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Kirby, R Lee; de Groot, Sonja; Cowan, Rachel E

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RESEARCH PAPER

Relationship between wheelchair skills scores and peak aerobic exercise capacity of manual wheelchair users with spinal cord injury: a cross-sectional study

R. Lee Kirby^a, Sonja de Groot^{b,c} and Rachel E. Cowan^{d,e}

^aDivision of Physical Medicine and Rehabilitation, Department of Medicine, Dalhousie University, Halifax, Nova Scotia, Canada; ^bAmsterdam Rehabilitation Research Center, Reade, Amsterdam, Netherlands; ^cCenter for Human Movement Sciences, University of Groningen, University Medical Center Groningen, Groningen, Netherlands; ^dDepartment of Neurosurgery, University of Miami Miller School of Medicine, Miami, FL, USA; ^eMiami Project to Cure Paralysis, Miami, FL, USA

ABSTRACT

Purpose: Although both wheelchair skills and fitness are important and probably inter-related, the extent and nature of the relationship between them are not well understood. The objective of this study was to test the hypothesis that there are significant relationships between wheelchair skills scores and the peak exercise capacity of community-dwelling manual wheelchair users with spinal cord injury.

Materials and methods: We studied 26 participants, recording Wheelchair Skills Test Questionnaire scores and peak power output from graded aerobic wheelchair exercise testing on a motorized treadmill.

Results: The median Wheelchair Skills Test Questionnaire capacity, confidence, and performance scores were 83.3%, 81.5%, and 76.7% and the median peak power output was 58.2 W. On regression analysis, there were significant relationships between the total Wheelchair Skills Test Questionnaire capacity, confidence, and performance scores and peak power output (R^2 0.270–0.709, odds ratios 1.043–1.150, $p < 0.05$).

Conclusions: Significant relationships exist between the wheelchair skills capacity, confidence, and performance scores and the peak exercise capacity of community-dwelling manual wheelchair users with spinal cord injury. These findings suggest that both wheelchair skills training and exercise training may be useful during the rehabilitation of people with spinal cord injury.

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Wheelchair; rehabilitation;
motor skills; mobility;
exercise; spinal cord injury

► IMPLICATIONS FOR REHABILITATION

- Moderate positive relationships exist between wheelchair skills capacity and the peak exercise capacity of community-dwelling manual wheelchair users with spinal cord injury.
- Moderate positive relationships exist between wheelchair skills confidence and the peak exercise capacity of community-dwelling manual wheelchair users with spinal cord injury.
- Although further research is needed, these findings suggest that clinicians should address *both* wheelchair skills training and exercise training during the rehabilitation of people with spinal cord injury and not assume that either alone is sufficient.

Introduction

Improving wheelchair users' wheelchair handling skills not only improves their mobility but can also enhance their participation [1–6]. Improving wheelchair users' exercise capacity can enhance their health [7,8] and quality of life [9,10]. Both wheelchair skills and wheelchair exercise capacity can be improved by training [8,10–15]. It seems plausible that enhancing fitness could be used as a means of improving wheelchair skills (especially for those skills requiring strength or aerobic capacity) and conversely that improved wheelchair skills could allow wheelchair users to become more active and access fitness opportunities more readily. However, there is surprisingly little in the literature regarding the extent and nature of any relationship between wheelchair skills and wheelchair exercise capacity.

Kilkens et al. [16] reported correlations of 0.51–0.82 between physical capacity (peak power output [PO_{peak}] on a motorized treadmill) and wheelchair skill capacity (what the person *can do*)

[17] on the Wheelchair Circuit during the inpatient rehabilitation of 97 people with spinal cord injury (SCI). The Wheelchair Circuit consists of 8 skills including propulsion on a motorized treadmill [18–20].

In comparison with the Wheelchair Circuit, the Wheelchair Skills Test (WST) [21–23] does not require a treadmill and, by assessing 34 skills, is a more granular measure of skill capacity. Another advantage of the WST is that there is a questionnaire version (the WST-Q) that, in addition to capacity, permits the assessment of wheelchair skill confidence (self-efficacy) [24] and wheelchair skill performance (what the person *does do*) [17]. The total capacity scores of the WST and WST-Q are highly correlated, although WST-Q values tend to be slightly higher [25,26]. Total WST-Q capacity scores are also correlated with WST-Q confidence and performance scores, but exceed these values slightly [26–28]. Saltan et al. [29] found that the total WST-Q capacity and performance scores of wheelchair basketball players were significantly higher than those of non-players.

