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ORIGINAL RESEARCH

Cardiovascular Stress During Inpatient Spinal Cord Injury Rehabilitation

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Abstract

Objectives: (1) To measure the amount of cardiovascular stress, self-reported physical activity, and accelerometry-measured physical activity by individuals with spinal cord injury (SCI) during physical therapy (PT) and occupational therapy (OT); and (2) to investigate the relations between these measures.

Design: Observational study.

Setting: Two inpatient SCI rehabilitation centers.

Participants: Patients with SCI (N = 87) were recruited from consecutive admissions to rehabilitation.

Interventions: Not applicable.

Main Outcome Measures: Heart rate was recorded by a Holter monitor, whereas physical activity was captured by self-report (Physical Activity Recall Assessment for People with SCI questionnaire) and real-time wrist accelerometry during a total of 334 PT and OT inpatient sessions. Differences between individuals with paraplegia and tetraplegia were assessed via Mann-Whitney *U* tests. Spearman correlations were used to explore the relation between measurements of physical activity and heart rate.

Results: Time spent at a heart rate within a cardiovascular training zone (≥40% heart rate reserve) was low and did not exceed a median of 5 minutes. In contrast, individuals reported at least 60 minutes of higher-intensity time during therapy. There was a low but statistically significant correlation between all measures.

Conclusions: The cardiovascular stress incurred by individuals with SCI during inpatient PT and OT sessions is low and not sufficient to obtain a cardiovascular training effect to optimize their neurologic, cardiovascular, or musculoskeletal health; this represents a lost opportunity to maximize rehabilitation. Self-reported minutes of higher-intensity physical activity do not reflect actual time spent at a higher intensity measured objectively via a heart rate monitor.

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Cardiovascular disease is a leading cause of death in persons with spinal cord injury (SCI)[1,2] and has a higher prevalence, earlier onset, and occurs at an accelerated rate after SCI compared with the general population.[3,4] Exercise training in individuals with SCI has the potential to improve cardiovascular health and alleviate numerous medical complications associated with being physically inactive,[5-8] which underscores the importance of participating in an exercise program after SCI.[9]

Early after SCI, a prolonged amount of bed rest contributes to very low levels of physical activity and cardiovascular fitness.[9] Physical capacity, defined as the combined ability of the

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cardiovascular and musculoskeletal systems to perform at a given level of activity, is extremely low in individuals with acute SCI[10] and improves over time,[11] likely because of a number of factors, including improvements in neurologic status, recuperation from trauma, and training effects of the rehabilitation program. There is also increasing evidence that aerobic activity may facilitate neuroplasticity[12]; for example, Leech and Hornby[13] found that increases in serum brain-derived neurotrophic factor were greater with higher-intensity exercise in individuals with incomplete SCI. However, little information exists on how much, if at all, conventional rehabilitation protocols (that typically include physical therapy [PT] and occupational therapy [OT] to achieve goals related to functional recovery) in SCI challenge cardiovascular fitness.

It is well known that physical activity of a sufficiently high intensity confers cardiovascular benefits not obtained by lighter activity,[14] and the importance of this fact is accounted for in physical activity recommendations by various organizations. For both able-bodied individuals[15] and individuals with disability,[16] it is recommended that, throughout the week, one obtains at least 150 minutes of moderate-intensity activity, 75 minutes of vigorous-intensity activity, or an equivalent combination of moderate- and vigorous-intensity aerobic activity in bouts of no less than 10 minutes. More recently, SCI-specific guidelines suggest individuals accrue, at a minimum, 2 bouts of 20 minutes of moderate- to vigorous-intensity aerobic activity per week.[17] Unfortunately, it appears most individuals with chronic SCI do not meet these guidelines at 1 year after discharge from rehabilitation.[18] Indeed, individuals with SCI have been shown to have the lowest physical activity levels when compared with persons with different chronic diseases.[18] One might assume that the cardiovascular stress experienced after SCI injury would be equally low. However, one study[19] assessed 8 individuals with paraplegia and 3 with tetraplegia over a typical rehabilitation day and concluded that there was sufficient strain to improve aerobic fitness, but there was heterogeneity of the subjects (participants with paraplegia/tetraplegia/walking ability were combined), and subsequently large variability in the data. Clearly more research is required.

