Pushrim Kinetics During Advanced Wheelchair Skills in Manual Wheelchair Users With Spinal Cord Injury

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Objective: To assess the peak force during wheelchair propulsion of individuals with spinal cord injury propelling over obstacles from the Wheelchair Skills Test. **Participants/Methods:** Twenty-three individuals with spinal cord injury (SCI) who are full-time manual wheelchair users were included in this prospective study. A SmartWheel (Three Rivers Holdings, LLC) was used to analyze each push while subjects negotiated standardized obstacles used in the Wheelchair Skills Test, including tile, carpet, soft surface, 5° and 10° ramps, 2 cm, 5 cm, and 15 cm curbs. **Results:** When the peak forces of the advanced skills were compared to level 10 m tile/10 m carpet, there was a statistically significant increase in all peak forces (*P* value ranged from .0001 to .0268). **Discussion:** It is well documented that a large number of individuals with SCI develop upper limb pain. One of the recommendations to preserve the upper limb is to minimize force during repetitive tasks. **Conclusion:** Advanced wheelchair skills require an increase in force to accomplish. The increase in forces ranged from 18% to 130% over that required for level 10 m tile/10 m carpet. **Key words:** kinetics, manual wheelchair, peak force, propulsion, spinal cord injury, wheelchair skills test

It is reported that for individuals with spinal cord injury (SCI) the prevalence of upper limb pain is 55% to 72.7%.¹⁻⁴ The pain may originate in the wrist, elbow, or shoulder. Research has been done on the factors contributing to upper limb pain, and recommendations have been given for injury prevention. One of the factors promoting upper limb pain in SCI is the repetitive task of manual wheelchair propulsion. Recommendations for injury prevention during wheelchair propulsion are to decrease repetition, to propel with a semicircular stroke pattern, to use the lightest possible wheelchair that is properly fitted, and to minimize peak forces.⁵

Given that an active manual wheelchair user traverses many surfaces and obstacles, it is valuable to know the effort required to do these advanced skills. The SmartWheel (Three Rivers Holdings, LLC) has been used to analyze wheelchair propulsion on a variety of surfaces. Our objective was to use the SmartWheel to determine the forces required to do advanced wheelchair skills taken from the Wheelchair Skills Test (WST) that are often encountered in community mobility.

Methods

Subjects

Twenty-three individuals with SCI who are full-time manual wheelchair users were included in the study. The participant characteristics are as follows: mean age 38 years (range, 21-62), 5 with tetraplegia (C6-T1) and 19 with paraplegia (T4-L3), mean time since injury 14.8 years (range, 1-48), 12 Black and 11 White, and 20 males and 3 females. All subjects had previously completed the WST as participants in another research study.

Measures

A SmartWheel was used to analyze each push while subjects negotiated standardized obstacles used in the WST (version 4.1). The SmartWheel

is a commercially available device that records propulsion characteristics through sensors on the pushrim.

The WST includes 32 skills. With one SmartWheel, we could only capture data from one side of the wheelchair, so we selected skills that did not require maneuvering or turning. The 8 skills that we tested were 10 m tile; 10 m carpet; soft surface; 5° and 10° ramps; and 2 cm, 5 cm, and 15 cm curbs. The Wheelchair Skills Test defines different ways to test the soft surface. We used a foam gym mat covered with a layer of carpet foam and a layer of carpet so that it was 10 cm thick.

Procedures

All subjects presented in an ultralight wheelchair (CMS code K0005) and were tested in their own wheelchair. The right wheel of all wheelchairs was removed and replaced with a SmartWheel. The set-up of the chair was not altered. All subjects performed a practice test of each skill that was not recorded and then one recorded trial. They were instructed to push at their normal comfortable pace. The starting position for each skill was self-selected by the participants at a distance that allowed them to complete the skill. All participants successfully completed each skill except the 15 cm curb, which was completed by only 6 subjects.

Analysis

The peak force calculation was a direct output of the SmartWheel software. For the 10 m tile, 10 m carpet, and soft surface, the peak pushrim force was taken from the entire duration of the test, which included the start-up pushes. For the ramps and curbs, the peak force was taken specifically from the push(es) that allowed successful completion of the skill. During the recording, study staff documented the number of pushes and what occurred at each push. For example, on the 5 cm curb, pushes 1 to 3 were pre curb, and push 4 got the participant up and onto the curb. In this situation, we took the peak force from push 4. Paired *t* tests were conducted to compare the mean peak force of each skill with the mean peak force on the 10 m tile.

Results

The mean peak pushrim forces of all participants for each skill were: 10 m tile, 101 N; 10 m carpet, 103 N; soft surface, 148 N; 5° ramp, 138 N; 10° ramp, 157 N; 2 cm curb, 119 N; 5 cm curb, 155 N; and 15 cm curb, 232 N (*n*=6). When the mean peak forces were compared to the mean peak force on level 10 m tile, there were statistically significant increases in all mean peak forces ($P = .0001-.0267$), with the exception of the 10 m carpet.

Discussion

Among the skills we tested, the results demonstrate that the more difficult the skill, the more pushrim force is required. Although this is not surprising, it is the first time that the amount of force exerted during advanced wheelchair skills has been quantified.

One of the recommendations from the Clinical Practice Guideline for the Preservation of Upper Limb Function Following Spinal Cord Injury⁵ is to minimize force during repetitive upper limb tasks. Manual wheelchair users push an average of 2,000 to 3,000 times per day. This study demonstrates the increased pushrim forces that are required by advanced wheelchair skills. This should be taken into consideration by clinicians and wheelchair users in the effort to preserve upper limb function.

Limitations of this study were the small sample size and the inclusion of only individuals with SCI. Therefore, the results cannot be generalized to the population of all wheelchair users. We did not ask our subjects if they had current or a history of upper limb pain. We also did not examine their propulsion technique or wheelchair fit. Future research could be done to document pain, propulsion technique, and wheelchair fit and the correlation between these factors and the amount of force a person exerts during wheelchair propulsion.

Conclusion

The advanced wheelchair skills that we tested required an increase in pushrim force to accomplish. The increase in forces ranged from 18% to 130% over that required for level 10 m tile.

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