The overall goal of this study was to replicate and extend the work of Kilkens et al. [16] by using the WST-Q (as Saltan et al. [29] have done) rather than the Wheelchair Circuit as the measure of wheelchair skills and by studying experienced, community-dwelling wheelchair users rather than those undergoing inpatient rehabilitation. Our objective was to test the hypothesis that there are moderate relationships between the total WST-Q capacity, confidence, and performance scores and the PO_{peak} values (as measured by a graded wheelchair exercise test on a motorized treadmill) of experienced, community-dwelling manual wheelchair users with SCI. The identification of such a relationship would be of clinical significance, suggesting that greater attention should be paid to enhancing both fitness and wheelchair skills during rehabilitation.

Materials and methods

Study design

This study was part of a larger cross-sectional study [30] on wheelchair outcome measures. The study was conducted according to the Strengthening the Reporting of Observational Studies in Epidemiology guidelines [31].

Ethical issues

The project was approved by the University of Miami Medical Institutional Research Board (Protocol #20160005, IRB-A #IRB00005621). All participants provided written informed consent.

Recruitment and screening

We studied 26 participants, a sample of convenience, with a sample size based on the larger study of which this was a part. We recruited participants by direct contact with persons who visited the Miami Project, by direct contact with persons who have previously participated in research at the Miami Project and have agreed to be contacted for future research opportunities, and by posting study-related information on the Miami Project to Cure Paralysis website. Participants were compensated \$30 for completing a visit, to offset their expenses.

Inclusion/exclusion criteria

Each participant had an SCI or spinal cord disease, was ≥ 18 years of age, had an injury duration of ≥ 6 months, used a manual hand-rim wheelchair for $\geq 50\%$ of daily propulsion, and independently propelled him/herself. A potential participant was excluded if he/she was hospitalized, had significant shoulder pain during daily activities (that we defined as a cutoff score of >60 on the Wheelchair Users Shoulder Pain Index) [32], had a resting heart rate ≥ 120 beats/minute, had a resting systolic blood pressure >180 mm Hg, had a resting diastolic blood pressure >100 mm Hg, had a self-reported history of unstable angina or myocardial infarction within the previous month, was unable to provide consent, was incarcerated, was pregnant, or if scheduling difficulties precluded recording any data.

Demographic, clinical, and wheelchair data

Each participant self-reported his/her age, sex, height, racial ethnicity, duration of injury, injury level, and duration of current wheelchair use. We measured the weight of the participant (weight of occupied wheelchair – weight of unoccupied wheelchair) and

Figure 1. Participant on motorized treadmill during a graded exercise test. The soft mask, portable oxygen-consumption equipment, vest, tethers, incline measurement tool, and pulley system are shown.

used inspection to document the wheelchair frame type (solid vs. folding).

Outcome measures

Wheelchair Skills Test Questionnaire (WST-Q)

For each of the 34 individual skills that comprise version 4.3 of the WST-Q, we recorded WST-Q capacity, confidence, and performance scores, using 0–2 ordinal scales according to the procedures described in the Wheelchair Skills Program Manual [21]. The total percentage WST-Q scores (0–100%) were calculated, as were subtotals (0–100%) based on the three skill levels (basic, intermediate, and advanced) [21]. The timing of the WST-Q administration varied in relationship to the timing of the graded exercise test but most tests were on the same day and the maximum time between tests was 7 days. Because of the brief questionnaire nature of the WST-Q, we did not consider that the order of testing would affect the results.

Graded exercise test

Participants completed a continuous incremental aerobic fitness test on a wheelchair treadmill (PushOn Treadmill, Max Mobility, Antioch, TN, USA) in their own wheelchairs [33–35]. Participants first completed a short familiarization period (generally <5 min) on the treadmill. The warm-up allowed the participant to become familiar with treadmill propulsion and allowed the investigator to select the treadmill speed to be used during the test protocol. Our choice of speed was based on which one worked best with the pulley weights to achieve the target PO range. Typically, participants with tetraplegia were assessed at a treadmill speed of 0.44 m/s whereas participants with paraplegia were assessed at 0.44, 0.78, or 1.11 m/s depending on their fitness levels.

After the familiarization period, the systems to record oxygen consumption and heart rate were attached (Figure 1). A soft mask covered the nose and mouth and the recording and transmitting modules (Oxycon mobile device, CareFusion Corporation, San Diego, CA, USA) were carried in a vest. Heart rate was monitored using a chest strap (Polar Electro Inc., Lake Success, NY, USA). Then the participant sat quietly in the wheelchair for 5 min to acclimatize to the equipment and to establish baseline values for heart rate and oxygen uptake.

