (n = 3: IPAP = 5, EPAP: 3 cmH_2O). **Outcome Measures:** Aerobic efficiency (OUES) was collected at baseline (sham condition) and after 3 months of training (test in NIV and sham condition) performing maximal exercise tests.	1. Training with NIV increased OUES both compared to baseline (4.1 ± 1.1 vs. 3.4 ± 1.0, $p < 0.05$) and sham (p = 0.01) while no change was found in sham (1.8 ± 0.3 vs. 2.1 ± 0.8, after vs. before respectively. This result was found without NIV during the final test. Adding NIV during the final test did not provide additional improvement in OUES (4.1 ± 1.5 and 2.0 ± 0.7, in NIV and Sham respectively). 2. In participants with reliable measures of VO_2peak, a homogeneous improvement was also found in VO_2peak in those using NIV (+0.21 ± 0.04 L/min) while the response was, randomly

		changed in the sham group (+0.08 ± 0.10 L/min). 3. Improvement in OUES was associated with an overall reduction in peak breathing frequency after training with NIV while it tended to increase with Sham (− 3 ± 6 [range: from 33 to 52 to 30–38 bpm] vs. +4 ± 8 [range: from 33 to 46 to 35–51 bpm], p = 0.19). 4. $V_T$peak was unchanged in both groups. 5. Peak SpO2 ranged between 94% and 99% without differences between groups, but there was a slight drop in VD/VT in the NIV group from 0.24 ± 0.09 to 0.22 ± 0.06 which was not found in the sham group, suggesting improvement in OUES was related to improved alveolar ventilation rather than change in O_2 delivery.
Mat Rosly et al. 2017 Malaysia Cohort Level 2 N = 17	**Population:** 17 participants with SCI; 16 males and one female; mean age 35.6 (± 10.2) years; neurological level of injury T4 and above (n = 4) and T5 and below (n = 13); AIS A (n = 11), AIS B (n = 3), AIS C (n = 2) and AIS D (n = 1); and mean (SD) time since injury 14.1 (± 5.6) years. **Intervention:** Participants performed, in a randomized order, two different boxing sessions of 15 minute (set at a minimum of 2 days and maximum of 14 days apart). Modalities consisted in: ● Exergaming boxing: The game was projected and run by a video game	1. Both exergaming and heavy-bag boxing achieved moderate intensities of exercise with 4.3 ± 1.0 MET and 4.4 ± 1.0 MET being achieved, respectively. 2. No significant differences in the physiological or perceived exertional responses between boxing modalities were found.

	console with two controllers and a sensor camera. ● Conventional heavy-bag boxing: Utilized a 1.65-m, 35-kg punching bag hung in suspension. **Outcome measures:** Heart rate (HR), resting HR, VO_2, energy expenditure (EE), total energy expenditure, V_E, metabolic equivalent (MET), RPE (0-10), and self-constructed survey were collected at before and during the exercise sessions.	3. There was a significant preference ($P<0.05$) for exergaming boxing over heavy-bag boxing among responses in the self-constructed survey.
Chen et al. 2016 China RCT PEDro = 4 Level 2 N = 98	**Population:** 98 males with traumatic SCI paraplegia; C5-C7; mean (SD) age 62.7 (± 10.8) years; mean (SD) time since injury 41.6 (± 10.8) years; and injury level T1-T2 (n = 39), T3-T4 (n = 32), and T5-T6 (n = 32). **Intervention:** Participants were divided in two groups: ● Experimental group (n = 49) acquired pulmonary rehabilitation exercise for 12 months, consisting in breath training and strength training. Strength training consisted in 20 min and one time a day session, with an expected 75-85% of maximum HR. ● Control group (n = 49). All patients acquired conventional rehabilitation, including psychological rehabilitation and dietary guidance. **Outcome measures:** Pulmonary function (FEV_1, FVC, MVV) and FEV_1/FVC) and QOL (SF-36) were detected at baseline; during pulmonary rehabilitation at 2 months, 4 months, and 12 months; and 1 month after pulmonary rehabilitation.	1. The data analyses for 2 months, 4 months and 12 months displayed highly significant differences in pulmonary function and life-quality ($P < 0.01$) between experimental group and control group. 2. There was no difference ($P > 0.05$) one month after pulmonary rehabilitation between experimental group and control group.
Soriano et al. 2022 Croatia Pre-post Level 4	**Population:** 11 people with a traumatic cervical SCI; 7 males and 4 females; mean (SD) age 40 (± 10) years; mean (SD) time since injury 17.73 (± 9.40) years; level of injury C3 (n = 1), C4 (n = 1),	1. V_E (0.67 ± 0.23 L/min, p = 0.008), V_T (70 ± 30 mL, p = 0.008), and end-tidal PO_2 (2.6 ± 1.23 mm Hg; p = 0.030) were increased.

