Table 4. Exercise and Activity-Based Therapy (ABT) for Sitting Balance

Author Year Country Research Design Score Total Sample Size	**Methods**	**Outcome**
Nam et al. (2023); Republic of Korea RCT PEDro=4 Level 2 N=24	**Population:** 24 participants with tetraplegia who were using a manual wheelchair for independent mobility. • Wheelchair skills training program Group (n=12): Mean (SD) age: 36.02 (7.16) years; 9M, 3F; injury level: C5-C6 (n=7), C7-T1 (n=5); AIS: AIS B (n=6), AIS C (n=6); and mean (SD) time since injury: 34.92 (8.35) months • Control Group (n=12): Mean (SD) age: 35.81 (4.51) years; 8M, 4F; injury level: C5-C6 (n=6), C7-T1 (n=6); AIS: AIS B (n=5), AIS C (n=7); and mean (SD) time since injury: 36.41 (9.19) months **Treatment:** Both groups underwent an 8-week intervention consisting of three 1 h sessions per week, including warm-up, training programs, and cool-down activities. Participants were assigned to: • The wheelchair skills training program involved various wheelchair-related tasks, such as wheelchair propulsion, navigating obstacles, and transferring to and from a wheelchair. • The control group underwent conventional physical therapy concurrently with the training group. Conventional physical therapy included upper extremity strengthening and endurance exercises on an arm ergometer, as well as aerobic exercise with indoor track cycling. Conventional physical therapy was performed at 70% maximum heart rate intensity (or a Borg rating of 3–4). **Outcome Measures:** Activity-based Balance Level (ABLE), pulmonary function, and Wheelchair Skills Test	1. A significant increase in ABLE scores was observed in the wheelchair skills training program group across all intervention periods (baseline to 4 weeks, 4 to 8 weeks, and baseline to 8 weeks) ($p<0.05$). However, no significant changes were observed in the control group at any intervention period ($p>0.05$). 2. The wheelchair skills training program group demonstrated significantly higher changes in ABLE scores, compared to the control group in the baseline to 4 weeks and baseline to 8 weeks periods.

	(version 4.1) were assessed at baseline and at the end of the intervention.	
Qi et al. (2018); China RCT PEDro=5 Level 2 N=40	**Population:** 40 participants with SCI, right-handed, and able to maintain a sitting posture for more than 30 min in a wheelchair. • Wheelchair Tai Chi (WCTC) group (n=20): Mean (SD) age: 38.3 (10.24) years; 15M, 5F; injury level: C6-T1 (n=3), T2-T5 (n=5), T6-T12 (n=8), and below L1 (n=4); AIS: AIS B (n=2), AIS C (n=3), and AIS D (n=8); and mean (SD) time since injury: 5.61 (3.76) months • Control group (n=20): Mean (SD) age: 43.05 (11.80) years; 16M, 4F; Injury level: C6-T1 (n=4), T2-T5 (n=6), T6-T12 (n=7), and below L1 (n=3); AIS: AIS B (n=2), AIS C (n=2), and AIS D (n=8); and mean (SD) time since injury: 5.11 (3.94) months **Treatment:** All participants in both groups were undergoing individual standard rehabilitation according to each patient's condition (consisted of personalized rehabilitation education, teaching mobility and transfer skills, preventing injury progression, handling spasticity, managing secondary complications, and helping patients to become more independent). • Participants in the control group only received the standard rehabilitation intervention. • The WCTC intervention involved a 30-min session, two sessions per day, and five days per week for a total of six weeks. The program consisted of three parts: a 5-min warm-up session, WCTC movements that encompassed 16 easy-to-learn and easy-to-perform forms, and a 5-min cool-down session. **Outcome Measures:** Muscle strength (trunk muscles and hand dynamometry), static sitting balance (the total displacement of center of	1. Compared with the control group, static sitting balance, left handgrip strength, and the psychological domain of quality of life improved significantly in the WCTC group (time by group interaction, $p<0.05$).

