ANALYSIS OF VIBRATIONS AND SHOCKS INDUCED DURING WHEELCHAIR PROPULSION.

Written by: **OLGA FOMINA, EMT, ATP, CRTS®**

NRRTS THANKS KI MOBILITY FOR SPONSORING THIS ARTICLE.

INTRODUCTION

Every wheelchair user experiences shocks and vibrations transferred from the ground to the rider's body multiple times throughout the day. Thresholds, doorways, curbs, uneven terrain, grass, gravel, random cracks and other obstacles affect the smoothness and effort requirements of wheelchair propulsion. Shock and vibrations experienced by typical manual wheelchair users can decrease a rider's comfort, increase the rate of fatigue, cause spasticity, decrease propulsion distance and momentum, and consequently limit endurance, mobility and independence.

Let's first look at the essential differences between shock and vibration. Vibration is low-magnitude repeated loads. Vibrations are most frequently experienced when riding over uneven surfaces such as tactile paving and gravel. Shock is infrequent high loads. In a wheelchair, this is a sudden and singular vertical descent. Wheelchair users experience shocks when wheeling off the curb or crossing a threshold or speed bump.

PREVIOUS RESEARCH OBSERVATION AND FINDINGS

The number of people using a wheelchair is estimated at 2.2 million in the United States and 750,000 in the United Kingdom (Vorrink, Van der Woude, Messenberg, Cripton, Hughes, Sawatzky, 2008); however, little is known about how vibration affects rider comfort and seat forces. In one study, vibration was studied in conjunction with acceleration force and momentum (VanSickle, Cooper, Boninger, DiGiovine, 2001). Other studies have focused on physiological parameters. The initiative to study whole-body vibration (WBV is the vibration transmitted by supporting surfaces to the entire human body), and its effect on spasticity was taken in 2008 with a study of different types of wheels (Spinergy versus traditional steel-spoked wheelchair wheels) and spasticity reduction (Vorrink, Van der Woude, Messenberg, Cripton, Hughes, Sawatzky, 2008). Researchers concluded that under the current standardized conditions, the Spinergy wheelchair wheels, as compared with the standard steel-spoked wheelchair wheels, neither absorb more vibration at the footplate or the axle nor reduce perceived spasticity or improve comfort in individuals wheeling over rough surfaces and obstacles. Prolonged exposure to seated whole-body vibration (WBV) is also considered a risk factor for neck pain and low back pain (LBP) (Nagai, Bansbach, Faherty, Abt, Sell; 2016).

UNDERSTANDING VIBRATION

The complex rehab manual wheelchair is engineered and specified to accommodate the needs of most users. The vibrations experienced by the rider can originate from multiple sources:

- Wheelchair components: the cross brace, caster forks, swing-away legrests, footplates, back posts, armrests, axles and more (see Figure 1).
- The terrain that wheelchairs travel on: sidewalks, streets, curb-cuts, hiking trails, gravel, grass, asphalt, etc. (see Figure 2).
- A moving vehicle when a rider is transported in the wheelchair. In this scenario, the wheelchair is in a static position, but the rider is still experiencing vibrations transferred to the body through the wheelchair frame (see Figure 3).

Optimizing propulsion performance is a major goal in the rehabilitation of the client with paraplegia due to spinal cord injury (SCI). The wheelchair user puts an intense load upon the muscles and joints of the upper trunk and extremities during wheelchair propulsion and in almost every other daily activity such as transfers, driving, and household activities. This upper extremity loading leads to musculoskeletal pain. The majority of users with paraplegia also experience spasticity and LBP, which effect independence and wheelchair maneuvering efficiency. Many active wheelchair users report that whole-body vibration triggers spasticity and LBP.

FIGURE 1 The cross brace, axile and footrest hangers can all translate vibration to the client.

FIGURE 2 The terrain can lead to WBV in a wheelchair user.

FIGURE 3 Vibration from a moving vehicle can be translated through the wheelchair to the rider.

Manufacturers have designed wheelchairs and components to improve the effectiveness and comfort of the ride. Examples include innovative casters, anatomically supportive frames and suspension systems to reduce shocks and vibration. The consequences of whole-body vibration, such as LBP and spasticity, in active wheelchair users are also well-known and well-defined in the Complex Rehab Technology (CRT) industry. Design to reduce vibration is also targeted at reducing these issues.

The vibration and shocks individuals encounter on a daily basis while propelling their wheelchair may be sufficient to cause injury. Therefore, knowledge of the forces and accelerations experienced by the rider is important for successful wheelchair design which reduces vibration and shocks.

CASE STUDY

In this case study, we are focusing on vibrations experienced by people with low level spinal cord injuries who have good trunk balance and full function of their upper extremities.