The primary goals of PT and OT include motor and functional recovery; however, SCI rehabilitation also has opportunity to reverse the cycle of reduced cardiovascular fitness that limits functioning.[11] Cardiovascular stress can improve physical capacity, and in turn contribute to better performance of activities of daily living (ADL).[11] Furthermore, awareness of the demands placed on the cardiovascular system by rehabilitation interventions may play a role in both patient safety and for optimizing activity prescription.

Noninvasive, low-cost options of physical activity measurement include accelerometry and self-report. Wrist accelerometry is a valid indicator of physical activity for wheelchair users in laboratory and community-dwelling environments,[20] and self-report is the most widely used method for measuring physical activity.[21] Although the subjective nature of self-reported physical activity renders it prone to recall error and social desirability bias,[22] it does offer information not available from objective measures. For example, accelerometry may measure when and how much an individual moves the upper limbs, whereas self-report captures information on how difficult this activity was and the purpose of the activity (eg, leisure, ADL). Despite increasing emphasis on aerobic activity for neuroplastic recovery and for cardiovascular fitness, it is not yet known whether accelerometry and self-report physical activity measures reflect the actual intensity of aerobic activity engaged in by patients in rehabilitation.

Therefore, the purpose of this study was (1) to measure the amount of cardiovascular stress experienced by individuals with SCI during inpatient rehabilitation, and (2) to investigate the relation between this cardiovascular stress and other measures of physical activity (self-reported physical activity and wrist accelerometry) during inpatient rehabilitation. It was hypothesized that the amount of time spent in PT and OT at an intensity sufficient to achieve a cardiovascular training effect ($\geq$40% heart rate reserve [HRR]) would be low (not meeting the recommendations of SCI physical activity guidelines). It was expected that the different measures would be correlated because they measure constructs of physical activity.

List of abbreviations:

ADL	**activities of daily living**
AIS	**ASIA Impairment Scale**
HRR	**heart rate reserve**
OT	**occupational therapy**
PARA-SCI	**Physical Activity Recall Assessment for People with SCI**
PT	**physical therapy**
SCI	**spinal cord injury**

Methods

Participants

Participants were recruited as part of a larger study examining consecutive traumatic and nontraumatic SCI admissions to inpatient subacute care at 2 stand-alone rehabilitation centers.[23] Nontraumatic SCI was defined as SCI resulting from spinal stenosis, tumor, ischemia, transverse myelitis, and infection.[24] All adults with a new SCI of any etiology, severity, or level, who were admitted for SCI rehabilitation, were eligible. In addition, the admission criteria for Canadian rehabilitation hospitals require patients to be able to tolerate 2 to 3 hours of rehabilitation therapy daily. Patients were excluded if they were a readmission, they had a traumatic brain injury that notably affected the content and delivery of therapy (as determined by their health care team), consent could not be obtained within the first week of admission, or their length of stay in rehabilitation was projected to be $<$4 weeks because it precluded the ability to potentially progress their rehabilitation activities prior to discharge.

Approval for this study was obtained from the university and hospital ethics boards, and all participants provided informed consent prior to measurements.

Data collection protocol

Data were collected over 2 weekdays in the second-last week of inpatient rehabilitation stay because it was expected that at this point in time participants would be near their peak inpatient recovery and would be able to maximally participate in rehabilitation activities. On each day, a research assistant met the participant in their room in the morning where they were fitted with a Holter monitor and accelerometer(s). In the evening of each day, when participants had returned to bed, the research assistant returned to collect the Holter monitor and accelerometer(s) and administer the self-report physical activity questionnaire.