VARIABILITY OF UPPER EXTREMITY KINEMATICS AND SHOULDER PAIN DURING WHEELCHAIR PROPULSION: A VECTOR CODING ANALYSIS

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INTRODUCTION

Shoulder pain is common among manual wheelchair users with approximately 70% of them reporting having shoulder pain [1]. Although variability of kinematics and kinetics of locomotion has been found to be indicative of motion dysfunction in gait literature, few studies have investigated the relationship between variability and dysfunction of upper extremities during wheelchair propulsion. One of the commonly used techniques to study variability is vector coding [3]. In this study, the peak angular deviation of the vector coding coupling angle (VCADpeak) was used to study the variability as it represents the maximum amount of variability present in the system. The variability of upper extremity kinematics as a function of pain is assessed through VCADpeak. It was hypothesized that variability of the upper extremity coupling will be lower in people with severe shoulder pain.

METHODS

24 manual wheelchair users (11 female, 13 males, age = 24.3±10.1 years) with more than one year of experience were recruited for the study from the community. University IRB approval and informed consent were obtained. The average length of wheelchair usage was 15.0±8.5 years. Injury types included: spinal cord injury (N=11), spina bifida (N=8), amputation (N=2), spinal cyst (N=1), scapular agenesis (N=1), and arthrogryposis (N=1).

Data collection and reduction

Wheelchair User Shoulder Pain Index (WUSPI) surveys were collected. WUSPI survey consists of 15 questions about the level of pain (no pain=0, severe pain=10) when performing various daily activities. The total WUSPI score, which ranges from 0 (no pain) to 150 (extreme pain) was calculated by adding the score of each item.

Each participant’s wheelchair was bilaterally fitted with force and moment sensing wheels (SmartWheel, Three River Holdings LLC; Mesa, AZ) and placed on a stationary roller system. Real-time feedback of the propulsion speed was provided. The participants were asked to push at slow (0.7 m/s), fast (1.1 m/s) and a self-selected speed for three minutes in separate trials. Reflective markers were placed on anatomical landmarks and kinematic data were collected (Cortex 2.5, Motion Analysis Co.; Santa Rosa, CA). Both the kinematic and kinetic data were collected simultaneously at 100 Hz. SmartWheel data were used to define the start and end of a cycle. Each cycle was normalized to 100% propulsion cycle. The kinematic data were filtered with 2nd order Butterworth filter at 8Hz. Data from the fifth cycle onwards (i.e. steady-state behaviors) were analyzed.

Vector coding

Segment angles of the upper arm (θAD) and forearm (θFA) in the sagittal plane were calculated at each % cycle. An angle-angle plot of θAD vs. θFA was created and the vector coding coupling angle θFA was calculated [3]:

\[ \theta_{VA,i} = \arctan \left( \frac{\theta_{VA,i+1} - \theta_{VA,i}}{\theta_{FA,i+1} - \theta_{FA,i}} \right), i = 0 - 99 \% \]  

(1)

Peak angular deviation of θVA (VCADpeak) was used to analyze the variability of the upper extremity, where larger number indicates greater variability of the coupling between two segments.

Data analysis

Data were categorized into three groups based on the severity of pain: WUSPI=0 (N=6); WUSPI
between 1 and 30 (N=15); and WUSPI greater than 30 (N=3). The stroke patterns of each participant were classified (See Table 1) [4]. A one-tailed one-way ANOVA was performed to test the statistical differences between groups (α=0.05). All statistical analyses were performed in SPSS Version 20.

**Table 1**: Distribution of stroke patterns and self-reported pain status.

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<tr>
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<tbody>
<tr>
<td>WUSPI = 0</td>
<td>5</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0&lt;WUSPI&lt;30</td>
<td>7</td>
<td>2</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>WUSPI≥30</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>N =</td>
<td>14</td>
<td>3</td>
<td>2</td>
<td>5</td>
</tr>
</tbody>
</table>

**RESULTS AND DISCUSSION**

No statistical differences were found between groups of different severities of pain (Table 2).

**Table 2**: The VCAD<sub>peak</sub> at the three speeds.

<table>
<thead>
<tr>
<th>[Speed] (m/s)</th>
<th>Average ± S.D. (deg)</th>
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<tbody>
<tr>
<td>[1.18 ± 0.06]</td>
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<tr>
<td>[0.97± 0.20]</td>
<td></td>
</tr>
<tr>
<td>[0.76 ± 0.04]</td>
<td></td>
</tr>
<tr>
<td>WUSPI = 0</td>
<td>53.3 ± 18.7</td>
</tr>
<tr>
<td>0&lt;WUSPI&lt;30</td>
<td>54.4 ± 13.7</td>
</tr>
<tr>
<td>WUSPI≥30</td>
<td>31.3 ± 17.1</td>
</tr>
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</table>

As previous studies have suggested, kinematics and kinetics differences exist between different stroke patterns [4]. When VCAD<sub>peak</sub> values were broken into groups according to the stroke pattern (Fig. 1), decreasing VCAD<sub>peak</sub> was observed as the severity of pain increased in SC pattern. Therefore, a one-way ANOVA was performed on the group with SC stroke pattern. Due to the small sample size, we were not able to perform statistical analysis to compare the differences between different pain severities for other stroke patterns.

The analysis revealed statistical differences between groups of pain severity at fast speed (p=0.044). The LSD post hoc test showed that the group with WUSPI≥30 had significantly lower VCAD<sub>peak</sub> compared to the other two groups. However, there were no significant differences between WUSPI = 0 and 0<WUSPI<30. No group differences in VCAD<sub>peak</sub> were observed for the trials at self-selected and slow speeds.

These results indicate an association between increased shoulder pain and reduced peak variability in coupling between the forearm and upper arm motions when pushing at a more challenging pace. One possible reason is that the coupling between forearm and upper arm became stiffer as a response to underlying injury status.

Previous gait variability literature has shown differences in the amount of variability in spatiotemporal parameters at different percentages of comfortable speeds [5]. Our results are consistent with the literature.

**Figure 1**: A plot of VCAD<sub>peak</sub> at fast speed categorized into different stroke patterns.

Limitations of this study were the small sample size of participants in the severe pain group and limited age range. Future studies shall incorporate wheelchair users with varying age and pain levels, and understand how stroke patterns affect variability.

**REFERENCES**


**ACKNOWLEDGEMENTS**

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