

ORIGINAL ARTICLE

Determination of normative values for 20 min exercise of wheelchair propulsion by spinal cord injury patients

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Study design: This was a retrospective observational study.

Objective: The objective was to determine the normative values for 20 min exercise of wheelchair propulsion in spinal cord injury (SCI) subjects.

Setting: Sarah Rehabilitation Hospitals Network, Brazil.

Methods: A total of 413 medical records for SCI patients at different levels and classifications at the Sarah Rehabilitation Hospitals Network, Brazil, who performed 20 min exercise in a rehabilitation programme between the years 2004 and 2009 were consulted. Information regarding patient and performance characteristics was obtained, including distance travelled, mean velocity, rest and exercising heart rate and perceived exertion. The data were analysed by gender and by injury level group: tetraplegia (TT) or paraplegia (PP).

Results: The participants' ages ranged from 18 to 64 years, and the median time since injury was 1.2 years. The men and women had different performances regardless of their level of injury. The distance ranged between 495 and 2106 m for men and between 300 and 1901 m for women. The mean velocity of propulsion ranged from 25 to 105 m min⁻¹ for men and from 15 to 95 m min⁻¹ for women.

Conclusions: This study provides normative data for the 20 min exercise that could be used to estimate the resistance capacity by manual wheelchair users with SCI and evaluate the effects of training and other therapeutic interventions.

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Keywords: spinal cord injuries; heart rate; oxygen consumption; wheelchairs; rehabilitation

INTRODUCTION

Changes in motor and sensory functions are common after spinal cord injuries (SCIs). The majority of people with SCI depend on a wheelchair for mobility.¹ Wheelchair use is among the most important rehabilitation interventions. The evaluation of parameters such as endurance and wheelchair skills has attracted scientific attention.

Establishing realistic goals for a rehabilitation programme depends, among others factors, on evaluations of individual physical capacity.² Such evaluations can be based on personal reports or laboratory tests. However, objective testing is preferred over subjective ratings by wheelchair users and family members because of the probability that patients and family may overestimate the patient's abilities.

Laboratory tests allow a detailed evaluation of the systems involved in physical exercise, for example, the maximum cardiopulmonary fitness. However, these tests require sophisticated equipment and qualified professionals. Although there is a correlation between aerobic capacity and functional performance in individuals with SCI,^{3–5} peak oxygen value may not reflect the actual performance for daily wheelchair use.

Field tests have been proposed in the literature as alternatives to laboratory tests that permit the observation of performance at a lower cost.⁶ In some of these tests, distance is used to assess aerobic fitness or the ability to maintain high and steady oxygen uptake for energy

generation, which is influenced by an individual's maximum aerobic capacity. The choice of the test depends on the clinical question involved and the resources available.

A few years ago, two units (Center and North Lake) of the Sarah Network of Rehabilitation Centers began using 20 min exercise¹ to evaluate patients' functional capacity to propel a wheelchair for long periods, reflecting the endurance for mobility at a self-selected and comfortable speed, that is, submaximal level. Other articles have used the same length of time for different types of analyses and objectives.^{1,7}

In terms of applicability, the clinical parameters obtained with the 20 min exercise may be useful for monitoring and evaluating wheeling at various levels of injury with easy and cost-effective application. The results of this evaluation may allow the rehabilitation team to (1) obtain objective data about endurance for propelling a wheelchair; (2) support inferences about the community mobility, social participation and quality of life of individuals with SCI; (3) quantify the status and progress of patients after an intervention; (4) motivate individuals with SCI to be physically active by providing quantitative information on their health; (5) recognise possible athletic ability; (6) assist rehabilitation professionals in setting goals for rehabilitation and beyond; and (7) monitor the effectiveness of training and rehabilitation programmes.

Although this exercise is a routine physical examination for SCI patients, normative values are not known for this population and may

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be influenced by many factors, including the level of injury, the time since injury, age and gender. The normative values can quantify the patient's status and progress after an intervention. In addition, objective, easy and low-cost data can be useful as a tool to help professionals define rehabilitation goals and recognise athletic ability in the SCI population.

