REVERSE STRATEGY FOR WHEELCHAIR RAMP ASCENT IN WINTER

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INTRODUCTION

Winter conditions provide numerous difficulties for people who use manual wheelchairs. Considering the number of countries with prolonged snow and ice seasons, a remarkably small amount of literature exists on non-sport winter activities. Therefore, building guidelines and standards are predominately based on "dry-land" studies. For residential access ramps, wheelchair users often identify winter accessibility problems due to snow and ice.

Wheelchair users typically use ramps and motorized lifts to access buildings with raised doorways or multiple floors. Ramps with a 1:12 slope are often recommended for building accessibility, although a 1:20 slope is considered most appropriate for all wheelchair users. The application of ramp standards or guidelines remains inconsistent.

From the literature, young wheelchair users can ascend ramps up to a 1:8 slope, in dry controlled conditions. However, Rousseau et al. [1] noted that the effects of snow, ice, and rain have not been considered in these studies. Most studies reported increased physical demands as ramp slope increased past 1:20. Even at a 1:20 ramp slope, upper-extremity joint moments can exceed 30% of the user's capacity. Kulig et al. [2] showed that shoulder forces and moments more than doubled when ascending an eight-degree incline with a wheelchair.

In the consumer literature, Smith [3] qualitatively analyzed nine powered wheelchairs while ascending and descending a 10-degree ramp with 7.5 cm of snow cover. All powered chairs were able to ascend and descend the ramp; however, control of mid and front-wheel drive chairs was difficult. Slopes greater than 10 degrees were considered as very difficult to negotiate in winter.

As reported by Lemaire et al. [4] in a controlled study of wheelchair ramp navigation under snow and snow-ice conditions, snow accumulation on 1:10 grade ramps will render the ramp inaccessible for many wheelchair users who do not have external assistance. The transition area, from level ground to the first 2 m of ramp incline, was the most difficult to traverse for both ascent and descent. This was due to soft snow conditions that inhibited forward progression of the front wheels and rear wheel slip.

One subject, who was unable to ascend the 1:10 grade with forward progression, successfully completed all ramp grades by rolling backwards and pushing on both handrails. This approach avoided the problems with the smaller front wheels digging into the snow when the torso rotated forward during propulsion. Only one mild and one moderate obstruction were recorded for backwards ascent.

This paper examined the biomechanical outcomes for the backwards ramp ascent under snow conditions.

METHODS

Testing Environment

All testing took place at the National Research Council, Centre for Surface Transportation Technology (CSTT), Climatic Engineering and Testing Division (Ottawa). This facility is Canada's largest climatic chamber. Controlled snow conditions were produced by CSTT staff and the snow was packed by foot on the ramp to provide a typical snow condition.

An adjustable, modular, wheelchair ramp was modified to provide a safe testing environment at 1:10, 1:12, and 1:16 grades. One handrail was set to the maximum height of 38 inches.

A self-braking belay descender device and mountain climbing rope were added to the ramp as a safety tether system, which could be engaged if an unsafe condition occurred during data collection. Additional strapping was affixed to the client's wheelchairs at the front and rear to provide secure attachment points for the safety rope. Since the tether was attached to the wheelchair, a lap belt was fitted to each subject and their wheelchair to keep the subject in their wheelchair in the event that the safety line engaged.

Subject

The backward ascent subject usually self-propelled his wheelchair in winter, and was recruited through The Ottawa Hospital Rehabilitation Centre. The subject was male, 58 years of age, and was at a moderate functional level. He used an Invacare X4 wheelchair with 24" Primo HP and + 5" soft roll tires.

Kinematic Measurement

A ten-camera Vicon MX motion capture system was used to record 3D upper limb, head, and trunk motions during ramp navigation (100 Hz). Cameras were positioned with four cameras along the left and right sides of the ramp and a camera at the ramp's front and back. Due to the ramp's length, the cameras were oriented such that the markers at the beginning and end of the ramp were visible by three cameras. In the mid-ramp region, markers were visible by four cameras.

