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Prevalence of shoulder pain in adult- versus childhood-onset wheelchair users: A pilot study

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Abstract—Shoulder pain is a common overuse problem in long-term adult wheelchair users. The current study examined whether the prevalence of shoulder pain in adult wheelchair users who began using their wheelchairs during childhood (childhood-onset [CH-O] group) is similar to those who began using their wheelchairs as adults (adult-onset [AD-O] group). We compared 31 CH-O and 22 AD-O wheelchair users using the Wheelchair User's Shoulder Pain Index (WUSPI), an overall pain score (Brief Pain Inventory), and a lifestyle questionnaire to determine frequency and duration of physical activity. Shoulder pain (WUSPI) was greater in the AD-O wheelchair users compared with the CH-O group ($p < 0.008$), even though their general lifestyles were not different. The immature skeleton can possibly respond to the repetitive forces of wheeling better than that of those who begin using a wheelchair once their skeletal structure is completely developed.

Key words: adults, biomechanics, bone remodeling, pain, pain inventory, pediatrics, rehabilitation, shoulder pain, spina bifida, spinal cord injury, wheelchair.

INTRODUCTION

Shoulder pain and the resultant dysfunction are expected problems in individuals with spinal-cord injury (SCI) [1–4]. Researchers have associated shoulder pain in the SCI population with overuse related to weight bearing. More than two-thirds of SCI manual wheelchair users report suffering or having suffered shoulder pain [2], and the frequency of the attacks and their duration increase with the time since the onset of disability. By 20 years postinjury, all patients had complaints of shoulder pain and/or paresthesias [3].

Lesion level also is indicated as having an effect on shoulder pain. The prevalence and intensity of shoulder pain during the performance of functional activities have been reported to be significantly higher in subjects with tetraplegia than in subjects with paraplegia [2]. Similarly,

Abbreviations: AD-O = adult onset, BPI = Brief Pain Inventory, CH-O = childhood onset, MRI = magnetic resonance imaging, SCI = spinal cord injury, WUSPI = Wheelchair User's Shoulder Pain Index.

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overall incidence of shoulder pain was reported to be lower in individuals with paraplegia compared with those with tetraplegia [4].

During propulsion of a wheelchair, the shoulder is repetitively forced through an arc of motion against resistance. At a low intensity of wheeling, the contact forces within the shoulder are low, but the muscle forces in the rotator cuff are high and may indicate muscle damage [5]. Wheeling at a low intensity may not cause severe damage to the shoulder joint, but because of its repetitive nature, and along with the many other activities of daily living that place higher stresses on the shoulder joint, wheelchair users are reporting high levels of shoulder pain [2]. Data from painless shoulder joints of five individuals with paraplegia showed that the pressure in the shoulder joint during transfers exceeds the mean arterial pressure by more than 2 1/2 times, which may contribute to shoulder problems, in addition to the abnormal load distribution in the load [6]. Many individuals with paraplegia engage in exercise to improve upper-body strength; however, Bayley et al. showed that fewer patients participated in resistance activity if they had a history of shoulder pain [6]. In addition, individuals with tetraplegia were less likely to perform the most strenuous functional activities with increasing age or duration of wheelchair use [2]. A concern for individuals with SCI is that shoulder pain could lead to loss of independence.

When Boninger et al. studied shoulder pain in individuals with paraplegia, 32 percent of subjects reported shoulder pain in the month prior to the study, and more than half (54%) presented one or more abnormalities upon physical examination [7]. Magnetic resonance imaging (MRI) abnormalities were identified in all the subjects, with osteolysis of the distal clavicle being the most common. In terms of pain, individuals who had experienced pain were not significantly more likely to have abnormalities in physical examination, plain radiographic imaging, or MRI.

The research reports between 32 and 100 percent prevalence of shoulder pain in long-time wheelchair users, but research has primarily focused on adult SCI [2–4,8–9]. Currently, no incidence of shoulder pain in individuals with SCI (either congenital or traumatic) who have used wheelchairs since early childhood has been reported. Whether the prevalence and pathology of shoulder pain is similar in individuals who began using a wheelchair during childhood compared with adult SCI wheelchair users is unknown. With a long-term goal of reducing and eliminating shoulder pain in all wheelchair users, we examine the important issue of shoulder pain and pathology in childhood-onset (CH-O) wheelchair users and compare those findings with a somewhat comparative group of our own population of adult wheelchair users.

