Body Composition

There are a number of articles that assess body composition changes in participants who use an exoskeleton. All articles looked at a population with spinal cord injury (SCI). These publications are mostly case series and pre-post studies, but there are also three randomized controlled trials (RCTs) or crossover designed studies in addition to four known reviews. Different aspects of body composition and body perception are examined, with DXA scan, appendage circumferences, and body fat mass being examples of assessment types. Most studies utilized the Ekso1.1/GT/NR device, referred to as "Ekso" in this paper.

Spinal Cord Injury (SCI)

A few randomized trials exist that examine body composition or perception. One study randomized 16 subjects to receive 24 weeks of interventions offered three times per week with either the Ekso or activity based training. Bone mineral density was maintained for the Ekso group but significantly reduced in the activity based group in the hip and femoral neck by 0.03 and 0.06 g/cm^2.[1] Both groups improved arm fat-free soft tissue mass, but did not experience these changes in the legs.[1] Another study utilized 161 veterans who either only used their wheelchair or wheelchair use plus at-will use of an exoskeleton device over the period of 4 months. In the exoskeleton group, 17.9% of participants reached >1kg of lost total body fat mass whereas 19.3% met this loss in the group that only used their wheelchair.[2] This was not significantly different.[2] Muscle volume and intramuscular adipose tissue were measured during a cross-over trial of 6 persons with acute SCI. They either received early or late start of the intervention, which was defined as using Ekso with functional electrical stimulation (FES) at least 3 days per week, in addition to standard inpatient therapy. On average, muscle volumes for all 16 muscle groups assessed increased significantly during the intervention period as compared to the control period, with an average difference of 12.2%.[3] There was also a trend towards a lower percent of fat infiltration during intervention compared to control.[3] A final randomized trial split 42 subjects evenly into groups receiving treatment with Ekso or conventional physical therapy and examined their body uneasiness test. Those in the Ekso group showed major improvements in global severity index subscore and positive symptom distress index subscale items with a moderate effect size when compared to controls.[4]

One potential complication of SCI is decreasing bone density and therefore increased risk of fractures. Some studies have examined patients before and after an exoskeleton program looking for any changes in bone density utilizing a dexa scan. In one study that had participants walking in Ekso three times a week for 6 weeks, a statistically significant improvement of 14.5% in the bone mineral density of the tibia was reported.[5] While small in sample, the one participant of five who began this study with a diagnosis of osteoporosis improved his status to osteopenia at the conclusion of the intervention.[5] Another study had 10 participants complete a 16 week program of walking in Ekso between 1 and 3 times per week. Meaningful increases in bone mineral density were observed at the femur and tibia.[6] Bone strength index of the femur, which is the resistivity to compression, increased by 9.6% while stress-strain index of the femur, which is the resistivity to bending, increased by 11%.[6]

Dexa scans were also used to measure fat mass in certain studies. Some studies utilized circumferential measurements as well. Multiple studies agreed that using an exoskeleton can decrease fat mass.[5,7,8] One study of 5 participants who used Ekso 18 times over 6 weeks showed significant improvement in leg and appendicular lean body mass, total, leg, and appendicular fat mass, and cross sectional area of the calf muscle mass after the intervention.[5] Trunk fat mass and arm lean body mass did not show significant changes.[5] Subcutaneous adipose tissue and intermuscular adipose tissue also remained similar pre and post intervention.[5] Another study of eight men with chronic SCI completed 12 weeks of Ekso walking 2-3 time per week. Significant body composition improvements over the span of the intervention were seen including seated waist circumference, seated abdominal circumference, supine abdominal circumference, total body percent fat mass, leg percent fat mass, and trunk percent fat mass.[7] Lean mass in all body regions and supine waist circumference, however, did not change significantly.[7] A third study of 8 adults with chronic SCI ambulated in ReWalk three times per week for a total of 40 sessions, which resulted in significant loss of total body fat mass averaging 1.8±1.2 kg.[8] Of the participants, 75% lost visceral adipose tissue averaging 0.141 kg.[8] One study combined epidural spinal cord stimulation with 24 sessions of Ekso walking for an adult with a C7 complete SCI who showed a reduction in regional and total body fat mass.[9] Total body fat mass decreased from 25.14 kg to 23.4 kg, with the arms, legs, and trunk all showing some reductions contributing to the total decrease.[9]