N = 11	C5 (n = 5), C6 (n = 3), and C7 (n = 1); AIS A (n = 5), AIS B (n = 4), and AIS C (n = 2). **Treatment:** A single session of passive leg cycling in supine, performed for 10 min at 29 ± 1 rpm using a motorized cycle. **Outcome Measures:** Beat-by-beat arterial blood pressure, heart rate (HR), stroke volume and cardiac contractility, blood velocity of the right middle cerebral artery and left posterior cerebral artery, V_E, V_T, end-tidal fractional concentration of O_2 and CO_2, mean arterial pressure, mean velocity in the MCA and PCA, cardiac output, total peripheral resistance, cerebrovascular conductance, femoral artery diameter and function, blood velocity, flow-mediated dilation, and safety.	2. There were no exertional hypotension or major adverse effects except for one patient who suffered an episode of autonomic dysreflexia and was excluded of the analysis.
Leathem et al. 2021 USA Pre-post Level 4 N = 6	**Population:** 6 participants with SCI; 5 males and 1 female; incomplete injury (n = 4) and complete injury (n = 2); cervical injury (n = 4) and thoracic injury (n = 2); mean (SD) age 33 (± 18.6) years; and mean (SD) time since injury 7 (± 4) years. **Treatment:** Treatment consisted in two modalities: ● Spinal Mobility X class: Performed once per week for 8 consecutive weeks. Each four-hour class was comprised of three circuits: strengthening, aerobic training, and spinal mobility. ● IMT as a home exercise program. **Outcome Measures:** Subjective survey, transfer test, t-shirt test, four directional reach test, and four-directional trunk test were collected before and after the program.	1. None of the participants reported adverse effects due to the respiratory training; and subjects reported various improvements in the surveys. 2. Mean difference for all measures across participants indicates overall improvement in all four functional outcome measures.
Brizuela et al. 2020 Spain Pre-post Level 4	**Population:** 11 participants with traumatic cervical SCI; 8 males and 3 females; mean (SD) age 36.5 (± 10) years; AIS A (n = 8) and AIS B (n = 3); injury level C4 (n = 1), C5 (n = 5), C6 (n =	1. VC and FVC showed a slight but non-significant tendency (p = 0.14 and p = 0.17,

N = 11	2), and C7 (n = 3). **Treatment:** Participants were divided in two groups: ● Higher CSCI (C4-C5) (n = 6). ● Lower CSCI (C6-C7) (n = 5). They performed a stationary armcrank exercise for 8 weeks, twice a week. Exercise duration augmented progressively each 2 weeks until reach 30-40 min at the end of the program. Constant cadence and resistance were set individually with the aim of maintain a RPE (Borg scale) between 2-3/10 (light to moderate) during training sessions. **Outcome Measures:** Quadriplegia index of function questionnaire, Arm-crank power output (Ppeak), heart rate variability, and spirometric variables (VC, FVC and MVV) were measured before and after the training program.	respectively) to increase after the ACE program. 2. All functional and pulmonary variables showed significant differences between levels of injury, with higher values for participants with lower-level CSCI.
[Panza et al. 2019](#) USA Pre-post Level 4 N = 3	**Population:** 3 male patients with incomplete SCI; mean (SD) age 25.33 (± 8.74) years; AIS C (n = 3); C4 (n = 1) and C5 (n = 2); and mean (SD) time since injury 39.0 (± 19.97) months. **Treatment:** Overground locomotor training (OLT) (training used part-to-whole-practice sequences based on the task-specific movements in the gait cycle, and containing five consecutive training segments: joint mobility, volitional muscle activation, task isolation, task-integration, and activity rehearsal). Participants used only volitional control and training was conducted without body-weight support, robotic devices, or ES. Sessions lasted 90 min and were conducted twice a week for 12 weeks. **Outcome Measures:** Weight, cardiorespiratory variables (VO_2, VCO_2, V_E, V_T, and end-tidal partial pressure of CO_2 [$P_{ET}CO_2$]), work of breathing, and RPE. Testing protocol consisted in a 6-min walking bout at their individually	1. As a group (n = 3), there was a 2% increase in V_E and a 9% decrease in V_T. Neither V_E (d = 0.1) or V_T (d = 0.4) during rest demonstrated a large effect size. 2. The phasic response to exercise improved (became faster) following OLT. 3. Data showed medium to large reductions in V_E variability (24%), V_T variability (29%), estimated work of breathing, VCO_2 and $P_{ET}CO_2$, and RPE (30%) following OLT.