	pressure in the anteroposterior (COP_{AP}) and mediolateral (COP_{ML}) directions were collected), and quality of life (WHOQOL-BREF) were collected at baseline and after the intervention period.	
Harvey et al. (2011); Australia/Bangledesh RCT PEDro=8 Level 1 N=32	**Population**: 32 participants - 30 males and 2 females; motor level T1 – L1; 29 AIS A, 2 AIS B, 1 AIS C; age range= 24-31y; years post injury= 8-17 weeks **Treatment**: In the control group, participants received 6 weeks standard inpatient rehabilitation. In the experimental group, participants received 6 weeks standard inpatient rehabilitation + 3 additional 30-min sessions/wk of 84 task specific exercises with 3 levels of difficulty (252 exercises) in unsupported sitting. **Outcome Measures:** Maximal Lean Test (Maximal Balance Range), Maximal Sideward Reach Test, Performance Item of the Canadian Occupational Performance Measure (COPM)	1. The mean between-group differences for the Maximal Lean Test, Maximal Sideward Reach Test and the Performance Item of the COPM were –20 mm, 5% arm length, and 0.5 points respectively.
Boswell-Ruys et al. (2010); Australia RCT PEDro=8 Level 1 N=30	**Population:** 30 participants- 25 males and 5 females; 25 AIS A, 15 AIS B; level of injury: T1-12; mean age=45y; mean years post injury= 14.5y. **Treatment:** Participants in the experimental group received 1hr of 84 task specific exercises with 3 grades of difficulty in an unsupported sitting 3 times a week for 6 weeks. The control group did not receive any intervention. **Outcome Measures:** Primary measures were: Upper Body Sway Test, Maximal Balance Range Test; Secondary measures were: Alternating Reach test (supported and unsupported), Seated Reach Test 45°to right, Coordinated Stability Test (Version A), Upper Body Sway Test (lateral and antero-posterior components).	1. The between-group MD for the maximal balance range was 64mm (p=0.006).
Tsang et al. (2015); Hong Kong	**Population:** 19 wheelchair users with SCI, assigned to: • Control group (n=8): Mean (SD) age: 46.2 (11.8) years; 7M, 1F; injury	1. No adverse events (AEs) and complications (e.g., dizziness) were reported during the training period.

Prospective controlled trial Level 2 N=11	level: C6-T1 (n=3), T2-T7 (n=2), and T8-L1 (n=1); AIS: AIS B (n=6), AIS C (n=0), AIS D (n=2); and mean (SD) time since injury: 17.3 (7.8) years • Sitting Tai Chi Group (n=11): Mean (SD) age: 49.1 (10.3) years; 4M, 7F; injury level: C6-T1 (n=6), T2-T7 (n=1), and T8-L1 (n=4); AIS: AIS B (n=5), AIS C (n=3), AIS D (n=3); and mean (SD) time since injury: 14.7 (13.7) years **Treatment:** Participants participated in either Tai Chi intervention or control group activities according to their preferences: • The Tai Chi Intervention. The sitting Tai Chi intervention involved two 90-minute sessions, 2 times per week for 12 weeks. A 12-form sitting version of Yang's Tai Chi style was designed for the experiment. Each session included a 5-minute warm-up and 5-minute cool- down with rests as necessary. The whole 12 forms required approximately 3 minutes to complete and it took 6 lessons for the participants to learn the whole sitting Tai Chi routine. The participants spent the rest of the training sessions in polishing the forms and engaging in sitting balance training. The participants were encouraged to also practice at home for 90 minutes each week. • Participants in the control group were involved in educational talks and social activities of equivalent duration and frequency. **Outcome Measures:** Sitting balance control (involving the limits of stability test and a sequential weight shifting test in the participant's own wheelchair), handgrip strength, and quality of life (WHOQOL-BREF) were conducted at baseline and post-intervention.	2. Changes in the Limits of Stability: a. A significant time by group interaction effect (p = 0.042; effect size = 0.263) was found in the reaction time. Paired t-tests revealed that only the sitting Tai Chi group had significantly better reaction time performance (p = 0.025) after three months of training. No significant change was found in the control group over time (P = 0.469). b. A significant time by group interaction (p = 0.016; effect size = 0.349) was found in the average maximum excursion. Only the sitting Tai Chi group achieved an improvement in the CoP distance travelled (p = 0.006) after three months of training. No significant change was found in the control group (p = 0.613). c. A significant time by group interaction (p = 0.025; effect size = 0.310) was found in the average directional control. The sitting Tai Chi trainees showed a significant improvement (p = 0.047) after three months of training while there was no significant change in the control group (p = 0.076) over time. 3. Changes in Sequential Weight Shifting Performance: a. The total time to complete the sequential weight shifting test showed a significant time by group interaction (p = 0.035; effect size = 0.281). Paired t-tests showed that only the Tai Chi group showed a significant average improvement (p=

