# Concurrent Validity of the Wheelchair Propulsion Test

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## ABSTRACT

The Wheelchair Propulsion Test (WPT) was developed to provide an inexpensive method to describe and quantify wheelchair propulsion. Our objective was to assess the concurrent validity of the WPT derived measures by comparing them to those obtained by an instrumented rear wheel (SmartWheel). A pilot sample of 11 manual wheelchair participants was recruited. All participants used the same wheelchair that was instrumented with a SmartWheel device. The WTP was performed while collecting data from the SmartWheel, using the auto-start and stop 10 meters tile protocol. Speed (m/s), cadence (cycles/s) and push effectiveness (distance/cycle) outcomes from the WPT and SmartWheel software were compared. Correlation coefficients were greater than 0.7 ($p<0.01$) and differences in outcomes were not significant. The WPT appears to provide a valid method of measuring speed, cadence and push effectiveness and may be a useful outcome measure when higher technology tools are not available.

## BACKGROUND

Upper-limb pain and injury have been found to be very prevalent in manual wheelchair users (Boninger et al. 2005; Finley et al. 2004). Because of this, it has been suggested that there is a need to optimize wheelchair users' push mechanics to help reduce upper-limb injury (Robertson et al. 1996).

Despite the potential importance of wheelchair propulsion training, there is no inexpensive and simple test available for the assessment of manual wheelchair propulsion on smooth level surfaces that is intermediate between the Wheelchair Skills Test (that does not provide quite enough detail for this single skill) and the use of an instrumented rear wheel (too expensive and time-consuming for use in some settings). This perceived need led to the development of the Wheelchair Propulsion Test (WPT) (Askari & Kirby, 2011a; 2011b). This test was developed to provide a quantification of propulsion along with description of the propulsion method. Derived measures include speed (m/s), cadence (cycles/s) and push effectiveness (m/cycle). Its content validity and reliability have been reported (Askari & Kirby, 2011a, 2011b).

### Objective

Our objective was to assess the concurrent validity of the WPT by comparing its derived measures against a gold standard for wheelchair propulsion measurement, namely an instrumented rear wheel (SmartWheel).

## METHODS

### Participants

Wheelchair–using participants were a sample of convenience recruited by clinicians known to them. The study was approved by the Research Ethics Board of the Capital District Health Authority. A pilot sample of 11 participants who used two-hand propulsion was recruited from a larger study investigating the WPT. All participants met the following inclusion and exclusion criteria: was 17 years of age or older, had used a manual wheelchair for at least 14 days, used a manual wheelchair for at least 1 hour/day, was able to transfer with minimal assistance, was willing to participate, was competent to provide informed consent and did not have any unstable medical condition. Participants were screened for inclusion and exclusion criteria by the attending or housestaff physician.

### Demographic, Clinical and Wheelchair-Usage Data

Demographic, clinical and wheelchair-usage data were collected by interview and chart review from each participant. Information such as sex, age, height, weight, diagnosis accounting for wheelchair use, major comorbidities that could affect wheelchair propulsion, how long using any wheelchair and how long using the current wheelchair were collected.

### The Wheelchair Propulsion Test (WPT)

The wheelchair user wheeled 10m on a smooth level surface from a standing start. For safety, the tester served as a spotter, being especially alert to rear tip-over during the initial push cycle. The collected raw data included the direction of travel (forward or backward); the limbs contributing to propulsion, steering or braking; the limb used for counting cycles; time (to the nearest sec); number of cycles; and whether, if propelling forwards with the two-hand propulsion technique, the participant used proper contact and recovery phases. For participants who used the two-hand propulsion method, a correct contact phase was defined as when the hands began contact with the hand-rims behind the top dead centers of the rear wheels and remained on the hand-rims until ahead of top dead center. A correct recovery phase was defined as when the hand returned to the hand-rims using a path that was primarily beneath the hand-rims (Koontz, Roche, Collinger, Cooper & Boninger, 2009). Derived measures included speed (m/s), cadence (cycles/s) and push effectiveness, the average distance per push (m/cycle).

