Introduction

Individuals with spinal cord injuries (SCI) who utilize manual wheelchairs for mobility must transfer into and out of their wheelchair frequently during the day to complete daily activities such as: using the toilet, entering a vehicle, and using a recreational wheelchair for a sport. Wheelchair users can be assisted in transfers, but independent transfers, wherein an individual transfers himself or herself unaided, promote rehabilitation and improved mental health. [1] However, safety remains paramount; an incorrect transfer can easily result in injury from a minor skin abrasion to a serious fall. Repeated improper movements may cause pain and exacerbate preexisting musculoskeletal pathologies. [2] Therefore, transfer technique which mitigates these small injuries and successfully moves the individual to and from the target is necessary. First, the current transfer technique must be examined.

Often individuals with SCI will participate in adaptive sports, such as wheelchair racing, which provide socialization, physical exercise and personal fulfillment. [3] The specialized recreational wheelchairs needed for these sports differ from the typical manual wheelchair which can alter transfer. In racing, competitors must use a hand cycle the seat of which is lower than the typical wheelchair. This study compares the elbow kinematics of an independent wheelchair transfer from a manual wheelchair into a hand cycle at a seat elevation equal to that of the manual wheelchair and 10 centimeters below.

Methods

This study was approved by the University of South Florida Institutional Review Board (IRB). To be included in this study, the subject must:

- Be 18 years of age or older
- Be a long term manual wheelchair user of two or more years
- Be able to independently transfer without assistance
- Have a low level SCI at T1 or below.

For this study, kinematics were collected using the motion capture system, Vicon Nexus with Nexus 1.8.2 software, and passive, reflective markers adhered to the subject’s upper limbs and torso. The hand cycle used was the Top End Eliminator Racing Wheelchair with Open V Cage (Racer) (Figure 1).

The subject was instructed to transfer at their own pace as they were in an ordinary situation and given opportunity to rest between transfers. The subject transferred three times each into the Racer with the seat height equal to that of their own wheelchair and the seat height 10 centimeters below.

Results

From the literature, a transfer is broken into three phases. The phase of interest for this study is the lift phase, since it is the weight-bearing phase of transfer. [4] The start and end of the lift phase was defined as the time at which the subject’s pelvis moved off the seat to when subject’s pelvis was placed on the seat of the racer. Joint angles were calculated with the biomechanics analysis software, C-Motion Visual 3D, and the joint coordinate system used for the elbow was that recommended by the Standardization and Terminology Committee of the International Society of Biomechanics. [5] The mean and standard deviation of elbow angle was calculated for each arm from the three trials. The data was normalized to the percent of the lift phase.

![Figure 1: Top End Eliminator Racing Wheelchair with Open V Cage](image)

![Figure 1: Leading arm elbow angle for equal height, b) Leading elbow angle for equal height, c) Trailing arm elbow angle for lower height, d) Trailing arm elbow angle for equal height](image)

For the elbow angles reported, the neutral position with the elbow in neither flexion nor extension is defined as 0 degrees. Elbow flexion is reported as positive degrees from the neutral position, and elbow extension is reported as negative degrees from the neutral position.

For Figure 2a-d, the mean elbow angle is denoted by a solid black line and one standard deviation above and below the mean is denoted by a gray region. The leading arm is defined as the arm which was placed on the racer during the lift phase of transfer, and the trailing arm is defined as the arm which remains on the subject’s wheelchair during the lift phase of transfer. [6]

Results Cont.

The mean elbow angle of the leading arm is a fairly smooth curve and a small standard deviation when the racer is set at the lower height (Figure 2a). The mean elbow angle of the leading arm when the racer is at an equal height also has a fairly small standard deviation, but shows a spike at around 60% of the lift phase (Figure 2b). The mean elbow angle of the trailing arm when the racer is set to the lower height shows a large standard deviation throughout the lift phase except for around 50% of the lift phase (Figure 2c). The mean elbow angle of the trailing arm when the racer is at an equal height shows a large standard deviation for only the first 50% of the lift phase (Figure 2d).

Discussion & Conclusion

The large standard deviations for the trailing arms may be due to the subject attempting different movement strategies wherein the trailing arm is positioned at a different place on their personal chair. The subject may rely more on the leading arm to guide their body to the desired position on the racer, whereas the trailing arm is used more for propulsion and support. A similar study by Koontz et al. shows similarly large deviations from the mean of the elbow angle during the lift phase for the trailing arm, but greater deviations from the mean of the elbow angle for the leading arm. [4] However, the comparison may not be sound due the greater number of subjects in the other study.

This study carried many limitations. A single subject may not show as much variation between techniques as multiple subjects may. This may contribute to the discrepancy between the standard deviations of the elbow angle of the leading arm in this study and the Koontz study. Furthermore, the subject was accustomed to transferring independently so much that they reported that they could complete a floor to chair and chair to floor transfer unaided. Because of the subject’s proficiency and prior experience with recreational wheelchairs, they may have been much more at ease transferring.

Continuing this study with more subjects and examining other upper limb joint angles may better characterize the transfer technique. Currently, more subjects are being recruited to further the study. Though not addressed in this publication, this study is also recording the muscle activation of the biceps brachii through electromyography (EMG) in order to support the kinematic findings. Notwithstanding these limitations, this case study is a good initial step to characterizing the current independent transfer technique, adds to the current body of knowledge of transfer kinematics, and sheds light on how to improve future studies.

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References


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