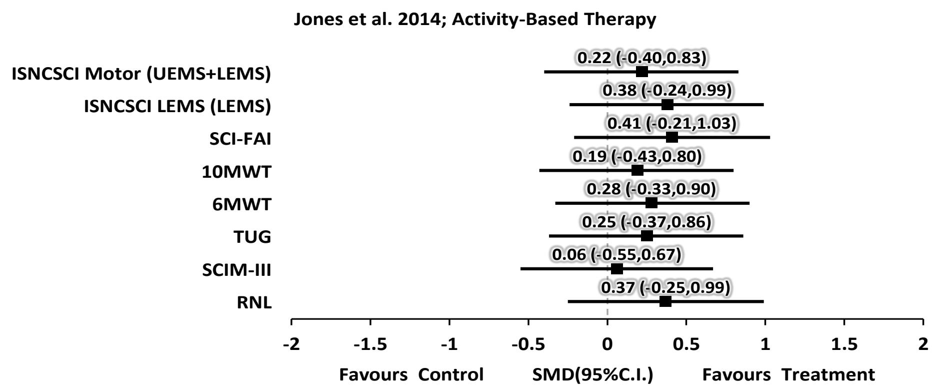
Table 10. Non-Body-Weight Supported Training and Standing Balance

Author Year Country Score Research Design Total Sample Size	Methods	Outcome
Unger et al. (2021); Canada RCT PEDro=8 Level 1 N=21	**Population:** 21 participants with chronic motor incomplete SCI; 7 males and 13 females; mean (± SD) age 56.9 (± 14.4) years; level of injury cervical (n=10), thoracic (n=8) and lumbar (n=2); AIS C and D (n=n/a); and mean (± SD) time since injury 90.4 (± 109.7) months. **Treatment:** Participants were randomized into Perturbation-based Balance Training group (n=10) or Conventional Intensive Balance Training group (n=11) for 1 hour, three times per week for 8 weeks. Both groups received a balance training which comprised on individualized, challenging static and dynamic balance tasks. The Perturbation-based Balance Training group also experienced manual pushes and pulls from one member of the research team. **Outcome Measures:** Reactive balance by stimulating a forward fall (measured by the behavioral response and foot contact time during the Lean-and-Release test); Mini-BESTest; Community Balance and Mobility Scale (CB&M) (only 13 participants [Perturbation-based Balance Training n=7, Conventional Intensive Balance Training n=6] were able to complete the CB&M); lower extremity manual muscle testing of 12 muscles groups bilaterally (hip flexors, extensors, adductors, abductors, internal rotators, external rotators, knee flexors and extensors, ankle dorsiflexors and plantarflexors, invertors, and evertors); gait parameters (step length, walking speed, cadence, and double support percentage) during two passes of the walkway at a self-selected speed using a gait aid if necessary; balance confidence (ABC Scale); and fall concern (FES-I) were assessed at baseline (x 2), at midpoint (4-week), at final of treatment (8-week), at 3 months post-training follow-up and at 6	1. Six Conventional Intensive Balance Training and seven Perturbation-based Balance Training participants were able to progress to spending time outside of the harness during training. 2. Participants in the Perturbation-based Balance Training group experienced more single step responses ($p=0.01$) and multi-step ($p=0.03$) but not fall responses ($p=0.41$) during training. 3. For Lean-and-Release test, there were improvements in reactive stepping ability ($p=0.049$). There were no differences in reactive stepping ability between groups. 4. There was a significant effect of time ($p<0.01$), but no group or interaction effects for Mini-BESTest, CB&M, FES-I, and ABC Scale changes. 5. There were improvements from baseline to 4-week ($p<0.05$) and baseline to 8-week ($p<0.05$) but not between the 4- week and 8-week scores. There were no differences between groups with respect to the proportion of participants who exceeded the MDC ($p=0.12$). 6. At the 3-month assessment all participants retained their gains as demonstrated by significant effects of time on the Lean-and-Release test