Therefore, the aim of this study was to evaluate the performance of individuals with different levels of SCI during 20 min exercise of wheelchair propulsion to define normative values. In addition, the relationships between age, neurological level, time since injury and distance and velocity were assessed to analyse the influence of subject characteristics and performance parameters. The hypothesis of this study is that distance and average speed are highly correlated with injury level, time since injury and age.

MATERIALS AND METHODS

Data collection

A total of 413 patient records from 2004 to 2009 at the Spinal Cord Injury Neurorehabilitation Program of Sarah Hospital Units (Center and North Lake) were analysed. The study was approved by the institutional review board and the ethics committee of the Sarah Hospital (no. 890).

The patients were classified according to the ASIA (American Spinal Injury Association) classification. The subjects' information (age, time since injury, gender and neurological level of injury) were collected from electronic medical registers. For the analysis, the patients were categorised into three groups: tetraplegia (TT), C4 to C8; high paraplegia (HP), T1 to T6; and low paraplegia (LP), below T7.

This division criterion is commonly used in SCI studies, and it considers the involvement of the upper limbs and sympathetic nervous system and trunk instabilities.^{8,9} Records were included in the study if the patient had a SCI diagnosis, was a wheelchair user aged at least 18 years and was assessed using the 20 min exercise during the rehabilitation programme. Both male and female patients were included. Records were excluded if they contained incomplete data (concerning velocity and distance) or were registered incorrectly (Figure 1).

The 20 min exercise

The 20 min exercise consists of propelling the wheelchair at a comfortable speed for 20 min in closed paths with tight turns (70 and/or 60 m diameters on flat, solid and smooth surfaces). The exercise is administered during the first or second week of hospitalisation. Before starting the exercise, the patients are kept at rest for 5 min on the wheelchair for heart rate measurements. Before the exercise, the wheelchair's tires are calibrated according to the manufacturer's instructions, and the patients receive standardised instructions. Patients use their own wheelchairs or a wheelchair on loan from the hospital during the rehabilitation programme. The travel direction should be chosen to allow the subject's stronger or dominant arm to be on the outside of the track. Adjustments to the wheelchair rim (for example, pins or rubber tubing) or the use of gloves for improved gripping are allowed to meet the patient's usual propulsion conditions. The total distance travelled is determined by the total laps completed multiplied by perimeter of the course plus the fractional distance. The comfortable propulsion speed (m min^{-1}) is obtained by calculating the ratio between the distance travelled and the total time. Heart rate is recorded continuously using a portable heart monitor (Polar T5, Kempele, Finland) during rest periods and exercise. The average of each period was considered for the analyses. At the end of the exercise, perceived exertion was assessed using the Borg Scale (0–10). All of the exercises were administered by the authors of this article.

The exclusion criteria for the 20 min exercise were inability to participate in rehabilitation programme; the presence of cardiovascular, cardiac or orthopaedic surgery that would restrict wheelchair locomotion; a history of metabolic disorders; or the use of medication that might affect heart rate.