Because the shoulder joint is not designed for the weight-bearing activities typically performed by those dependent on wheelchairs [6], we consider the possibility that the weight-bearing, skeletally immature, pediatric shoulder has adapted to its new role because of its propensity to remodel. Research on individuals with proximal femoral focal deficiency found significant soft-tissue adaptations that allowed weight-bearing to occur through the abnormal hip joint [10]. Similarly, in infants with a muscle imbalance due to partial shoulder paralysis, MRI was able to identify shoulder joint deformation, specifically humeral head retroversion [11]. Whether a similar type of remodeling occurs in the shoulders of CH-O wheelchair users or if this type of remodeling is possible in mature, adult bone and soft tissue is unknown.

This pilot study compared the prevalence of shoulder pain in adult wheelchair users who began using their wheelchairs during childhood (immature skeleton) with those who began using their wheelchairs as adults (mature skeleton). We also wanted to begin a preliminary investigation into the behavioral and lifestyle patterns of the two populations. We hypothesized that subjects who began using their wheelchairs as children would have less shoulder pain than those who began as adults (over 16 yr).

METHODS

This cross-sectional study of childhood and adult SCI populations (traumatic or congenital) investigated variables associated with shoulder pain. The primary variable was age of onset of wheelchair use. Covariates included length of wheelchair use, frequency and duration of activity, and other activities of daily living. This study was approved by the local hospital and university clinical research ethics approval boards.

Subject Recruitment

Subjects were recruited from the Spina Bifida Clinic at the local children's hospital and from the Spinal Cord Injury Registry at the local rehabilitation center. An information letter was sent to potential subjects. A total of 53 subjects were recruited and gave informed consent

to participate in this study. All subjects were older than age 18 and had paraplegia due to an SCI (traumatic, congenital, or tumor). The CH-O user group was defined as those who began wheelchair use (>50% time) at age 16 or earlier. The adult-onset (AD-O) users were those who began using a wheelchair after age 16. All subjects had been wheelchair users for a minimum of 1 yr. Individuals who had trauma to their shoulder or were cognitively unable to independently answer the questionnaires were excluded.

Interview

Upon consent, subjects participated in a 10 to 20 min interview, either by telephone or in person, during which we recorded information on general demographics and subject disability (shunt, scoliosis surgery, etc.). We documented each subject's medical history, including past surgeries and current medications, to assess comorbidities and their management. One of the two research assistants assigned to this study administered the following questionnaires.

Wheelchair User's Shoulder Pain Index

The Wheelchair User's Shoulder Pain Index (WUSPI), a reliable and valid 15-item questionnaire, was developed specifically for manual wheelchair users who are functionally independent [12]. It measures how shoulder pain has interfered with different daily activities, such as transferring, wheeling, and self-care. Each item is scored from 0 to 10, with 10 representing shoulder pain that has completely interfered with the activity during the past week. One derives a total score by adding the item scores and dividing by a possible total of 10 for each item answered. The WUSPI score was modified in this study to be reported as a percentage of scores that were answered, since not all activities in the questionnaire applied to all subjects (i.e., pain during driving).

Brief Pain Inventory

The Brief Pain Inventory (BPI) (Short Form) was used to assess the subject's general experience of overall body pain, not isolated to the shoulder joint. It assesses location and duration of pain for different areas of the body and how that pain interferes with different aspects of the individual's life. It scores pain from 0 to 10, based on how much pain during the last 24 h has interfered with sleep, wheeling, mood, etc. (a score of 10 means pain completely interferes) [13]. The score reported in this study was the average pain the subject experienced during the past 24 h in seven different activities (wheeling ability, mood, work/school, relations with other people, sleep, enjoyment of life, and general activities).

Physical Activity Lifestyle Questionnaire

An inventory of frequency and length of physical activity (and sports participation) was also documented during the interview. We used self-report questions taken from the nationwide Canada Fitness Survey to determine activity involvement [14]. These questions described the frequency (daily, weekly, monthly, or none) and duration (<30 min, 30 min–1 h, or >1 h) of the different activities in which subjects were involved, and were used to help discriminate between individuals who occasionally participate in sports versus those who are serious, dedicated athletes (recreational or competitive). The questions were multiple choice, where subjects chose the response category that best described their current physical activity status. This survey was used in previous work [15]. Subjects were also asked whether shoulder pain specifically interfered with their participation in sports (yes/no).

