Validation of a Standardized Navigation of Winter Mobility & Accessibility Network

Edward M. Giesbrecht[1], Jacquie Ripat[1] & Jaimie Borisoff[2]

[1]University of Manitoba, Department of Occupational Therapy; [2] British Columbia Institute of Technology

INTRODUCTION

Persons with spinal cord injury (SCI) who use a manual wheelchair (MWC) as their primary means of mobility typically experience seasonally-related accessibility barriers in winter. Environmental barriers such as icy or snow-covered surfaces and snow windrows have been reported as frequent barriers to mobility in studies of MWC users [1,2]. These seasonal barriers can influence both the frequency and quality of community participation. Findings from a 12-month longitudinal study of 11 wheelchair users confirmed that during non-summer (vs. summer) months, on winter days with (vs. without) snow accumulation, and on winter days when temperatures were below (vs. above) 0°C, people made fewer trips per day and wheeled shorter distances at slower speeds [3]. A focus group with eight wheelchair users concluded that winter community participation should be considered a right for all citizens [4]. Taken together, this body of research provides evidence to support the detrimental effect of inclement winter-related barriers on community participation among individuals with SCI who use a MWC.

Observations and recall interviews of MWC users have identified a variety of factors that contribute to the challenges of using a MWC in winter conditions. The formation of ice or hard-packed snow on travel surfaces can result in loss of traction and slippage for both the larger rear drive wheels and the smaller front casters. This loss of traction can impede forward movement or create an undesired change of direction due to asynchronous wheel rotation. When a cross slope is present (e.g., wheeling on a sidewalk or across a driveway), the MWC may begin sliding sideways due to gravity and reduced traction. These conditions require additional expenditure of energy to achieve mobility and increase the risk of collisions and tipping sideways. When snow accumulates (e.g., deeper snow; snow windrows [snow piles left following plowing of streets or sidewalks]), the small front casters are more likely to sink into the travel surface, preventing forward progress. When the user is traveling forwards with momentum, sinking casters can result in a sudden stop causing the user to fall forwards out of the chair. When the casters become imbedded in snow, the user may exert considerable push force on the drive wheels to overcome this resistance and elevate the casters out of the snow, introducing a considerable risk of tipping the MWC backwards. These issues are exacerbated when the user ascends or descends a ramp, orienting the wheelchair out of a horizontal alignment and making it more susceptible to tipping. Gravity creates additional resistance when traveling up an incline and generates undesirable momentum when traveling down a slippery slope. In addition, the accumulation of snow or slush at the lower end of the ramp (the ground/ramp transition), when ascending or descending, can impede caster roll, causing a sudden stop and risk for tipping or falling forwards. Over time, if accumulated snow is not cleared on level ground, ruts will develop. When the MWC user wants to change course, these ruts present a vertical barrier. The user must traverse the outer margins of the ruts, which is particularly difficult with small casters, and may slide back into the rut or tip over backwards when attempting to elevate the casters up and out of the rut margins. In summary, navigating a MWC in winter conditions is highly compromised by decreased control due to slippage; increased effort expenditure due to rolling resistance; and stability/safety issues (i.e., risk of tips and falls) due to impeded caster movement.

While recommendations have been made to identify and improve technology that promotes safe and effective winter MWC, use only a few studies have explored the most effective strategies and devices for improving outdoor winter mobility [1,5]. Experienced MWC users' performance in ascending and descending a snow-covered ramp and performance of inexperienced MWC users' with four types of wheelchair casters on snow-packed surfaces and inclines have been targeted areas of previous investigation [6,7]. Beyond these preliminary attempts to examine winter-specific strategies and products for MWC users, there remains a dearth of knowledge in this area. A scoping review of peer-reviewed literature recently identified only 25 studies examining *any* aspect of winter mobility and including *any* type of mobility device (e.g., canes; scooters; manual and power wheelchairs) [8]. Extant studies of winter mobility have been conducted in simulated experimental conditions, such as the WinterLab at the Toronto Rehabilitation Institute (http://www.idapt.org/index.php/labs-services/research-labs/ceal-labs/winterlab), where researchers recreate winter conditions of snow, ice, and windchill in a controlled environmental chamber. While these have been useful in advancing this area of research, the study settings lack the ecological validity and dynamic weather and environmental challenges of authentic winter conditions. Creating a context that incorporates specific problematic winter mobility barriers and that can be replicated in a standardized and consistent manner would be highly beneficial. This could be used for assistive technology development (e.g., prototyping and testing), assistive technology evaluation (e.g., testing of different wheelchairs and winter-related modifications), clinical device prescription (e.g., comparison of different wheelchair devices), and clinical training of wheelchair mobility skills. The investigators have developed a prototype environment - the *Standardized Navigation Of Winter Mobility & Accessibility Network* (SNOWMAN) – through a collaborative process engaging end-users and experts in rehabilitation, engineering and architecture. SNOWMAN is intended to prove a safe and semi-protected, but ecologically valid, evaluation context. Development has included identification of essential accessibility barriers and obstacles to include and the protocols for constructing and measuring consistency of these barriers. The next step in SNOWMAN development is to evaluate the prototyped version with wheelchair users.

