Table 6. Electrical Stimulation for Sitting Balance

| Author Year<br>Country<br>Research Design<br>Score<br>Total Sample Size | Methods | Outcome |
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| Goel et al. (2023);<br>India<br>RCT<br>PEDro=6<br>Level 1<br>N=18 | **Population:** 18 participants with SCI and AIS B, C, or D:<br>• VR + CPT Group (n=9): 8M, 1F; mean age: 39.11 years; and mean time since injury: 7.56 months<br>• FES + CPT Group (n=9): 7M, 2F; mean age: 41.89 years; and mean time since injury: 6.89 months<br>**Treatment:** Eligible participants were randomized into the VR group and FES group; both groups received conventional physical therapy (CPT) treatment as well.<br>Each participant was exposed to 45-min session of VR or FES along with the CPT session of 30 min, conducting five sessions per week for 4 consecutive weeks:<br>• VR training: Immersive type of VR, with games focused on trunk movements while the participant was in sitting position.<br>• Functional Electrical Stimulation: FES was used to induce muscle contraction in erector spinae and rectus abdominis in the thoraco-lumbar area, bilaterally on the motor points. Participants were in sitting position with back unsupported and, hands crossed and kept on shoulders or while performing reach outs. Three phases in the FES program used were as follows: first warmup, followed by work phase, and lastly recovery phase in simultaneous mode was used. The pulse frequency for warmup and recovery was set to 3 Hz. Both of these phases last for 5 min. The duration of the work phase was 30 min with a frequency set to 18 Hz. The intensity of the current was individually elevated to a level at which visibly strong contraction is | 1. mFRT: Within-group analysis reported statistically significant improvement (p=0.001) in VR + CPT group as well as in FES + CPT Group. Between-group analysis revealed that trunk stability was more significantly improved in VR + CPT group as compared to FES + CPT group (p=0.003) with a 95% CI of 1.52–6.07. The calculated mean change between both the groups of 4.79 cm was more than the previously established MCID value with a large effect size (1.67), thus indicating clinical improvement.<br>2. FIST: Statistically significant result has been calculated in VR + CPT group (p=0.01) as well as in FES + CPT group (p=0.01). Between-group analysis revealed significant differences proving VR is a more effective treatment than FES (p=0.002) within the calculated range of −2–13 points. Clinical significance was reported with calculated changes in scores (7 points) being more than MDC of the scale and medium effect size (0.72) for both the groups.<br>3. SCIM-III: For all domains, there was statistically significant improvement in the VR + CPT group (p=0.01) and the FES + CPT group (p=0.01). |

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| | obtained, but he/she having no unpleasant sensation. Muscles were activated simultaneously to generate co-activation and, therefore, to stiffen the trunk.<br>CPT consisted of 2 sets of 12 repetitions of each range of motion exercises for both upper and lower limbs and mat exercises like rolling, long sitting and kneeling (2 repetitions with 5 min hold each).<br>**Outcome Measures:** mFRT, FIST (both static and dynamic components were evaluated), and SCIM-III were assessed at baseline, 2 and 4 weeks after intervention. | 4. The VR + CPT group was found to be more statistically significant than the other group, with a p=.006, 0.004, and 0.006 in self-care, mobility, and total scores, respectively, but non-significant in respiration and sphincter management. In both groups, no significant difference was noted in terms of the level of independence clinically as median changes in total scores (8 points) were less than the established MCID. |
| Bayraktar et al. (2024);<br>Turkey<br>RCT<br>PEDro=5<br>Level 2<br>N=34 | **Population:** 34 participants with complete (AIS A) SCI at least 3 months prior and able to sit unsupported in a wheelchair.<br>• Experimental group (n=17): Mean (SD) age: 34.8 (12.8) years; 6F, 11M; injury level: T4-T7 (n=8), T8-T12 (n=9)<br>• Control group (n=17): Mean (SD) age: 39.5 (13.6) years; 4F, 13M; injury level: T4-T7 (n=8), T8-T12 (n=9)<br>**Treatment:** Both groups underwent routine rehabilitation during hospitalization, including active or passive range of motion exercises, stretching and balance coordination exercises. Additionally, for three times a week for four weeks, participants were assigned into one of two groups:<br>• The control group received abdominal isometric strengthening exercises, applied three sets per session. The therapy provided to the control group was identical to that of the experimental group, with the exception of the stimulation.<br>• The experimental group received abdominal muscle stimulation for 10 min per session. Five minutes were allocated to bilateral rectus abdominis and 5-min to bilateral obliques externus, obliques internus and transversus abdominis muscles. To reduce muscle fatigue, the stimulation frequency was set at 25 | 1. Significant changes were observed in the experimental group's mFRT and trunk control test between the pre- and post-assessment points ($p<0.05$). Similarly, in the control group, significant changes were observed ($p<0.05$).<br>2. The MD between groups for the mFRT area was 242.8 $cm^2$ (95% CI: 181.3–329.8; effect size 0.92; $p<0.001$) and 5.0 points for trunk control test (95% CI: 3.9–6.0; effect size 0.98, $p<0.001$), favoring the experimental group. |