	months post-training follow-up. During the 6-month follow-up period the number of falls experienced by participants were tracked by conducting a fall survey.	behavioral response (p=0.03), Mini-BESTest (p=0.01), and FES-I (p=0.01), but not on the ABC Scale (p>0.05). 7. There was one AE: A controlled fall during a training perturbation occurred for a Perturbation-based Balance Training participant who was practicing activities outside of the harness without resulting in any injury.
Amatachaya et al. (2021); Thailand RCT PEDro=6 Level 1 N=54	**Population:** 54 ambulatory persons with SCI, with the ability of independent walking over at least 17 m with or without assistive devices (or a FIM locomotor score of 5-7); 36 males and 18 females; mean (± SD) age 51.7 (± 15.4) years; paraplegia (n=34) and tetraplegia (n=20); AIS C (n=15) and D (n=39); and mean (± SD) time since injury 88.3 (± 79.6) months. **Treatment:** Participants were randomly stratified into: • Participants in the control group (n=26) performed an overground walking training over a hard flat, and smooth surface. • Participants in the experimental group (n=28) performed a walking training on a walking track (10m long) with different surfaces (walking track with different surfaces consisted of artificial pebbled, grass, and soft areas). Training program was performed for 30 min/d, 5 d/wk over 4 weeks; and participants walked at their usual speed without fatigue. **Outcomes Measures:** 10MWT, TUG, FTSST, 6MWT, and fall data were assessed at baseline, after 2- and 4-week training, and at 6 months follow-up.	1. All participants in the experimental group could safely walk over a walking track with different surfaces without any AEs. 2. Only the participants in the experimental group showed significant improvements after 2- and 4-week training for the 10MWT, 6MWT, TUG, and FTSST (p<0.001). 3. There were no significant differences after 6 months follow-up compared with at baseline for both training programs. 4. During 6-month follow-up, 5 (9 falls in total) participants in the experimental group and 12 (39 falls in total) in the control group experienced falls, with a relative risk of 0.39 for participants in the experimental group as compared to those in the control group.
Lotter et al. (2020); USA RCT PEDro=6	**Population:** 16 participants with motor incomplete SCI and the ability to walk overground at self-selected speeds <1.0 m/s without physical assistance but with devices and bracing below the knee as needed; 10 males and 6 females; mean age 48.5 years; injury level C1-C4 (n=6), C5-	1. Task-specific training group had significant higher stepping parameters and average peak heart rate reserve during the training; however, average number of sessions completed, and

Level 1 N=16	C8 (n=4) and T1-T10 (n=6); and mean time since injury 4.1 years. **Treatment:** Participants were randomized to receive up to 20 sessions of either task-specific or impairment-based training (both of 40 min sessions) over less than 6 weeks followed by the alternate training paradigm, with a break of at least 4 weeks between interventions: • Task-specific training consisted of stepping practice in variable contexts (i.e., speed-dependent treadmill training, skill-dependent treadmill training, overground training, and stair climbing) within 1-hour sessions. • Impairment-based training consisted of non-walking interventions, including strengthening, balance tasks, aerobic conditioning and practice of transfers to improve lower extremity and trunk strength and coordination. A primary intent of both strategies was to achieve high cardiovascular intensities (e.g., 70%-80% heart rate reserve and RPE >14). **Outcome measures:** Fastest speed over short distances, peak treadmill speed, self-selected speed, 6MWT, BBS, FTSTS, ABC scale, PROMIS-Mobility score, LEMS, and incidence of AEs were assessed prior to and following each training protocol.	average and maximum RPEs were similar between groups. 2. For BBS, there were no differences of time x training group-interactions, but there was a significant time effect. 3. Significantly greater gains in ABC but not in PROMIS-Mobility score were observed following task-specific vs. impairment-based training (10 ± 11 vs. 1.8 ± 11, p=.02). 4. There were no serious AEs during training intervention; however, between-group analysis revealed significantly greater cumulative incidence of minor AEs during task-specific (n=23) vs. impairment-based training (n=8), p<.01; with specific differences included greater number of falls (p=.03).
Brazg et al. (2017); USA RCT cross-over PEDro=6 Level 1 N=15	**Population:** 15 participants with a chronic motor incomplete SCI at neurological injury level of T10 or above; 11 males and 4 females; mean (± SD) age 49 (± 8.1) years; injury level high cervical (C1-C4) (n=4), low cervical (C5-C8) (n=6), and thoracic (T1-T10) (n=5); AIS C or D (n=15); and mean (± SD) time since injury 7.7 (± 7.9) years. **Treatment:** Participants were randomized to receive sessions of either a high- or low-intensity locomotor training over 4 to 6 weeks, followed by a 4-week wash-out. Both high- and low-intensity locomotor training consisted of up to 20 one-hour sessions at a frequency of 3 to 5 days/week over ≤ 6 weeks. The goals of sessions were	1. No significant AEs were noted. 2. The average number of sessions completed and number of steps within sessions were not significantly different between groups. 3. No significant main or interaction effects were observed for BBS scores.