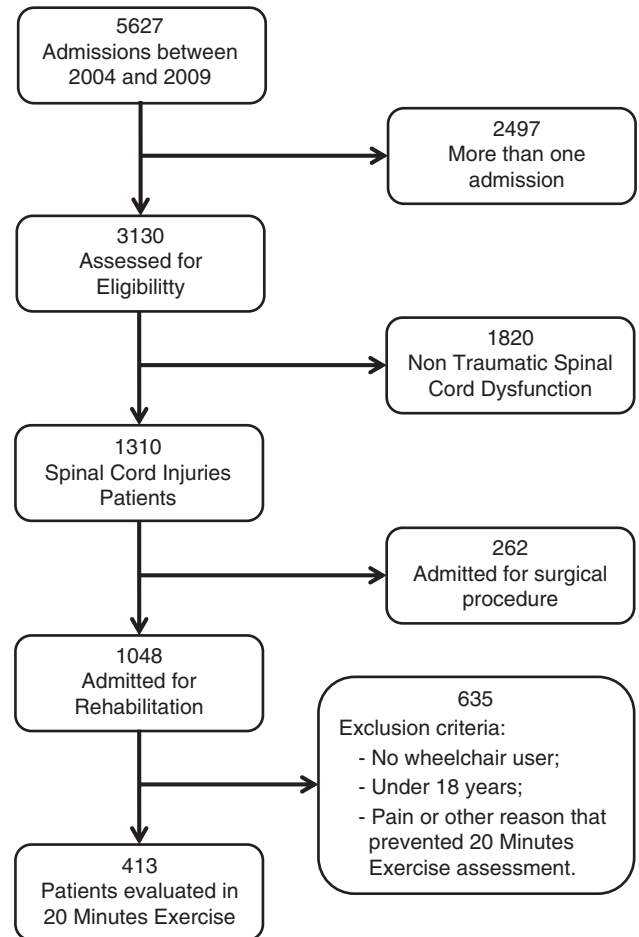


Figure 1 Flow diagram of included and excluded patients.

Statistical analysis

The variables were checked for normality using the Kolmogorov–Smirnov test. The comparisons of means between groups were performed using one-way analysis of variance for variables with normal distribution and, if significant, the Bonferroni *post hoc* test. This test reduces the chance of finding false differences (type I error). In case of variables with nonnormal distribution, the Kruskal–Wallis test was used to compare groups.

Descriptive statistics were reported as means and s.d. for normally distributed variables and medians and variation for nonnormal variables.

Percentile tables were constructed and classified as follows: Poor (below the 10th percentile), fair (25th percentile), average (50th percentile), good (75th percentile) and excellent (above the 90th percentile).

Pearson's correlation was used to examine the relationships of time since injury, age, neurological level of injury and gender with distance and velocity. Cohen's classification was used to determine the degree of correlation (none: 0.00–0.09; low: 0.10–0.30; moderate: 0.31–0.50; high: 0.50–1.00).

The statistical packages SPSS (SPSS Inc., version 13.0, Chicago, IL, USA), G*Power (SPSS Inc., version 3.1.6, Stuttgart, Germany) and MedCalc (version 9.0.1.0, Mariakerke, Belgium) were used for data processing. For a medium to small effect size (0.20), a statistical significance of $P < 0.05$ and a power of 95%, a total sample of 390 was required.

RESULTS

Sample characteristics

There were no significant gender differences for the variables age and time since injury among the TT, HP and LP groups (Table 1).

Performance parameters

Overall, the patients travelled an average distance of 1408 m (± 422 m). Among the groups, the TT patients had the lowest distance value, with a mean of 946 m (± 329 , $P < 0.0167$; Figure 2). The average speed of wheelchair propulsion was 70.4 m min^{-1} (± 21.1). Men and women had different performances regardless of the level of injury; women were slower and travelled less distance.

Although the data showed a trend towards higher values among PP patients with lower levels of injury, there were no significant gender

Table 1 Sample characteristics with mean, s.d., median, range and frequency (%)

	TT	HP	LP	Total
N	83 (20.1)	151 (36.6)	179 (43.3)	413 (100.0)
Gender, N (%)				
Male	70 (84.3)	118 (78.1)	136 (76.0)	324 (78.5)
Female	13 (15.7)	33 (21.7)	43 (24.0)	89 (21.5)
Age, years				
Mean (\pm s.d.)	28.7 (8.8)	29.4 (9.2)	30.6 (10.0)	29.8 (9.5)
Median	26.0	26.9	28.4	27.1
Range	18.5–58.6	18.0–62.1	18.0–64.2	18.0–34.2
TSI, years				
Mean (\pm s.d.)	2.6 (3.0)	2.2 (3.1)	2.3 (4.4)	2.3 (3.7)
Median	1.5	1.1	1.1	1.2
Range	0.1–17.6	0.1–24.3	0.1–42.3	0.1–42.3
ASIA, N (%)				
A	42 (50.6)	131 (86.7)	147 (82.1)	320 (77.5)
B	20 (24.1)	15 (9.9)	13 (7.3)	48 (11.6)
C	17 (20.5)	3 (2.0)	15 (8.4)	35 (8.5)
D	4 (4.8)	2 (1.3)	4 (2.2)	10 (2.4)
Unit				
Sarah Center	47 (56.6)	129 (85.4)	165 (92.2)	341 (82.6)
Sarah North Lake	36 (43.4)	22 (14.6)	14 (7.8)	72 (17.4)

