

## Trunk

There are six known articles that examine trunk function in participants who walk in an exoskeleton. Most of the articles (4) use subjects who are post stroke (CVA). There is one article each on subjects with Multiple Sclerosis (MS) and spinal cord injury (SCI). One study used electromyography (EMG) to measure the electrical activity of the trunk muscles. Most studies (4) utilized the Trunk Control Test (TCT), which is a 4 item test with a maximum score of 100 that asks subjects to roll to both sides, balance in a sitting position, and sit up from lying down. Higher scores indicate more normal function. One study utilized the Trunk Impairment Scale (TIS) which has a maximum score of 23 that is derived from three subscales: static sitting balance, dynamic sitting balance, and coordination. Similar to the TCT, higher scores indicate more normal function. All studies examining trunk function used the Ekso1.1/EksoGT/EksoNR, referred to as “Ekso” in this paper.

### Stroke (CVA)

Four studies examined patients post CVA walking in the Ekso and assessed them using the TCT. None of these studies had trunk function as the primary outcome measure.

One study showed an improvement in trunk function regardless of treatment type. This was a multicenter randomized control trial of 75 subacute stroke subjects randomized into an Ekso group (n=38) or a control group (n=37) that received 3 weeks of treatment at a frequency of 5 times per week.<sup>1</sup> TCT improved for both groups over the duration of treatment, and there were no significant between group differences.<sup>1</sup>

Another study demonstrated improvement in the whole sample of 20 subjects with subacute CVA who completed 15 sessions of Ekso walking over three weeks in addition to conventional physical therapy. While the average TCT score changed by  $17.88 \pm 13.79$ , this was not calculated as a significant change.<sup>2</sup> It is important to note that a ceiling effect may have caused these non-significant results, as each subject's TCT score was the maximum of 100 at post-test.<sup>2</sup>

Some studies demonstrated a different impact on trunk function resulting from using Ekso in different chronicity or impairment of subjects. In one study, 23 participants (12 subacute, 11 chronic) walked for 12 sessions scheduled 3 times per week in Ekso.<sup>3</sup> In the subacute participants, while the median score for the TCT remained the same, there was a statistically significant change between baseline and midway point, as well as between baseline and end of study.<sup>3</sup> However, there was no change noted in TCT for the patients with chronic CVA.<sup>3</sup> Forty-six subacute stroke patients were enrolled and completed  $15 \pm 2$  sessions of Ekso walking offered 3-5 times per week.<sup>4</sup> At the initiation of the study, 32 patients were able to walk independently and 14 were not.<sup>4</sup> In the overall sample, TCT improved from baseline to end of study (median 61 to 74), but this was largely due to the magnitude of improvement seen in ambulant patients who improved from a median of 61 to 87.<sup>4</sup> Those who became ambulant and those who remained non-ambulant showed no change in TCT.<sup>4</sup> This study also separated subjects based on motor impairment, and TCT did not increase significantly in those with severe motor impairment.<sup>4</sup>



### Spinal Cord Injury (SCI)

The single article looking at trunk function includes only 8 participants with chronic motor-complete paraplegia.<sup>5</sup> Each participant walked in three conditions at the same speed: Ekso assisted walking overground, Ekso assisted walking on a treadmill, and Lokomat assisted walking, which is a treadmill based robotic system.<sup>5</sup> During each condition, EMG signals were recorded bilaterally on the trunk.<sup>5</sup> Results demonstrated greater recruitment of trunk muscle EMG elicited with Ekso walking compared to Lokomat.<sup>5</sup> It was also found that outcomes in Ekso were similar when walking overground and on a treadmill, indicating that using an assistive device was not the cause for the differences in muscle activation.<sup>5</sup> Trunk muscle activation patterns during Ekso walking were comparable to EMG patterns seen in able-bodied subjects while walking on a treadmill.<sup>5</sup> Trunk muscle activation in the Lokomat was comparable to quiet supine lying.<sup>5</sup> The level of muscle activation facilitated by walking in Ekso was greater than the subjects could produce by voluntarily contracting these muscles.<sup>5</sup>

### Multiple Sclerosis (MS)

The only existing study using subjects with MS is a case study examining a female aged 51 with secondary progressive MS who received 15 sessions of Ekso gait training completed twice weekly.<sup>6</sup> While she improved on other measures, her TIS score remained the same throughout the course of the study at 4, with points being given only in the static sitting subscale.<sup>6</sup>

### Conclusion

While there is not extensive research examining trunk function and exoskeleton use, the research that does exist is positive to neutral. It is possible that using Ekso elicits higher trunk activation and improved trunk function in participants with CVA, SCI, and MS.

