Published in final edited form as:

Top Spinal Cord Inj Rehabil. 2009 September 29; 15(2): 79–89. doi:10.1310/sci1502-79.

Impact of Gender on Shoulder Torque and Manual Wheelchair Usage for Individuals with Paraplegia: A Preliminary Report

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Abstract

Background—The prevalence of women with spinal cord injury is increasing, and their unique attributes merit attention, specifically, shoulder strength and community wheelchair propulsion.

Results—Shoulder torques were 62%–96% greater in men than women, average daily distance traveled was greater for men, and average speeds were similar.

Conclusions—Community wheelchair propulsion speed was similar between men and women but men were significantly stronger, therefore daily mobility requires a higher relative effort for women's shoulder muscles. This demand may increase susceptibility to fatigue and development of shoulder pain.

Keywords

community wheelchair propulsion; gender; paraplegia; shoulder strength; spinal cord injury

The prevalence of women with spinal cord injury (SCI) is increasing, and their unique attributes and needs merit attention. In the United States, the incidence of women sustaining SCIs since the year 2000 has increased to 22.2% (56,766 persons) compared to the incidence prior to 1980 of 18.2%.¹ Women are faced with gender-specific challenges related to differences in their upper extremity (UE) structure, strength, and roles in the home and society.^{2–5} Together, these challenges impact their experience of aging with an SCI and their risk for developing UE pain. A closer look at gender influences on shoulder torque and manual wheelchair (WC) usage may

help identify causative factors of UE pain and therefore assist with preventive efforts to avoid and/or reduce pain.

UE Structure and Strength

Typically, women are smaller anthropometrically than men.² Women have shorter limbs relative to body length, in particular, a shorter humeral bone and a narrower shoulder girdle. These differences lead to a shorter lever arm and thus place women at a biomechanical disadvantage for UE activities compared to men.

Gender differences in strength and strength ratios between men and women have been documented.³ A comparison of nonathletic able-bodied men and women revealed that women had normalized isokinetic peak torques that were 47%–56% weaker than men.⁶ Women may be predisposed to injury because of their weaker muscles, particularly after sustaining an SCI. A comparison of age- and size-matched women with and without SCI revealed similar UE isokinetic torque strengths except for the dominant UE shoulder flexors, in which women with SCI were weaker and elbow extensors in which the women with SCI were stronger.⁷ Women with SCI often report pain in the shoulder region (weaker region) with little to no reports of pain in the elbow region (stronger region), thus supporting the idea that muscle weakness can contribute to fatigue and secondary impairments including pain. Even though the anthropometric differences between men and women are not modifiable, muscular strength can be increased to provide a protective role for the prevention of injury and subsequent pain.

Societal and Home Roles

Following SCI, the UEs must compensate for the loss of function in the lower extremities. The significant increase of functional demands on the UE is unavoidable and introduces risk for cumulative trauma. An understanding of the influence of gender on functional demands within society and the home will assist with modification of UE activities aimed at preserving the integrity of the UE to prevent injury and subsequent pain.

Significant differences between men and women have been documented in the amount of time spent in homemaking, working, and attending school, with the traditional gender roles supported.^{4,5} Women with SCI spend more than twice as many hours as men in homemaking tasks including parenting, housekeeping, and meal preparation (17.4 vs. 7.7 hrs/wk respectively).⁵ This includes overhead reaching activities, a known risk factor for injury. On average, women appeared to spend about 8 more hours a week in productive activities than men (49.2 and 41.0 hrs/wk, respectively), although hours out of bed and hours out of the house per week were similar. This implies a greater amount of UE activity per time out of bed and a greater potential for injuries due to overuse. Self-reports about community integration, measured by the Craig Handicap Assessment and Reporting technique, were similar for both men and women,⁸ despite the fact that paid employment is significantly greater for men than women.⁵ More than half (57.4%) of persons with SCI reported being employed prior to injury. Employment 10 years post injury is reported at 32.4% for persons with paraplegia and 24.2% for those with tetraplegia¹; among those employed, women spend less time at work than men.⁹

UE Pain and Pathology

The presence of UE pain in individuals with SCI has been reported to range from 36% to 73%,^{10–17} and the incidence increases with time post injury.^{15,17} This is more than three times greater than the prevalence indicated in a postal survey of randomly selected adults, with shoulder and neck pain reported at 12%.^{18,19} There appear to be gender differences in reports of UE pain.^{7,13,20} In an investigation of 80 individuals with paraplegia and shoulder pain, the

