Movement Amplification to Improve Gait Stability in Spinal Cord Injury: A Case Series

Shawna Anderson SPT[1], Logan Davis SPT[1], Samantha Feller SPT[1], Heidi Howald SPT[1], Dana Miller SPT[1], Brenna Murphy SPT[1], Samantha Woodward SPT[1], Kyle Bostedt SPT[1], Madeline Lee SPT[1], Ashley Smith SPT[1], Derek Stone SPT[1], Jane Woodward PT, DPT, NCS[3], Jennifer H. Kahn PT, DPT, NCS[1], Keith Gordon PhD, ATC, CSCS[1,2].

[1]Department of Physical Therapy & Human Movement Science, Northwestern University, Chicago, IL; [2]Edward Hines Jr. VA Hospital, Hines, IL; [3]Shirley Ryan Ability Lab, Chicago, IL

Background and Purpose

- Individuals with chronic incomplete spinal cord injury (iSCI) have gait instability that may result in injury[1,2].
- This case series used principles of error augmentation to challenge gait stability with a robotic device that amplified lateral velocity of the center of mass (COM) to encourage exploration of new dynamic balance strategies[3].
- Training parameters were adjusted to maintain high intensity.
- Our purpose was to determine the feasibility and effectiveness of movement amplification training (MAT) for improving gait stability in individuals with chronic iSCI. We hypothesized MAT is feasible and will improve gait stability.

Case Description and Methods

Participants:

- Three individuals with American Spinal Injury Association Impairment Scale D.

Training Protocol:

- Trained with MAT on a treadmill 16-19 45-minute sessions over 9 weeks.

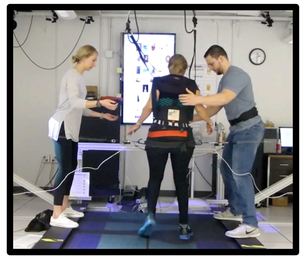

Figure 1. Agility Trainer set-up for lateral movement amplification

Training tasks to increase difficulty:
- Increased movement amplification
- Increased speed
- Lateral stepping
- Image identification to promote forward gaze
- Obstacle negotiation

Parameters recorded each session:
- Peak heart rate
- Rate of perceived exertion (RPE)
- Minutes walked
- Peak treadmill speed

Measures:

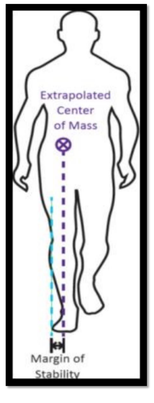

Figure 2. Margin of stability (MOS) is calculated by measuring the distance between lateral base of support (blue dashed line) and extrapolated center of mass

Clinical Outcome Measures
1) Walking Index for SCI II
2) Lower Extremity Motor Scores
3) Functional Gait Assessment (FGA)
4) 10 Meter Walk Test (10MWT)
5) Reactive Balance – Mini-BESTest
6) Activities Specific Balance Scale (ABC)
7) WHO-Quality of Life BREF (WHO-QOL BREF)
Lab Outcome Measures
1) Peak Lateral COM Speed
2) COM Excursion
3) Step Width
4) Lateral Margin of Stability
5) Step Length
6) Foot Placement Estimator (FPE)*

*Correlation between COM and foot placement

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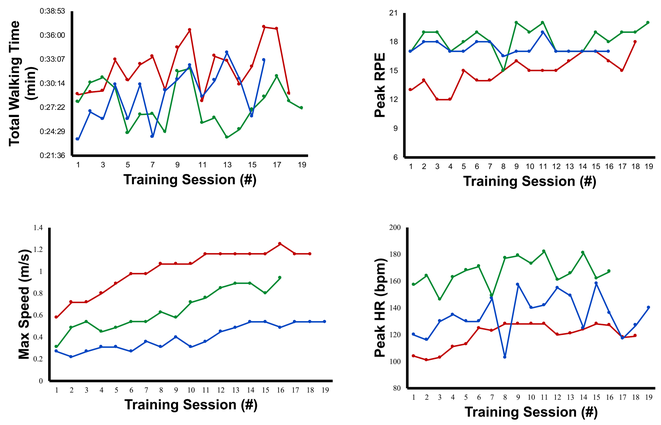
Outcomes

Training Parameters:

- Average total walking time varied across sessions: 32:04, 27:43, and 28:52.
- Subjects increased peak treadmill speeds throughout training by 0.67, 0.27 and 0.63 m/s.