		0.012) after the three months of training. No significant change was found in the control group (p = 0.399). Between-group comparisons demonstrated that the difference between the two groups was statistically significant after the intervention (p = 0.001). 4. A significant time by group interaction (p = 0.033; effect size = 0.286) was also found in terms of directional control, but there was no significant change in either group after the three-month intervention.
Kim et al. (2010); Korea Prospective Controlled Trial Level 2 N=12	**Population:** 12 participants - 9 males and 3 females; 11 AIS A, 1 AIS B; level of injury: T6-12. mean age= 40.86y. **Treatment:** The control group received conventional PT. The experimental group received conventional PT and goal-oriented training on a rocker board. The patients sat on a stable surface with their legs straight on the floor. Forward, left and right reach were all measured. Sessions were 5 sets of 10 reps 5 times a week for 4 weeks. **Outcome Measures:** mFRT, sway area and sway velocity using the Balance Performance Monitor.	1. There was an increase in the mFRT distance in the experimental group. 2. The experimental group showed a decrease in sway area with both opened and closed eyes after training. 3. The experimental group showed a significant difference before and after training compared to the control, as shown by MFRT distance and swaying area.
de Oliveira et al. (2023); Australia Case series Level 4 N=13	**Population:** 13 participants with SCI and a minimum total score of 2 points on the Modified Rivermead Mobility Index; mean (SD) age: 32.1 (12.4) years; 9M, 4F; injury level: C3-L1; AIS: AIS A (n=6), AIS B (n=5), AIS C (n=1), and AIS D (n=1); and mean (SD) time since injury: 46.5 (65.9) months **Treatment:** Participants received the activity-based therapy (ABT) Program. Exercise programs were individually tailored according to the person's goals and functional abilities. The intervention involved three key elements: (i) task-specific training, (ii) weight-bearing tasks and (iii) whole-body muscle strengthening. This	1. There was an increase of 9% in the standardized reach distance (95% CI 2–16) for sitting balance.

	approach included training in different positions such as sitting on the edge of the bed, 4-point kneeling, kneeling, standing with partial or full body-weight, body-weight supported treadmill training (BWSTT), active-assisted exercises, resistance training, neuromuscular electrical stimulation and balance and coordination tasks. All exercises were performed out of the wheelchair, incorporating whole-body movements. Participants were encouraged to perform all exercises to their maximum capacity with 1 to 5 min for recovery, if required, between exercises. The length of intervention varied from 4 to 24 weeks with a frequency of 2 to 4 times per week. Each session was 2 h long. **Outcome Measures:** Seated Reach Distance test (SRD) was assessed at baseline (during the multiple-baseline 4-week period, weekly), at the start and end of the intervention period, at 2-week intervals during the intervention period, and at 8-week follow-up.	
Larson (2022); USA Prospective controlled trial Level 2 N=23	**Population:** 23 participants were included into three groups: • OMA (Olfactory mucosa autografts) Group (n=7): Mean (SD) age: 30.3 (9.1) years; 7M, 0F; level of injury: C4-T4; AIS: A (n=5), B (n=1), C (n=1), D (n=0); tetraplegia (n 6), paraplegia (n=1); mean (SD) time since injury: 2.9 (1.9) years • MC (matched controls) Group (n=6): Mean (SD) age: 28.4 (10.5) years; 6M, 0F; level of injury: C4-T5; AIS: A (n=4), B (n=1), C (n=1), D (n=0); tetraplegia (n=5), paraplegia (n=1); and mean (SD) time since injury: 5.0 (6.2) years • Other group (n=10): Mean (SD) age: 30.9 (10.8) years; 7M, 3F; level of injury: C6-T11 & cauda equina; AIS: A (n=5), B (n=0), C (n=3), D/cauda equina (n=1/1); tetraplegia (n=2), paraplegia (n=8);	1. ABT (average dose: 7 hours per week over 4.6 months) appeared to promote improvements in sitting strength in four directions (0.6-0.8 kg per month) and dynamic balance in four of five directions (0.7-1.3 cm per month). 2. Individuals who had undergone an OMA had similar, but not greater, improvements in static and dynamic balance when compared with those who had ABT alone.

