INTRODUCTION

Forty-nine to 63% of conventional manual wheelchair (CMW) users suffer from carpal tunnel syndrome (CTS). This wrist pathology is likely induced by a combination of large forces transmitted through the wrist and an extreme wrist range of motion (ROM) that are both typical of CMW propulsion. Boninger et al. [1] determined that median nerve function was most highly related to the rate of rise of the pushrim force, with faster loading resulting in poorer median nerve function. Additionally Keir et al. [2] determined that wrist orientation beyond 48.6° of flexion, 32.7° of extension, 21.8° of radial deviation, and 14.5° of ulnar deviation leads to high carpal tunnel pressure levels (>30 mmHg) which are typical of carpal tunnel syndrome. High carpal tunnel pressure results in paresthesia, reduced median nerve conduction, and an increased probability of nerve impairment.

The ergonomic hand drive mechanism (EHDM) tested in this study utilizes a more neutral wrist orientation. Further, because the EHDM uses continuous contact between the lever and hand, more constant force application and therefore reduced jerk (Δa/Δt) should result.

Previously a similar analysis was conducted in which wrist jerk and angular orientation were evaluated during CMW and EHDM use [3]. The extreme wrist angles used (15° of flexion, 15° of extension, 5° of radial deviation, and 10° of ulnar deviation) were based on more general ergonomic recommendations for hand tools, however. The purpose of this project is to evaluate wrist jerk in relation to angular orientation while using the EHDM with revised wrist angles specific to CTS.

METHODS

Fourteen adult full-time CMW users were recruited to participate in this study (41.3±15.7 yrs, 73.4±16.7 kg, 172.4±12.9 cm). All participants were medically and functionally stable and at least six months post injury.

Motion data were captured by 11 cameras as participants propelled across a length of 8 m. Each participant completed five trials in a CMW and five trials in the same CMW fitted with the EHDM. The EHDM remained attached to the CMW during all ten trials and was rotated to the back of the chair, out of the way, when not in use.

Angular kinematics of the wrist were computed in the planes of flexion/extension and radial/ulnar deviation using Vicon Nexus software. A custom Matlab program was used to further process the data. Jerk was calculated as the third derivative of the wrist position data. At least one push phase was analyzed per trial and all trials were combined to calculate an average push per participant. This average push was then divided into ten consecutive time intervals representing ten percent intervals of the total push. The maximum jerk value (MJV) from each interval was calculated and then the angular orientations of the wrist in both planes of motion at the MJV were compared between conditions using paired samples t-tests (α=0.05). Additional analyses were performed on these intervals exhibiting statistically different angular orientations that were outside of the neutral range of motion as specified by Keir et al. [2]. The MJV at these extreme ranges of wrist motion were compared between conditions using paired samples t-tests (α=0.05). All statistical procedures were performed using SPSS 17.0.
RESULTS AND DISCUSSION

Use of the EHDM resulted in reduced wrist extension during the first half of the ten intervals (p<0.05), during which time CMW wrist orientation was consistently outside of the neutral range of wrist extension (<-32.1°). CMW propulsion resulted in reduced wrist extension during the last four intervals (p<0.05). During these last four intervals however, EHDM propulsion utilized a wrist orientation within the neutral range.

During the first interval, CMW propulsion exhibited radial deviation while EHDM propulsion exhibited ulnar deviation, although both were within the neutral ROM. During the last five intervals, however, EHDM propulsion resulted in reduced ulnar deviation, with CMW propulsion consistently outside of the neutral range of ulnar deviation (<-14.5°).

After reducing the data to only include orientation and MJV that were significantly different between conditions and outside of the healthy ROM, it was found that EHDM use resulted in more instances of unhealthy range of motion (26 v. 19 for extension, 11 v. 9 for ulnar deviation), but CMW propulsion exhibited larger jerk values at all of these instances in time (p<0.05, Figure 1).

CONCLUSIONS

In general EHDM use resulted in reduced extension and ulnar deviation as compared to CMW use throughout the push. Additionally, while EHDM use resulted in more instances of significantly different angular orientations occurring outside of a neutral range of wrist motion, CMW propulsion resulted in consistently higher jerk values at all of these time points. These results evince more constant force application with EHDM use and infer a reduction in wrist joint reaction forces throughout a more neutral ROM, which may lessen both the symptoms as well as the likelihood of developing CTS.

REFERENCES


ACKNOWLEDGEMENTS

Supported by the Clinical and Translational Science Institute Pilot & Collaborative Research Projects (NIH). The hand drive mechanism used in this study is the intellectual property of Shands Healthcare.