Data Analysis

We analyzed demographical information between the two groups using independent *t*-tests. *T*-tests also compared shoulder pain (WUSPI scores and BPI scores) between the AD-O and CH-O wheelchair user groups. Bonferonni corrections accommodated for the small and uneven sample size, with the significance set at $p < 0.008$. Chi-squared tests analyzed group differences for variables that were reported as frequencies, including frequency of physical activity, hours of sport participation, mode of transportation, lifting chair into car, etc. We performed a Pearson's correlation to look at the relationship between the WUSPI and BPI scores, as well as WUSPI and age, and years of wheelchair use. For the chi-squared tests and Pearson's correlations, we set the significance level at $p < 0.05$.

RESULTS

This study had 53 participants, 22 in the AD-O wheelchair user group, and 31 in the CH-O wheelchair user group. The number of years of wheelchair use was the same between the two groups, although the two groups were significantly different for current age (**Table 1**). All

Table 1.
Wheelchair users population characteristics.

Characteristic	CH-O Group (*n* = 31)	AD-O Group (*n* = 22)
Current Age (Mean ± SD)*	22.3 ± 6.3	40.3 ± 10.5
Age at Wheelchair Onset (Mean ± SD)*	6.8 ± 3.6	29.8 ± 8.7
Years in Wheelchair (Mean ± SD)	15.3 ± 7.9	10.6 ± 10.3
Hours per Day in Wheelchair (Mean ± SD)*	11.8 ± 3.6	14.4 ± 4.3
Type of Spinal Cord Injury*		
Traumatic (%)	19.4	100
Congenital (%)	80.6	0
Lesion Level*		
Upper Thoracic (T1–T7)	2	8
Lower Thoracic (T8–T12)	7	13
Lumbar	19	1
Unknown	3	0

*$p < 0.05$ AD-O = adult onset
CH-O = childhood onset SD = standard deviation

subjects in both the AD-O and CH-O groups had paraplegia. Lesion level of the two groups is described in **Table 1**.

Shoulder Pain

Shoulder pain, as measured by the WUSPI, was greater in AD-O wheelchair users (18.8 ± 20.1, mean ± standard deviation) than CH-O wheelchair users (7.6 ± 10.5) ($p < 0.05$) (**Figure**). Overall pain, as measured by the BPI, was significantly higher in the AD-O wheelchair users (3.7 ± 1.7) than in the CH-O wheelchair users (2.4 ± 1.9). However, shoulder pain was reported to be a limitation to sports participation in 36 percent of AD-O wheelchair users, but in none of the CH-O wheelchair users.

A modest correlation existed between WUSPI and BPI ($r = 0.35$) for all subjects, collectively. This translates to shoulder pain accounting for 12 percent of the variance of average whole body pain. No correlation existed between shoulder pain and the number of years of wheelchair use or shoulder pain and age.

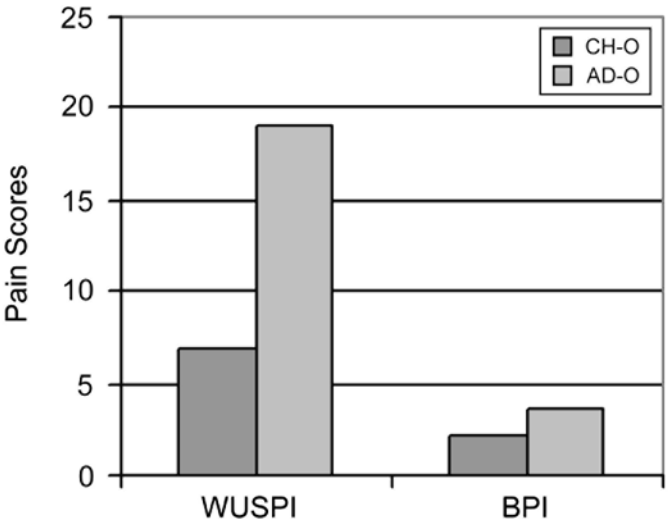

Figure.
Wheelchair User's Shoulder Pain Index (WUSPI) and Brief Pain Inventory (BPI) scores for childhood-onset (CH-O) and adult-onset (AD-O) wheelchair users.

Lifestyle Characteristics

The transportation choices of the AD-O and CH-O wheelchair users are quite different (**Table 2**). All AD-O wheelchair users either drive independently or take the bus as their primary means of transportation. In contrast, more than half the CH-O wheelchair users were passengers in a car. Of those who used a car for transportation, more AD-O than CH-O wheelchair users lifted their chairs into their cars independently.