Abbreviations: ASIA, American Spinal Injury Association classification; HP, high paraplegia group; LP, low paraplegia group; TSI, time since injury (years); TT, tetraplegia group.

differences in the performance variables between the PP groups (Table 2 and Figure 2). Based on this result, the PP groups were combined to create a percentile table that shows the normative values of performance parameters for the 20 min exercise for men and women (Table 3).

Heart rate and Borg Scale

On average, the resting heart rate of all patients was 93 b.p.m.; the heart rate during exercise was 130 b.p.m. The mean heart rate variation was 37 b.p.m. for the entire group. The mean heart rate showed no significant difference between genders, except in the HP group during rest ($P < 0.05$).

Among men, heart rate was lower in TT patients compared with PP patients, both at rest and during exercise. Similar differences were observed in the delta heart rate. Among the female patients, the exercising heart rate of the TT group differed from that of the HP group ($P < 0.0167$). Perceived exertion did not differ statistically between groups for both genders.

Correlations

For the whole group, correlations were found between performance (speed and distance) and age, completeness of lesion and exact level of injury ($P < 0.01$). However, the strength of these correlations was low to modest ($r = -0.24$, $r = -0.20$ and $r = 0.48$, respectively). When a correlation analysis considered the average of performance variables at each level of injury, the correlation was high ($r = 0.82$ for men and $r = 0.72$ for women). For the whole group, performance was not correlated with the time of injury for men ($r = 0.01$ and $P = 0.84$) or for women ($r = 0.09$ and $P = 0.38$); however, for paraplegics with high injuries, there appeared to be a tendency towards a correlation for both men ($r = 0.183$ and $P = 0.048$) and women ($r = 0.36$ and $P = 0.038$).

Correlations between age and distance in each group for both genders were low to modest and were not significant in the TT groups. We therefore decided not to stratify the distance by age.

In summary, other results showed that: (1) for men and women, the higher the delta heart rate, the better the performance, and this correlation was stronger among both men and women in the PP group (this correlation was not found for TT women); (2) there were

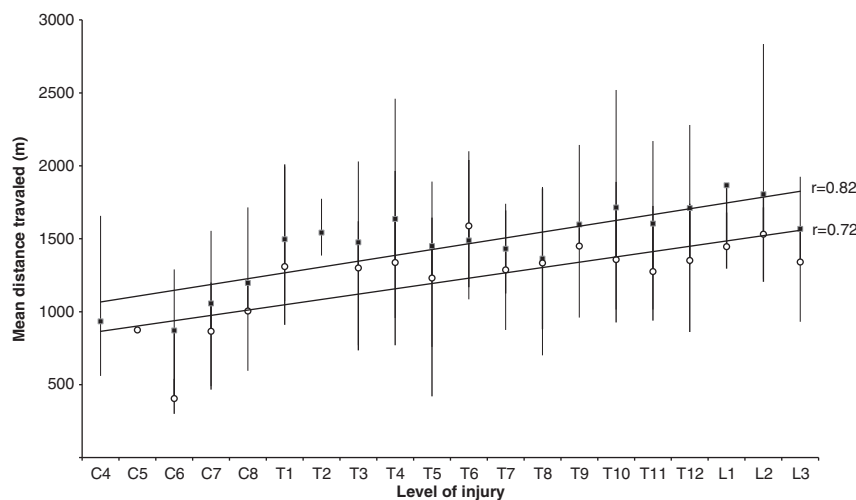


Figure 2 Mean distance travelled in the 20 min exercise, distributed according to lesion level for male (■) and female (○) subjects. Values are the mean and ranges for the whole group in metres. The thin and thick lines represent the Pearson's correlation coefficient for males ($r = 0.82$) and females ($r = 0.72$), respectively.