In 2019, a new innovative frame concept (Ki Mobility Ethos) was introduced to eliminate or significantly reduce spasticity by reducing vibration. Being a new design, this requires in-depth research and observation to understand to which degree spasticity and LBP can be reduced. The frame is separated, and four ISO tech polymers are added in between the seat frame and the base frame of the wheelchair. The purpose of this case study is to evaluate whole-body vibration exposure on manual wheelchair users in their communities and to determine if use of this new frame design reduces vibration and subsequent user impact.

Three active manual wheelchair users agreed to participate in the case study. We conducted our research under typical propulsion conditions, including urban streets, parks, apartments and work environments. Subjects also performed curb descents of various heights (1, 2.5 and 5 inches) and propulsion over various terrains including grass, gravel, street, tactile paving and hardwood floors on a created course in three different manual wheelchairs. Questionnaires were administered after each wheelchair trial, and time measurements were taken during each obstacle course wheelchair trial. Results were compared to report findings. This study utilized a mixed-method design — direct observation, interview and secondary data analysis. We hypothesized that the wheelchair design would reduce vibration experienced by individuals during propulsion.

SPECIFIC AIM:

To test different wheelchair frame designs to determine if addition of ISO tech polymers with separation of the wheelchair frame (specifically the Ki Mobility Ethos frame design) will reduce user spasticity and musculoskeletal pain.

CONTINUED ON PAGE 48

TABLE 1

	PARTICIPANT 1			PARTICIPANT 2			PARTICIPANT 3		
	Own wheelchair trial	Titanium rigid wheelchair with frog legs	Ethos Ki Mobility Trial	Own wheelchair trial	Titanium rigid wheelchair with frog legs	Ethos Ki Mobility Trial	Own wheelchair trial	Titanium rigid wheelchair with frog legs	Ethos Ki Mobility Trial
Appearance	5	4	4	4	4	5	3	5	5
Function on smooth surface	5	5	5	5	5	5	4	5	4
Function on uneven surface	2	3	4	1	3	4	3	3	4
Mechanical performance	3	4	4	4	4	3	5	4	3
Vibration damping	1	2	4	3	1	4	2	2	4
Low back pain (5 - no LBP, 1 -high level of LBP)	4	3	4	3	4	4	4	2	4
Spasticity (5 - no spasticiy triggered, 1 - high level of spasticity)	3	3	4	3	2	4	2	2	4
Overall impression	4	4	4	4	3	5	4	3	4
Mean per trial	3.375	3.5	4.1	3.375	3.25	4.25	3.375	3.25	4

Mean for own wheelchair trial	3.375
Mean for titanium rigid wheelchair with frog legs trial	3.333
Mean for Ethos Ki Mobility trial	4.13

ANALYSIS OF VIBRATIONS...
(CONTINUED FROM PAGE 47)

PHASE 1 — INTERVIEW AND DISCUSSION

Participants identified the types of surfaces and obstacles traversed when using their manual wheelchair. The Human, Activity, Assistive Technology, and Context (HAAT) model was utilized (Cook & Polgar, 2008). Specifically, the discussion focused on when the obstacles occur, how often they occur, what propulsion strategy is used to traverse obstacles, and the amount of vibration and spasticity experienced when negotiating the obstacles.

PHASE 2 — COURSE CREATION

Participants identified, in their opinion, the objectives, constraints and metrics of a device that could decrease the transmission of vibration, shock and motion to individuals using a manual wheelchair.

An obstacle course was created for the subjects that required propulsion throughout curb descents of various heights (1, 2.5 and 5 inches) and various terrains (grass, gravel, street, tactile paving and hardwood floor).

Participant 1 has been using a titanium rigid frame TiLite wheelchair with Roho Nexus seat cushion and reported a significant increase in LBP level while riding over uneven surfaces.

Participant 2 has been using an aluminum rigid TiLite wheelchair with suspension caster forks and Roho Quadro seat cushion and reported spasticity while riding over tactile paving and uneven surfaces.

Participant 3 has been using an aluminum rigid Quickie wheelchair with suspension caster forks and Ride Designs Custom seat cushion and reports LBP when riding over uneven terrain.

All three participants were similar in physical presentation, ability level, and seating and positioning needs.

PHASE 3 — OBSERVATION

All three participants completed the obstacle course and filled out a questionnaire three times in total: 1) in their own optimally configured wheelchair, 2) in an optimally configured titanium rigid wheelchair with suspension caster forks frog legs, and 3) in an optimally configured Ki Mobility Ethos wheelchair.