Participants then began propelling on the treadmill at the velocity selected during the familiarization period (0.44, 0.78, or 1.11 m/s) and an initial pulley load. Each minute, the researcher

increased the external load (i.e., the power output in Watts [W]) by adding weights to a pulley system attached to the back of the participant's wheelchair. Pulley mass was determined from the results of an individualized wheelchair drag test [36]. Participants kept propelling until they reached volitional exhaustion or they could not keep the wheelchair in the front two-thirds of the treadmill belt. Resistance increments were individualized, based on injury level and reported activity level, with the goal of achieving peak effort in 8–10 min.

The PO_{peak} was defined as the highest resistance maintained for at least 30 s. Individual power output was the product of force (the rolling resistance plus the additional force applied via the pulley system) and treadmill velocity [36]. The PO_{peak} is considered to be a better overall measure of wheelchair capacity than peak oxygen uptake [16,37], with which there is a high correlation [38]. We also recorded the peak heart rate, the peak respiratory exchange ratio (30 s average) [39], and the peak rate of perceived exertion (from a modified 10-point Borg scale 0–10) [33]. We considered an exercise test to be maximal if the peak respiratory exchange ratio was ≥ 1.10 and/or the peak rate of perceived exertion was ≥ 9 . After the test, the pulley system was detached and the participants propelled without resistance for 5 min to cool down.

For participant safety, we attached tethers to the wheelchair frame near the casters on each side, the resistance was eliminated if the wheelchair drifted too far back on the treadmill belt and an emergency stop button was positioned beside the tester.

Data analysis

We used statistical software (SPSS statistical software version 20, IBM Corporation, Armonk, NY, USA) for the analysis and an α level of 0.05. Descriptive statistics were computed for all variables. The normality of continuous data was assessed with the Shapiro Wilks test to guide the choice of parametric versus nonparametric statistics. If the data were normal, we reported the means (standard deviations [SDs]); if not, we reported the medians (interquartile ranges [IQRs]). There were no missing data. Because the WST-Q outcome measures were not normally distributed, for the regression models we dichotomized the outcome measures by using the medians as the cutoff scores.

Thereafter, we developed logistic regression models for each of the three total WST-Q measures, to study the associations between wheelchair skills measures and wheelchair exercise capacity. In each case, the dichotomized WST-Q score (low = 0,

high = 1) was the dependent variable and PO_{peak} (W) was the independent variable. To confirm our selection of PO_{peak} (W) as the appropriate independent measure to represent exercise capacity (as Kilkens et al. [16] have done), we performed Spearman correlations between the WST-Q outcomes and both PO_{peak} (in W) and PO_{peak} (in W/kg); PO_{peak} (in W) correlated most strongly with the WST-Q scores ($r = 0.577$ – 0.727 , $p < 0.01$). Due to our small sample size, we checked for only a limited number of possible confounders (age [years], sex [male = 0, female = 1], injury level [paraplegia = 0, tetraplegia = 1], and time since injury [years]) by adding these one-by-one to the models. If the regression coefficient of the independent variable changed 10% or more when adding the demographic or lesion characteristic, this characteristic was added to the final model [40,41]. Because of apparent ceiling effects we observed for the basic- and intermediate-level WST-Q scores, we also performed post hoc logistic regression analyses for the advanced-level scores to explore whether such analyses would be more sensitive than the total WST-Q scores.

Results

Demographic, clinical, and wheelchair data

The demographic, clinical, and wheelchair data are shown in Table 1. Participants were generally in their mid-thirties, were mostly male, and had a mean Body Mass Index under 25 kg/m^2 . Almost half were Hispanic, with the remainder almost equally African-American or white. About 80% of the participants had spinal cord levels at the paraplegic level and the median time since injury was over 10 years. The median duration of time using their current wheelchairs was 4 years and about three-quarters of the wheelchairs had rigid frames.

WST-Q data

The WST-Q data are shown in Table 2. The median values were generally high. The basic-level subtotal scores were the highest, followed by the intermediate- and advanced-level subtotal scores. The capacity total and subtotal scores were generally higher than the confidence scores and the performance scores, in order.

Fitness testing data

The median (IQR) total test time was 10.3 (8.2–11.3) min. The fitness data are shown in Table 3. The median PO_{peak} was almost 60 W. One participant with tetraplegia did not meet our peak respiratory exchange ratio criteria (≥ 1.10) for a maximal test but his peak rate of perceived exertion was 10. The median peak respiratory exchange ratio was 1.4 and the median peak rate of perceived exertion was 10.