Wheelchair User's Shoulder Pain Index (WUSPI) average pain scores were significantly greater and nearly double for women than men, 4.4 vs. 2.5, respectively (scale 0–10).²⁰ When pain is present, it is reported at a greater rate in women than men and is most frequently reported in the shoulders (73% women, 71% men), followed by the wrists (55% women, 53% men) and hands (45% women, 35% men).^{7,13} Radiographic evidence shows more degenerative changes in the shoulders of women than men (89% and 65%, respectively).²¹ Even in the able-bodied population, women experience a greater prevalence of shoulder pain than men.²² These studies of women, both with SCI and able-bodied, suggest that the anatomy of the shoulder in women is less tolerant of the forces that result in shoulder joint pathology and pain.

For both men and women with SCI, shoulder pain is most often associated with pressure raises, transfers, WC mobility, pushing up ramps or inclines outdoors, loading the WC into the car, and lifting objects down from an overhead shelf.^{10,13} Of those who reported pain, 86% quantified it as moderate, severe, or very severe during the above activities, and 89% reported limitations in their ability to perform daily activities. The majority of problems (54%) associated with shoulder pain in men and women with SCI are related to self-care activities, as measured using the Canadian Occupational Performance Measure (COPM).²³ Women with SCI reported more frequent interference in their ability to complete activities of daily living (ADLs) due to pain than did men with SCI.⁵ Specifically, 63%–77% of women with SCI reported having pain during ADLs and during outdoor wheeling.⁷ The consequences of shoulder pain are greater for persons with SCI because of their reliance on their UEs. Rest is a necessary prescription but one that is difficult for persons with SCI to incorporate into their lives because they rely on their arms to provide care for themselves and others.

We are currently investigating the factors that contribute to the development of shoulder pain. These data are from a preliminary analysis of a 3-year prospective observational study grant supported by the National Institutes of Health (NIH).

Study Aims and Hypothesis

Women face gender-specific challenges, some modifiable and some fixed. We will document the impact of modifiable factors that place women with SCI at high risk for shoulder pain. The purpose of this preliminary analysis is to determine the impact of gender on shoulder muscle strength and community WC usage in individuals with paraplegia.

Method

Participants

Participants included 67 persons with paraplegia resulting from SCI, 60 men and 7 women. Participants were recruited predominately from outpatient clinics at Rancho Los Amigos National Rehabilitation Center (RLANRC), Downey, California.

Inclusion criteria were as follows: (a) paraplegia (ASIA A, B, or C; traumatic or non-traumatic), (b) absence of shoulder pain with a total score of ≤ 12 on the WUSPI, (c) between 2 and 20 years post SCI, (d) manual WC user (for $\geq 50\%$ of locomotion), and (e) ≥ 18 years of age. Exclusion criteria consisted of the presence of rotator cuff tendinopathy, bicipital tendonitis, adhesive capsulitis, cervical radiculopathy, shoulder injury, and surgery or injuries impacting UE function. Persons were excluded from the study if they had pain with isometric external rotation when the shoulder was positioned at neutral or had a positive result on any of the following impingement tests: Empty Can Test, Codman's Drop Arm Test, Speed's Test, Hawkins-Kennedy Impingement Test.

Prior to data collection, participants read and signed an informed consent that had been approved by the Rancho Los Amigos Institutional Review Board.

Equipment and procedures

Maximal isometric peak torque was measured using a Biodex System 3 Pro dynamometer (Biodex Medical Systems, Inc., Shirley, NY). Bilateral shoulder strength for a total of six motions was assessed: shoulder flexion, extension, abduction, adduction, internal rotation, and external rotation. The participant was tested in a seated position with the trunk and pelvis secured by two chest straps and a lap strap. Shoulder flexion and extension were tested with the UE positioned in 45° of flexion with the forearm in neutral. Shoulder abduction and adduction were tested with the UE positioned in 45° of abduction with the forearm pronated. External and internal rotation were tested with the UE positioned in 90° of abduction, the elbow in 90° of flexion, and the forearm pronated. Each participant was instructed to push or pull against the lever arm using their maximum voluntary effort for a duration of 5 seconds. Following practice to familiarize the participant to the test, two trials were performed with a 10- to 15-second rest break between trials. The average peak values of the two trials for both UEs were averaged and normalized to body weight.