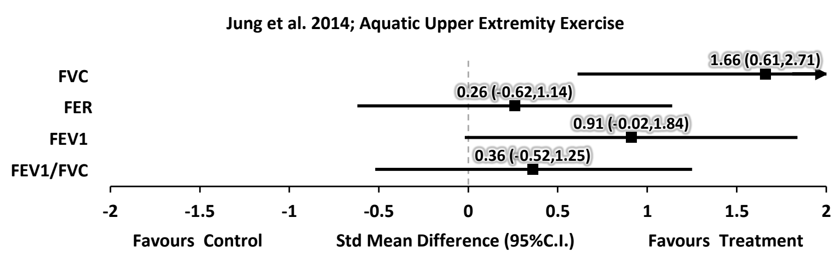
	determined preferred walking speed, 6 min rest, and the second 6 min walking bout with a self-selected faster walking speed than the first bout (analysis was performed of the second bout). Testing protocol was performed before and after OLT (12 weeks) at the same speeds.	
Panza & Guccione 2020 USA Pre-post, Repeated Measures Level 4 N = 8	**Population:** 8 male patients with incomplete SCI; mean (SD) age 45 (± 16.3) years; injury level C3-C6 (n = 6), T5 (n = 1) and T12 (n = 1); and mean (SD) months since injury 44.3 (± 17.3). 8 able-bodied, 7 males and one female, mean (SD) age 34.6 (± 11.3) years. **Treatment:** OLT (training used part-to-whole-practice sequences based on the task-specific movements in the gait cycle containing five consecutive training segments: joint mobility, volitional muscle activation, task isolation, task-integration, and activity rehearsal). Participants used only volitional control and training was conducted without body-weight support, robotic devices, or ES. Sessions lasted 90 min and were conducted twice a week for 24 weeks (training period was divided in two 12-weeks cycles of OLT). **Outcome Measures:** Weight, cardioventilatory parameters (VO_2, VCO_2, V_E, V_E variability, V_T, breathing frequency [Bf]), work of breathing, and RPE. Testing protocol consisted in a 6-min walking bout at their individually determined preferred walking speed (constant work rate), 6 min rest, and then, patients had to walk at the same self-selected pace until a volitional fatigue or 30 min, whichever came first (analysis was made based on the second walking bout). Participants performed the treadmill testing protocol at baseline, at post first OLT (post 1) and post second OLT (post 2).	1. Ventilatory response to exercise is accelerated after 12 and 24 weeks of OLT, with concomitant improvements in walking endurance and reductions in RPE after 12 and 24 weeks of OLT. 2. Ventilatory variability reduced at 12 weeks, but returned to pre-OLT values after an additional 12 weeks of training despite the continued reduction in RPE and improvements in walking endurance. 3. V_E variability was correlated with the change in RPE through the study. 4. 12 and 24 weeks of OLT resulted in significant improvements in treadmill walking time.