	mean (SD) time since injury: 6.8 (8.4) years **Treatment:** All participants participated in an outpatient and individualized ABT program with a minimum dose of three to five 3-hour sessions per week over 3 to 6 months. The ABT program included 1 hour each of (a) pre-gait (e.g., weight bearing in multiple positions, posture and balance training, crawling, and standing pre-gait activities) and/or gait training (e.g., BWSTT and overground gait training), (b) intense exercise (e.g., repetitive neuromuscular facilitation, mat mobility, strengthening and endurance exercises, WBV, biofeedback, virtual gaming, and/or musculoskeletal interventions), and (c) FES cycling and/or dynamic standing frame activities. * Participants in the OMA group underwent the OMA procedure (mean time since OMA = 3.7 ± 3.9 months) **Outcome Measures:** handheld dynamometer (peak force), measuring sitting strength – static balance, and the multi-directional reach test in sitting position measuring dynamic balance were assessed at initial examination, every 30 days, and at discharge from the ABT program.	
Williams et al. (2020); Canada Pre-post Level 4 N=14	**Population:** 14 participants with chronic SCI, been able to use an arm crank ergometer and with the ability to maintain an unsupported seated posture for at least 1 min; 8 males and 6 females; mean (± SD) age 44.3 (± 10.4) years; level of injury C4 (n=1), C5 (n=2), C6 (n=1), C7 (n=1), T4 (n=3), T5 (n=1), T11 (n=1), and T12 (n=3); AIS A (n=6), AIS B (n=5), AIS C (n=2), and AIS D (n=1); and mean (± SD) time since injury 21.7 (± 13.0) years. **Treatment:** Participants took part in a 5-week arm crank ergometry training program, which was delivered as a group "spin" 60 min class. Classes were held 3×/week and were standardized following an interval	1. 12 participants are reported for all outcomes. 2. After training, there were no significant improvements in any of the static balance measures during the eyes open condition; however, in the eyes closed condition, there was a significant improvement in root mean square velocity (p=.013) and AREA-CE (p=.047); and a trend toward significance in root mean square distance (p=.074) after training. 3. There were no significant improvements in LOS distance from pre- (387.5 mm