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| | Hz (low frequency) and to increase the number of stimulated muscle fibers, the stimulus duration was adjusted to 300 μs. The amplitude was increased to a maximum of 100 mA until a noticeable contraction was observed. The experimental group received electrical stimulation triggered by electromyography (EMG) activity during 10-s intervals. Each stimulation epoch was initiated by flexing the head. During each stimulation period, participants voluntarily flexed their head, inducing contraction in the abdominal muscles. The EMG device detected this contraction and delivered electrical stimulation. The experiment consisted of cycles of 10 s of stimulation followed by 10 s of rest, totaling 20 s per cycle, at a rate of three cycles per minute.<br><br>*Electromyography triggered electrical stimulation (EMG-ES) is a method that uses a biofeedback-enabled electrical stimulation device to detect muscle contractions. The EMG signal triggers the muscle stimulation mode of the device.<br><br>**Outcome Measures:** mFRT, trunk control test, trunk muscles ultrasonographic muscle thickness measurement, and pulmonary function tests were assessed before and after the treatment. | |
| Bergmann et al. (2019);<br>Estonia<br>RCT (cross-over trial)<br>PEDro=5<br>Level 2<br>N=5 patients with SCI and 8 participants without SCI | **Population:** 5 participants with tetraplegia; mean age (± SD) 39.2 (± 7.1) years; level of injury C5-C6; AIS B (n=4) and AIS C (n=1); and mean (± SD) time since injury 10.8 (± 30) years. 8 control group participants, whose gender and age were matched with participants with SCI' respective characteristics.<br><br>**Treatment:** Participants with SCI were grouped in two groups (SCI_FES+TE and SCI_TE) and a cross-over design with a 7-month break was performed:<br>• Therapeutic exercise (TE) home program consisted of 8 different exercises (aimed at improving sitting balance and upper body posture) for 6 weeks, twice a week. Control group | 1. After six weeks of intervention, LOS of flexion increased 31.3% in SCI_FES+TE (p=0.465) but decreased by 12.1% in SCI_TE (p=0.345); LOS of lateral flexion right increased 5.0% in SCI_FES+TE (p=0.686) and 2.7% in SCI_TE (p=0.465) with no statistically significant difference between the 3 study groups post-intervention (p=0.054); and LOS of lateral flexion left increased 20.1% in SCI_FES+TE (p=0.686) and 21.3% in SCI_TE (p=0.500) with no significant |

