

EFFECTS OF CASTER TYPE ON WHEELCHAIR PROPULSION WORK REQUIREMENTS

W. Mark Richter, MSME; Logan G. Smith; Kenneth A. Chizinsky, MSBE;
Denise A. Chesney, MEBME; Peter W. Axelson, MSME
Beneficial Designs, Inc.
Santa Cruz, California, U.S.A

ABSTRACT

Wheelchair casters are available in a variety of sizes and styles. Caster size and style affect wheelchair performance characteristics. This study investigated the effects of caster type on the work required to propel a wheelchair along a straight path. Seven different casters were tested on six surfaces: grass, dirt, wood chips, two types of carpet, and a plywood ramp. The casters ranged from 3 in. to 8 in. in diameter and included both pneumatic and solid designs. Propulsion work was measured using ASTM PS 83 test methods. The results showed that the pneumatic casters required less work than the solid casters of the same size, and the 8 in. casters required less work than the 6 in. casters for both the pneumatic and solid designs.

BACKGROUND

A wide variety of caster types are available for use on wheelchairs. Each caster type has an effect on performance characteristics of the wheelchair such as ride comfort, obstacle climbing ability, ease of turning, and rolling resistance. Different casters may not perform equally on a particular surface type. Some casters are better suited for hard, smooth surfaces while others may perform best in softer surfaces and still others ideal for use on rocky or obstacle intensive environments. Objective measurements of these performance characteristics would serve to inform potential users as to which caster type was best suited for the activities and environment of anticipated use.

RESEARCH QUESTION

In an effort to provide one objective measurement of caster performance, how does caster type affect the amount of work required to propel a wheelchair along a straight path across various surface types?

METHODS

Seven different caster types were tested on six surfaces. The seven caster types were: 3 x 0.75 in. solid Rollerblade (3S), 5 x 1.25 in. solid (5S), 6 x 1.25 in. solid and pneumatic (6S,6P), 8 x 1.25 in. solid and pneumatic (8S,8P), and 6 x 3 in. semi-solid Zimbabwe wheel (ZB). Pneumatic casters were inflated to the maximum rated pressure. The standard caster fork was replaced by an adjustable length fork. The length of the caster fork was adjusted for each caster such that the height of the wheelchair frame remained constant. The six test surfaces evaluated were: a plywood ramp with a 7.1% (1:14) grade (R), cedar chips (CC), carpet with a 0.33 in. pile height without a pad and at a 1% grade (C1), carpet with a 0.75 in. pile height and a 0.25 in. pad (C2), level compacted dirt (D), and grass with an average grade of 2.5% and 1.5% cross slope (G).

The wheelchair propulsion work requirements were measured using the ASTM PS 83 test procedure [1]. A wheelchair was propelled in a straight line across a test surface using four uniform pushes. During propulsion, the torque applied to the pushrim was measured. The work required for propulsion was a product of the applied torque and the resulting angular displacement of the wheel. Five trials with each caster type were performed on each surface.

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A 16 in. width rehab wheelchair (Quickie 2 by Sunrise Medical) with 24 in. pneumatic rear tires and 20 in. pushrims was used as the test wheelchair. A SMART^{Wheel} [2], with the same dimensions as the rear wheels, was mounted onto the wheelchair and used to measure the torque applied during propulsion. The wheelchair weight with 8 in. pneumatic casters was 34 lbs.. A laptop computer and an external battery pack were mounted onto the wheelchair. The total weight of the wheelchair with the computer and power source was 54 lbs.. The wheelchair rider weighed 183 lbs. and was seated such that when statically measured, the front to rear weight distribution was 40/60 %.

The wheelchair was propelled 2 (+0.2, -0.0) m in 7 (+/- 1) seconds using four uniform pushes. Torque applied to the pushrim was recorded at 240 Hz and was then filtered. The average torque for each trial was found by numerically integrating the torque as a function of time and then dividing by the total trial time. Propulsion work for one wheel was determined by multiplying the average torque by the total angular displacement of the rear wheel. The total propulsion work was two times the work required for one wheel. The total propulsion work for each trial was then normalized per meter of distance traveled by dividing the total work by the total distance traveled. The average work per meter value was determined by averaging the five trials.

Statistical analysis was performed on the work per meter values to determine if changing the caster type significantly affected the results. A 95% confidence interval for the average work value for each caster type was calculated using an independent samples t-test. Differences between average work values were considered statistically significant if no overlap existed between the 95% confidence intervals.