Panza et al. 2017 USA Pre – post Level 4 N = 6	**Population:** 6 patients with incomplete SCI (AIS C); 5 males and one female; mean (SD) age 36.17 (± 19.36) years; injury level C4-C5 (n = 5) and C5 (n = 1); and between 2- and 5-years post injury. **Treatment:** OLT program performed in two 90-minute training sessions per week for 12 weeks. Each training session involved five consecutive training segments, all with a particular focus as follows: joint mobility; volitional muscle activation; task-isolation; task-integration; and activity rehearsal. Participants were required to perform all exercises under volitional control, but without the assistance of body-weight support harnesses, robotic devices, ES or orthoses and other lower-extremity supportive devices. **Outcome Measures:** Height, weight, cardiorespiratory variables (V_T, Bf, V_E and V_E variability). All participants underwent a 6-minute volitional unaided walking bout at a constant work rate on a motorized treadmill. Participants were instructed to stand quietly for 3 min, prior to walking at their preferred walking speed for 6min. The same testing procedures were repeated after 12 weeks of OLT at the same walking speed used at pre-testing.	1. The averaged group data for resting and for exercise V_E, V_T and Bf showed no difference before and after training. 2. Exercising V_E variability was significantly reduced in four of the five participants resulting in a group average reduction of 11.87 arbitrary units. The group V_E variability was reduced by 46.7% on average. These data didn't show a phasic ventilatory response to treadmill walking at preferred walking speed before or after OLT.
Gollie et al. 2017 USA Pre-post Level 4 N = 6	**Population:** 6 patients with chronic (2 to 5 years post injury), cervical incomplete SCI, 5 males and one female, age range between 19 and 67 years, 5 AIS C (n = 5) and AIS D (n = 1). **Treatment:** The OLT protocol consisted of two 90-minute training sessions per week and it was performed during 12-15 weeks. Each training session involved five consecutive training segments, all with a particular focus as follows: joint mobility; volitional muscle activation;	1. OLT did not result in any adverse events. 2. After training, overground walking speed was significantly increased during the 10-MWT (0.36 ± 0.20 vs. 0.5 ± 1.24m/s, $P < 0.001$, $d = 0.68$) with a range of overground walking speeds of 0.24 to 0.88m/s.

	task-isolation; task-integration; and activity rehearsal. Participants were required to perform all exercises under volitional control, but without the assistance of body-weight support harnesses, robotic devices, ES or orthoses and other lower-extremity supportive devices. **Outcome Measures:** Overground walking speed, RER, VO_2, and VCO_2, HR, and BMI were collected pretest and posttest (each testing visit consisted of a 10-m walk test (10-MWT) and a constant work rate submaximal treadmill test while walking at a self-selected walking speed).	3. During constant work rate treadmill walking VO_2 was significantly lower after training than before training (6.6 ± 1.3 vs. 5.7 ± 1.4 mL·kg·min, P = 0.038, d = 0.67). Furthermore, VCO_2 was significantly reduced after OLT (753.1 ± 125.5 vs. 670.7 ± 120.3 mL/min, P = 0.036, d = 0.67). The VO_2 required above standing rest during self-selected walking was significantly greater than the estimated VO_2 both before (6.6 ± 1.3 vs. 1.9 ± 0.78 mL·kg·min, P < .05) and after training (5.7 ± 1.4 vs. 1.9 ± 0.78mL·kg·min, P < 0.05).
Gorgey & Lawrence 2016 USA Pre-post Level 4 N = 10	**Population:** 10 participants with chronic motor complete SCI (C5-T10); 9 males and 1 female; mean age 44 (± 9.5) years; and AIS A or B. **Intervention:** An acute bout of FES-lower extremity cycling (FES-LEC) until fatigue (10 ± 8 min). **Outcome Measures:** Body composition assessment (whole-body impedance analyzer at the familiarization session), V_E, VCO_2, ventilation-to-carbon dioxide (VE/VCO_2) ratio, RER and substrate utilization were measured using indirect calorimetry during resting, warm-up, exercise, and recovery phases.	1. Breathing frequency increased significantly from 15 ± 4 breaths/min during rest and 16 ± 4.5 breaths/min during warm-up periods to 18 ± 5 breaths/min during exercise (P = 0.017) and remained significantly elevated during the recovery period (18 ± 4.5 breaths/min; P = 0.049). 2. V_E significantly increased (14.5 ± 6.4 L/min; P = 0.008) and remained significantly (13.3 ± 4.3 L/min; P = 0.001) elevated during the recovery period compared with the resting period. 3. VCO_2 increased significantly from 0.18 ±