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| | carried out only one round of therapy to collect reference data.<br>• FES: Erector spinae and rectus abdominis were stimulated simultaneously and bilaterally with a 4-channel FES device for 30-40 min.<br>**Outcome Measures:** Dynamic sitting balance (LOS using a CONFORMat sensor) was assessed on the last therapy session of the first intervention period and the first therapy session of the second intervention period after a seven-month break. | differences between groups (p=0.116) after the intervention.<br>2. After the seven-month break period, LOS of flexion decreased by 31.9% (p=0.138), LOS of lateral flexion right decreased by 27.3% (p=0.225), and LOS of lateral flexion left decreased by 46.4% (p=0.043). |
| Tharu et al. (2023);<br>China<br>Pre-post<br>Level 4<br>N=5 | **Population:** 5 participants with complete (AIS A) and chronic SCI and with impaired trunk and sitting function; 2 males and 3 females; mean (± SD) age 42.0 (± 13.7) years; level of injury C4 (n=1), C5 (n=2), C6 (n=1), and C7 (n=1); and mean (± SD) time since injury 9.3 (± 7.4) years.<br>**Treatment:** Participants underwent two phases of treatment (each lasting for 12 weeks [TSCS + task-specific rehabilitation followed by task-specific rehabilitation alone]). Participants attended one to three sessions per week.<br>• Task-specific rehabilitation (TSR) consisted in the training in a variety of positions, ranging from sitting in a wheelchair to lying on a bed or a floor mat.<br>• For transcutaneous electrical spinal cord stimulation (TSCS) + TSR treatment, the participant was asked to perform various task-specific exercises for 45–60 min each session.<br>TSCS were applied with two stimulation electrodes attached between T11–T12 and L1–L2.<br>**Outcome Measures:** mFRT; static and dynamic balance (by trunk control test; functional sitting balance (by FIST); and ISNCSCI motor levels were assessed at baseline; at 6, 12, 18 and 24 weeks; and at 6 weeks follow-up. | 1. Compared to baseline, the overall forward reach distance significantly increased after TSCS+TSR (p=0.026), and further slightly raised during TSR (p=0.024), which was maintained throughout the follow-up period (p=0.026).<br>2. The overall mean trunk control test and mean FIST scores significantly increased after TSCS+TSR administration, increased further during TSR, and showed a slight reduction at the follow-up period. All these values were significantly greater than the baseline values ($p$<0.01). However, there was no significant difference between TSCS+TSR and TSR, between TSCS+TSR and follow-up, or between TSR and follow-up. |
| Tefertiller et al. (2022);<br>USA | **Population:** 50 participants with cervical SCI receiving outpatient therapy; mean (± SD) age 34.1 (± 16.7) years; level of injury C1 (n=3), C2 (n=2), C3 (n=6), C4 (n=21), C5 (n=7), | 1. The mFRT effect size was moderate to large as the mean improvement (13.6 |

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| Pre-post<br>Level 4<br>N=50 | C6 (n=9), and C7 (n=2); AIS A (n=5), AIS B (n=8), AIS C (n=23), and AIS D (n=14); and mean (± SD) time since injury 5.4 (± 2.4) months.<br>**Treatment:** Upper extremity training sessions were performed for 1.5 hours/day, 5 days/week for a minimum of 40 sessions and consisted of 3 components:<br>• 60 min of functional task-specific practice in combination with wide pulse/high frequency FES (WPHF-FES) to the trunk and upper extremities.<br>• 15 min of functional training without WPHF-FES.<br>• Home integration training.<br>The Sage System (pulse width available of 500 μs) (n=f) and XciteÔ system (pulse width available of 1000 μs) (n=15) were used to stimulate the muscle groups.<br>**Outcome Measures:** Trunk stability (mFRT) was assessed at baseline and at outpatient therapy discharge. | cm) was greater than established MDC (5.16 cm).<br>2. After adjusting for completeness of injury; the motor incomplete group experienced a moderate to large effect size for mFRT (15.6 cm, p<.001); and the motor complete group experienced non-significant improvement in changes in mFRT (6.5, p=.074).<br>3. After adjusting by treatment pulse width, significant results for mFRT remained robust across all analyses. However, the 1000 μs group showed more changes in the mFRT scores than the 500 μs group (23.4 cm vs. 10.0 cm). |
| Kouwijzer et al. (2022);<br>The Netherlands<br>Post-test<br>Level 4<br>N=11 | **Population:** 11 wheelchair rugby athletes with tetraplegia; 10 males and one female; mean age 41.6 years; level of injury C4 (n=2), C4-C5 (n=2), C5-C6 (n=1), C6 (n=4) and C7 (n=2); and mean time since injury 17.5 years.<br>**Treatment:** A single session of electrical stimulation was applied on the rectus abdominis, obliquus externus abdominis and erector spinae muscle simultaneously to create co-contraction.<br>**Outcome Measures:** Trunk stability (n=9) (reaching task [the participant sat in his/her own daily wheelchair without any strappings with the purpose of to push away a tube as far as possible in a forward, lateral and diagonal direction]) was measured and compared between the electrical stimulation and non-electrical stimulation condition. | 1. Total reaching with electrical stimulation was significantly (p=0.03) higher (9%, large effect size) compared with the non-electrical stimulation condition.<br>2. Of the individual reaching directions, the diagonal direction with dominant arm was the only task that scored significantly (p=0.04) higher with electrical stimulation (33%, medium effect size) compared with the non-electrical stimulation condition. |