

A Systematic Review of Robotic Assisted Stepping to Increase Cardiovascular Fitness in Individuals with Incomplete Spinal Cord Injury

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Overview

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Introduction

- ▶ Sedentary lifestyles are common among Individuals with incomplete spinal cord injuries (iSCI)¹
- ▶ Increased risk for developing premature cardiovascular disease¹
 - ▶ Heart disease is one of the leading causes of death in SCI population
- ▶ Decreased life expectancy compared to general population²
- ▶ Higher risk of re-hospitalization and premature death due to cardiovascular disease²



Introduction

- ▶ Traditional modes of exercise to improve physical fitness in this population include arm ergometry and leg exercise with functional electrical stimulation (FES)³
- ▶ Body weight support treadmill training and robotic assisted gait training provide alternative modes of exercise to improve cardiovascular function³



Purpose

To determine the effects of robotic assisted stepping in increasing cardiovascular fitness in individuals with incomplete spinal cord injury (iSCI)



ASIA Impairment Scale

The extent of spinal cord injury is defined by the American Spinal Injury Association (ASIA) Impairment Scale⁴ using the following categories:

A	Complete	No sensory or motor function is preserved in the sacral segments S4-S5
B	Incomplete	Sensory but not motor function is preserved below the neurological level and includes the sacral segments S4-S5
C	Incomplete	Motor function is preserved below the neurological level, and more than half of key muscles below the neurological level have a muscle grade less than 3
D	Incomplete	Motor function is preserved below the neurological level, and at least half of key muscles below the neurological level have a muscle grade greater than or equal to 3
E	Normal	Sensory and motor function is normal



What is robotic assisted step training?

Lokomat Device

- ▶ Components³:
 - ▶ Robotic gait orthosis
 - ▶ Treadmill
 - ▶ Bodyweight support (BWS)
- ▶ Commonly used for gait training
- ▶ Physiological gait pattern ensured by adjustable exoskeleton and BWS system
 - ▶ Hip and knee joint angles can be individually adjusted during training to tailor to specific needs of patients³
- ▶ Speed, BWS and level of assistance are adjustable



What is robotic assisted step training?

Tilt table with integrated robotics-assisted stepping device²

- ▶ Standard tilt table
- ▶ Robotic orthoses
- ▶ Upper body harness
- ▶ Foot plates with integrated spring system



What is robotic assisted step training?

Tilt table with integrated robotics-assisted stepping device²

- ▶ The orthoses impose a stepping trajectory on the lower limbs in a manner that approaches nondisabled, physiological hip kinematics
- ▶ Guidance force of the robotic orthoses can be adjusted to match the functional ability of the patient
- ▶ Spring system of foot plates become loaded during hip/knee extension and provide resistance to movement
 - ▶ The springs release during hip/knee flexion



Methods

- ▶ **Literature Search:**
 - ▶ ProQuest
 - ▶ CINAHL
 - ▶ PubMed
- ▶ **Search Limits:**
 - ▶ English Language
 - ▶ Human subjects
 - ▶ Date range: 2007-2017
- ▶ Three reviewers independently assessed each article for methodological quality and came to consensus using Sackett Level guidelines.



Search Terms

(Robot* Assisted)

AND

(Spinal Cord Injury **OR** SCI)

AND

(Cardiovascular Fitness)



Eligibility Criteria

Inclusion:

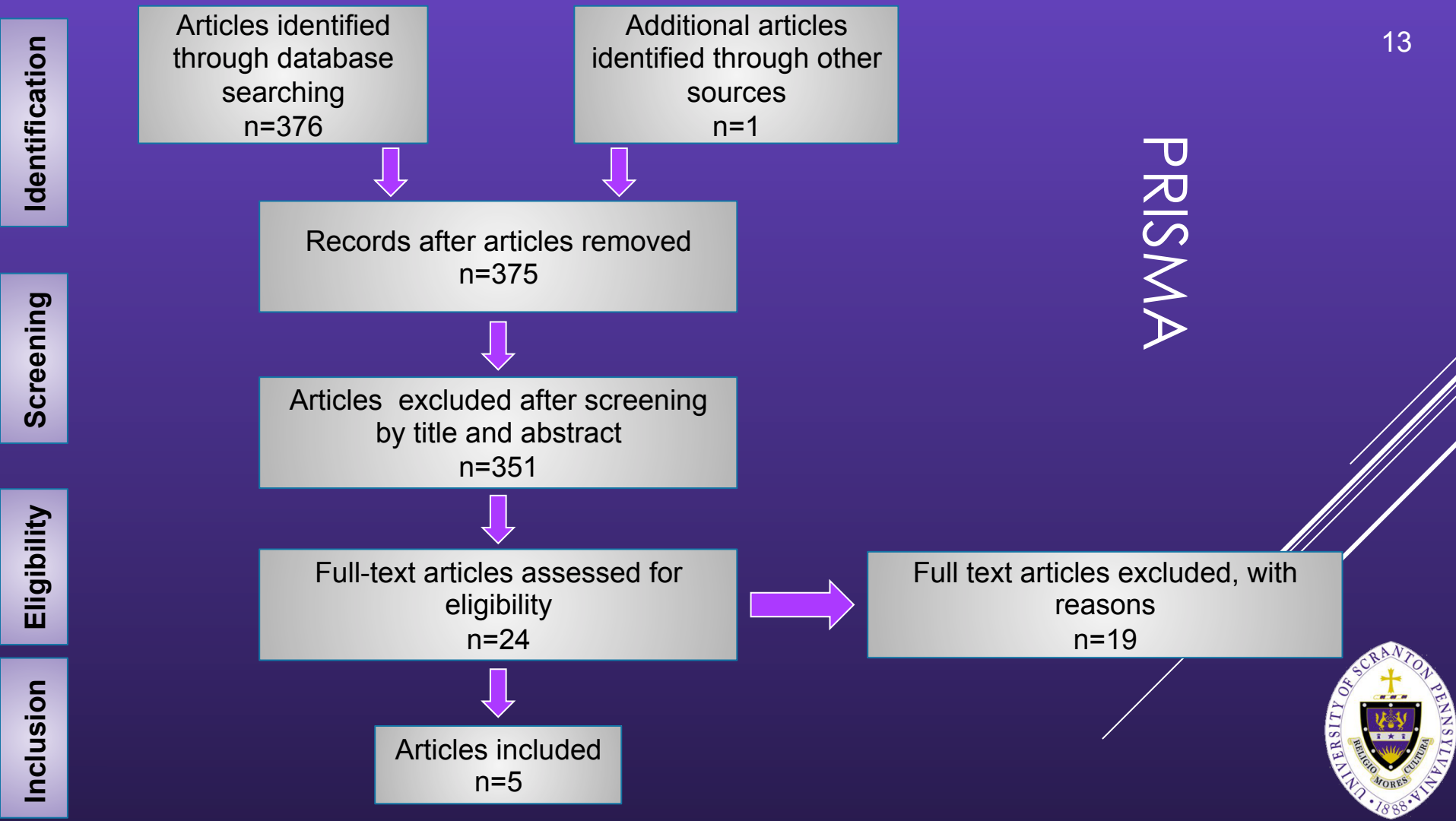
- ▶ Peer reviewed
- ▶ Age 18+
- ▶ Incomplete SCI
- ▶ Outcome measure of maximal oxygen consumption (VO_{2peak})
- ▶ ASIA level C or D

Exclusion:

- ▶ Irrelevant
- ▶ ASIA level A or B
- ▶ Outcome measures not including VO_{2peak}