		0.085 L/min during rest to 0.45 ± 0.21 L/min during exercise (P = 0.004) and remained significantly elevated during the recovery period (0.36 ± 0.12 L/min; P = 0.001). 4. Compared with resting (40.5 ± 4.5) and warm-up (38 ± 5; P = 0.055) periods, VE/VCO_2 ratio dropped significantly during FES-LEC exercise (32 ± 4; P = 0.0001) and remained depressed during the recovery (34.5 ± 3; P = 0.099) period. 5. RER did not change between resting (0.85 ± 0.06) and warm-up (0.83 ± 0.09) periods. However, it did increase significantly (P = 0.001) during exercise (1.09 ± 0.15) and remained elevated during the recovery (1.09 ± 0.06) period.
Qiu et al. 2016 USA Pre-post Level 4 N = 12	**Population:** 12 participants with SCI at T2 and above, 11 males and one female, mean (SD) age 33.3 (± 3.8) years, and mean (SD) time post-injury 8.3 (± 3.3) years. **Intervention:** FES-RT for 6 weeks, three times weekly, 30 minute each session with the goal of reaching an exercise intensity of 75%–85% of HRpeak. **Outcome Measures:** VO_2, VCO_2, RER, expired VO_2 and CO_2 gas fractions, V_E, V_T, peak aerobic capacity (VO_2peak), peak ventilation (VEpeak), VTpeak, peak breathing frequency (BFpeak), RERpeak, HRpeak and OUES were collected at baseline (once	1. Compliance to the 6-month training program averaged 1.8 ± 0.2 rowing sessions per week, corresponding to 59% of planned sessions. 2. VO_2peak increased on average by 12%, from 15.3 ± 1.5 to 17.1 ± 1.6 $mL \cdot kg^{-1} \cdot min^{-1}$ (P = 0.02), meanwhile the average $V_E$peak did tend to be higher (modest increase) (37.5 + 4.4 vs. 40.7 + 3.0 $L \cdot min^{-1}$, P = 0.09)*.

	participants were able to perform more than 10 min of continuous FES rowing) and after 6 months of training, with a graded exercise test.	3. Both before and after training, injury level was directly related to $V_E$peak (R^2 = 0.48 and 0.43) and VO_2peak (R^2 = 0.70 and 0.55). Before training, the relationship of VO_2peak to $V_E$peak was strong (R^2 = 0.62), however, after training, this relationship became almost completely linearized (R^2 = 0.84). 4. For all 12 participants, the average OUES was higher after 6 months of FES-RT (1.24 ± 0.11 vs. 1.38 ± 0.12, $P < 0.05$). * Hence, improvements of cardiopulmonary reserve appear to be derived from cardiovascular and skeletal muscle adaptations and not from any improvement in ventilatory capacity.
Brurok et al. 2013 Norway Cross-over repeated measures Level 2 N = 15	**Population**: N=15 participants with AIS-A SCI Mean (SD) age: 39.0 (12.9) years Mean (SD) DOI: 13.2 (10.8) years **Treatment**: ACE: arm cycling FES_H: FES hybrid cycling (leg cycling + ACE) FES_{IH}: FES iso hybrid cycling (lower extremity pulsed isometric muscle contractions + ACE) **Outcome Measures:** Mean peak ventilation (V_E) and other physiological measures.	1. Significantly higher V_E during FES_{IH} (mean increase +8.21L/min) and during FES_H (+11.0L/min) compared to ACE in participants with SCI above T6. 2. No significant difference in V_E during FES_{IH} and during FES_H compared to ACE in participants with SCI below T6.
Jung et al. 2014 South Korea	**Population:** N=20 with SCI (12M, 8F) Mean (SD) age: 46.6 (10.5) years Mean (SD) DOI: 8.45 (3.56) years	1. Significant between-group difference in change values of FVC

