ACRM
AMERICAN CONGRESS OF REHABILITATION MEDICINE

Archives of Physical Medicine and Rehabilitation

journal homepage: www.archives-pmr.org

Archives of Physical Medicine and Rehabilitation 2013;94:1260-7

ORIGINAL ARTICLE

Patterns of Changes in Wheelchair Exercise Capacity After Spinal Cord Injury

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Abstract

Objectives: (1) To identify different patterns of changes in wheelchair exercise capacity in the period between the start of active spinal cord injury (SCI) rehabilitation and 5 years after discharge; (2) to examine the pattern determinants of the change in wheelchair exercise capacity.

Design: Prospective cohort study. Measurements were recorded at the start of active inpatient rehabilitation, 3 months after the start, at discharge of inpatient rehabilitation, 1 year after discharge, and 5 years after discharge.

Setting: Eight rehabilitation centers.

Participants: Persons with SCI (N = 130; age range, 18−65y), who were wheelchair-dependent, at least for long distances.

Interventions: Not applicable.

Main Outcome Measure: Wheelchair exercise capacity: peak power output (W).

Results: We found 4 different patterns of the change of peak power output (mean ± SD): (1) a pattern with high and progressive scores (33% of total study group): high progressive scores (start of rehabilitation: 49±15W to 5 years after discharge: 77±17.2W); (2) a pattern of improvement during inpatient rehabilitation and deterioration after inpatient rehabilitation (12%): progressive scores during inpatient rehabilitation with deteriorating scores after discharge (start of rehabilitation: 29±8.7W, to discharge: 60±8.4W, to 5 years after discharge: 39±13.1W); (3) a pattern with low and only slightly progressive scores (52%): low progressive scores (start of rehabilitation: 20±10.1W to 5 years after discharge: 31±15.9W); and (4) a pattern with low scores during inpatient rehabilitation and a sharp rise after discharge (3%): low inpatient scores with strong progressive scores after discharge (start of rehabilitation: 29±15.5W to 5 years after discharge: 82±10.6W). A logistic regression of factors that may distinguish between patterns with high and progressive scores and patterns with low and only slightly progressive scores revealed that older age, being a woman, having a tetraplegic lesion, and low functional status were associated with patterns with low and only slightly progressive scores. The pattern of improvement during inpatient rehabilitation and deterioration after inpatient rehabilitation showed more neuropathic pain and lower sports participation than patterns with high and progressive scores.

Conclusions: For the vast majority of patients, wheelchair exercise capacity after SCI shows a positive trend and can be described in distinct patterns that are dependent on personal, lesion, and functional characteristics.

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A spinal cord injury (SCI) is a devastating medical condition that highly affects the exercise capacity of the persons involved as a result of muscle weakness, loss of autonomic control below the level of injury, and subsequent changes in metabolic and vascular functions.[1-5] Most people with an SCI have a sedentary lifestyle, and the maintenance of an adequate exercise capacity is hindered by medical problems, social barriers, low activity levels, and low sport participation.[1,3,4,6-8] This potentially leads to a debilitative cycle of exercise capacity and exposes these individuals to an increased risk of developing medical conditions, such as metabolic

† Deceased.

No commercial party having a direct financial interest in the results of the research supporting this article has or will confer a benefit on the authors or on any organization with which the authors are associated.

0003-9993/13/$36 - see front matter © 2013 by the American Congress of Rehabilitation Medicine
http://dx.doi.org/10.1016/j.apmr.2013.02.025

syndrome and cardiovascular disease, which is the leading cause of death in persons with an SCI.[9]

Longitudinal research on the change in exercise capacity is scarce. We previously have shown the recovery of exercise capacity up to 1 year after discharge from inpatient rehabilitation[10] and subsequent stabilization up to 5 years after discharge.[11] The most previous research on exercise capacity in SCI had a cross-sectional design, and their results were influenced by an overrepresentation of active and young patients with paraplegia.[12-14] Variable-centered statistical approaches revealed that age, sex, and lesion level and completeness to be longitudinal,[10,11] and that cross-sectional[12-14] was related to exercise capacity. Other determinants of exercise capacity were secondary impairments, pain, and activity levels.[15-17] However, clinical observations suggest a certain amount of heterogeneity in the change of exercise capacity after SCI. A person-centered statistical method known as latent class growth mixture modeling (LCGMM)[18-20] is an appropriate method to unravel this heterogeneity, which may help us understand how individuals differ in their physical adaptation to an SCI. Follow-up rehabilitation care of persons with an SCI may be improved by identifying the different patterns and characteristics of people at risk for persistently low levels or the deterioration of exercise capacity.