Purpose and Objectives

The purpose of the study is to evaluate the validity and feasibility of the SNOWMAN to address the identified research gap. The study will address objectives specifically related to questions of face, content and construct validity as well as feasibility of administration:

a) **Face validity**: Does the course authentically represent the wheelchair user experience with winter appropriate mobility conditions and barriers?
b) **Content validity**: Does the scope of conditions incorporated in the course design sufficiently cover those typically experienced by wheelchair users in winter?
c) **Construct validity**: Does the course allow for sufficient variation in wheelchair mobility performance to discriminate differences between device types?
d) **Feasibility**: Is the course administration protocol sufficiently robust to allow data collection efficiently, safely, and effectively?

METHODS

This validation study uses a mixed methods study design to collect quantitative outcomes, including a subjective patient-reported outcome measure and objective performance measures, as well as qualitative user experience data. A concurrent triangulation/convergence design entails collecting qualitative and quantitative data at the same time and then juxtaposing the data during analysis to compare and contrast findings to enhance interpretation [9]. Participants attempt to navigate each SNOWMAN obstacle course component using a) their own MWC and b) their own MWC mounted on a Freedom Trax™ product - an electrically powered platform with tracks, with a rest period in between. Following course completion in each of the two conditions, participants view video footage of their performance and provide feedback about their experience.

Participants

Up to 8 individuals who use a MWC in the community during winter months (November-April) will be recruited to participate. Participants must be 18 years of age, used a MWC for at least two years, and be in stable health.

Procedures

Participants complete a series of mobility skills on the SNOWMAN course twice in random sequence; once using their MWC in its standard configuration and once with their MWC mounted on the Freedom Trax™ (Figure 1). Freedom Trax™ is "a motorized [electric] track system designed to transform a manual wheelchair into an off-road vehicle that can traverse sand, snow, gravel and mud." The Freedom Trax™ was selected for use in this portion of the study as it represents a device configuration that should permit relative ease of mobility over virtually all course obstacles, with limited effort or risk for the MWC user. To establish validity of this course, the Freedom Trax™ operates as a "best case" scenario for comparison purposes.

Figure 1. Freedom Trax

Prior to data collection, the obstacle conditions of the course are measured using a standard protocol and recorded on a data record form. A standardized protocol and checklist are used to direct participants to complete the obstacle course (Figure 2). Participant trials of the obstacle course are video recorded to obtain performance data (i.e., obstacle completion time; evaluation of objective wheelchair skill capacity) and to facilitate qualitative data collection. Data collection was only undertaken on days when the ambient temperature was warmer than -25°C (including wind chill). Participants were offered protective hand wear (gloves, mitts) and warming devices ("hot shots") if desired. The obstacle course was in close proximity to a warm indoor environment (< 1 minute away) and each data collection period outdoors was a maximum of 30 minutes.

To address Face Validity and Content Validity, qualitative data is collected during the rest break following each trial. The video recording is used to facilitate an audio-recorded "go along" interview [10], where investigators ask participants to articulate out loud their experience performing each of the course obstacles. After completing both trials, participants are asked a series of Likert-scale questions about their perception of the authenticity and scope of the obstacle course challenges relative to their actual winter mobility experience. Affirmation by participants of authenticity of winter conditions will support face validity, and confirmation of comprehensiveness in the scope of obstacles encountered will support content validity.