RCT PEDro = 5 Level 1b N = 20	Injury level C8-L5, AIS-B to D. **Treatment:** Aqua group (10, aquatic exercise) Land group (10, control) Both groups performed upper extremity exercises; 1h sessions 3 times/week for 8 weeks. **Outcome Measures:** FVC, forced expiratory flow rate (FER), FEV_1, FEV_1-FVC ratio (FEV_1/FVC).	(Aqua=1.8±1.3L, Land=0.31±1.6L; mean±SD) and FEV_1 (Aqua=1.1±1.2L, Land=0.21±0.3L). 2. Significant within-group increase in FVC (2.5±0.7 to 4.3±1.4L), FER (80.5±15.5 to 90.5±17.0L/s), FEV_1 (2.1±0.9 to 3.2±1.2L) and FEV_1/FVC (89.3±3.8 to 93.0±3.6%) in aqua group. 3. Significant within-group increase in FER (85.2±18.0 to 90.6±18.0L/s) in land group.
	Effect Sizes: Forest plot of standardized mean differences (SMD ± 95%C.I.) as calculated from pre- and post-intervention data. 	
[Tiftik et al. 2015](#) Turkey Prospective controlled trial Level 2 N = 52	**Population**: N=52 with SCI (40M, 12F) Mean (SD) age: 33.4 (13.9) years Mean (SD) DOI: 12.6 (13.0) months 18 AIS-A, 34 AIS-B/C/D 44 traumatic SCI, 8 non-traumatic SCI 17 cervical, 15 thoracic, 20 lumbosacral **Treatment:** Group A (26): locomotor training (using body weight supported treadmill training) + conventional rehab program; Group B (26): conventional rehab program only **Outcome Measures:** VC, FVC, FEV_1, FEV_1/FVC, forced expiratory flow rate 25-75% (FEV25-75), PEFR, MVV.	1. Significant increase in FVC (3.5±0.8 to 3.6±0.9L; mean±SD), FEV_1 (3.1±0.7 to 3.2±0.7L), FEV25-75 (3.8±1.0 to 4.0±1.1L) and VC (3.4±0.9 to 3.6±0.9L) in group A only. 2. Significant increase in FVC and VC in all group A subgroups after stratifying for injury completeness and severity. 3. Significant increase in MVV in both groups (Group A: 82.3±22.8 to 89.1±24.8L/min; Group

		B: 76.4±18.2 to 84.4±23.9L/min).
Taylor et al. 2014 USA Pre-post Level4 N = 14	**Population:** N=14 people with SCI (13M 1F) Mean age (SD): 39.2(3.3) Mean DOI (SD): 9.7(2.6) years All AIS-A, level T3-T11 **Treatment**: 6 months of FESRT. **Outcome Measures:** $V_E$peak, peak aerobic capacity.	1. Significantly increased $V_E$peak after training. 2. Significant relation between level of injury and $V_E$peak before and after training.
Terson de Paleville et al. 2013 USA Pre-post Level 4 N = 8	**Population:** 8 participants with complete (AIS-A) SCI and tetraplegia (7M, 1F). Mean (SD) age: 37 (18) years Mean (SD) DOI: 25 (12) months 5 cervical, 3 thoracic **Treatment:** Locomotor training with body weight support and treadmill. **Outcome Measures:** FVC, FEV_1, MIP, MEP, respiratory muscle sEMG and respiratory motor control assessment.	1. Significantly increased FVC, MIP, MEP, FEV_1 post compared to pre. 2. Significantly less baseline overall sEMG activity in SCI compared to NI* 3. Significantly increased overall sEMG activity post locomotor training for all tasks** 4. 7 participants had increased sEMG amplitudes for all tasks** after locomotor training 5. No significantly changes in distribution of sEMG activity post locomotor training for all tasks** 6. 1 participant developed activation in muscles post which were not activated pre 7. Lower rate of muscle unit recruitment in patients with compered to NI* 8. Significantly faster muscle unit recruitment post compared to pre *Non-injured controls (NI), 9M 5F