Table 2 Performance parameters with mean (s.d.) for each group

	TT	HP	LP	Total
<i>Distance (m)</i>				
Male	985 ^{a,b} (± 320)	1528 (± 353)	1618 (± 354)	1448 (± 72)
Female	735 ^{a,b,c} (± 305)	1339 ^c (± 362)	1359 ^c (± 276)	1260 (± 63)
<i>Velocity (m min⁻¹)</i>				
Male	49.3 ^{a,b} (± 16)	76.0 (± 18)	81.0 (± 18)	72.0 (± 21)
Female	36.8 ^{a,b,c} (± 15)	67.0 ^c (± 18)	68.0 ^c (± 14)	63.0 (± 19)
<i>Borg</i>				
Male	3.8 (± 1.5)	3.6 (± 1.3)	3.2 (± 1.2)	3.4 (± 1.3)
Female	4.0 (± 1.7)	3.9 (± 1.3)	3.6 (± 1.3)	3.7 (± 1.4)
<i>Rest HR (b.p.m.)</i>				
Male	78 ^a (± 13)	95 (± 15)	95 (± 14)	92 (± 16)
Female	89 (± 12)	103 (± 17)	99 (± 15)	99 (± 16)
<i>Exercise HR (b.p.m.)</i>				
Male	104 ^{a,b} (± 14)	140 ^b (± 23)	130 (± 18)	129 (± 23)
Female	106 ^a (± 10)	141 (± 22)	130 (± 19)	132 (± 22)
<i>Δ HR (b.p.m.)</i>				
Male	26 ^{a,b} (± 12)	44 ^b (± 22)	35 (± 17)	37 (± 19)
Female	17 (± 9)	39 (± 21)	31 (± 16)	33 (± 18)

Abbreviations: HP, high paraplegia group; HR, heart rate; LP, low paraplegia group; TT, tetraplegia group.

^aSignificant difference with HP ($P < 0.0167$).

^bSignificant difference with LP ($P < 0.0167$).

^cSignificant difference with male ($P < 0.05$).

Table 3 Normative values for 20 min exercise (percentiles)

	Percentiles						
	5	10	25	50	75	90	95
<i>Men</i>							
<i>Distance</i>							
TT	494.8	558.2	741.0	988.0	1215.0	1465.5	1546.4
PP	998.2	1106.7	1312.1	1600.6	1842.5	1997.5	2106.0
<i>Velocity</i>							
TT	24.7	27.9	37.1	49.4	60.8	73.3	77.3
PP	50.0	55.4	65.6	80.1	92.1	99.9	105.3
<i>Women</i>							
<i>Distance</i>							
TT	—	300.0	473.0	780.0	974.9	1188.0	—
PP	847.4	921.6	1168.4	1331.1	1579.5	1756.2	1901.3
<i>Velocity</i>							
TT	—	15.0	23.7	39.0	48.8	59.4	—
PP	42.4	46.1	58.4	66.6	79.0	87.8	95.1

Abbreviations: PP, paraplegia group; TT, tetraplegia group.
Velocity is shown as m min⁻¹.

no correlations between perception of effort and performance, regardless of group or gender; (3) no correlation was observed between delta heart rate and perceived exertion; and (4) a significant but low correlation between the completeness of injury and performance was observed only for men in the 20 min exercise ($r = -0.22$ and $P < 0.001$).

DISCUSSION

The purpose of this study was to use retrospective data and a nonrandom sample to investigate the wheelchair propulsion 20 min exercise performance of individuals with different levels of SCI and determine normative values for this population. Our results showed that the higher the injury level, the lower the speed and distance travelled by both men and women. These performance parameters, however, were not related to time since injury for the sample studied. Although these findings are consistent with the literature,¹⁰ this is the first study to present normative performance data for the 20 min exercise.

Sample

The study included a wide variety of subjects that was comparable to international data.¹¹ The groups were homogeneous in terms of anthropometric characteristics and age, which made them comparable with each other and close to clinic reality.