The marker set used four markers to define the wheelchair seat plane, for both a measure of wheelchair orientation and a reference for trunk angles. Three markers were attached to each wheel to calculate wheel kinematics. Multiple markers on the upper torso/back, upper arms, lower arms, and head were used to identify these body segments. A standardized origin was set on the ramp for the motion analysis system so that the wheelchair and all segments could be referenced to the ramp dimensions.

Figure 1: Backwards ramp ascent.

RESULTS

Backwards ramp ascent was a successful strategy for this subject. The subject pushed on both handrails simultaneously to propel the wheelchair backwards up the ramp. At the 1:10 ramp grade, the shoulder required approximately 107 degrees of extension and 30 degrees of abduction to perform the main propulsive phase (i.e., from grasp of the railing behind the wheelchair to the end of forward hand progression). The maximum right shoulder flexion/extension angular velocities averaged 724 deg/s, with a maximum of 604 deg/s for the left arm, over this period. The 1:12 grade results were similar, but the maximum propulsive shoulder angular velocities were lower for the 1:16 grade (average of 392 deg/s for right arm and 461 deg/second for the left arm). The shoulder range of motion used for this approach was in the normal range, and therefore should be accessible for people without restrictive shoulder problems.

The upper trunk angle, relative to the wheelchair seat, had a small range of 10 degrees at the 1:10 grade (Figure 3). This range was consistent with maximum trunk flexion at the initiation of the propulsive phase. In contrast with typical wheelchair propulsion, the trunk flexed to position the hands on the railings then extended during the propulsive phase.

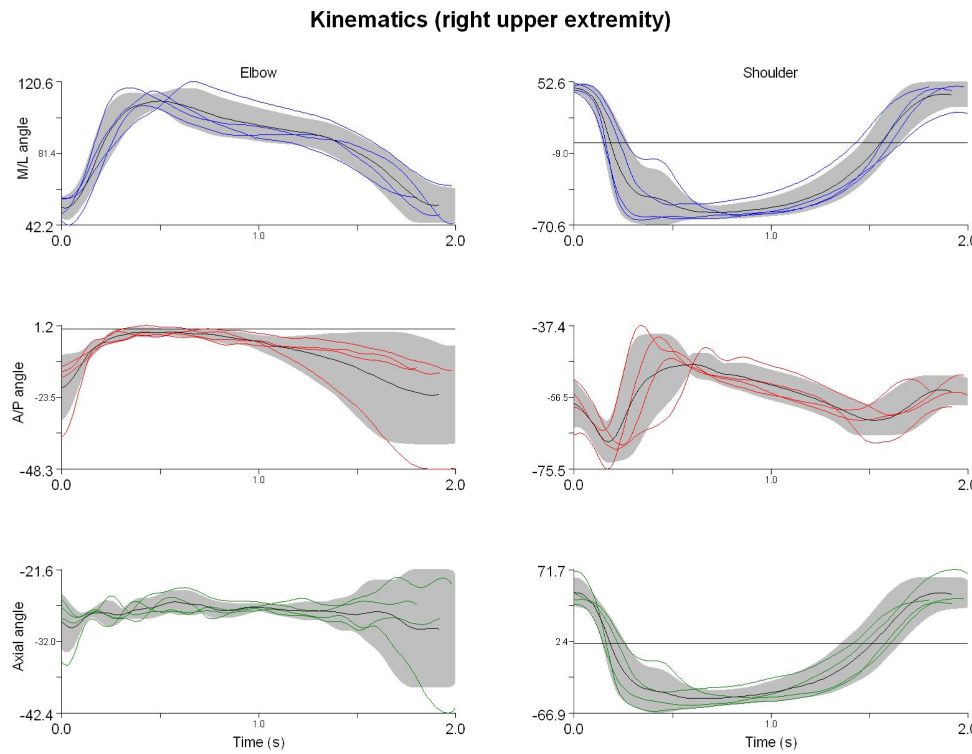

Figure 2: Elbow and shoulder angles for backwards ramp ascent (snow condition, 1:10 grade), initiated from railing grasp, through propulsion, to railing regrasp. Standard deviation is in gray. The average curve is in black.