PHASE 4 - DATA ANALYSIS

The Wheelchair Satisfaction Questionnaire (WSQ) is a valid method to assess the overall wheelchair user's level of performance and satisfaction with their wheelchair. The WSQ is comprised of 16 visual analogue scale questions; each question includes a qualitative explanatory comment. High mean satisfaction scores on the follow-up questionnaire support face and content validity of the WSQ. The results support the WSQ as a reliable measure, confirming the WSQ as a reliable tool for user feedback on wheelchair function. The WSQ is designed to provide user feedback with enough granularity to give data on particular aspects of wheelchair structure and function (Bane, 2019). The questionnaire used to obtain data for our study was a modified version of the WSQ with both forced-choice and open-ended questions, focusing on the aims of our research. Participants were asked to rate eight wheelchair characteristics on a 5-point Likert scale in which 1 = poor and 5 = excellent. The six factors were appearance, function on a smooth surface, function on an uneven surface, mechanical performance, level of vibration transferred through the user's body, low back pain, spasticity and overall impression. The average of the eight scores represents the overall level of satisfaction.

Each participant completed and submitted a questionnaire after each wheelchair trial (see Table 1).

RESULTS:

Based on the results of the questionnaires and observations, we can exclude the optimally configured Titanium rigid wheelchair with frog legs from our case study and simply compare results of the users own optimally configured wheelchair trial against the trail in the Ethos wheelchair. SCI wheelchair users who participated in our case study reported an over 18.3% decrease in spasticity and musculoskeletal pain triggered by whole-body vibration while propelling the Ethos frame design. The study used a small sample size and did not use objective vibration measures. However, this study does demonstrate the significance and importance of vibration damping in pain and spasticity reduction.

CONTACT THE AUTHOR

Olga may be reached at OLGA.FOMINA@NSM-SEATING.COM.

REFERENCES

1.VORRINK S, VAN DER WOUDE L, MESSENBERG A, CRIPTON P, HUGHES B, SAWATZKY B. COMPARISON OF WHEELCHAIR WHEELS IN TERMS OF VIBRATION AND SPASTICITY IN PEOPLE WITH SPINAL CORD INJURY. JOURNAL OF REHABILITATION RESEARCH & DEVELOPMENT. 2008; 45:1269-1280.

2. VANSICKLE D, COOPER R, BONINGER M, DIGIOVINE C. ANALYSIS OF VIBRATIONS INDUCED DURING WHEELCHAIR PROPULSION. JOURNAL OF REHABILITATION RESEARCH AND DEVELOPMENT. 2001; 48:409-421.

3. SEIDEL H, BLUETHNER R, HINZ B. EFFECTS OF SINUSOIDAL WHOLE-BODY VIBRATION ON THE LUMBAR SPINE: THE STRESS-STRAIN RELATIONSHIP. INTERNATIONAL ARCHIVES OF OCCUPATIONAL AND ENVIRONMENTAL HEALTH. 1986;57(3):207-23.

4. NAGAI T, BANSBACH H, FAHERTY M, ABT J, SELL T, LEPHART S. EFFECTS OF SEATED WHOLE-BODY VIBRATION EXPOSURE ON CERVICAL AND TRUNK PROPRIOCEPTION AND STATIC AND DYNAMIC POSTURAL STABILITY. JOURNAL MUSCULOSKELET DISORDER TREATMENT, JMDT-2-024, (VOLUME 2, ISSUE 4), RESEARCH ARTICLE.

5. COOK A, POLGAR J. COOK & HUSSEY'S ASSISTIVE TECHNOLOGIES: PRINCIPLES & PRACTICE. 3RD ED. ST. LOUIS, MO: MOSBY ELSEVIER; 2008. PP. 3-33.

6. BANE H, SHEAFER V, RISPIN K. FACE AND CONTENT VALIDITY FOR THE WHEELCHAIR SATISFACTION QUESTIONNAIRE. DISABILITY AND REHABILITATION ASSISTIVE TECHNOLOGY JOURNAL. PUBLISHED ONLINE: 14 NOV 2019. RESEARCH ARTICLE.

RESOURCES

THE WHEELCHAIR SATISFACTION QUESTIONNAIRE: WWW.LETU.EDU/GLOBAL-INITIATIVES/WHEELS/FILES/WSQ-QUESTIONNAIRE.PDF

Olga Fomina, EMT, ATP, CRTS®, has a Master of Arts in journalism from Moscow University and earned her EMT certification from City College of San Francisco. She started as a journalist more than 10 years ago with in-depth research of clinical experience, primarily in mental health, in a variety of settings including inpatient hospitals, outpatient partial hospitalization programs, public schools and community-based settings. She additionally received her EMT license and worked in variety of EMS agencies. Dealing with many acute cases, Fomina eventually decided to pursue rehabilitation and assistive technologies application in long-term care. Fomina worked abroad in Brazil, Poland and Russia as a consultant and is currently employed by National Seating & Mobility Inc.