## References

1. Molteni F, Guanziroli E, Goffredo M, et al. Gait Recovery with an Overground Powered Exoskeleton: A Randomized Controlled Trial on Subacute Stroke Subjects. *Brain Sciences*. 2021;11(1):104. doi:10.3390/brainsci11010104
2. Infarinato F, Romano P, Goffredo M, et al. Functional Gait Recovery after a Combination of Conventional Therapy and Overground Robot-Assisted Gait Training Is Not Associated with Significant Changes in Muscle Activation Pattern: An EMG Preliminary Study on Subjects Subacute Post Stroke. *Brain Sciences*. 2021;11(4):448. doi:10.3390/brainsci11040448
3. Molteni F, Gasperini G, Gaffuri M, et al. Wearable robotic exoskeleton for overground gait training in sub-acute and chronic hemiparetic stroke patients: preliminary results. *Eur J Phys Rehabil Med*. 2017;53(5). doi:10.23736/S1973-9087.17.04591-9
4. Goffredo M, Guanziroli E, Pournajaf S, et al. Overground wearable powered exoskeleton for gait training in subacute stroke subjects: clinical and gait assessments. *Eur J Phys Rehabil Med*. 2020;55(6). doi:10.23736/S1973-9087.19.05574-6
5. Alamro RA, Chisholm AE, Williams AMM, Carpenter MG, Lam T. Overground walking with a robotic exoskeleton elicits trunk muscle activity in people with high-thoracic motor-complete spinal cord injury. *J Neuroeng Rehabil*. 2018;15(1):109. doi:10.1186/s12984-018-0453-0
6. Wee SK, Ho CY, Tan SL, Ong CH. Enhancing quality of life in progressive multiple sclerosis with powered robotic exoskeleton. *Mult Scler*. 2021;27(3):483-487. doi:10.1177/1352458520943080

# All known articles assessing the trunk in participants using an exoskeleton

Title	Authors	Journal	Device	Diagnosis
Functional Gait Recovery after a Combination of Conventional Therapy and Overground Robot-Assisted Gait Training Is Not Associated with Significant Changes in Muscle Activation Pattern: An EMG Preliminary Study on Subjects Subacute Post Stroke	Infarinato F, Romano P, Goffredo M, Ottaviani M, Galafate D, Gison A, Petruccelli S, Pournajaf S, Franceschini M	Brain Sci. 2021 Apr 1;11(4):448	Ekso	CVA
Enhancing quality of life in progressive multiple sclerosis with powered robotic exoskeleton	Wee SK, Ho CY, Tan SL, Ong CH	Mult Scler. 2021 Mar;27(3):483-487	Ekso	MS
Gait Recovery with an Overground Powered Exoskeleton: A Randomized Controlled Trial on Subacute Stroke Subjects	Molteni F, Guanzioli E, Goffredo M, Calabrò RS, Pournajaf S, Gaffuri M, Gasperini G, Filoni S, Baratta S, Galafate D, Le Pera D, Bramanti P, Franceschini M	Brain Sci. 2021 Jan 14;11(1):104	Ekso	CVA
Overground wearable powered exoskeleton for gait training in subacute stroke subjects: clinical and gait assessments.	Goffredo M, Guanzioli E, Pournajaf S, Gaffuri M, Gasperini G, Filoni S, Baratta S, Damiani C, Franceschini M, Molteni F	Eur J Phys Rehabil Med. 2019 Dec;55(6):710-721	Ekso	CVA
Overground walking with a robotic exoskeleton elicits trunk muscle activity in people with high-thoracic motor-complete spinal cord injury	Alamro RA, Chisholm AE, Williams AMM, Carpenter MG, Lam T	J Neuroeng Rehabil. 2018 Nov 20;15(1):109	Ekso	SCI
Wearable robotic exoskeleton for over-ground gait training in sub-acute and chronic hemiparetic stroke patients: preliminary results	Molteni F, Gasperini G, Gaffuri M, Colombo M, Giovanzana C, Lorenzon C, Farina N, Cannaviello G, Scarano S, Proserpio D, Liberali D, Guanzioli E.	Eur J Phys Rehabil Med. 2017 Oct;53(5):676-684	Ekso	CVA

CVA = stroke, MS = Multiple Sclerosis, SCI = spinal cord injury