Relationships between WST-Q and fitness data

The relationships between the WST-Q total scores and PO_{peak} are shown in Table 4. There were significant relationships between the total WST-Q capacity, confidence, and performance scores and PO_{peak} (R^2 0.270–0.709, odds ratios [ORs] 1.043–1.150, $p < 0.05$). An OR of 1.150 means that for each 1 W increase in PO_{peak} , the odds are 1.150 higher that the person is in the group with a high versus low WST-Q score. The only significant confounder identified was sex for WST-Q performance only, but the small number of females (2) in the sample limited this assessment. The relationships are illustrated as scatterplots in Figures 2–4. Visual inspections of these figures show that the WST-Q scores and PO_{peak}

Table 1. Participants' demographic, clinical, and wheelchair data ($N = 26$).

Parameter	Sub-parameter or units	Statistic shown	Value
Age	Years	Mean (SD)	36.4 (2.5)
Sex	Male	N (%)	24 (92.3%)
	Female	N (%)	2 (7.7%)
Body Mass Index	kg/m^2	Mean (SD)	24.2 (4.9)
Racial ethnicity	Hispanic	N (%)	12 (46.2%)
	African-American	N (%)	7 (26.9%)
	White	N (%)	6 (23.1%)
	Other	N (%)	1 (3.8%)
SCI level	Paraplegia	N (%)	21 (80.8%)
	Tetraplegia	N (%)	5 (19.2%)
Duration of SCI	Years	Median (IQR)	11.5 (3.5–17.0)
Frame type	Rigid	N (%)	20 (76.9%)
	Folding	N (%)	6 (23.1%)
Time using current wheelchair	Years	Median (IQR)	4.0 (2.0–6.0)

n: number; SD: standard deviation; IQR: interquartile range; SCI: spinal cord injury.

values were generally lower for participants with tetraplegia than paraplegia. For the logistic regression analyses using the subtotal advanced-level WST-Q scores, injury level was a confounder for all three WST-Q scores. The advanced-level WST-Q capacity and confidence scores were significantly related to PO_{peak} ($p = 0.045$) but the advanced-level WST-Q performance scores were not ($p = 0.061$).

Discussion

This study has replicated and extended the work of Kilkens et al. [16], by using the WST-Q rather than the Wheelchair Circuit as the measure of wheelchair skills and by studying experienced, community-dwelling wheelchair users rather than those undergoing inpatient rehabilitation. Our findings are also consistent with those of Saltan et al. [29] who reported that WST-Q scores were higher in basketball players (who were probably fit) than non-players. We were able to corroborate our hypothesis that there are significant relationships between wheelchair skills scores and PO_{peak} . The strength of the relationship was the lowest for WST-Q performance. Performance as measured by the WST-Q reflects

how the World Health Organization has conceptualized performance [17], namely indicating what a person does in his/her actual environment and daily life. A lack of confidence, for instance, may affect the extent to which a wheelchair user performs the skills that he/she has the capacity to perform.

Our analysis of confounders was conducted by adding participant characteristics one-by-one to the models and only including in the final model those that changed the regression coefficient of the independent variable by 10% or more. The only significant confounder identified in this way was sex for WST-Q performance, but the small number of females in the sample limited this assessment. However, as the scatterplots illustrated in Figures 2–4 and as confirmed by the logistic regression analyses using the subtotal advanced-level WST-Q scores, injury level was a confounder for all three WST-Q scores.

As shown in the scatterplots (Figures 2–4) for WST-Q capacity and confidence total scores, the relationships with PO_{peak} appeared to be linear between 15 and 80 W, but not beyond 80 W. For WST-Q performance, the relationship with PO_{peak} appeared to be linear below about 70 W and there was more variability in the relationship. Although our data only provide evidence of associations and not causality, it is tempting to wonder whether, if a wheelchair user with a PO_{peak} below a threshold of about 80 W could improve this value by fitness training, such an improvement might contribute to a higher WST-Q score. Conversely, for a wheelchair user with a $PO_{peak} > 80$ W, no value with respect to WST-Q scores would be likely due to fitness training. Previous studies [42–44] suggest that a PO_{peak} of 80 W is achievable for many people with SCI, particularly men with paraplegia. A similar relationship between strength and sprint power has been observed in people with cerebral palsy [45]. The phenomenon of a nonlinear association between strength/power and performance holds true across populations. Among ambulatory older adults, gait speed (activity) is related to leg strength (body-function) in weak but not strong individuals [46]. This phenomenon is also present in SCI, with strong associations between fitness and activities of daily living independence in people with tetraplegia but only weak associations were identified in people with paraplegia [47].

