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ORIGINAL RESEARCH

Relationship of Fitness and Wheelchair Mobility With Encounters, Avoidances, and Perception of Environmental Barriers Among Manual Wheelchair Users With Spinal Cord Injury

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Abstract

Objective: To assess (1) if fitness and mobility are related to behavior and perception of physical barriers and (2) if behavior and physical barrier perception are related.

Design: Cross-sectional case series.

Setting: Academic Medical Laboratory.

Participants: Manual wheelchair users (N=50) with chronic spinal cord injury (62% paraplegia).

Intervention: None.

Main Outcome Measures: Participants completed the following assessments: (1) fitness: graded exercise test (aerobic) and Wingate (anaerobic); (2) mobility: 6-minute push test and 30-second sprint test; (3) physical barrier behavior: Encounters of Environmental Features in the Environmental Aspects of Mobility Questionnaire (EAMQ); (4) physical barrier perception: Craig Hospital Inventory of Environmental Factor (CHIEF) Environmental Barriers domain.

Results: Individuals with paraplegia had higher fitness, mobility, and environmental barrier encounter rates and lower avoidance per encounter rates vs tetraplegia (all $P \leq .05$). For individuals with tetraplegia only, as mobility and fitness increased, frequencies of (1) encounters increased; (2) avoidances per encounter decreased, in multiple EAMQ domains (all $P \leq .05$). Perception of barriers did not differ between lesion levels ($P = .79$). Mobility and fitness were not related to environmental barriers perception in both groups (all $P > .17$).

Conclusions: Fitness and mobility are associated with barrier behaviors (ie, encounters and avoidances) among individuals with tetraplegia, but not paraplegia. Despite a greater barrier avoidance rate, persons with tetraplegia do not perceive more physical barriers than persons with paraplegia. Surprisingly, fitness and mobility were not related to perception of barriers in either group. More research is required on if barrier perception, behavior, or both influence participation, to enable rehabilitation programs to tailor interventions to enhance participation.

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Participation is a primary quality of life (QOL) determinant after spinal cord injury (SCI).[1,2] Lack of fitness, impaired mobility, and the physical environment[3-5] can restrict participation.[6-10] The World Health Organization's International Classification of Functioning, Disability and Health (ICF) framework indicates that participation restrictions emerge from interactions among body functions (fitness), activities (mobility), and environmental factors (physical environment).[11] This manuscript focuses on determining if there are relationships among fitness, mobility, and how manual wheelchair users perceive and behave in relation to the physical environment.

Aerobic capacity is a commonly used fitness metric.[12-17] There is a positive relationship between aerobic fitness and participation among individuals with SCI.[18,19] However, participation assessments often focus on social roles such as working. The ability to fulfill these roles requires that an individual be able to push a wheelchair within and between environmental spaces. The

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average continuous propulsion period for community-dwelling individuals with SCI is less than 3 minutes, which is an anaerobic rather than an aerobic timeframe.[20] Therefore, it is possible that anaerobic fitness will be more strongly related to environmental barrier perception and behavior than aerobic fitness.

Under the ICF, mobility is a global term encompassing many activities, such as walking, moving around using equipment (eg, wheelchair), and using transportation (eg, car or bus).[21] Ambulatory adults age ≥65 in the United States classified as disabled by mobility measures were more likely than their nondisabled counterparts to be observed avoiding physical features in the environment.[22] These results were mirrored by a Taiwanese study[23] reporting an inverse association between mobility capacity and environmental barrier perception among older adults. As 46% of individuals with SCI report at least one perceived physical environmental barrier,[24] we suggest that wheelchair mobility may be related to environmental barrier perception and behavior among nonambulatory persons.

Traditionally, barriers in the physical environment are quantified by asking how often a feature is encountered and the difficulty it presents.[25,26] While perception is important, perception may not capture environmental barrier behavior. A Finnish study[27] reported a weak relationship between objective and subjective measures of physical barriers in and around the home of older adults. To our knowledge, no one has assessed if there is a relationship between environmental barrier perception and behavior in persons with SCI.