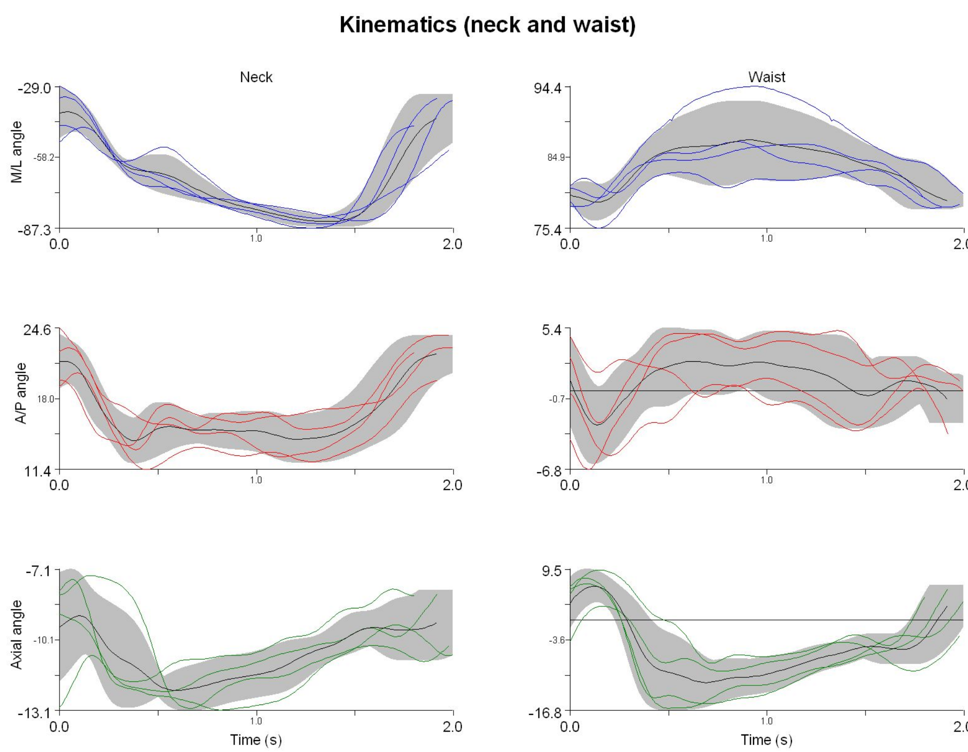

Figure 3: Neck and trunk (waist) angles for backwards ramp ascent (snow condition, 1:10 grade), initiated from railing grasp, through propulsion, to railing regrasp. Standard deviation is in gray. The average curve is in black.

The largest trunk flexion/extension range was for the 1:12 grade (12.6 deg); however, the forward angle was still over 70 degrees to the seat plane. The shape of the 1:12 and 1:16 trunk angle curves were similar (Pearson r=0.98), but with an offset averaging 7.5 deg (Figure 3).

The ability to accomplish the ramp ascent task with less trunk flexion could be of benefit for some wheelchair users. Standard technique for 1:10 snow ascent required 20 degrees more flexion than backwards ascent.

CONCLUSION

Backwards ramp ascent on snow packed slopes was demonstrated to be an effective strategy. Since the subject that used this strategy was at a moderate functional level and the shoulder and trunk ranges of motion were within a typical range, this strategy may be applicable for people who manually propel their wheelchairs in winter. More research on backwards ascent is warranted to verify how this approach can be used by lower functioning wheelchair users and to determine if wheelchair and environmental issues exist when extended to a larger population.

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