		**Cough, inspiration/expiration tasks
[Moreno et al. 2013](#) Brazil Pre-post Level 4 N = 15	**Population:** 15 male tetraplegic participants with SCI divided into control (n=7) and rugby players (n=8) groups. Control group: mean (SD) age: 33(9) yrs; DOI: 73(53) months. Rugby player group: mean (SD) age: 26(6) yrs; DOI: 87(52) months. **Treatment:** Experimental group participated in a regular 1-year wheelchair rugby training program that involved stretching, strength exercises, and cardiovascular resistance training (2-hour sessions 3-4x per week). **Outcome measures:** FVC, FEV_1, MVV.	1. There was a significant increase in all variables after training: mean (SD) FVC increased from 2.7 (0.9) L to 3.0 (1.0) L; FEV_1 increased from 2.5 (0.9) to 2.8 (1.0) L; MVV increased from 107 (28) to 114 (24) L/min. However, comparisons with the control group are not presented.
[Lee et al. 2012](#) Korea Cohort Level 2 N = 38	**Population:** 38 patients with cervical SCI divided into experimental (MIE Feedback Resistive training) (n=19) and control groups (n=19). MI-EFRT group: 17M 2F; mean (SD) age: 45.7 (3.4) yrs; DOI: 20.0(1.5) months. Control group: 16M 3F; mean (SD) age: 50.1(3.6); DOI: 21.4(1.2) months. **Treatment:** Joint mobilization, stretching, and muscle strengthening for both groups 2x / day for 30 min, 5 x per week over 4-week period. A forced positive measure MI-E, along with expiratory muscle feedback respiration exercise was practiced by the experimental group, each for 15 mins. **Outcome measures:** Lung capacity, FVC, FEV_1, FEV_1/FVC	1. In the comparison of the values of respiratory function before and after the respiratory rehabilitation treatment, the experimental group showed a significant increase in VC(SD) from 42.3(4.9) to 47.0(4.7)%, FEV_1 from 1.3(1.1) to 1.5(0.1)L, and UPCF from 153.4(29.0) to 188.1(30.2) L/min. 2. Treatment had no significant effect on FEV_1/FVC. 3. In the comparison of changes in respiratory function after the respiratory rehabilitation treatment between the experimental and control group, there were significant differences between

		the changes in VC% (%), FEV_1 (L), and UPCF (L/min).
Jacobs 2009 USA Prospective controlled trial Level 2 N = 18	**Population:** 18 participants with SCI with complete motor paraplegia (level of injury T6-T10); participants were assigned either resistive training (RT) or endurance training (ET): RT group: 6M 3F; mean(SD) age: 33.8 (8.0) yrs ET group: 6M 3F; age: 29.0(9.9) yrs **Treatment:** Endurance training: 30 min of arm cranking exercise 3 times per week for 12 weeks; Resistance training: similar training but with training weights gradually increased every week. **Outcome Measures:** VO_2peak; $V_E$peak.	1. Significant increase in VO_2peak in resistance training group (15.1%) and endurance training group (11.8%). 2. No significant change in $V_E$peak in either group.
Janssen & Pringle 2008 Netherlands Pre-post Level 4 N = 12	**Population:** 12 men with SCI (6 with tetraplegia and 6 paraplegia), including 4 participants (mean (SD) age: 44(14) yrs, DOI: 13(8) yrs) who had previous training on ES-LCE. **Treatment:** Computer controlled ES induced leg cycle ergometry (ES-LCE); total of 18 training sessions with each session lasting 25-30 min. **Outcome Measures:** VO_2, VCO_2, pulmonary ventilation (V_E).	1. Significantly higher peak values for VO_2 (+29%), VCO_2 (+22%), and V_E (+19%).
Valent et al. 2008 Netherlands Cohort Level 2 N = 137	**Population:** 137 participants with SCI; C5 or lower; aged 18-65 years. *Hand cycling group*: 35 participants with paraplegia, 20 with tetraplegia. *Non-hand cycling group*: 56 with paraplegia, 26 with tetraplegia. **Treatment:** All participants followed the usual care rehabilitation program in their own rehabilitation centres, with or without regular hand cycling exercise. Study included three measurements: 1) when participants could sit in a wheelchair for three hours; 2) on discharge; 3) 1 year after discharge. **Outcome Measures:** VO_2peak; FVC; PEFR.	1. Significant increase (26% in hand cycling group vs. 8% non-hand cycling group) in VO_2peak in paraplegic patients, whereas tetraplegic patients showed no change. 2. No change in pulmonary function (FVC or PEFR) found in either participants with paraplegia or tetraplegia.