	to achieve 40 min of stepping practice while maintaining the desired HRs or RPEs (high-intensity training [70%-85% HR_{max}, 15 to 17 {"hard" to "very hard"}] vs. low-intensity training [50%-65% HR_{max}, 11 to 13 {below "somewhat hard"}]). Each session was composed of 4 different stepping tasks practiced over ~10 min per session, including speed-dependent treadmill training, skill-dependent treadmill training, overground training, and stair climbing. **Outcome Measures:** 6MWT, peak treadmill speed, walking speed over short distances at self-selected speeds and fastest-possible speeds, BBS, and LEMS were assessed prior to and following each 4- to 6-week training paradigm.	
Jones et al. (2014a); USA RCT PEDro=5 Level 2 N=38	**Population**: 38 participants - 27 males and 11 females; chronic, motor incomplete SCI; AIS C or D; age range= 22-63y; years post injury= >12 months. **Treatment**: A total of 9h/wk of ABT for 24 weeks including developmental sequencing; resistance training; repetitive, patterned motor activity; and task-specific locomotor training. Algorithms were used to guide group allocation, FES utilization, and locomotor training progression. **Outcome Measures:** Neurologic function (ISNCSCI), 10MWT, 6MWT, and TUG test, community participation (SCIM-III, and Reintegration to Normal Living Index), metabolic function (weight, body mass index, and Quantitative Insulin Sensitivity Check).	1. Average time for completing the TUG test was substantially (but not significantly) decreased for experimental (-37.2s) versus control group (-6.2s) participants. 2. Significant improvements were noted on the modified SCI-FAI for participants in the experimental group. Scores improved by an average of 5±8.03 points compared with no gain for participants in the control group. 3. The intervention had no immediate beneficial impact on SCIM-III and Reintegration to Normal Living Index).
Jones et al. (2014b); USA Secondary analysis of results from an RCT PEDro=5 N=38	**Population**: 38 participants - 27 males and 11 females; chronic, motor incomplete SCI; AIS C or D; age range= 22-63y; years post injury= >12 months. **Treatment**: A total of 9h/wk of ABT for 24 weeks including developmental sequencing; resistance training; repetitive, patterned motor activity; and task-specific locomotor training. Algorithms were used to guide group allocation, FES utilization, and locomotor training progression. **Outcome Measures:** Walking speed and endurance (10MWT and 6MWT) and functional ambulation (TUG test).	1. On the basis of the most conservative estimate, 18%, 26%, and 32% of the participants demonstrated clinically significant improvements on the TUG test, the 10MWT, and the 6MWT, respectively. 2. This secondary analysis identified likely responders to ABT on the basis of injury characteristics: AIS classification, time since

<table>
<tr><td></td><td></td><td>injury, and initial walking ability.
3. Training effects were the most clinically significant in AIS grade D participants with injuries <3 years in duration.</td></tr>
<tr><td></td><td colspan="2">Effect Sizes: Forest plot of standardized mean differences (SMD ± 95%C.I.) as calculated from pre- and post-intervention data.