The sample was subdivided into three groups to verify the influence of trunk instability, parasympathetic autonomic nervous system, grasping and upper limb strength deficits on wheelchair propulsion performance. Other studies^{8,12} also reported similar results for the HP and LP groups, reinforcing the finding that differences in trunk stability and possible parasympathetic nervous system involvement did not significantly affect propulsion during submaximal exercise at a comfortable speed on flat and smooth ground. The speed decreases observed in the TT group may be explained by upper limb strength deficits and an inability to directly grasp the tyre. However, there may be differences within this group, such as patients with lesions at C6 who may present reduced or lost strength in muscles such as the triceps brachii and sternal pectoralis major that provide the force needed to propel the wheelchair.¹²

Differences in propulsion ability between genders were found in an earlier study. According to Gutierrez *et al.*,¹³ this difference can be explained by women's shorter propulsion cycle. In another study, Hatchett *et al.*¹⁴ examined daily wheelchair use and noted that men travel longer distances, but average speed was similar between genders, suggesting that community mobility demands require a relatively greater effort for women because of their biomechanical and force disadvantages compared with men.

Performance parameters (distance and speed of propulsion)

Several different types of exercise lasting 20 min, including arm ergometer,¹⁵ handcycling¹⁶ or wheelchair,¹ have been conducted to evaluate the performance of people with SCI.

Consistent with the evidence that tetraplegics have lower physical capacity than paraplegics, performance parameter results were inversely correlated with injury. Thus, we found evidence that the higher the patient's injury level, the worse his or her performance in the 20 min exercise.

Normative values were based on a sample that included individuals with varying degrees of SCI completeness. Among the participants, 11% had incomplete injuries (AIS B, C and D). Within the groups, different injury classifications did not affect performance, showing that possible changes in the autonomic nervous system or the amount of active muscle mass in the lower limbs made no difference in speed. Thus, the results may be generalised to the whole group.

Comfortable speed

In a nonfunctional context, such as the lab, propulsion speed reflects the level of physical fitness and muscle strength. In the community, however, different situations imposed by architectural barriers

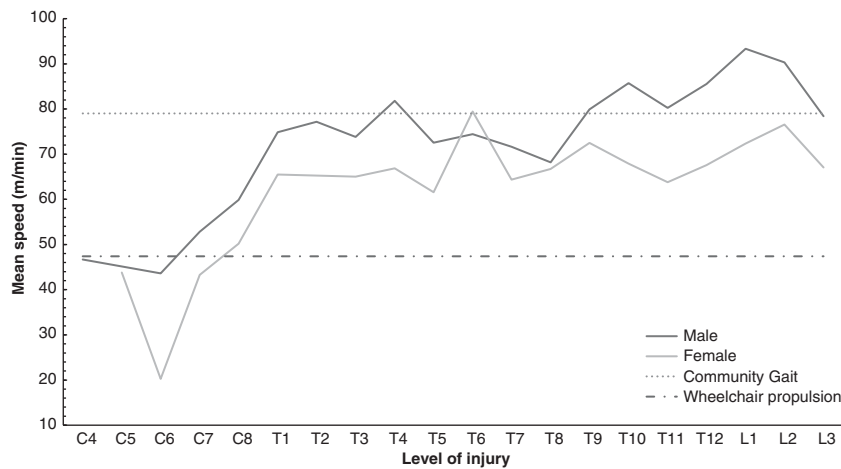


Figure 3 The mean speed of wheelchair propulsion distributed according to lesion level. The upper line is community speed gait (Andrews *et al.*), and the lower one is the mean speed of wheelchair propulsion in general (Tolerico *et al.*²⁰). The article of Andrews *et al.*¹⁹ is the most recent study of community gait speed.

influence speed selection, and wheelchair skill has a considerable influence on the user's speed.¹⁴ The literature points to a community mobility speed gaits of 48 m min⁻¹,¹⁷ 63.5 m min⁻¹,¹⁸ and 79 m min⁻¹,¹⁹ and a distance of 500 m¹⁷ to 680 m as minimum criteria. This variation depends on the characteristics of the community. In a wheelchair context, Tolerico *et al.*²⁰ found a total daily mobility of 2500 m, which included 270 m of uninterrupted use and an average speed of 47.4 m min⁻¹ for 8.3 h per day (Figure 3).

