Rolling Resistance in Manual Wheelchairs: Applying the Evidence

SHEILAGH SHERMAN
Sunrise Medical Canada

Our high school physics classes taught us about Newton’s first law of motion, which states that a body at rest tends to stay at rest, while a body in motion tends to stay in motion, unless acted upon by an external force. When we apply this law of motion to manual wheelchairs, we can think about the forces required to initiate propulsion and the forces that cease movement.

Inertia, the tendency of an object to resist change in its motion, must be overcome in order to initiate propulsion in a manual wheelchair. Greater force must be used in order to begin propulsion from a stopped position compared to maintaining a constant self-selected pace. In order to maintain a constant speed over a level surface, a person using a wheelchair must overcome rolling resistance.

Rolling resistance
Rolling resistance is defined as the force that resists the motion when an object rolls on a surface. Rolling resistance will limit the distance a manual wheelchair coasts after a force, such as from a push stroke, is applied. Minimizing the rolling resistance in a manual wheelchair enables more efficient propulsion, reducing the force and frequency of strokes required to propel the wheelchair, which helps to reduce the risk of upper extremity pain and injury.

Several factors contribute to rolling resistance in a manual wheelchair. These factors include the mass of the user and the mass of the system, the weight distribution between the front casters and the rear wheels, and the size and type of casters and tires selected, and the surface on which the wheelchair is used.

Weight distribution between rear wheels and front casters
The position of the rear wheel on a manual wheelchair relative to the frame affects the position of the centre of gravity and will affect the performance of the wheelchair. When a person sits in a wheelchair, the person’s mass is distributed between the front casters and the rear wheels. How the mass is distributed between the front casters and the rear wheels – that is, the relative distribution of weight between the front casters and the rear wheels – affects performance indicators, such as rolling resistance and manoeuvrability. When the rear wheels are in a rearward position relative to the frame of the wheelchair, the mass of the person using the wheelchair is distributed to a greater extent over the front casters than compared to when the rear wheel is in a more forward position relative to the frame. When an increased percentage of weight is distributed over the front casters, rolling resistance is increased and the wheelchair is more difficult to propel, whether through hand propulsion, foot propulsion, or a combination of the two. More strength and energy is required to propel the wheelchair.

One of the benefits of having the rear wheels in a more rearward position is that there is stability in the wheelchair; that is, the wheelchair is less likely to tip backwards. This stability, however, means that it is difficult to “de-weight” the front casters to perform a wheelie, which may be required for mobility, such as when crossing obstacles.

When the rear wheels are in a more forward position, the opposite effects occur. The percentage of weight going through the front casters is decreased. As a greater proportion of weight goes through the rear wheels, rolling resistance is decreased, making it much easier to propel the wheelchair. Because less effort and strength is required to propel and manoeuvre the wheelchair, energy expenditure is lessened when rolling resistance is decreased.

Just as stability is increased when the rear wheel is in a more rearward position, stability is decreased when the rear wheel is in a more forward position. This means that the wheelchair has the potential to tip backwards. Ideally, the rear wheel should be adjusted as far forward as possible without
compromising the stability of the person using the wheelchair or interfering with the front casters.\textsuperscript{5,6} This may need to be done incrementally to allow the person using the wheelchair to become accustomed to the increased rearward instability with forward movement of the rear wheel.\textsuperscript{6}

**Size and type of rear wheels and front casters**

Just as the forward/rearward position of the rear wheels affects rolling resistance, so too does the choice of rear tire. It is the inelastic deformation of the materials of the tire and/or the surface on which it rolls that affects the rolling resistance.\textsuperscript{7} Often solid tires are chosen due to lack of maintenance required. Studies have shown, however, that solid tires have greater rolling resistance than pneumatic tires.\textsuperscript{7,8} As load on the tires increases, solid tires demonstrate even greater increases in rolling resistance than pneumatic tires.\textsuperscript{7} From a clinical perspective, this means that the weight of the user will impact upon rolling resistance of the tires. Solid tires demonstrate greater deformation as the load increases than pneumatic tires. This means that a heavier individual will experience even greater rolling resistance with solid tires than will someone who weighs less. Tire tread and tire size also effect rolling resistance. Low profile tires have less rolling resistance than full profile tires.\textsuperscript{7} A larger tire radius will have less rolling resistance than a similar tire of smaller radius.\textsuperscript{9}

Tire pressure also has an effect on rolling resistance. A study assessing the effect of tire inflation on rolling resistance found that pneumatic tires “showed no statistically significant difference in rolling resistance until pressures had decreased to 50\% of the recommended value”\textsuperscript{8} (p. 1480). The study further found that pneumatic tires inflated to at least 50\% of the recommended value had less rolling resistance than solid tires. The authors indicated that wheelchair tires need to be pumped once per month to maintain adequate pressure, based on the finding that wheelchair tires lose 10 to 25\% of their pressure in the first two weeks following inflation and 25 to 40\% of their pressure after one month following inflation.

Caster selection also influences rolling resistance in a manual wheelchair. In a study in which casters were classified into soft roll casters, standard casters and roller casters, standard casters were shown to have the highest rolling resistance, followed by the soft roll casters, and finally by the roller casters, when comparing similar radius.\textsuperscript{9} As the radius of a caster increases, the rolling resistance factor decreases.

Thus, rolling resistance is effected by a number of different factors. The weight distribution between the rear wheel and front casters, the size and type of rear wheels and front casters, and the surface on which a wheelchair is propelled (e.g., hard, smooth surface versus a soft surface such as a carpet) will all effect rolling resistance. Because rolling resistance increases the effort required to propel a manual wheelchair, it is important to look at unique requirements and maintenance capabilities when configuring a manual wheelchair for an individual.

**References:**


**Speaker Bio:**
Sheilagh Sherman is the Clinical Educator for Sunrise Medical Canada. Since graduating as an occupational therapist from McMaster University in 1994, she has worked in a variety of settings, including in-patient neurological rehabilitation, complex continuing care, and community rehabilitation. Since joining Sunrise Medical in 2010, Sheilagh has led numerous seminars, workshops and in-services on seating and mobility in Canada.