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<tr><td>Jayaraman et al. (2013);
USA
RCT cross-over
PEDro=5
Level 2
N=5</td><td>Population: Five participants with chronic SCI; 5 males; mean (SD) age: 50 (12) years old; injury level: C2 (n=1), C3 (n=1), C5 (n=1), C6 (n=1), T7 (n=1); AIS C (n=2) and AIS D (n=3); and mean time since injury: 211,2 months.
Treatment: Participants were randomly assigned to 4 weeks (12 sessions) of either maximal-intensity intermittent resistance training or conventional progressive resistance training (2-months washout). Targeted muscle groups included bilateral knee flexors/extensors and ankle dorsiflexors/plantarflexors.
• Maximal-Intensity Resistance Training: The protocol was conducted using an isokinetic dynamometer. Participants performed 3 sets of 10 repetitions of maximum volitional effort of isometric contractions, each repetition lasting 5 seconds with a 5-second rest between repeated maximum volitional efforts. A 2-minute rest period was given between each set of 10 repetitions. Verbal encouragement, asking the participants to give their maximal effort with every contraction and visual feedback through a</td><td>1. The BBS of the maximal-intensity resistance training condition showed a significant increase when compared with the conventional progressive resistance training condition (p=0.05).
2. Conventional progressive resistance did not show any within-condition difference for BBS following training. However, with the maximal-intensity resistance training condition, BBS showed significant increases in the balance scores (p=0.01).</td></tr>
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	computer screen showing their torque curves, was provided during the training. • Conventional Progressive Resistance Training: The protocol was conducted using specific strength training machines designed for the targeted muscle groups. The exercise regimen was developed using the American College of Sports Medicine's general recommendations for physical rehabilitation interventions for individuals with neurological injuries. Participants began their first training session by performing up to 12 repetitions at 60% to 65% of their predetermined one-repetition maximum. After completing 3 sets of 10 to 12 repetitions, a 5% to 10% increase in weight was added for the next training session. Verbal encouragement and rest breaks between exercise sets were similar to the other training condition. **Outcome Measures:** BBS was assessed 1 day before and 1 day after the training protocols.	
Sadeghi et al. (2019); Iran RCT PEDro=4 Level 2 N=16	**Population:** 16 participants with SCI; mean age 36.15 years; level of injury between T1 and T12; AIS A (n=6), AIS B (n=6), AIS C (n=2) and AIS D (n=2); and mean time since injury 5.15. **Treatment:** Participants were randomly assigned to rebound group (n=8) or control group (n=8). The rebound group received rebound therapy exercise (in a sitting or lying position) to increase their balance and stability using an appropriate trampoline. The exercise programs lasted 10 to 30 min (with a progression through the intervention period). Exercise durations were set at 5-min intervals (with heart rate reserve maintained at 50% to 70%) with 3-min rest periods 3 times per week over the 12 weeks. **Outcome Measures:** Standing stability parameters (i.e., excursion, velocity, and path length of the CoP in mediolateral	1. Interactions were significant for all 6 variables except excursion of CoP in mediolateral plane and the path length of CoP in anteroposterior plane; meaning that the control group had no progress, whereas the rebound group made a significant improvement (e.g., the mean values of the center of pressure excursion in the antero-posterior plane were 37.8 [15.4] mm and 20.6 [8.4] mm before and after the exercise [p=0.05], respectively; or the velocity of center of pressure in antero-posterior was 39.6 [15.5] m/s before and 22.7 [14.9] mm/s after the exercise [p=0.004]).