Some studies, however, show insignificant results regarding body composition. A study of one participant who had weekly Ekso sessions and underwent repeated dexa scans showed a slight reduction of 1.7 kg fat mass after 3 months of training, however this is within the accepted measurement error of repeated scans.[10] This study also approximated potential weight loss based on energy expenditure, and estimated that persons with SCI using an exoskeleton weekly could lose between 0.13 to 0.22 kg per month, which at most, amounts to about 5.8 pounds annually.[10] Calf circumference showed no changes in 5 participants who walked in ExoAtlet over 4 weeks, indicating no further muscle atrophy but also no muscle mass gain.[11]

Review Articles

Four review articles examining a multitude of devices looked at body composition in their analysis. One specifically aimed to examine the effects that an exoskeleton has on body composition, while the other three comment on this in addition to many other outcomes. The review that focuses on body composition found that use of a robotic exoskeleton reduced fat mass in adults with SCI.[12] This review included 10 studies with a total of 105 participants. It showed mixed results in terms of body weight, with two studies reporting a loss of body weight and two further studies finding an increase.[12] Fat free mass also had mixed results that mostly were increases, but occurred in different parts of the body.[12]

Of the other three reviews, minimal conclusions were found. One examined 39 articles and concluded mixed outcomes regarding changes in bone mineral density resulting from robotic assisted gait.[13] Another review focusing on all types of rehabilitation reported that there were little improvements on osteoporosis regardless of how the intervention was provided, highlighting that 4 studies supported the acute phase mitigation of bone density reduction and the improvement of bone mass in the chronic phase by verticalization and walking supported by a robotic device.[14] Another review states that while we hypothesize that weightbearing may reduce the progressive loss of bone mineral density, there is not currently enough evidence to fully support this.[15]

Conclusion

Body composition encompasses numerous different measurements including bone density, fat mass, circumferential measurements, and weight. It appears that walking in a robotic exoskeleton could improve aspects of body composition, though the results are mixed. Because there is not a wide breadth of articles on this topic combined with many different ways to measure composition, there is not a firm conclusion to make on this topic. Another important limitation is the duration of these studies. It is possible that a higher dosage is needed to see significant changes in body composition, but that has not been studied.

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All known articles assessing body composition in participants using an exoskeleton

Title	Authors	Journal	Device	Diagnosis
Exoskeletal-Assisted Walking in Veterans With Paralysis: A Randomized Clinical Trial	Spungen AM, Dematt EJ, Biswas K, Jones KM, Mi Z, Snodgrass AJ, Morin K, Asselin PK, Cirnigliaro CM, Kirshblum S, Gorman PH, Goetz LL, Stenson K, White KT, Hon A, Sabharwal S, Kiratli BJ, Ota D, Bennett B, Berman JE, Castillo D, Lee KK, Eddy BW, Henzel MK, Trbovich M, Holmes SA, Skelton F, Priebe M, Kornfeld SL, Huang GC, Bauman WA	JAMA Netw Open. 2024 Sep 3;7(9):e2431501	ReWalk	SCI
A systematic review of the effects of robotic exoskeleton training on energy expenditure and body composition in adults with spinal cord injury	Rigoli A, Francis L, Nicholson M, Weber G, Redhead J, Iyer P	Int J Rehabil Res. 2024 Jun 1;47(2):64-74	Multiple – Review Article	SCI
Potential Effects of an Exoskeleton-Assisted Overground Walking Program for Individuals With Spinal Cord Injury Who Uses a Wheelchair on Imaging and Serum Markers of Bone Strength: Pre-Post Study	Bass A, Morin SN, Guidea M, Lam J, Karelis AD, Aubertin-Leheudre M, Gagnon DH;	JMIR Rehabil Assist Technol. 2024 Jan 1:11:e53084	Ekso	SCI
Muscle adaptations in acute SCI following overground exoskeleton + FES training: A pilot study	Hohl K, Smith AC, Macaluso R, Giffhorn M, Prokup S, O'Dell DR, Kleinschmidt L, Elliott JM, Jayaraman A	Front Rehabil Sci. 2022 Oct 13:3:963771	Ekso	SCI
The Outcomes of Robotic Rehabilitation Assisted Devices Following Spinal Cord Injury and the Prevention of Secondary Associated Complications	Nistor-Cseppento CD, Gherle A, Negrut N, Bungau SG, Sabau AM, Radu AF, Bungau AF, Tit DM, Uivaraseanu B, Ghitea TC, Uivarosan D	Medicina (Kaunas). 2022 Oct 13;58(10):1447	Multiple – Review Article	SCI
Robotic walking to mitigate bone mineral density decline and adverse body composition in individuals with incomplete spinal cord injury: A pilot randomized clinical trial	Shackleton C, Evans R, West S, Derman W, Albertus Y	Am J Phys Med Rehabil. 2022 Oct 1;101(10):931-936	Ekso	SCI