The aims of the present study are (1) to identify different patterns of the change of wheelchair exercise capacity in the period between the start of active SCI rehabilitation and 5 years after discharge and (2) to examine the determinants of these different patterns of wheelchair exercise capacity. We hypothesized that different wheelchair exercise capacity patterns would be identified and that older age, being a woman, tetraplegia, a complete lesion, a nontraumatic lesion, a long rehabilitation period, poor functional independence, low activity level, and suffering from pain or other secondary impairments would be identified as determinants of a low or deteriorating pattern of wheelchair exercise capacity.

Methods

Participants

Eight rehabilitation centers specializing in SCIs participated in the project. The participants were eligible to join the project if they had an acute SCI, were between 18 and 65 years of age, were classified as grades A to D on the ASIA Impairment Scale (AIS), and were expected to remain wheelchair-dependent for at least long distances. The exclusion criteria were SCI because of malignancies, progressive disease, known cardiovascular disease, or psychiatric problems, and insufficient command of the Dutch language to understand the goal of the study and the testing methods. The Medical Ethics Committee of the Stichting Revalidatie Limburg/Institute for Rehabilitation Research in Hoensbroek and all local medical ethics committees approved the research protocol in 1999. The Medical Ethics Committee of the University Medical Center Utrecht approved the sequel research protocol in 2006. All participants gave written informed consent.[21]

List of abbreviations:

AIS	ASIA Impairment Scale
BIC	Bayesian information criterion
BLRT	bootstrapped likelihood ratio test
BMI	body mass index
LCGMM	latent class growth mixture modeling
MET	metabolic equivalent of task
PASIPD	Physical Activity Scale for Individuals with Physical Disabilities
PO_{peak}	peak power output
SCI	spinal cord injury
Vo_{2peak}	peak oxygen consumption

Procedure

Measurements were performed at the start of active inpatient rehabilitation, defined as the day that a person could sit for 3 to 4 hours accumulatively, 3 months after start of active inpatient rehabilitation, at discharge from inpatient rehabilitation, 1 year after discharge, and 5 years after discharge. These 5 measurements included a medical history and physical examination by a rehabilitation physician, an oral interview with a trained research assistant, a self-reported questionnaire, and a peak wheelchair exercise test. For persons with a short inpatient rehabilitation period, the 3-months measurement was replaced with the measurement at discharge.

Instruments

Peak power output and peak oxygen consumption

Wheelchair exercise capacity, expressed as peak power output (PO_{peak} [W]) and peak oxygen consumption (Vo_{2peak} [L/min]), was determined in a peak wheelchair exercise test on a motor-driven treadmill. The testing protocol and equipment have previously been described.[10,22,23,a,b,c] At every occasion before the maximal exercise test for each subject, the wheelchair drag force (N) for the wheelchair-user combination on the treadmill was recorded in a drag test. The participants performed 2 blocks of submaximal exercise of 3 minutes each, separated by a 2-minute rest. After 2 minutes of rest, the peak exercise test started at the same constant velocity, and the inclination was increased .36° every minute. The test was terminated when the subject was exhausted or could no longer keep pace with the speed of the treadmill. The individual testing protocol was identical for each of the testing occasions. Peak Vo_2 was defined as the highest value of oxygen consumption recorded during a 30-second period. Peak PO was defined as the power output at the highest inclination that the subject could maintain for at least 30 seconds.

Personal and lesion characteristics

Demographic characteristics

The demographic characteristics collected at the first test were age, sex, body mass, and height. Body mass (kg) was measured by the trained research assistant with each subsequent test. Body mass index (BMI) was calculated in $kg \cdot m^{-2}$.

Lesion characteristics

Lesion characteristics were assessed according to the International Standards for Neurological Classification of Spinal Cord Injury.[24] AIS grades A and B were considered motor complete, and grades C and D were considered motor incomplete. Neurologic lesion level was defined as the highest motor level. Neurologic levels below T1 were defined as paraplegia, and neurologic lesion levels at or above T1 were defined as tetraplegia. The cause of injury was