PRISMA



Sackett Levels of Evidence

Gorman PH, Scott W, York H, Theyagaraj M, Price-Miller N, McQuad J, Eyvazzadeh M, Ivey FM, Macko RF. Robotically assisted treadmill exercise training for improving peak fitness in chronic motor incomplete spinal cord injury: A randomized controlled trial. <i>The Journal of Spinal Cord Medicine.</i> 2016;39(1): 32-44. ¹	Level IB
Hoekstra F, van Nunen MPM, Gerrits KHL, Stolwijk-Swuste JM, Crins M, Janssen TWJ. The effect of robotic gait training on the cardiorespiratory system in incomplete spinal cord injury. <i>Journal of rehabilitation research and development.</i> 2013; 50(10): 1411-22. ³	Level IV
Kressler J, Nash MS, Burns PA, Field-Fote EC. Metabolic Responses to 4 Different Body weight Supported Locomotor training Approaches in Persons with Incomplete Spinal Cord Injury. <i>Archives of Physical Medicine and Rehabilitation.</i> 2013; 94(8): 1436-1442. ⁵	Level IB
Craven CTD, Gollee H, Coupaud S, Purcell MA, Allan DB. Investigation of robotic-assisted tilt-table therapy for early-stage spinal cord injury rehabilitation. <i>J Rehabil Res Dev</i> 2013; 50: 367-378. ²	Level IV
Fenuta AM, Hicks AL. Metabolic demand and muscle activation during different forms of bodyweight supported locomotion in men with incomplete SCI. <i>BioMed Res Int.</i> 2014;2014:10. ⁶	Level III

Results

- ▶ Samples ranged from 3 to 62 subjects
 - ▶ Total of 100 subjects with iSCI
- ▶ Primary outcomes assessed:
 - ▶ $\text{VO}_{2\text{peak}}$
 - ▶ Metabolic equivalent (MET)



Results

- ▶ Hoekstra (IV) demonstrated immediate effects on VO_{2peak} of moderate intensity physical activity levels supporting future cardiorespiratory improvement with training continuation³
- ▶ Fenuta et al. looked at immediate effects on VO_{2peak} ⁶
 - ▶ Results demonstrated achievement of a suboptimal MET level
 - ▶ This does not support cardiorespiratory improvement with training continuation
 - ▶ This shows that a higher level of training is needed to improve VO_{2peak}
- ▶ Gorman et al found long-term improvements in VO_{2peak} following robotically assisted step training (IB)¹



Results

- ▶ The study by Kressler showed no changes in $\text{VO}_{2\text{peak}}$ between the first and last training sessions^{5,3}
 - ▶ This may be due to the dosage and intensity of exercise
- ▶ Ideal $\text{VO}_{2\text{peak}}$ levels within the first year were between 5.3 and 11.0 mL/kg/min, which is a MET equivalent of approximately 1.5 to 3.1²



Limitations

- ▶ Minimal RCT's on this subject
- ▶ Small sample sizes
- ▶ Varied outcome measures
- ▶ Lack of long-term follow up



Conclusion

- ▶ There is preliminary evidence of strength IIB in support of VO_{2peak} improvements with robotic assisted step training in patients with iSCI
- ▶ Cardiovascular training with iSCI should focus on oxygen uptake MET equivalent as opposed to step speed during training
 - ▶ Ensures the training dose maintains an appropriate level of intensity
 - ▶ A focus on MET equivalent will assure more volitional effort



Clinical Relevance

- ▶ Cardiovascular deficits commonly seen among SCI population
 - ▶ VO_2 is an ideal outcome measure to assess improvements of cardiovascular fitness
 - ▶ It is possible to produce improvements in peak VO_2 with robotic assisted step training interventions in those with iSCI
- ▶ Volitional muscle activation should be taken into consideration when selecting robotics as a treatment option
 - ▶ Individuals with higher levels of motor function may be more likely to succeed with this type of training
 - ▶ It is important to note lower and upper extremity muscles available for active participation



Suggested Future Research

- ▶ Determine the training dose and MET level for optimal improvements in VO_{2peak}
 - ▶ Amount of remaining muscle activation necessary to achieve adequate levels of intensity to see a response
 - ▶ Factors that impact metabolic cost during training
- ▶ Determine the impact that level of impairment has on outcomes when implementing robotic assisted step training
- ▶ Neuroplasticity and robotic assisted step training
 - ▶ Complete SCI and upper cervical injuries



Thank You

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References

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6. Fenuta AM, Hicks AL. Metabolic demand and muscle activation during different forms of bodyweight supported locomotion in men with incomplete SCI. *BioMed Res Int*. 2014;2014:10.



Questions?