Table 2. WST-Q data (total and subtotal scores).

Parameter	Sub-parameter or units	Value*
WST-Q capacity	Total (%)	83.3 (74.2–94.1)
	Basic level (%)	95.1 (94.0–100.0)
	Intermediate level (%)	93.3 (90.3–100.0)
	Advanced level (%)	61.5 (35.2–81.8)
WST-Q confidence	Total (%)	81.5 (68.1–96.0)
	Basic level (%)	92.2 (90.0–100.0)
	Intermediate level (%)	91.3 (79.0–100.0)
	Advanced level (%)	60.8 (39.8–87.5)
WST-Q performance	Total (%)	76.7 (69.3–86.8)
	Basic level (%)	92.5 (84.0–100.0)
	Intermediate level (%)	87.1 (77.0–96.5)
	Advanced level (%)	49.9 (27.3–70.5)

*Median (IQR) values are shown.

IQR: interquartile range; WST-Q: Wheelchair Skills Test Questionnaire.

Table 3. Fitness testing data.

Parameter	Sub-parameter or units	Statistic shown	Value
Baseline heart rate	Beats per minute	Mean (SD)	78 (3)
Peak heart rate	Beats per minute	Median (IQR)	164 (114–177)
Baseline oxygen consumption	ml/kg/min	Median (IQR)	4 (3–5)
Peak oxygen consumption	ml/kg/min	Mean (SD)	16.2 (5.4)
PO_{peak}	W	Mean (SD)	58.2 (5.3)
PO_{peak}	W/kg	Mean (SD)	0.78 (0.33)
Peak respiratory exchange ratio		Mean (SD)	1.4 (0.04)
Rate of perceived exertion (last stage)	0–10	Median (IQR)	10 (9.75–10)

kg: kilogram; PO_{peak} : peak power output; W: Watts.

Table 4. Outcomes of the logistic regression analyses to investigate the associations between wheelchair skills (WST-Q) scores and wheelchair exercise capacity (PO_{peak}).

Independent variable	WST-Q capacity			WST-Q confidence			WST-Q performance		
	Beta (SE)	Odds ratio*	p	Beta (SE)	Odds ratio*	p	Beta (SE)	Odds ratio*	p
Constant	−7.99 (3.37)	0.0003 (4.5×10^{-7} –0.25)	0.018	−7.99 (3.37)	0.00 (4.5×10^{-7} –0.25)	0.018	−2.59 (1.25)	0.075 (0.006–0.87)	0.038
PO_{peak} (W)	0.14 (0.06)	1.15 (1.02–1.29)	0.017	0.14 (0.06)	1.15 (1.02–1.29)	0.017	0.04 (0.02)	1.043 (1.00–1.08)	0.038
R^2	0.709			0.709			0.27		

*Odds ratios (95% confidence intervals) are shown.

Significant relationships are shown in bold font.

SE: Standard Error; W: Watt; WST-Q: Wheelchair Skills Test Questionnaire.

Figure 2. Scatterplot of total WST-Q capacity score (%) versus peak power output (W). The solid horizontal line is the median. The open and solid circles represent male participants with paraplegia (PP) and tetraplegia (TP), respectively. The open diamonds represent female participants with paraplegia.

Figure 3. Scatterplot of total WST-Q confidence score (%) versus peak power output (W). The solid horizontal line is the median. The open and solid circles represent male participants with paraplegia (PP) and tetraplegia (TP), respectively. The open diamonds represent female participants with paraplegia.

As for the strength of the relationships between wheelchair skill measures and exercise capacity, we did not expect these to be strong; different participant characteristics are represented by the two measures (wheelchair skills being *activities* and limited exercise capacity being an *impairment* in terms of the International Classification of Function [17]). For instance, knowing how much resistance a person with SCI can tolerate on a smooth level motorized treadmill belt moving at a constant speed may be predictive of wheelchair skills in a general way (as our study and that of de Groot et al. [48] have shown) and exercise capacity is likely important for skills where strength is a prerequisite (e.g., floor to chair transfers) even if technique is also important. However, such data cannot reasonably be expected to predict much about skills that are more technical in nature (e.g., whether that person can descend a steep incline in the wheelie position).