Community WC usage was measured using the Topeak® bicycle odometer system (Topeak Inc., Taichung, Taiwan). Each participant's WC was equipped with a sensor mounted onto the WC frame, two magnets mounted to each wheel (so the wheels could be interchangeable), and an odometer containing a computer chip to capture the data. The odometer was calibrated according to the WC wheel circumference. Data were collected on all manual WCs used more than 4 hours per week. Therefore, participants who used an additional WC, such as for sports, had the second WC similarly equipped. Participants were contacted by phone approximately once per month over 6 months to collect and record odometer information including average distance traveled and velocity.

Results

Participants

Sixty men and seven women participated. The mean age of participants was 35 years (range 21–55 years). Average duration of the SCI was 9.9 years (range 2–20 years). Self-reported involvement in a vocation outside of the home (including paid work, volunteer work, or attending school) was 66% (44 participants). The most common activity reported was volunteer work, with 37% (25) participating on a full- or part-time basis. Of the men, participation in a vocation was 84% (37), with 43% (26) reporting full-time and 18% (11) part-time participation. Of the women, participation in a vocation was 100% (7), with 43% (3) reporting full-time and 57% (4) part-time participation. The overall employment rate (full-time and part-time) was 22% (15), with 23% (14) of men and 14% (1) of women returning to work. Details of descriptive characteristics can be found in Table 1.

Data

Data were analyzed using the SPSS 12.0 software (SPSS, Inc., Chicago, IL). The Shapiro-Wilk statistic determined that the majority of data were normally distributed. Thus two group *t* tests were used to compare gender differences between shoulder torque and community WC usage. Significance was set at $p < .05$.

Shoulder torque

There was a significant difference in normalized shoulder torque between men and women. Women were 62%–96% weaker than men ($p < .0001$; see Figure 1). Shoulder torques followed

the same trend for both men and women in regard to stronger versus weaker muscle groups. The shoulder adductors were the strongest muscle group (men = 46.8 N·m/kg, women = 28.0 N·m/kg), followed by the shoulder extensors (men = 44.6 N·m/kg, women = 27.4 N·m/kg). Shoulder external rotators were the weakest muscle groups (men = 21.7 N·m/kg, women = 12.6 N·m/kg).

Community WC usage

There was a significant difference in the average daily distance traveled in the community, with men propelling their WCs 3.1 ± 1.7 km/day and women propelling 1.8 ± 1.2 km/day ($p < .05$; see Figure 2). We performed post hoc analysis to find predictors of average daily distance traveled using stepwise regression. The dependent variable was average distance traveled, and the independent variables were shoulder torques normalized to body weight. The strongest predictor was normalized external rotation torque ($R = 0.368$, $R^2 = 0.136$, $p = .008$); once that was entered into the equation, no other variable provided further explanation of average distance pushed in the community. There was no significant difference in average velocity of propulsion between men and women (55.9 ± 14.8 m/min and 48.7 ± 9.2 m/min, respectively; see Figure 3).

Discussion

The current study documents substantial and significant differences in shoulder torque and community WC usage between men and women with paraplegia. The literature has shown that women are weaker than men in the able-bodied population and the SCI population. Consistent with the literature, we found that isometric shoulder strength normalized by body weight is 62%–96% weaker in women compared to men. Similarly, Das and Black²⁴ reported maximum isometric push and pull strengths for women with paraplegia that were 68% and 77%, respectively, that of men with paraplegia. In this study, both men and women had similar shoulder strength patterns, with the adductors being the strongest shoulder muscle group, followed by the shoulder extensors. The weakest muscle group was the external rotators (rotator cuff muscles). Considering the anatomy of the shoulder and the relative strength deficit of the external rotators, it is not surprising that rotator cuff pathology is a common injury and is considered the most common cause of shoulder pain.¹⁷