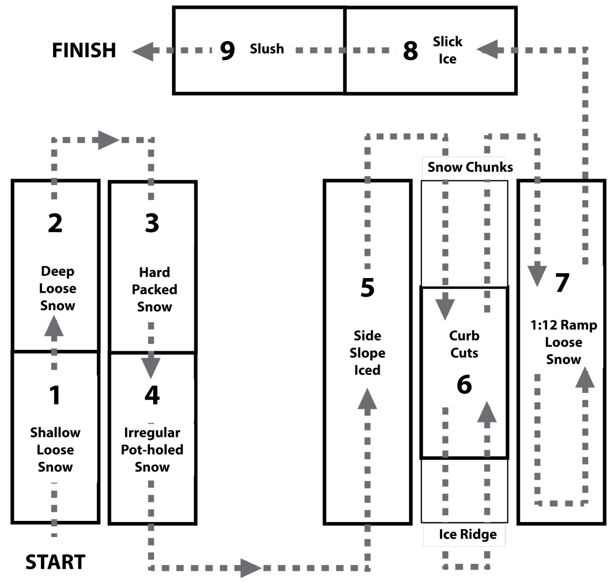

Figure 2. SNOWMAN course layout

To address Construct Validity, participants complete the primary outcome measure, the Quebec User Evaluation of Satisfaction with assistive Technology 2.0 (QUEST 2.0) questionnaire during the rest break following each trial [11]. The QUEST Device subscale evaluates user satisfaction with 8 performance criteria for an assistive device using a 5-point Likert Scale, producing a total score between 5 and 40. Secondary measures include a Winter Wheelchair Skill Capacity (WWSC) measure and time to complete obstacle components; one research assistant (the spotter) scores these during administration and the second research assistant scores retrospectively using video recordings. The WWSC measure was developed by the investigators specifically for this study, but is reflective of an established measure of wheelchair skill capacity (Wheelchair Skills Test v. 5.0) modified to reflect winter obstacle course components using the same scoring scale [12].

To address Feasibility of administration, research assistants document each protocol step during administration, including completion of protocol components, administration time, severe/minor adverse events, and major/minor protocol deviations. Following administration with the first and last participant, research assistants collaboratively complete the NASA Task Load Index (TLX) and the System Usability Scale (SUS). The TLX is a 6-item questionnaire to rate perceived workload for task completion and the SUS is a 10-item Likert scale questionnaire measuring user perceptions of system usability. The TLX and SUS scores are used to assess administration demands and usability of the SNOWMAN protocol.

Data Analysis

For Face and Content Validity, responses to the Likert-scale questions of verisimilitude and scope of environmental obstacles encountered will be summarized with descriptive statistics; ≥ 75% responses of 4 or 5 will be considered supportive. For construct validity, a Repeated Measures ANOVA statistic will be used to compare the primary outcome (mean QUEST score), as well as the secondary measures of WWSC and obstacle course completion time. Our hypothesis is that participants will rate and demonstrate superior performance with the Freedom Trax configuration compared to their own wheelchair configuration. A significant difference in QUEST score, WWCT score, and obstacle course completion time between the two wheelchair configurations will support validity in measuring the construct of performance in winter conditions. The "go along" interview recordings will be transcribed verbatim and thematically analyze between the two wheelchair configurations (i.e., standard vs Freedom Trax) using a qualitative analysis framework [13]. The thematic analysis will then be superimposed on a matrix of QUEST total and item scores (by device configuration) to provide depth of interpretation of scores and additional insights into participants' rationale for scores. For administration feasibility, investigators will summarize the data from each protocol checklist using descriptive statistics. SUS scores following first and last participant administration will be evaluated against the Sauro-Lewis grading scale and TLX scores will be evaluated descriptively using both weighted and unweighted values [14]. Both composite and comparative TLX and SUS scores (i.e., following first and last participant administration) will be evaluated to determine whether perceived usability and workload change over time.

RESULTS

Participant data collection is currently underway, but not yet sufficient for preliminary analysis. We anticipate that data collection will be complete by March 2023, at which time we will be able to complete the analysis and report on the specific results and findings of the study.

DISCUSSION

Despite the numerous challenges MWC users face in winter months, there is little evidence for how to improve winter mobility for MWC users. During winter months, MWC users face considerable environmental and mobility challenges such as icy or snow-covered surfaces and snow windrows [1]. The current design of MWC does not support winter use and leaves MWC users with no choice but to decrease their frequency and quality of community participation. The solution to this seasonal struggle would be to identify and improve technology that promotes safe and effective winter MWC use [2,5]. The SNOWMAN course is designed to mimic winter challenges MWC users face in a safe and semi-protected context. The findings from this study will establish evidence for the validity and feasibility of SNOWMAN for evaluating real-world challenges of winter, with the potential for development, testing, prescription and training of mobility-related assistive technologies.

CONCLUSION

SNOWMAN can be a safe and ecologically valid evaluation context that could contribute to significant innovation for both clinical and research purposes, to developing strategies and technologies that improve MWC user mobility during the winter.

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