

# **USER EVALUATIONS OF THREE LOW-IMPACT PUSHRIM DESIGNS**

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## **ABSTRACT**

One purposed approach to reduce the likelihood of developing upper extremity pain and injury in manual wheelchair users is the use of a low-impact pushrim. Low-impact pushrims incorporate flexibility between the wheel and the pushrim which absorb impact forces during propulsion. This study investigated the effects of three low-impact pushrim designs on users perception of control, comfort, and effort after maneuvering across a test course. In general, when subjects perceived differences between low-impact pushrim concepts and a rigid pushrim, the results were negative, either decreased control and comfort, or increased effort required. The results of this study serve to provide a more defined set of design specifications for future low-impact pushrim concepts.

## **BACKGROUND**

Wheelchair pushrim design had changed little since its inception. Pushrims provide wheelchair users with a very intuitive and effective mechanism by which to control and maneuver their wheelchairs. Despite these attributes, pushrim design may not prove to be without some fundamental problems.

Upper extremity (UE) pain and injury is common among manual wheelchair users (MWUs). Sie et al., in a study of 239 MWUs, found that 64% of paraplegics and 55% of quadriplegics experienced UE pain (2). The most common sites of UE pain were at the shoulder and wrist. UE pain limits MWUs strength and range of motion, decreasing mobility and functionality, thus resulting in a loss of independence. Robertson et al., in a study relating wheelchair propulsion biomechanics to upper extremity pain and injury identified impact loading of the UE, as the hand first contacts the pushrim, during the beginning of the drive phase, as the probable injury mechanism (1). One purposed solution is the use of a low-impact pushrim (LIP), one designed specifically to reduce impact forces.

## **RESEARCH QUESTION(S)**

The basis of LIP design is to incorporate flexibility between the wheel and the pushrim. The use of a LIP may reduce the likelihood of developing UE pain and injury but it is unclear how it will affect the users ability to control and maneuver their wheelchair. Will the use of a LIP result in a loss of control, comfort, or an increase in effort required to maneuver the wheelchair? Is there an appropriate amount of flexibility such that a LIP does not adversely affect the user?

## **METHOD**

Seven experienced MWU volunteered for and gave written consent to participate in this study. The subjects had a spinal cord injury at a level T-2 or below. The average number of years using a manual wheelchair was 15.3, ranging from 3 to 30 years.

Three different low impact pushrim (LIP) concepts were investigated. Each LIP concept is referred to by its primary type of interface mechanism: rubber Shock Mount (SM), Extension Spring (EP), and Bungee Cord (BC). The load-deflection characteristics of the LIP concepts are shown in Figure 1. The load was applied tangentially to the pushrim and the displacement measured in the direction of the applied load.

Subjects were asked to maneuver their own wheelchair across a test course including a curved uphill path, a level sprint, a curved downhill path, a door threshold, a slalom course, a carpet, a

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wheelie, and a standard ramp using a rigid pushrim and then again with each of the LIP concepts. The LIP concepts were evaluated in a randomized order.

For the door threshold activity, subjects started with their rear wheels in contact with a 1.25 in. tall threshold and then in one push, rolled up and over it. The slalom and sprint activities were timed. Subjects were asked to achieve their best times for each trial. The carpet activity included a straight path, one 90 degree turns and one 360 degree turnaround. After each activity, subjects were asked about their perceived level of control, comfort, and effort when completing the task. Responses were then constrained to a comparison between the pushrim concept being used and the rigid pushrim, such that answers were either more, less, or about the same. After completing all eight activities with each LIP concept, subjects were asked to rate its overall performance. Upon completion of the activities using all of the LIP concepts, subjects were asked to compare the concepts and give general feedback.

## RESULTS

All seven subjects were able to complete the test course using each of the LIP concepts. Subject responses to control, comfort, and effort questions for each of the individual activities are shown in Figures 2, 3, and 4, respectively. From Figure 2, subjects generally perceived to have less control using the LIP concepts as compared to the rigid pushrim. However, response to the SM concept in particular indicate that there was very little perceived difference in control. From Figure 3, subjects generally perceive the LIP concepts to be less comfortable as compared to the rigid pushrim. However, there were noticeable improvements from the responses to control in the sprint, wheelie, ramp, and carpet activities. Again, as was the case for perceived control, specific responses to the SM concept indicate that there was very little perceived difference in comfort. From Figure 4, subjects generally perceived to expend more effort using the LIP concepts as compared to the rigid pushrim. Several subjects perceived a decrease in effort for some selected activities. As were the case for perceived control and comfort, specific responses to the SM concept indicate that there was very little perceived difference in effort. Subjects perceived little difference in their ability to maintain balance while using the