	training routine with varying bouts that manipulated resistance, cadence, and/or sitting condition. Approximately 30% of the 40-min arm crank ergometry workout consisted of sitting in unsupported posture. **Outcome Measures:** Seated balance control with participants seated on an elevated force plate (static balance [root mean square distance and root mean square velocity from the center of pressure trajectory; and the confidence ellipse area [AREA-CE]], and dynamic balance [LOS in eight cardinal directions]) were assessed within two weeks of the start and end of the intervention.	± 176.3 mm) to post-training (408.4 mm ± 205.2 mm) (p=.241).
Sliwinski et al. (2020); USA Case series Level 4 N=19	**Population:** 19 participants with SCI; level of injury C2-L5; complete injury (n=6), incomplete injury (n=10) and unknown (n=3); and mean time since injury 8.6 years. **Treatment:** Participants received Spinal Mobility program, which consisted in an 8-week community exercise program once a week in a community center setting for 4 hours and included a four-station circuit of resistance exercises, aerobic conditioning, trunk stability, and health education. **Outcome Measures:** mFRT was assessed at baseline and post-intervention.	1. The paired t-test for the mFRT demonstrated a statistically significant (p<0.001) improvement of 5 cm from 27.1 cm (± 16.7) to 32.1 cm (± 17.6) for participants at the conclusion of the intervention.
De Oliveira et al. (2019); Australia Case series Level 4 N=91	**Population:** 91 participants with non-progressive SCI; 65 males and 26 females; mean age (± SD) 35.3 (± 17.9) years; tetraplegia (n=49) and paraplegia (n=42); AIS A (n=31), AIS B (n=36), AIS C (n=15) and AIS D (n=9); and mean (± SD) time since injury 43.1 (± 51.4) months. **Treatment:** During 3 to 12 months, participants received ABT 1 to 4 times per week for 2-h sessions, which consisted in an exercise program individually tailored. The intervention involved three key elements (e.g., task-specific training, weight-bearing tasks and whole-body muscle strengthening) and involved training	1. There was a significant improvement over 12 months in overall mobility (p=.000), showing a change score in the Modified Rivermead Mobility Index of 2 points (95% CI: 1 - 2.3). 2. There was a significant improvement over 12 months in sitting balance (p=.000), showing a change of 0.2 in the SRD (95% CI: 0.1-0.22). 3. There were no interaction effects between time and the neurological level of injury,

	in different positions. Participants were encouraged to perform all modalities of exercise to their maximum capacity. **Outcome Measures:** General mobility (The Modified Rivermead Mobility Index) and balance in sitting (the seated reach distance [SRD]) were measured at baseline, 3-, 6-, 9-, and 12-month.	AIS score, or duration post-injury for most outcomes.
Bjerkefors et al. (2007); Sweden Pre-post Level 4 N=10	**Population:** 10 participants - 7 males and 3 females; 7 AIS A, 2 AIS B, 1 AIS C; level of injury between T3-12; mean age= 37.6 ± 12y; median years post-injury= 11.5y. **Treatment:** Participants paddled a modified kayak ergometer for 60 min 3 times a week for 10 weeks. **Outcome Measures:** anterior-posterior, medio-lateral angular and linear and twisting displacements on support surface translations – forward, backward and lateral; Kinematic Responses include: I-onset of acceleration (unpredictable), II-constant velocity, III-deceleration (predictable), IV-end of deceleration.	1. Anterior-posterior angular and linear and twisting angular during lateral translations for all kinematic responses were significantly decreased except II for anterior-posterior angular. 2. Medio-lateral angular displacements during lateral translations-significant decrease for kinematic response IV. 3. Medio-lateral linear displacement during lateral translations-no significant effects for all kinematic responses.
Bjerkefors & Thorstensson (2006); Sweden Pre-post Level 4 N=10	**Population:** 10 participants - 7 males and 3 females; 7 AIS A, 2 AIS B, 1 AIS C; level of injury between T3-12; mean age= 37.6 ± 12y; median years post-injury= 11.5y. **Treatment:** Participants paddled a modified kayak ergometer for 60 min 3 times a week for 10 weeks. **Outcome Measures:** Sit and reach tests.	1. Sit and reach tests significantly increased from 3.5cm at baseline to 5.8cm at the end of 10 weeks.
Grigorenko et al. 2004; Sweden Pre-post Level 4 N=24	**Population:** Experimental group: 12 participants - 9 males and 3 females; chronic SCI; 6 AIS A, 5 AIS B, 1 AIS C; level of injury: T2-11; mean age=40y; median years post-injury= 17y; Control group: 12 people without SCI who did not train. **Treatment:** Participants were involved in 2-3 modified kayak sessions on open water per week for 8 weeks.	1. Small effects in all 3 variables except on the median frequency in the sagittal plane (opposite to becoming normal). 2. Before training and comparing to the control group, all variables differed. 3. Small effects on balance variables-no significant effect. 4. Kayak training did not create significant sagittal or frontal

	Outcome Measures: sitting quietly on a force plate-standard deviation (SD), median velocity, median frequency.	CoP displacement with peoples with SCI. 5. 9 of 12 participants with SCI stated that they had noted improvements in balance control in their wheelchair directly after their period of training.