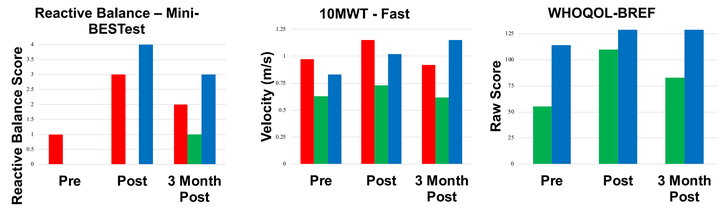


Subject A
Subject B
Subject C

Figure 3: Max treadmill speed gradually increased throughout training to reflect a peak RPE and HR that is consistent with high intensity training. Total walking time was variable due to progression of walking tasks.

Clinical Outcome Measures:

- The most consistent improvements were on the 10MWT, WHOQOL-BREF, and reactive postural control items from the Mini Balance Evaluation Systems Test.
- Subjects increased fast 10MWT by 0.1-0.22 m/s. Subject B and C increased self-selected 10MWT by 0.15-0.2 m/s. Subject B increased WHOQOL-BREF by 55 points.
- Subject A and C each improved reactive balance scores by 2-4/6.
- Subject A reported improved urogenital and sexual function. Subject B reported improved urogenital function.



Subject A
Subject B
Subject C

Figure 4: The reactive balance scores, 10MWT fast walking speed, and WHOQOL-BREF clinical outcome measures had the most consistent improvements across all subjects.

Laboratory Measures:

- Preferred treadmill speed increased for all subjects by 0.13-0.27 m/s. Subjects B and C reduced COM excursion by 31-35%.
- Step width and MOS decreased for Subjects B and C and increased for Subject A.
- Correlations between COM and foot placement (FPE) significantly increased post-training.

Laboratory Measures	Pre-Training			Post-Training		
Preferred Treadmill Speed (m/s)	0.54	0.18	0.31	0.71	0.31	0.58
COM Excursion (m)	0.07	0.13	0.08	0.05	0.08	0.05
Step Width (m)						
Left	0.30	0.31	0.35	0.33	0.27	0.29
Right	0.29	0.28	0.35	0.32	0.26	0.32
Margin of Stability (m)						
Left	0.09	0.08	0.08	0.08	0.07	0.09
Right	0.02	0.03	0.12	0.05	0.00	0.11
Foot Placement Estimator (r^2)						
Left	-	0.03	0.49	-	0.37	0.67
Right	-	0.01	0.15	-	0.30	0.50

Subject A
Subject B
Subject C

Table 1: Results of preferred treadmill speed, COM excursion, step width, margin of stability, COM excursion, and FPE for pre training and post training. Subject A's lab values were recorded while receiving feedback about position on the treadmill. Subjects B and C were recorded during preferred treadmill walking.

Discussion

MAT challenged dynamic balance and has potential to improve gait stability.

- Subject A increased control of COM motion post training. This was accomplished through decreased step variability and increased lateral MOS, suggesting the use of passive stabilization strategies.
- Subjects B and C also increased control of COM motion post training; however, were able to do so through increased active control given they could maintain stability with a decreased step width and decreased lateral MOS. Correlation between COM motion and foot placement locations also suggest improvements in active control strategies.

Conclusion: Overall, subjects improved control of COM, decreased step placement variability, increased walking speed, and two subjects improved ability to react to perturbations. MAT is a feasible intervention where both **active and passive strategies** can be trained to improve gait stability and may positively impact QOL. More research is needed to further understand how to target underlying mechanisms (active or passive strategies) for improving gait stability.

References and Acknowledgments

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