

# EFFECT OF A VINYL-COATED HANDRIM ON WHEELCHAIR USE

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## INTRODUCTION

There is a high occurrence of upper extremity injuries in the manual wheelchair user population. In a study of 239 manual wheelchair users, Sie *et al.* (1992) found that 64% of patients with paraplegia reported upper extremity pain. In a study of 34 manual wheelchair users, Boninger *et al.* (1999) found that incidence of injury was related to biomechanical loading during propulsion and concluded that reducing demands on the user should reduce the likelihood of developing injuries. Handrims are the primary interface by which the wheelchair user pushes, brakes, and turns the wheelchair. The standard handrim is an anodized aluminum tubing hoop, mounted offset to the side of each wheel. A vinyl-coated handrim is a standard handrim coated with vinyl. The coating provides increased friction between the hand and the handrim. Use of a vinyl-coated handrim was found to reduce the peak force applied to the handrim during propulsion by 10% (Koontz *et al.*, 1998). Unfortunately, the vinyl coating is a very poor conductor of heat. As a result, the heat generated during braking quickly exceeds the tolerance threshold of the user and the user has to let go of the handrim.

This study will focus on quantifying the potential advantages and disadvantages of the use of a vinyl-coated handrim for propelling and braking the wheelchair.

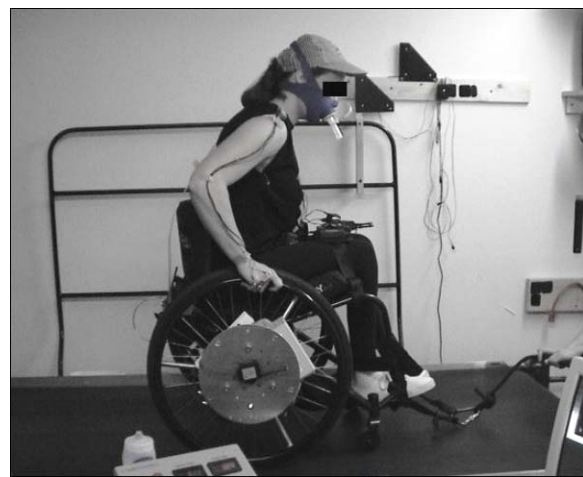
## METHODS

Nine subjects were randomly recruited from an internal database of local wheelchair users and participated in the evaluation of the vinyl-coated handrim. There were eight male participants and one female. The

average subject body weight was 159±39 lb. Subject disability consisted of eight spinal cord injuries ranging from L5 to T3 and one Spina Bifida.

Propulsion - Subjects propelled their wheelchairs on a treadmill for five minutes continuously using a standard handrim and a vinyl-coated handrim in a randomized order. Each propulsion bout on the treadmill consisted of a ramping profile with four grade/speed combinations. The treadmill profile involved the following stages: 1) 2% grade at 2.1 mph (0.94 m/s) for 2 minutes, 2) 4% grade at 1.1 mph (0.49 m/s) for 1 minute, 6% grade at 0.7 mph (0.31 m/s) for 1 minute, and finally, 3) 8% grade at 0.5 mph (0.22 m/s) for 1 minute. Subjects had a 15-minute rest period between trials.

Handrim forces and moments were measured during propulsion using a wheelchair propulsimeter (Figure 1). When using a propulsimeter, loads applied to the handrim pass through a load cell and are transferred to the wheel. Metabolic demand



**Figure 1.** Demand on the user was measured using a propulsimeter, a portable gas analyzer, and a heart rate monitor.

during propulsion was measured using a portable metabolic gas analyzer and a heart rate monitor.

**Braking** - Subjects were asked to brake their wheelchairs on a treadmill using a standard and a vinyl-coated handrim in a randomized order. The treadmill grade was set to a 10% decline and the braking speed was set to 5.5 mph (2.46 m/s). Subjects were instructed to continue to brake until they were uncomfortable, or unable to continue. Braking duration was measured using a stopwatch.

**Analysis** - Both metabolic and kinetic data were averaged over the last four minutes of the propulsion bout as a representative characteristic of performance over the spectrum of grades. Propulsion kinetics including peak force and moment, push frequency, push angle, work per push, and the fraction of the applied force in the tangential direction (FEF) were assessed for each push and then averaged over each trial. Propulsion metrics and braking time were compared between the handrim conditions using a paired samples t-test and determined to be statistically significant for  $p < 0.05$ .

## RESULTS AND DISCUSSION

Each of the subjects was able to complete the protocol without undue stress, discomfort, or fatigue. The resulting propulsion kinetics and timing characteristics are shown in Table 1.

Oxygen consumption (VO<sub>2</sub>) was reduced by 9% when using the vinyl-coated handrim. The percentage contribution of the tangential force component to the resultant force when using the vinyl-coated handrim was increased by 33%. Braking time for the vinyl-coated handrim was reduced by over 91% from the standard handrim. Trends identified included a decrease in peak force on the handrim, as found by Koontz et al., as

well as an increased push angle, decreased push frequency, increased work per push, and decreased heart rate.

**Table 1.** Handrim performance. \*= $p < 0.05$

| Performance Metric      | Standard | Vinyl        |
|-------------------------|----------|--------------|
| Peak Force (N)          | 76.3     | 70.2         |
| Peak Moment (Nm)        | 16.14    | 16.20        |
| Push Angle (deg)        | 85.8     | 87.3         |
| Push Frequency (Hz)     | 1.04     | 1.00         |
| FEF ( $F_t^2/F^2$ )     | 0.54     | <b>0.83*</b> |
| Work (J)                | 12.8     | 13.8         |
| Heart Rate (bpm)        | 105      | 101          |
| VO <sub>2</sub> (L/min) | 0.80     | <b>0.73*</b> |
| Braking Time (s)        | 103      | <b>9*</b>    |

## SUMMARY

This study provides evidence that use of a high friction handrim reduces demand on the wheelchair user during propulsion. However, results also show an unacceptable decrease in braking performance due to the low heat conduction characteristics of the vinyl-coating. Improvements in handrim design, which incorporate the advantages of vinyl-coating for propulsion without its adverse effects on braking would be a beneficial technological advancement.

## REFERENCES

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