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Exoskeleton-assisted Gait Training in Spinal Disease With Gait Disturbance	Jang TG, Choi SH, Yu SH, Kim DH, Han IH, Nam KH	Korean J Neurotrauma. 2022 May 2;18(2):316-323	ExoAtlet	SCI
Body Representation in Patients with Severe Spinal Cord Injury: A Pilot Study on the Promising Role of Powered Exoskeleton for Gait Training	Maggio MG, Naro A, De Luca R, Latella D, Balletta T, Caccamo L, Pioggia G, Bruschetta D, Calabrò RS	J Pers Med. 2022 Apr 11;12(4):619	Ekso	SCI
Exoskeleton Training and Trans-Spinal Stimulation for Physical Activity Enhancement After Spinal Cord Injury (EXTra-SCI): An Exploratory Study	Sutor TW, Ghatas MP, Goetz LL, Lavis TD, Gor gey AS	Front Rehabil Sci. 2022 Jan:2:789422	Ekso	SCI
Effect of Exoskeletal-Assisted Walking on Soft Tissue Body Composition in Persons with Spinal Cord Injury	Asselin P, Cirnigliaro CM, Kornfeld S, Knezevic S, Lackow R, Elliott M, Bauman WA, Spungen AM	Arch Phys Med Rehabil. 2021 Feb;102(2):196-202	ReWalk	SCI
The feasibility of using exoskeletal-assisted walking with epidural stimulation: a case report study	Gorgey AS, Gill S, Holman ME , Davis JC, Atri R, Bai O, Goetz L, Lester DL, Trainer R, Lavis TD	Ann Clin Transl Neurol. 2020 Feb;7(2):259-265	Ekso	SCI
Robotic Rehabilitation and Spinal Cord Injury a Narrative Review	Mekki M, Delgado AD, Fry A, Putrino D, Huang V	Neurotherapeutics. 2018 Jul;15(3):604-617	Multiple – Review Article	SCI
Robotic assisted gait as a tool for rehabilitation of individuals with spinal cord injury a systematic review	Holanda LJ, Silva PMM, Amorim TC, Lacerda MO, Simao CR, Morya E	J Neuroeng Rehabil. 2017 Dec 4;14(1):126	Multiple – Review Article	SCI
Exoskeleton Training May Improve Level of Physical Activity After Spinal Cord Injury: A Case Series.	Gorgey AS, Wade R, Sumrell R, Villadelgado L, Khalil RE, Lavis T	Top Spinal Cord Inj Rehabil. 2017 Summer;23(3):245-255	Ekso	SCI
Effect on Body Composition and Bone Mineral Density of Walking With a Robotic Exoskeleton in Adults With Chronic Spinal Cord Injury	Karelis A, Carvalho LP, Castillo MJ, Gagnon DH, Aubertin-Leheudre M	J Rehabil Med. 2017 Jan 19;49(1):84-87	Ekso	SCI

ABI = acquired brain injury, CVA = stroke, MS = multiple sclerosis, SCI = spinal cord injury