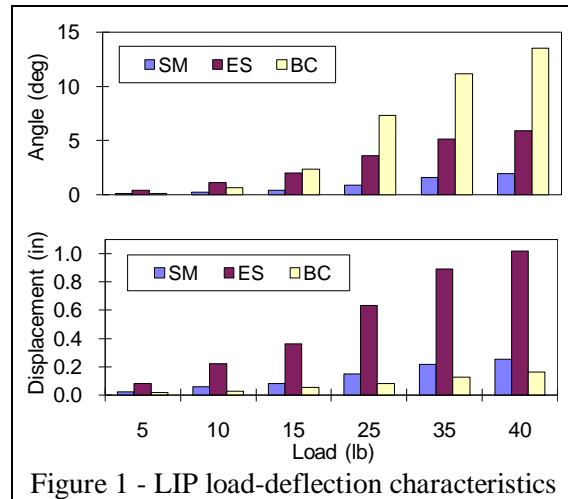


Figure 1 - LIP load-deflection characteristics

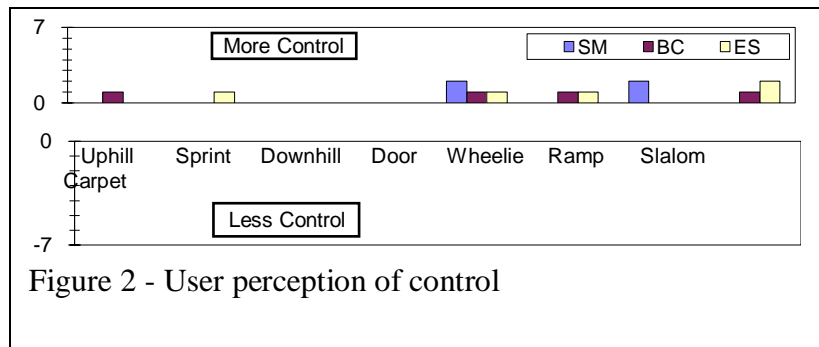


Figure 2 - User perception of control

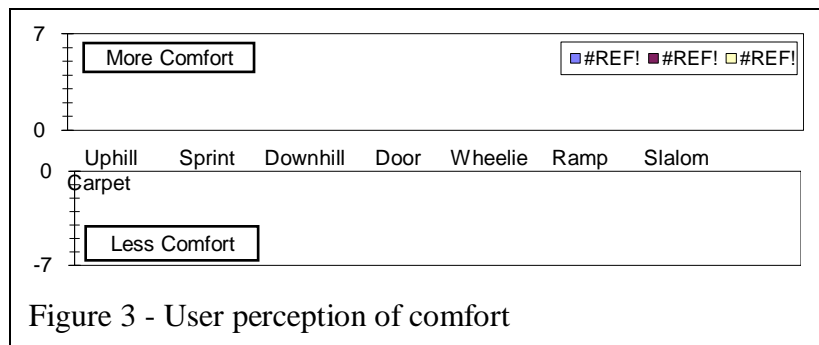


Figure 3 - User perception of comfort

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LIP concepts to complete the activities.

Only one subject perceived the SM concept to reduce impact forces but five of the subjects preferred it over the other concepts. Six subjects perceived the ES concept to reduce impact forces but only two preferred it to the other concepts. Five subjects perceived a springback of stored energy during

the final stages of the push when using the ES and BC concepts. All seven subjects responded that they would use the SM concept while only one subject would use the ES and BC concepts. Four subjects responded that they would change their mind and use their least favorite concept if it was shown to reduce the likelihood of developing UE pain and injury. All of the subjects responded that they would prefer to use the LIP concepts for a longer period of time in order to more completely evaluate their performance.

## DISCUSSION

In general, when subjects perceived differences between LIP concepts and the rigid pushrim, the results were negative, either decreased control and comfort, or increased effort required. The goal of LIP concepts is to reduce the likelihood of developing UE pain and injury due to impact forces during propulsion but without reducing the existing level of functionality or performance. This study has shown that a threshold of pushrim displacement may exist, defined by the SM concept, at which users do not perceive losses in control, comfort, or effort while still providing some impact force reduction. The results of this study serve to provide a more defined set of design specifications for future LIP concepts. Further work will investigate the effects of these LIP concepts on propulsion impact forces, kinematics, and efficiency.

## REFERENCES

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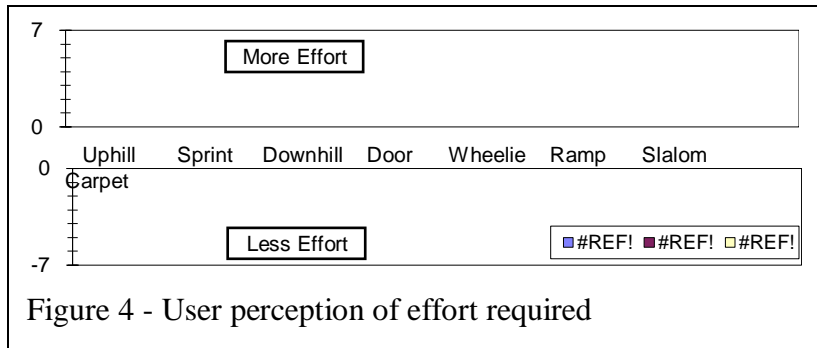


Figure 4 - User perception of effort required