RESULTS

The resulting average work per meter values for the ramp and cedar chips are shown in Figure 1,

the two carpets in Figure 2, and grass and dirt in Figure 3. On cedar chips, the 3S caster was not able to roll and therefore unable to complete the test.

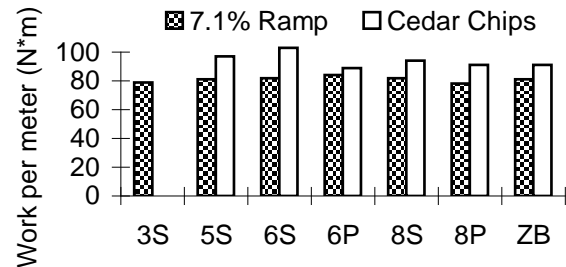


Figure 1. Work required on the ramp and cedar chips

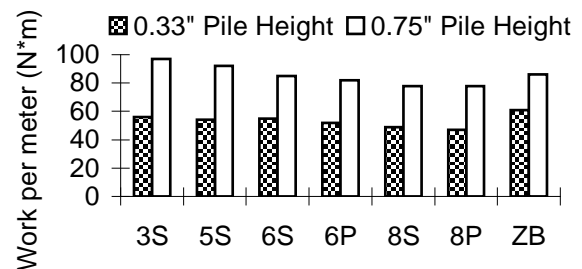


Figure 2. Work required on two carpet types

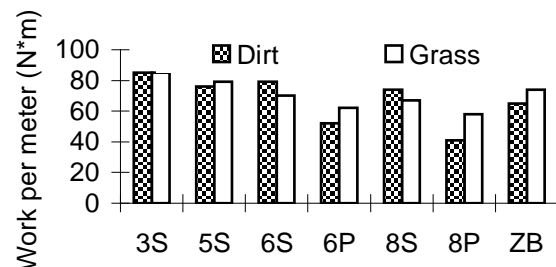


Figure 3. Work required on dirt and grass

Significant differences between the propulsion work required between any two caster types within the particular surfaces were found in 50% of the possible combinations. Caster comparisons found to be statistically significant for the six surface types are given in Table 1. There were no significant differences found between casters 3S and 5S, nor between casters 5S and 6S. Caster 8P required significantly less work than caster 6S on all of the surfaces tested. Caster 6P required significantly less

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work than caster 6S on cedar chips and dirt, and caster 8P required significantly less work than caster 8S on dirt and grass. On the cedar chips and dirt surfaces, propulsion work requirements for the 6 in. pneumatic caster decreased by 13.4% and 33.4%, respectively from that required with the solid caster. Similarly, on the dirt and grass surfaces, propulsion work requirements for the 8 in. pneumatic caster decreased by 46.8% and 11%, respectively from that required with the solid caster. Thus, when significant differences occurred, the pneumatic casters required less work than the solid casters of the same size. On the majority of the surfaces, the 8 in. pneumatic caster required significantly less work than either of the 6 in. casters. The 8 in. diameter caster produced the lowest work requirements for the greatest number of surface types.

	6P	6S	8P	8S	ZB
3S	R,C1,C2, D,G	R,C2, G	C1,C2,D,G	C1,C2,D, G	C1,C2,D, ,G
5S	C2,D,G		C1,C2,D,G	C1,C2,G	CC,C1
6P		CC,D	R,C1,D,G	D	C1,D,G
6S			R,CC,C1,C2, ,D,G	C1,C2	CC,D
8P				D,G	C1,C2,D, ,G
8S					C1,C2

Table 1. Significant differences in average work values for the six surfaces

DISCUSSION

The results of this study offer an objective comparison between straight propulsion work requirements for various caster types. The results of this study only compare caster performance in straight propulsion. Straight propulsion work is one of many caster performance factors and should not be used solely to select an appropriate cater type. Other factors such as ride comfort, obstacle climbing ability, and ease of turning should be considered. If another caster type performs adequately in straight propulsion work

requirements for the surface types of anticipated use and it excels in other performance characteristics, it may be the best caster to choose. For future studies, the same experimental methods could be used to study the effects of caster type on propulsion work requirements during turning or maneuvering.

REFERENCES

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- [2] Asato KT, Cooper RA, Robertson RN, Ster JF (1993). SMART^{Wheel} development and testing of a system for measuring manual wheelchair propulsion dynamics, *IEEE Transactions on Biomedical Engineering*, 40(12).

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Mark Richter
Beneficial Designs, Inc.
5858 Empire Grade
Santa Cruz, CA 95060