APPENDIX

Correction Method

The equation derived in Theisen et al. [1] for a wheelchair roller system was used to compute the rolling friction of each site's dynamometer. The general equation is:

$M_h = T_{tot} + [I_r R/r + I_w r/R] * \alpha_r$, **Equation 1**

Where,

M_h = torque applied by the subject's hand to the wheel

T_{tot} = sum of all unknown frictional torques

I_r and I_w = inertia of the dynamometer roller and inertia of the rear wheel

R, r = radius of each the rear wheel and dynamometer roller

α_r = angular acceleration of the roller.

STEP 1: Determination of Inertia Parameters

We computed the combined inertia of the SMARTWheel^{TM} and roller experimentally from the propulsion portion of the acceleration-brake-coastdown trial by simplifying the above equation, differentiating with respect to time, and solving for the unknown I:

$I = dM_h/d\alpha$, **Equation 2**

Where, I = combined inertia of the SMARTWheel^{TM} and roller

In **Equations 1** and **2**, it was assumed that T_{tot} was constant with respect to time. A unique inertia value was calculated for each person.

STEP 2: Determination of Rolling Resistance

As more differences between sites were found for the steady-state propulsion trials, we tested our correction methods first on the 0.9 and 1.8 m/s trials. So for each steady-state propulsion trial, we solved for the unknown frictional torque using Equation 2 and the subject's combined inertia. The frictional torque was equated to rolling resistance multiplied by radius of the wheel:

$T_{tot} = RR*r$, **Equation 3**

Where, RR = rolling resistance

r = radius of the SMARTWheel™

An instantaneous RR was determined during the time that the subject was not applying forces to the handrim (e.g., recovery phase of the stroke) to eliminate variability due to propulsion technique. We then averaged the RR over each recovery phase and then across all strokes within the trial. Finally, an average RR was determined for each site.

From the average site RRs we calculated an average coefficient of friction, μ. Based on the relationship:

$RR = \mu*N$, **Equation 4**

Where, N =normal force equal to the (total weight) * (percent distribution of weight over the rear wheel)

We solved for μ using the average total body weight at each site as the normal force. The percent distribution of weight does not need to be known as it cancels out in the next step.

STEP 3: Site-Normalization of the Pushrim Kinetic Data

Since HERL was the coordinating site for the study, we adjusted the force and moment data at UW and KMRREC with respect to HERL. A difference coefficient was determined for each speed trial by subtracting the coefficients at UW and KMRREC from the HERL coefficient. Then for each individual at UW, we calculated the additional rolling resistance that UW subjects would face if their dynamometer performed similarly to the dynamometer at HERL:

$RR_{UW} = \mu_{HK}*N_{UW}$ **Equation 5**

Where, RR_{UW} = additional rolling resistance faced by UW subjects

$\mu_{HK} = \mu_{HERL} - \mu_{UW}$, difference between the coefficients of friction at HERL and UW

N_{UW} = normal force = (total body weight of each UW subject) * (percent distribution of weight over the rear wheel)

We added RR_{UW} to the individual propulsion resultant forces at UW. To the moments, we added RR_{UW}*r, where r is equal to the radius of the wheel. The same procedure was used to adjust the KMRREC data but since the coefficient of friction was higher at KMRREC than HERL for the 0.9 m/s trial (see main paper RESULTS, Step 2), the rolling resistance computed in Equation 5 was subtracted from the forces and moments rather than added. The adjustment was made to the resultant force rather than the tangential force because prior research has shown that fraction of effective force (the ratio of tangential force to resultant force) changes only slightly (3-5%) for large increases in resistance [2]. The changes in resistance in this study were not intentional and were much smaller in comparison.

REFERENCES

1. Theisen D, Francaux M, Fayt A, Sturbois X. A new procedure to determine external power output during handrim wheelchair propulsion on a roller ergometer: A reliability study. Int J Sports Med. 1996;17(8):564–71. [PMID: 8973976]

2. Dallmeijer AJ, Van der Woude LH, Veeger HE, Hollander AP. Effectiveness of force application in manual wheelchair propulsion in persons with spinal cord injuries. Am J Phys Med Rehabil. 1998;77(3):213–21. [PMID: 9635556]