Rehabilitation Engineering & Applied Research Lab

Impact of Drive Wheels on Manual Wheelchair Propulsion Torque

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Introduction

The human effort required to maneuver a manual wheelchair is directly linked to the inertia and resistive losses of the system. In this study, we investigate the impact of three different commercial drive wheels on the propulsion torque of a straight maneuver and fixed wheel turning.

Methods

The Anatomical Model Propulsion System[1] (AMPS), was implemented to improve the repeatability of maneuvers and enable accurate measurement of task propulsion torque. We define task propulsion torque as:

$$\tau = r_{LW}(F_{tan})_{LW} + r_{RW}(F_{tan})_{RW}$$

where $'r'$ is the wheel radius and $'F_{tan}'$ is the tangential push force.

Maneuvers Performed	
Straight, accelerate to 1 m/s	In 1.5 s (0.29 m/s²)
	In 2.5 s (0.4 m/s²)
	In 3.5 s (0.67 m/s²)
Fixed wheel turn, accelerate to 0.4 m/s in 2.5 s (0.16 m/s²)	Right
	Left

The acceleration torque and steady-state torque were determined by averaging the measured propulsion torque (sampled at 200 Hz) over the acceleration phase and steady-state phase of the maneuvers, respectively. Propulsion torque values for turning were obtained by averaging results for left and right turns.

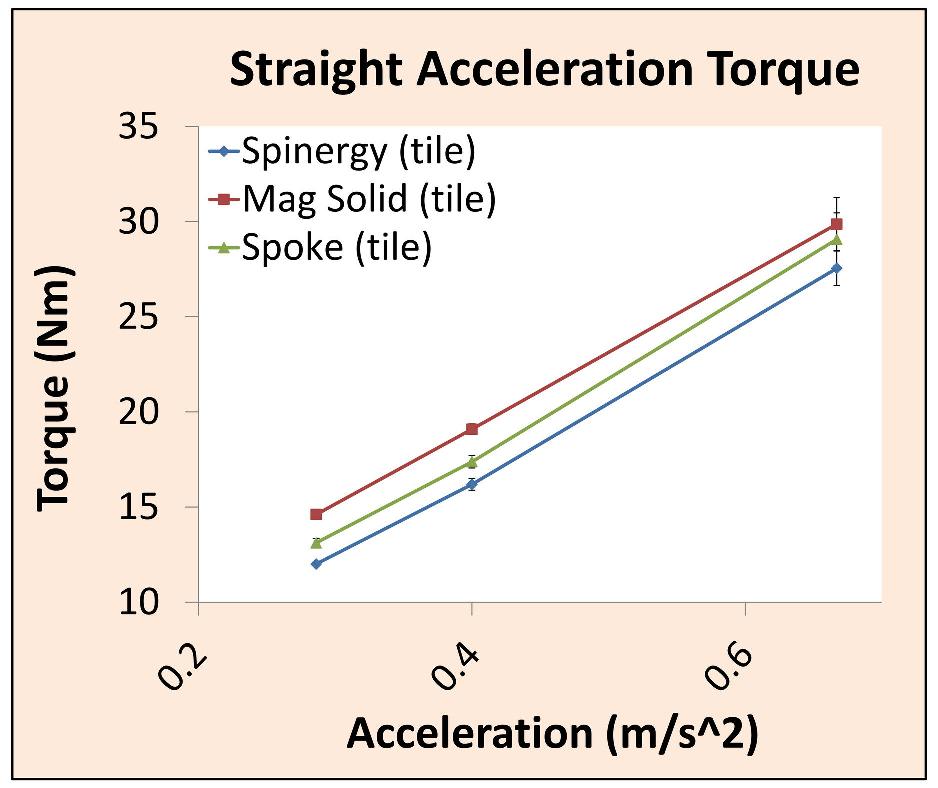
A Quickie GT wheelchair was configured with 3 tire types and tested by the AMPS on both carpet and tile. Tire rotational inertia was measured via a trifilar pendulum, and system mass and inertia were measured via the iMachine[2].