Community velocity takes into account propulsion under various conditions within the home and in the community. The present study documents community WC velocities that were similar between men and women (55.9 ± 14.8 m/min and 48.7 ± 9.2 m/min, respectively). This is contrary to a previous study simulating WC propulsion at self-selected free and fast speeds in a laboratory setting.²⁵ That study found that men with paraplegia propelled 36% faster than women with paraplegia (69 ± 13 m/min and 44 ± 8 m/min, respectively). The difference in velocity was attributed to a shorter cycle length in women due to decreased muscle strength. This suggests gender differences in propulsion capacity. When comparing the laboratory velocities of the previous study to the community velocities in the present study, men's self-selected free speed in the laboratory was faster than their self-selected speed in the community, whereas women's self-selected free speed in the laboratory was similar or slightly slower compared to that in the community. WC propulsion in the laboratory is separated from a functional context and reflects the individual's level of fitness and muscle strength. In the community setting, inherent situational demands influence the selection of propulsion speed. Individuals need to propel both slowly and quickly depending on the situation. The fact that community velocities for men and women were similar in the current investigation suggests that situational demands of community mobility require a higher relative effort for women than for men. Women must overcome their biomechanical and strength disadvantages to meet the demands of the "real-world."

Community WC propulsion distance was greater for men than women, with men propelling almost twice as far per day. Men propelled on average 1.90 miles/day (3.1 ± 1.7 km/day) while women traveled approximately 1 mile/day (1.8 ± 1.2 km/day). This study reports that normalized external rotation strength is a predictor of average daily distance traveled in the community. Women are weaker than men in external rotation, and this reduced strength may be limiting their community mobility. Another explanation for the differences in community WC propulsion distance may be related to societal roles and time spent outside of the home. Based upon self-reports of participation in a vocation (employment, volunteer work, or student), approximately half of the men (55%, 37) reported a vocation outside of the home, and the majority of these men (70%, 26) participated on a full-time basis. Full-time participation in an activity outside of the home is a possible explanation for the greater distance traveled noted in men. Although all of the women (100%, 7) reported participation in a vocation outside of the home, a little more than half of the women participated on a part-time basis. The part-time status of women allows them to retain their roles as homemakers, possibly accounting for their lesser distances traveled.^{4,5}

Furthermore, men were 1.64 times more likely to return to work than women, (23%¹⁴ compared to 14%¹, respectively). The likelihood of men returning to work compared to women is slightly less in this study than previously reported in the literature (1.64 compared to 1.75).⁹ Additionally, the employment rate for the participants in this study who average 9.9 years post SCI is 22%, also less than the reported employment rate for persons with paraplegia 10 years post SCI of 32.4%.¹

Age has been associated with ongoing shoulder pain,¹⁰ and shoulder pain has been associated with lower quality of life scores.^{20,26} Gainful employment was the only demographic factor linked to high quality of life scores,²⁶ and women reported lower scores in the area related to home life.⁸ This is important to note as women tend to spend more time at home than do men and typically report more pain than men. Return to work 1 year after onset for persons with SCI can be predicted by peak aerobic power output and WC skills performance.²⁷ Although the previous study did not address gender differences in return to work, men may be at a greater advantage to return to work because they are stronger (peak aerobic power output predictor), and this greater strength combined with better propulsion biomechanics based on body size would enhance their WC skills (WC skills or performance predictor).²⁸ Helping persons with SCI return to work and avoid or reduce shoulder pain could significantly improve a persons' quality of life following SCI and as they age.

Limitations

One limitation to the present study was the fact that the disparity in the number of men and women tested was greater than the nationally reported gender disparity in incidence of SCI. The men to women ratio in our sample was 90% (60) men and 10% (7) women, while the nationally reported incidence of SCI is 77.8% men and 22.2% women.¹ Attempts were made to recruit more women into the study, however many women did not meet inclusion criteria due to having chronic shoulder pain or using a power WC for mobility. We consider the number of women participants to be adequate for a preliminary analysis. Further research with a larger sample size is necessary to increase the strength of these results.

Another limitation is related to shoulder torque in that we did not investigate whether a difference in strength exists between the dominant and nondominant UEs. The present study averaged the shoulder torque of both UEs together and normalized that value to body weight. In addition, this study did not document WC skills or environmental barriers in the community, potential confounders to the average community WC distance traveled and velocity. Cautious interpretation is recommended as these are preliminary results.