No differences were found between AD-O and CH-O wheelchair users in either their sport activity duration or the distance wheeled per day. However, more CH-O wheelchair users than AD-O wheelchair users asked for assistance when wheeling for long distances or uphill (**Table 2**).

Table 2.
Transportation and activity characteristics of wheelchair user groups.

Characteristic	CH-O Group (n = 31)	AD-O Group (n = 22)
Mode of Transportation*		
Use Bus (%)	6.5	22.7
Drive Car (%)	35.5	77.3
Passenger in Car (%)	61.3	0
Lift Wheelchair into Car Independently (%)*	29.0	63.6
Sport Participation*		
None	25.8	4.5
Monthly	12.9	18.2
Weekly	51.6	31.8
Daily	9.7	45.5
Sport Activity Duration		
<30 min (%)	3.2	4.4
30 min–1 h (%)	29.0	39.1
>1 h (%)	63.6	56.5
Distance Wheeled per Day		
None (%)	3.2	0.0
1–3 Blocks (%)	48.4	31.8
1 km (%)	29.0	18.2
2–5 km (%)	16.1	27.3
>5 km (%)	6.5	22.7
Receive Assistance with Long Distances or Uphill (%)*	67.7	36.4

*$p < 0.05$
CH-O = childhood onset
AD-O = adult onset

When all wheelchair users (AD-O and CH-O) were combined into a single group, no relationship existed between shoulder pain and whether individuals independently lift their wheelchairs into their cars. Individuals who wheel independently uphill or over long distances have more shoulder pain (17.6 ± 20.3, compared with 7.3 ± 8.8) than those who receive help, and those who drive a car have increased shoulder pain compared with those who are passengers in a car (16.8 ± 18.0 vs. 4.8 ± 5.9, respectively).

DISCUSSION

The main results of this study demonstrate that individuals who began using a wheelchair as an adult experience greater pain, both overall and, more specifically, shoulder pain, than those who began using a wheelchair as a child. The WUSPI score of 19.1 for the AD-O group is comparable with values previously reported in the literature. When expressed as a percentage, adult wheelchair users in the Curtis et al. shoulder pain study scored 17.8 on the WUSPI [12]. To our knowledge, the BPI has not been used in the SCI population, but a BPI score of 3 to 4 indicates that overall body pain moderately interferes with different daily activities. We chose the BPI to indicate any pain secondary to shoulder pain that wheelchair users experience. WUSPI explained only 12 percent of the variance of overall body pain, indicating that individuals with SCI experience significant pain beyond the shoulder.

Age was not correlated to shoulder pain, in contrast to both Curtis et al. [12] and Fullerton et al. [16], who found shoulder pain to increase with age. Our finding that shoulder pain did not relate to number of years of wheelchair use agreed with Fullerton et al. [16]. It was surprising that shoulder pain did not relate to whether subjects independently lifted their chairs into their cars, while a different strenuous activity, wheeling independently uphill, was related to shoulder pain. We expected that tasks that put high stress on the shoulder joint would be related to shoulder pain. Again, the issue of repetition is important to consider. Individuals may wheel up multiple small hills over the course of each day, but only lift their chairs into their cars once or twice. Activities that are performed frequently are more likely to be associated with strain injuries [17]. Clearly, variables other than those investigated in this study play an important role in the shoulder pain of wheelchair users, specifically in the differences between the AD-O and CH-O groups. CH-O wheelchair users, who began using their wheelchairs while their skeletal structures were still immature, have fewer limitations due to shoulder pain than those who began using their wheelchairs as adults. From this, several possible inferences can be theorized.

Tissue Remodeling

First, there may be compensatory anatomical changes made within the shoulder joint to accommodate for the increased stresses on the weight-bearing shoulder. In an MRI study on proximal femoral focal deficiency (a congenital absence of the proximal femur), significant soft-tissue adaptations (hypertrophied sartorius, for example) were noted that allowed weight bearing to occur through the abnormal hip joint [10]. In a similar way that the malformed femur is not optimally designed for walking, the

structure of the shoulder joint is not optimally designed for the weight-bearing activities that wheelchair user's shoulders are subjected to every day [6]. The pediatric weight-bearing shoulder has been shown to remodel as a result of muscle imbalance due to brachial plexus injuries [11]. This type of remodeling may prove advantageous, and although it is known to occur in immature skeletal structures, it may not be possible to the same extent in mature adult bone and soft tissue.