Figure 4. Scatterplot of total WST-Q performance score (%) versus peak power output (W). The solid horizontal line is the median. The open and solid circles represent male participants with paraplegia (PP) and tetraplegia (TP), respectively. The open diamonds represent female participants with paraplegia.

However, exercise capacity and WST could both be proxies for a latent characteristic that is related to participation. It is unlikely that a wheelchair user with a very low exercise capacity would have very high WST-Q scores and vice versa.

Regarding the adequacy of the methods used in this study, both outcome measures performed reasonably well. The WST-Q values observed in this study were similar to those previously reported in the literature [27,49,50]. Some of the total and sub-total WST-Q scores in our study showed apparent ceiling effects, although this was not the case for the advanced-level subtotal WST-Q scores. Ceiling effects have been reported before for participants similar to ours [27,49,50] and such effects are understandable for our participants (highly experienced wheelchair users with SCI, most of whom were male and had SCI at the paraplegic level).

The graded exercise test on a motorized treadmill test also performed well. The median total test time was just over 10 min, as we had hoped. The exercise capacity values found in this study were similar to those previously reported in the literature [9,38,42,43]. The significant positive relationships between PO_{peak} values and the WST-Q measures found in our study add to the literature regarding the construct and concurrent validity of such graded exercise testing. Using a motorized treadmill, that requires the participant to maintain a constant direction, has face validity in comparison with roller ergometers that do not. A motorized treadmill, that utilizes the same propulsion mechanics that are used in overground propulsion, also has face validity in comparison with arm-crank ergometers. Both PO_{peak} and peak oxygen uptake values have high reliability and are sensitive to changes due to training [38]. However, individuals with SCI are not always able or willing to perform strenuous exercise tests. Although the motorized treadmill test is a well validated technique, in the clinical setting a graded exercise test on a treadmill is not always feasible. In clinical settings, a validated low-technology field test is needed.

Study limitations

The major limitation of this study was the small sample size, although it was adequate to confirm the relationships that we

hypothesized. The small sample size limited the number of independent variables that we were able to assess with our regression analyses. The small number of females in the study sample severely limited our ability to explore sex as a confounder in the relationships between WST-Q variables and PO_{peak} , although the advanced-level analyses did allow us to identify the effect of injury level.

Although we focused on aerobic fitness because of the nature of the data available to us, the time to complete many wheelchair skills is very short (<30s) [20,51,52] thus may be more strongly correlated with other types of fitness (i.e., strength and anaerobic power). Anaerobic and aerobic powers are strongly related in wheelchair exercise [53].

Another limitation was that this was a cross-sectional study, allowing the identification of associations but not causal relationships. However, from the clinical perspective, it might be considered irrelevant whether better exercise capacity contributes to better wheelchair skills, better wheelchair skills contribute to better exercise capacity, both or neither. Clinicians need not prioritize one form of intervention over the other, because both are known to be beneficial [1–10]. Presumably the two interventions complement one another and can be utilized as related elements in a multimodal rehabilitation strategy, as Gant et al. have suggested [54]. Although not explored in this study, during motor skills learning, performing a variety of types of fitness-related exercise in close proximity to the learning session has been shown to have a positive effect on motor skill retention [e.g., 55].

Future studies are needed to address these limitations. Evolution of the WST and WST-Q measures would be useful, to minimize ceiling effects among other refinements, if this can be done without adding to the burden of testing. From the standpoint of exercise testing, we perceive a need for a practical field test of wheelchair exercise capacity that does not require a motorized treadmill but that correlates well with PO_{peak} and peak oxygen uptake values [33]. As for determining causality, Durán et al. [56] reported an uncontrolled trial on 13 people with SCI in which a 16-week exercise program improved both exercise tolerance (arm-crank) and wheelchair skills. However, we envision the need for a randomized controlled cross-over trial in which one group starts with exercise training and the other group with wheelchair skills training. Then each group would add the opposite intervention. Such a trial would make it possible to estimate the relative contributions to the desired outcomes of each intervention alone and in combination, and provide insight into the preferred sequence of the interventions.

Conclusions

Despite the study limitations and the need for further study, this study adds to the literature about the relationships between wheelchair skills measures and exercise capacity. Significant relationships exist between wheelchair skills scores and the peak exercise capacity of community-dwelling manual wheelchair users with SCI. Although further research is needed, these findings suggest that clinicians should address *both* wheelchair skills training and exercise training during the rehabilitation of people with SCI.

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Disclosure statement

The authors report no conflicts of interest.

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