Carvalho et al. 2006 Brazil Prospective controlled trial Level 2 N = 21	**Population:** (1) *Treatment group*: 11 males with complete tetraplegia, ages 22-50, C4-C7, 25-180 months post-injury (2) *Control group*: 10 males with complete tetraplegia, ages 23-42, C5-C8, 24-113 months post-injury **Treatment:** Treadmill training with neuromuscular electrical stimulation (NMES): 20 min 30-50% BWS, 2x/wk. Conventional physiotherapy for control group. **Outcome Measures:** Metabolic and cardiorespiratory responses before and after training.	1. Significant differences were found in all parameters after treadmill training with NMES, except for HR and diastolic BP. During gait, VO_2 increased by 36%, VCO_2 increased by 43%, V_E increased by 30%, and systolic BP increased by 5%. 2. For the control group, only VO_2 and VCO_2 increased significantly at rest (31 and 16%, respectively) and during knee-extension exercises (26 and 17%, respectively).
Fukuoka et al. 2006 Japan Pre-post Level 4 N = 8	**Population:** N=8 (7M 1F); mean(SD) age: 46.5(8.3) yrs; AIS B; T7-L1. **Treatment:** *Wheelchair training program*: 30 min at 50% $HR_{reserve}$, 3x/wk, 60 day. **Outcome Measures:** VO_2 peak, HR.	1. Mean VO_2peak increased with training, became significant from 30th training day onwards (baseline = 17 ml/kg/min vs. T30 = 18 ml/kg/min). 2. Steady state HR decreased significantly by 15th training day, reached a plateau from day 15 onwards (baseline HR_{ss} = 123±11 bpm vs. at day 15 = 109±6 bpm).
Sutbeyaz et al. 2005 Turkey Pre-post Level 4 N = 20	**Population:** N=20 people with SCI (12 men, 8 women), 14 complete, 6 incomplete (T6-T12), mean(SD) age: 31.3(8.2) yrs; DOI: 3.8(5.8) yrs. **Treatment:** Ventilatory and upper extremity muscle exercise: 1h, 3x/wk x 6 wks; Diaphragmatic, pursed lip breathing for 15min; Air shifting for 5min; voluntary IH 10min; arm-crank exercise. **Outcome measures**: Spirometry.	1. After training, FVC, FEV_1, and VC, were significantly higher than the baseline values. 2. Exercise testing showed increased peak V_E and peak workload and a reduction in the ratio of physiological dead space to V_T

		compared to baseline values.
Le Foll-de-Moro et al. 2005 France Pre-post Level 4 N = 6	**Population:** N=6 participants (5M 1F), T6- & T11/12, mean (SD) age: 29 (14) yrs; mean DOI: 94 days. **Treatment**: Wheelchair Interval-training Program – 30 min (6 x 5 min bouts: 4 min moderate intensity and 1 min of high intensity) 3x/wk for 6 wks; Progressed throughout training program to achieve 50% and 80% of heart rate. **Outcome measures**: Spirometry.	1. At maximal exercise, peak V_E (75%), peak fb (-13.4%), peak V_T (+28.9%), and the ventilatory reserve (12.9%) improved after training. The oxygen cost of V_E decreased significantly (-20%) after training. 2. For the wheelchair test, at the same workload after training, V_E and fb decreased and V_T increased consistent with improved ventilatory efficiency and greater reliance on aerobic capacity after training. 3. Spirometric values and lung volumes showed small trends towards improvement after training.
Silva et al. 1998 Brazil Pre-post Level 4 N = 24	**Population:** 24 participants (12 people with paraplegia, 12 non-SCI participants), median age SCI: 31 yrs (range 22-54), control: 30 (range 22-52), T1-T12, all ASIA A, >3 yrs after injury. **Treatment:** Arm cranking aerobic training: 30 mins, 3x/wk x 6 wks. **Outcome measures**: Spirometry.	1. After aerobic training, SCI participants showed significant increases in FVC and the ventilatory muscle endurance, so that max voluntary ventilation at 70% time values post-training were not different from the initial values of non-SCI participants. 2. Severely limited ventilatory muscle endurance in people with paraplegia can be improved by arm cranking.

Hooker & Wells 1989 USA Pre-post Level 4 N = 8	**Population:** N=8 SCI (4M 4F); *Low intensity group*: C5-T7 (age range 26-36yrs); *Moderate Intensity group*: C5-T9 (age range 23-36yrs) **Treatment:** Aerobic training: WC ergometry 20 min 3x/wk for 8 wk Low Intensity exercised at a power output = 50-60% of maximal heart rate. Moderate Intensity exercised at a power output = 70-80% maximal heart rate. **Outcome measures:** maximal oxygen uptake, peak power.	1. After training, no changes to maximal oxygen uptake or peak power. 2. No detectable changes during submaximal or maximal exercise were detected. 3. Training intensity was insufficient, participants did not comply with the program, or study was underpowered due to small sample size and heterogeneity of participant responses.