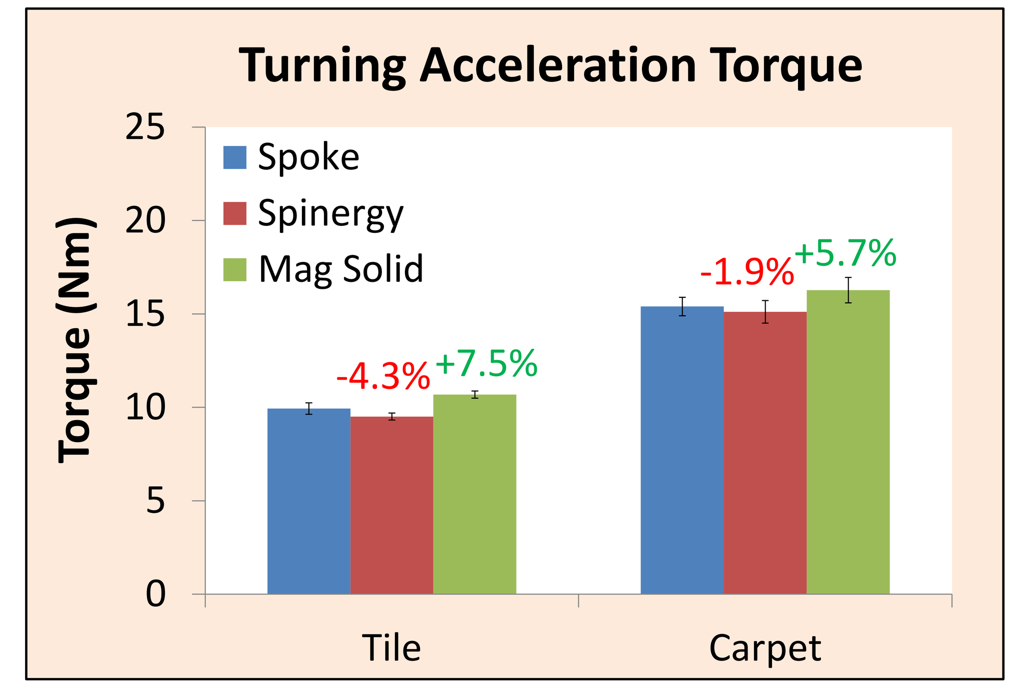
Spinergy rims
1" tires
100 psi

Spoke rims
1-3/8" tires
75 psi

Solid mag
trapezoidal
cross-section

Results



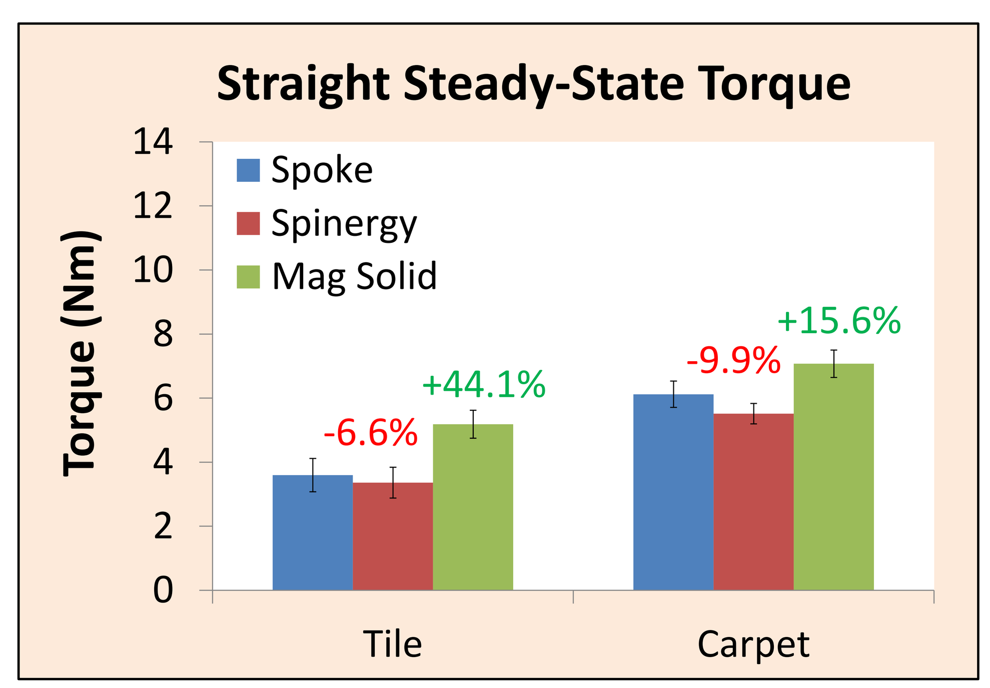


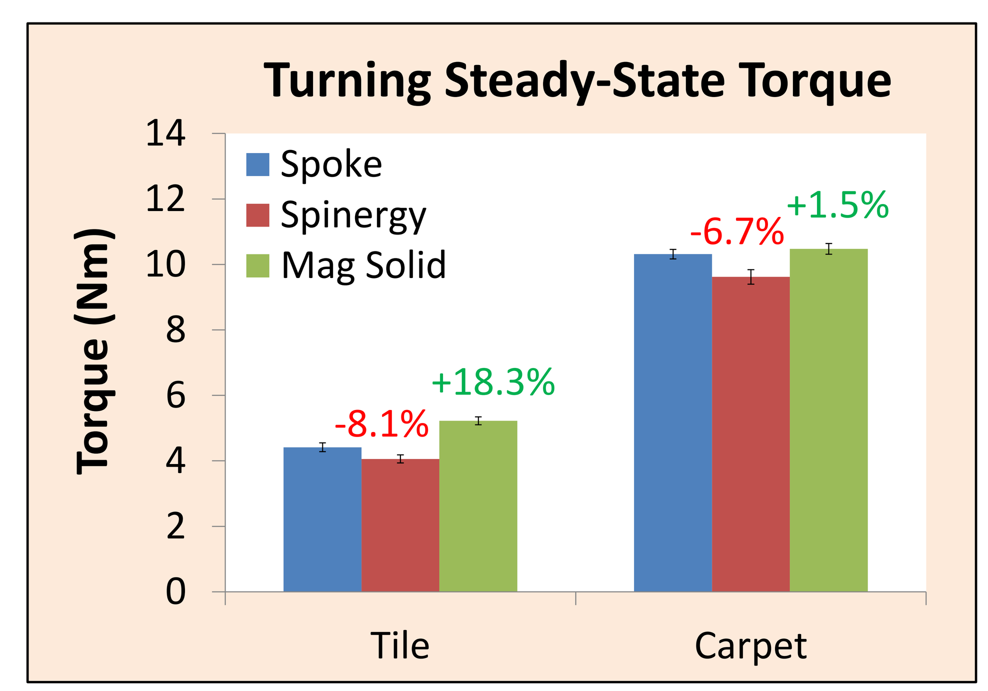
Versus propulsion torque of spoke configuration

Straight Acceleration (m/s²)	Tile		Carpet	
	Spinergy	Solid Mag	Spinergy	Solid Mag
0.29	-8.5%	+11.4%	-3.5%	+11.9%
0.4	-6.8%	+9.8%	-8.5%	+4.0%
0.69	-5.2%	+2.8%	-7.1%	-0.3%

Drive wheel and system inertia properties

Drive Wheel	System Mass (kg)	Yaw Inertia (kgm2)	Rotational Inertia (kgm2)
Spinergy	109.3	7.157	0.1087
Solid Mag	110.17	6.853	0.1203
Spoked	110.36	6.944	0.1201





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Discussion

- The difference in propulsion torque between wheels does not change significantly with acceleration.
- In straight motion, the Spinergy's reduction of propulsion torque can be attributed to **reduced system mass and rotational** inertia; the solid mag's elevated propulsion torque can be attributed to **increased rolling resistance**[3].
- In turning, the Spinergy's reduction of propulsion torque can be attributed to **reduced resistive losses and rotational inertia**; the solid mag's elevated propulsion torque can be attributed to **increased resistive losses**.
- Carpet propulsion torque is greater for all conditions due to a large increase in rolling resistance and scrub loss.

Conclusion

- The Spinergy wheel reduces propulsion effort due to its reduced mass, rotational inertia, and resistive losses.
- The solid mag wheel elevates propulsion effort due to its increased resistive losses.
- Changes in resistive loss due to different surface conditions may diminish the impact of inertial differences between drive wheels.

References

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2. Caspall, J. J., Seligsohn, E., Dao, P. V., Sprigle, S. *Changes in inertia and effect on turning effort across different wheelchair configurations.* Journal of Rehabilitation Research & Development, 2013. 50(10): p.1353-62
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