Any changes that occur to the joint structure and muscles of the shoulder alter the biomechanics of the glenohumeral joint, directly impacting the wheeling ability of the individual. Comparing any skeletal and soft-tissue adaptation differences between the CH-O and AD-O wheelchair users' shoulder joints will be useful, as will studying how these differences reflect the subjects' presence or absence of shoulder pain.

Biomechanics

Stroke pattern during wheelchair propulsion has been linked to injury in the wrist [18], and we hypothesize that it contributes to shoulder injury and pain. The biomechanics of wheeling differ greatly between individuals, and a variety of wheeling stroke patterns have been identified. Boninger et al. described four distinctive kinematic patterns: semicircular, arcing, double looping-over propulsion, and single looping-over propulsion [19]. Although single looping-over propulsion was the most common propulsive stroke, the semicircular propulsive motion appeared to be the most biomechanically efficient. Subjects wheeling with the semicircular motion had a slower cadence, with more time spent in the push phase at a given speed compared with the other propulsion techniques. Boninger et al. suggested that this propulsion pattern may reduce trauma to the upper limbs [19]. The kinematics of wheelchair propulsion have been examined in children and adults [20], but the propulsion patterns (as defined by Boninger et al. [19]) of CH-O wheelchair users have not yet been described. CH-O wheelchair users may have adopted a wheeling strategy that is less stressful to the shoulder joint and therefore minimizes the associated shoulder pain. Future research should focus on exploring the differences in propulsion patterns between these two groups.

In addition to the repetitive task of wheelchair propulsion, the shoulders of manual wheelchair users are relied on for less frequent tasks that require high force production at the shoulder joint (transferring, lifting wheelchair into car). Activities requiring high muscle force generation put the shoulder at greater risk of injury [21], and it is equally important that the biomechanical strategies of these tasks be studied.

Behavioral Compensations

We recognized that a significant limitation of this study is that the AD-O and CH-O wheelchair users represent two very different populations. In both the AD-O and CH-O groups, all subjects had paraplegic-level lesions. Although six individuals had a traumatic SCI in the CH-O group, the majority of this group had congenital injuries (spina bifida), while all AD-O wheelchair users had traumatic SCIs. Most individuals with spina bifida have been treated for hydrocephalus early in their lives and many have cognitive problems. For this study, only subjects who could answer the questions or complete the questionnaires independently were selected. All CH-O wheelchair users were attending college or working. We did not screen the AD-O group for head injuries at the time of their SCIs, but we feel the two groups compared fairly well cognitively.

Those who began using a wheelchair at a younger age may have lower expectations of independence compared with those who could ambulate independently prior to the SCI. The goal of rehabilitation for individuals who have had an SCI goal is to foster productivity and full participation in social, vocational, and leisure activities—in short, to return to a "normal" life. The long-term goals for children with disabilities are somewhat less defined and do not seem as focused on the same level of independence as adult SCI individuals. If AD-O wheelchair users have higher expectations of independence, they may be more likely to engage in activities that are associated with shoulder pain (such as lifting their wheelchairs into their cars or wheeling uphill independently) to maintain their independence. By avoiding some of these activities, the CH-O wheelchair users sacrifice some independence to minimize the strain on their shoulders.

Another important aspect to note is that, although current activity level may not be different between groups, the number of years at that activity level is likely quite different between the AD-O and CH-O groups. The CH-O wheelchair users are now functioning at an activity level comparable to the AD-O group, but during their early years in a wheelchair, they depended much more on others during most activities [22] and were probably pushed much of the time rather than wheeling independently. In comparison, apparently the AD-O wheelchair users have maintained their activity levels for the

duration of their injuries, thereby increasing the total strain that their shoulders have experienced.

CONCLUSION

In summary, results of the present study document a higher prevalence of both overall pain and shoulder pain in AD-O wheelchair users compared with CH-O wheelchair users. Because the experience of shoulder pain is different between these two groups of wheelchair users and could not be adequately explained by this study, our future research will attempt to explain these important differences. Some areas that will be investigated are the skeletal structure of the shoulder, choice of wheeling pattern, and any behavioral differences between the AD-O and CH-O wheelchair users. Any differences between the two groups may identify factors that affect shoulder pain. Long-term goals of our research are to identify strategies used by the CH-O group that may prevent shoulder pain and to use these strategies to make recommendations for all wheelchair users.