Future studies

The Pathokinesiology Laboratory at RLANRC aims to increase the sample size and follow participants for 3 years. Shoulder strength and community WC usage are modifiable risk factors for shoulder pain that will be measured. Additional measures include recording the prevalence of shoulder pain and evaluating the biomechanics of WC propulsion, a potential predictor of shoulder pain. Our aim with this prospective, longitudinal study is to determine the causes of shoulder pain and apply the information to the modifiable risk factors of shoulder pain to prevent the onset or reduce the severity of shoulder pain.

Conclusion

The present study has provided preliminary evidence that women are weaker than men, and women propel shorter distances in the community but at the same average velocity as men. Normalized external rotation torque was shown to be a predictor of average daily distance traveled in the community. Women have reduced strength in their external rotators, and this may be limiting their community mobility. A consequence of the gender differences in average community distance propelled and shoulder torque is that women are placing a greater relative demand on their shoulder muscles because they are propelling at the same average community velocity as men. This greater relative effort may predispose women to fatigue, another possible explanation for why they travel shorter distances. As well, the fatigue may be contributing to the higher prevalence of degenerative changes in the shoulder.²¹

More men participate in a full-time vocation and have a greater rate of return to work than women. This could be due to home and societal roles, but it could also be influenced by their greater ability to propel their WCs due to greater strength and lesser predisposition to degenerative shoulder changes and pain. Incidentally, we have clinically observed a trend for women to switch to powered mobility sooner after SCI onset than men. Additional research is needed to investigate this trend. The switch to powered mobility would help preserve the shoulder joint, but it comes with secondary complications such as increased costs, limited accessibility, and the need for complimentary adaptive equipment such as lifts or vans. WC design, guidelines, and technologies for women have long been overlooked. A focus group at RLANRC, formed by the Rehabilitation Engineering Research Center (RERC) on SCI, found that women indicated a need for WCs that could provide better matches to their functional activities and anatomy. Providing women with a safe and effective shoulder-strengthening program targeting the external rotators, along with a WC that suits their physiology and societal roles, could help women protect themselves from shoulder pain, increase their community mobility, and increase their return to work. It has been established that gainful employment and prevention/reduction of shoulder pain can greatly improve quality of life.^{20,26}

Acknowledgments

This research was supported by National Institutes of Health (NIH) grant no. 5R01HD049774.

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Figure 1. Maximal isometric shoulder torque normalized to body weight. There was a significant difference in strength for all motions. $p < .0001$. Labels are defined as Flex = Flexion, Ext = Extension, Abd = Abduction, Add = Adduction, IR = Internal Rotation, ER = External Rotation.

Figure 2.

Average daily distance propelled per day is a descriptor of community wheelchair (WC) usage. The average daily distance propelled per day was significantly different between men and women. $p < .05$.

Figure 3.

Average community velocity is a descriptor of community wheelchair (WC) usage. Average community velocity was not significantly different between men and women.

Table 1

Descriptive characteristics of 67 participants

	All participants (<i>n</i> =67)	Men (<i>n</i> =60)	Women (<i>n</i> =7)
	Mean $\pm$ SD (range)	Mean $\pm$ SD (range)	Mean $\pm$ SD (range)
Age, years	35 $\pm$ 7.3 (21–55)	34.8 $\pm$ 7.4 (21–55)	32.9 $\pm$ 6.6 (21–40)
Duration of SCI, years	9.9 $\pm$ 5.5 (2–20)	9.9 $\pm$ 5.6 (2–20)	10.0 $\pm$ 5.1 (3–16)
Level of injury	T2-L1	T2-L1	T2-T10
	% (<i>n</i>)	% (<i>n</i>)	% (<i>n</i>)
Vocation ^a	66 (44)	62 (37)	100 (7)
Full-time	43 (29)	43 (26)	43 (3)
Part-time	22 (15)	11 (18)	57 (4)
Employed	22 (15)	23 (14)	14 (1)
Full-time	15 (10)	15 (9)	14 (1)
Part-time	7 (5)	8 (5)	0 (0)
Volunteer	37 (25)	33 (20)	71 (5)
Full-time	25 (17)	25 (15)	29 (2)
Part-time	12 (8)	8 (5)	43 (3)
Student	6 (4)	5 (3)	14 (1)
Full-time	3 (2)	3 (2)	0 (0)
Part-time	3 (2)	2 (1)	14 (1)

^aVocation is defined as employed, volunteer, or student participation per self-report.