	and anteroposterior plane) were assessed before and after the exercise intervention by force plate.	
Neville et al. (2019); USA Pre-post Level 4 N=15	**Population:** 15 participants with chronic and incomplete SCI; 12 males and 3 females; mean (± SD) age 41.5 (± 16.9) years; level of injury cervical (n=10), thoracic (n=2) and lumbar (n=3); AIS C (n=12) and AIS D (n=3); and range time since injury 7-55 months. **Treatment:** The protocol consisted of 12 to 15 weeks of overground locomotor training 2 times per week, which consisted of three, 4-week segments. For each training session, focus alternated between uniplanar and multiplanar movements. Each 90-min training session consisted of 5 training segments: joint mobility, volitional neuromuscular activation, task-isolation, task-integration, and activity rehearsal. Individualized rate of progression over the training period was tracked in-session and altered by varying movement complexity, resistance, velocity, and volume of the specific tasks. All exercises were performed under volitional control without the assistance of BWS harnesses, robotic devices, or electrical stimulation. **Outcome Measures:** BBS and the SCI-FAI were assessed for all participants at baseline and post-intervention. Spatiotemporal measures were collected from the last 7 participants who walked on a 6-meter pressure-sensitive walkway.	1. 12/14 participants demonstrated increased BBS scores postintervention with a mean score improvement of 4.53 ± 4.09 ($p<0.001$). 2. 9/14 participants had improved SCI-FAI scores with a mean score increase of 2.47 ± 3.44 ($p=0.01$). 3. None of the gait parameters (captured overground by a pressure-sensitive walkway [e.g., step length, step width, percent stance, and stance-to-swing time ratio]) achieved statistical significance. 4. Step length increased 3.7 cm (40.6-44.3 cm; $p=0.55$) and step width increased 1.8 cm (14.5-16.3 cm; $p=.039$); meanwhile percent stance time decreased 2.8% (76.8%-74.0%; $p=0.25$) and stance-to-swing time ratio decreased 0.4 (3.5-3.1; $p=0.33$).
Holleran et al. (2018); USA Pre-post Level 4 N=4	**Population:** 4 participants with chronic SCI and able to walk 10 m without physical assistance but with assistive devices and bracing below the knee as needed; 3 males, 1 female; age range: 18-48 years; AIS C (n=2), AIS D (n=2); injury level: C5 (n=2), C7 (n=1), T3 (n=1); and duration post-injury (14-53 months). **Treatment:** Participants received up to 40 sessions at 3 to 5 times per week within 10 weeks. Each 1-hour session allowed up to 40 minutes of stepping training in variable contexts at high-intensity, with rest breaks as needed. Targeted training intensities were up to 85% of age-predicted maximum HR.	1. BBS scores increased 2.8 ± 0.96 from pre- to post-intervention. 2. In the participants who attended follow-up testing (n=3), gains in BBS were not maintained at least 1 year following training, with scores similar to pretraining assessments.

	• During the first 2 weeks (6-10 sessions), only forward stepping on a motorized treadmill was performed to allow participants to accommodate to the large volumes of stepping at higher cardiovascular intensities. Minimal BWS and handrail support were provided only as needed. • Training over the remaining weeks was divided into 10-minute increments of speed-dependent treadmill training, skill-dependent treadmill training (e.g., stepping in different directions, applied perturbations to challenge various aspects of stepping in the form of obstacles and/or weights on the trunk or limbs, limiting use of upper extremities, or inclined surfaces), overground training, and stair climbing, while trying to maintain the targeted HR range. **Outcome Measures:** BBS was tested prior to (*pre*) and following (*post*) up to 40 training sessions, with follow-up assessments at least 1 year post training.	
DiPiro et al. (2016); USA Pre-post Level 4 N=10	**Population:** 10 participants with chronic SCI; the ability to walk independently for a minimum of 10 m with or without an assistive device and a self-selected walking speed >0.1 and <1.15 m^{-1}; 5 males and 5 females; mean (SD) age: 57.9 (9.3) years; AIS C (n=1) and AIS D (n=9); injury level: Cervical (n=9) and thoracic (n=1); and mean (SD) time since injury: 11.1 (9.6) years. **Treatment:** Participants completed a 6-week (3 sessions per week; 20 min per session) non-task-specific, progressive aerobic exercise training program; performed on a NuStep T5xr recumbent cross-trainer. The selected exercise modality required bilateral reciprocal stepping against resistive forces and synchronized upper extremity movement; thus, a total-body workout was achieved. The weekly sessions included two steady-state exercise sessions at the target intensity and one high-intensity interval training session.	1. Although trends toward improvement were seen in the BBS, there were not statistically significant (p=0.15) changes.

	The intervention was developed to meet the SCI guidelines for aerobic activity and prepare participants to reach the levels of aerobic exercise recommended by the American College of Sports Medicine and 2008 Physical Activity Guidelines for Americans. **Outcome Measures:** BBS was assessed before and following the aerobic exercise training intervention.	
Oh & Park (2013); Korea Pre-post Level 4 N=4	**Population:** 4 participants with incomplete SCI (3M, 1F); 33-63 yrs old; 2 AIS C, 2 AIS D. **Treatment:** 4-week training program consisting of 4 stages with different community situations. In each stage, patients underwent 1 hr sessions of community-based ambulation training; 6 times/wk for a 4-week period. During the training period, the level of difficulty was increased weekly with progressive changes in environmental demands. **Outcome Measures:** 10MWT; 6MWT; community walk test, walking ability questionnaire, and ABC scale.	1. All outcome measures indicated an improvement in lower limb function from baseline to 4-wk follow-up, as well as from baseline to the 1-yr follow-up.