Therefore, our purposes are to assess if fitness and mobility are related to environmental barrier perception and behavior and assess if environmental barrier perception and behavior are related. We hypothesize that as fitness and mobility increase (1) encounters will increase; (2) avoidances will decrease; (3) perception will decrease. We also hypothesize that as encounter frequency increases, barrier perception will decrease.

Methods

Subjects

Fifty-six individuals with SCI provided written informed consent and completed the University of Miami Institutional Review Board approved protocol. Fifty individuals were analyzed. We excluded individuals from analysis if they did not complete key outcome measures (n=6). All participants had a SCI between the C5 and L2 levels; were at least 1 year postinjury, were aged 20 to 55 years; and could independently propel a manual wheelchair with their upper extremities. Individuals were excluded if any of the following was present: self-reported unstable angina or myocardial infarction within the past month; resting heart rate >120; systolic blood pressure >180 mm Hg, or diastolic blood pressure >100 mm HG. Exclusion criteria were consistent with American Thoracic Society (ATS) contraindications for performing the 6-minute walk test (6MWT).[28]

List of abbreviations:

6MWT	**6-minute walk test**
ATS	**American Thoracic Society**
CHIEF	**Craig Hospital Inventory of Environmental Factor**
EAMQ	**Environmental Aspects of Mobility Questionnaire**
ICF	**International Classification of Functioning, Disability and Health**
QOL	**quality of life**
RER	**respiratory exchange ratio**
SCI	**spinal cord injury**
$\dot{V}O_2$	**oxygen consumption**
VO_2peak	**peak oxygen consumption**

Outcome measures

All participants completed the following assessments (1) Peak Oxygen Consumption Assessment[29]; (2) Peak Anaerobic Power Assessment[29]; (3) Wheelchair Mobility Assessment: 6-minute push test[29] and 30-second sprint test; (4) Self-Reported Avoidances and Encounters of Environmental Features in the Environmental Aspects of Mobility Questionnaire (EAMQ)[22]; (5) Perception of Environmental Barriers in the Craig Hospital Inventory of Environmental Factor (CHIEF).[30] Participants self-reported injury level (ie, tetraplegia or paraplegia), which was confirmed with a brief active range of motion against gravity assessment (elbow flexion, wrist extension, elbow extension, and gross opening/closing of the hand). Participants who could complete all motions bilaterally were classified as paraplegic.

Peak oxygen consumption

The peak oxygen consumption (VO_2peak) test was completed using a calibrated electronically braked arm ergometer[a] Heart rate and oxygen consumption ($\dot{V}O_2$) were monitored continuously from baseline through recovery. Heart rate was measured by standard 12-lead electrocardiography and $\dot{V}O_2$ via the open-circuit method on a spirometer[b] calibrated before each session with reference gasses.

Participants rested quietly in their wheelchairs for 10 minutes before the test to establish baseline values. Thereafter, each subject began cranking on the arm ergometer at an individualized workload (0-60 watts), maintaining cadence at 60 rpm (+/-5rpm, digital display). Every 3 minutes resistance increased at an individualized level (5-30 watts), with smaller increments for persons with tetraplegia and individuals reporting an inactive lifestyle. Subjects continued until they were unable to maintain cadence above 55 rpm. Upon cessation, subjects rested quietly for 10 minutes. The highest 30-second average recorded during the test was selected as peak oxygen consumption (VO_2peak, $mL \cdot kg^{-1} \cdot min^{-1}$). For data analysis, we defined peak aerobic power ($W \cdot kg^{-1}$) as the highest power maintained for at least 30 seconds.

Peak anaerobic power (W/kg)

We used a standardized 30-second Wingate[c] power test that is valid and reliable in individuals with paraplegia and tetraplegia.[31,32] Participants propelled a table-mounted Monark 894e ergometer[d] with no added resistance (flywheel weight only) for a 5-minute warm-up, then were subsequently instructed to attain the fastest speed possible without resistance. When cadence plateaued, a constant resistance was applied and participants continued to crank at their maximum speed for 30 seconds. Resistance for each individual was set at 1.5%-3.0% and 3.5% of their body weight, as recommended for tetraplegia and paraplegia, respectively.[33,34] For data analyses, we selected the highest 5-second average power, operationally defined as anaerobic average power/weight (W/kg).