Instrumented Wheelchair Wheel

The commercially available SmartWheel provides wireless measurement of the three-dimensional wheelchair propulsion forces and moments through an instrumented pushrim (SmartWheel User's Guide Rev 3.0, 2010). This device records and calculates several variables including push frequency, peak push force, average push force, average speed and average distance per push (SmartWheel User's Guide Rev 3.0, 2010) . The SmartWheel has been shown to be accurate and precise (Cooper et al. 1997).

Procedure

Each participant attended a single session that lasted less than 90 minutes. All participants used the same wheelchair (Quickie LXI, Sunrise) that was instrumented on the left with a 61cm-diameter SmartWheel device and a matching wheel on the right side with metal hand-rims. Participants were given an opportunity to become familiar with the test wheelchair prior to performing the WPT. The WPT was performed while simultaneously collecting data from the SmartWheel, using the auto-start and stop settings over 10 meters and a protocol similar to the SmartWheel standard clinical evaluation protocol for tile.

Statistical Analysis

All data were entered into a spreadsheet. Descriptive statistics were calculated for all data using SPSS (Version 15). Nonparametric statistical tests were used due to the small sample size. Spearman two-tail correlation analysis compared speed, cadence and push-effectiveness measures obtained by the WPT and SmartWheel software. Differences between these measures were explored using the paired Wilcoxon Signed Ranks test. Statistical significance was defined as $p < 0.05$.

## RESULTS

Of the 11 participants, 6 were male and 5 female. There were 4 participants with diagnoses related to the amputee/ musculoskeletal category and 7 to the spinal cord injury/ neurological category. Participants' demographic and wheelchair-usage data are provided in Table 1. WPT and SmartWheel speed, cadence and push-effectiveness measures are provided in Table 2. The Spearman's rho correlation coefficients between WPT and SmartWheel speed, cadence and push effectiveness were 0.973 (p=0.000), 0.905 (p=0.000) and 0.739 (p=0.009). The differences were not significant with mean differences of 0.05 (+/- 0.18) m/s, -0.03 (+/- 0.16) cycles/s, and -0.042 (0.17) m/cycle respectively.

Table 1: Demographic, Clinical and Wheelchair-Usage Data

| Parameter | Mean (SD) | Median | Range |
|---|---|---|---|
| Age (years) | 63.9 (15.7) | 57.0 | 40.0-89.0 |
| Height (m) | 1.67 (0.13) | 1.70 | 1.42-1.88 |
| Weight (kg) | 68.2 (14.5) | 68.0 | 43.1-97.5 |
| How long using any wheelchair (years)? | 0.86 (1.57) | 0.29 | 0.03-5.00 |
| How long using current wheelchair (years)? | 0.78 (1.61) | 0.08 | 0.00-5.00 |
| Wheelchair daily use (hours) | 7.35 (4.24) | 8.00 | 1.50-12.00 |

Abbreviations: SD = standard deviation

Table 2: Data from WPT and SmartWheel

| Outcome | | Mean (SD) | Median | Range |
|---|---|---|---|---|
| **WPT** | Speed (m/s) | 0.62 (0.29) | 0.59 | 0.14-1.11 |
| | Cadence (cycle/s) | 1.03 (1.06) | 1.06 | 0.61-1.61 |
| | PE (m/cycle) | 0.60 (0.25) | 0.59 | 0.20-1.10 |
| **Smart Wheel** | Speed (m/s) | 0.67 (0.45) | 0.60 | 0.10–1.60 |
| | Cadence (cycle/s) | 1.03 (0.35) | 1.00 | 0.60–1.70 |
| | PE (m/cycle) | 0.64 (0.34) | 0.60 | 0.20–1.40 |

Abbreviations: SD = standard deviation, PE = push effectiveness

## DISCUSSION

These results suggest that the WPT provides a valid measure of wheelchair speed, cadence and push effectiveness over a 10 m tile surface. Some of the individual differences in speed and cadence calculations are most likely due to the fact that SmartWheel software calculates the steady-state velocity and cadence over the 10 m by removing the first 3 pushes. The WPT protocol could be altered to provide a rolling start prior to the 10 m if steady-state measures are desired. However, the static start and initiation of movement may provide useful information for intervention based studies. These concepts should be explored in future studies.

## CONCLUSION

The WPT provides a valid method of measuring speed, cadence and push effectiveness over smooth tile. The WPT may be a useful outcome measure for rehabilitation interventions when higher technology tools are not available.


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