The significant correlation between performance parameters and exercising heart rate for the entire group supports the premise that speed can also be indicative of the intensity of activity.²⁰ The low heart rate observed in the TT group at rest or during exercise can be explained by the limited chronotropic response to reduced cardiac sympathetic stimulation and a decreased metabolic rate by less active skeletal muscle mass.

Perception of effort, however, was not correlated with heart rate variation during exercise. This finding shows that the perceived exertion during exercise is not necessarily directly related to the cardiac requirements for propulsion. The literature has shown that perceived exertion is related to peripheral factors, such as muscle pain, and cardiovascular factors, such as heart rate and oxygen consumption.²¹ Thus, the physiological effects of a SCI can affect the ability to self-monitor exercise intensity.²² Aspects such as duration of activity, age and personal fitness may be considered in the future implementation of exercise to better evaluate perceived exertion.

Study limitations

This study has limitations inherent to retrospective studies; the use of historical data and the analysis of available information reduce the ability to control variables. Thus, this study did not control important aspects about wheelchair propulsion, such as the weight and type of wheelchair, the form of propulsion and time of wheelchair use. For the same reasons, other potential variables of interest were not consistently considered, including anthropometric data (body mass and height), the level of physical activity, physical capacity determinants and wheelchair performance by individuals with SCI.

Previous studies have shown that the wheelchair's mass can influence the performance.^{1,8} Ribeiro and Beraldo⁸ demonstrated that 10 and 20% changes in the weight of the wheelchair change the energy cost index based on heart rate. In contrast, Bednarczyk and

Sanderson²³ showed that adding 5 to 10 kg did not alter the kinematics of wheelchair propulsion on flat surfaces at a low speed and for short distances and that performance was more appropriately determined by kinetic and energetic outcome measures. Another study, however, reported that adding up to 5 kg to the weight of the wheelchair has no influence on performance and daily energy expenditure.²⁴ Thus, factors other than wheelchair mass have a greater influence on wheelchair propulsion performance.

Earlier publications suggested that the patient's time of wheelchair use may influence performance.²⁵ Improvement in mechanical efficiency is expected with increased wheelchair use because of enhanced propulsion technique, strength and cardiovascular fitness. De Groot *et al.*²⁵ noted lower mechanical efficiency of propulsion in newly injured patients and state that efficiency depends on the wheelchair user's skills and training status. However, time of wheelchair use can be represented by the time since injury variable, despite the possibility of nonequivalent individual recovery period after injury. In addition, no differences were observed between the groups in this regard.

Dallmeijer *et al.*²⁶ showed that participation in sports is an important determinant of changes in physical conditions after rehabilitation. Although the 20 min exercise was administered at the beginning of rehabilitation, we do not have data about individual experiences in rehabilitation, physical activity, patient performance before the injury or daily activity after injury. These data were unavailable because of the study's retrospective nature.

Despite these limitations, the study includes a broad spectrum of individuals and presents an exercise that appears to be an adequate instrument that rehabilitation professionals should use to assess, at least in part, wheelchair endurance at a self-selected and comfortable speed. Although the 20 min exercise was primarily used empirically in our clinical setting to evaluate the capacity to propel the wheelchair for long periods, future research should focus on the measure's validity, reliability and responsiveness to ensure that it has adequate properties for use as an appropriate evaluation of wheelchair propulsion ability and for research purposes.

CONCLUSION

Wheeling for 20 min at a comfortable speed should be a practical exercise that can assess performance at a submaximal level and can be

performed by people with different levels of fitness and spinal cord lesions. The results and analysis of the percentile table can aid evaluations of patients' physical condition, establish rehabilitation programme goals and encourage athletic counselling for men and women with SCIs.

DATA ARCHIVING

There were no data to deposit.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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