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REFERENCES

1. Waring WP, Maynard FM. Shoulder pain in acute traumatic quadriplegia. Paraplegia. 1971;29:37–42.
2. Curtis KA, Drysdale GA, Lanza RD, Kolber M, Vitolo RS, West R. Shoulder pain in wheelchair users with tetraplegia and paraplegia. Arch Phys Med Rehabil. 1999;80:453–57.
3. Gellman H, Sie I, Waters RL. Late complications of the weight-bearing upper extremity in the paraplegic patient. Clin Orthop Rel Res. 1988;233:132–35.
4. Silfverskiold J, Waters RL. Shoulder pain and functional disability in spinal cord injury patients. Clin Orthop Rel Res. 1991;272:141–45.
5. Veeger HEJ, Rozendaal LA, van der Helm FCT. Load on the shoulder in low intensity wheelchair propulsion. Clin Biomechan. 2002;17:211–18.
6. Bayley JC, Cochran TP, Sledge CB. The weight-bearing shoulder: the impingement syndrome in paraplegics. J Bone Joint Surg Br. 1987;69-A(5):676–78.
7. Boninger ML, Towers J, Cooper RA, Dicianno B, Munin M. Shoulder imaging abnormalities in individuals with paraplegia. J Rehabil Res Dev. 2001;38(4):401–8.
8. Nichols PJ, Norman PA, Ennis JR. Wheelchair user's shoulder? Shoulder pain in patients with spinal cord lesions. Scand J Rehabil Med. 1979;11:29–32.
9. Sie IH, Waters RL, Adkins RH, Gellman H. Upper extremity pain in the post-rehabilitation spinal cord injured patient. Arch Phys Med Rehabil. 1992;73:44–48.
10. Pirani S, Beauchamp RD, Li D, Sawatzky BJ. Magnetic resonance imaging in proximal femoral focal deficiency. J Pediatr Orthop. 1991;11(5):563–70.
11. van der Sluijs JA, van Ouwerkerk WJ, de Gast A, Wuisman P, Nollet F, Manoliu RA. Retroversion of the humeral head in children with an obstetric brachial plexus lesion. J Bone Joint Surg Br. 2002;84(4):583–87.
12. Curtis KA, Roach KE, Applegate EB, Amar T, Benbow CS, Genecco TD, Gualano J. Reliability and validity of the Wheelchair User's Shoulder Pain Index (WUSPI). Paraplegia. 1995;33(10):595–601.
13. Cleeland CS, Ryan KM. Pain assessment: global use of the Brief Pain Inventory. Ann Acad Med Singapore. 1994; 23(2):129–38.
14. Canada Fitness Survey, 1981 [cited June 2004]. Available from: http://www.cflri.ca/cflri/resources/pub.php#pub_CFS/
15. Sawatzky BJ, Macdonald H, Valentine N. Healing on wheels. Rehabil Manage. 2003;16(5):18–23.
16. Fullerton HD, Borckardt JJ, Alfano AP. Shoulder pain: a comparison of wheelchair athletes and nonathletic wheelchair users. Med Sci Sports Exerc. 2003;35(12):1958–61.
17. Hess GP, Cappiello WL, Poole RM, Hunter SC. Prevention and treatment of overuse tendon injuries. Sports Med. 1989;8(6):371–84.
18. Boninger ML, Cooper RA, Baldwin MA, Shimada SD, Koontz AM. Wheelchair pushrim kinetics: body weight and median nerve function. Arch Phys Med Rehabil. 1999;80(8):910–15.
19. Boninger ML, Souza AL, Cooper RA, Fitzgerald SG, Koontz AM, Fay BT. Propulsion patterns and pushrim biomechanics in manual wheelchair propulsion. Arch Phys Med Rehabil. 2002;83(5):718–23.
20. Bednarczyk JH, Sanderson DJ. Kinematics of wheelchair propulsion in adults and children with spinal cord injury. Arch Phys Med Rehabil. 1994;75(12):1327–34.
21. Perry J, Gronley JK, Newsam CJ, Reyes ML, Mulroy SJ. Electromyographic analysis of the shoulder muscles during

depression transfers in subjects with low-level paraplegia. Arch Phys Med Rehabil. 1996;77(4):350–55.
22. Brown M, Gordon WA. Impact of impairment on activity patterns of children. Arch Phys Med Rehabil. 1987;68(12):828–32.

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