Original Article

Access this article online
Quick Response Code:
Website:
www.joas.org.in
DOI:
10.4103/JOASP.JOASP_33_20

A cross-sectional study to evaluate the manual wheelchair-related factors associated with median nerve compression by ultrasonography

Aradhana Shukla, Anil Kumar Gaur, Anuradha Shenoy[1], Amit Mhambre

Departments of PMR, All India Institute of Physical Medicine and Rehabilitation, Mumbai, Maharashtra, [1]Department of PMR, AIIMS, Bhopal, Madhya Pradesh, India

Address for correspondence:
Dr. Aradhana Shukla, Department of PMR, All India Institute of Physical Medicine and Rehabilitation, Mumbai, Maharashtra, India.
E-mail: draradhanashukla@gmail.com

Received: 17 June 2020
Revised: 07 July 2020
Accepted: 20 August 2020
Published: 23 December 2020

Abstract:

OBJECTIVES: The objective is to know the prevalence of median nerve compression and determine the relationship of median nerve compression with wheelchair (WC)-associated parameters.

MATERIALS AND METHODS: A cross-sectional study was carried out from December 2016 to September 2018, where a total of 50 patients of either sex, aged 20–70 years, with spinal cord injury (D2 or below) who were independent manual WC ambulators (for >6 months) were included. The detailed demography, clinical details, and the wheel ergonomics (height of the shoulder from the axle of WC, weight of the WC) were noted. Ultrasonography of the bilateral median nerve was done at three levels to determine the median nerve thickness. The data were entered into the MS EXCEL spreadsheet, and analysis was performed using the Statistical Package for the Social Sciences (SPSS) version 21.0. A value of $P < 0.05$ was considered statistically significant.

RESULTS: Median nerve compression was present in 12 (24%) patients who had significantly more weight of WC (kg) (19.42 ± 2.02 vs. 18.74 ± 7.38, $P = 0.023$); comparable mean duration of WC use (months) (31 ± 21.78 vs. 20.9 ± 20.02, $P = 0.114$); and comparable height between shoulder and axle of WC (inches) (28.17 ± 2.86 vs. 27.16 ± 2.32, $P = 0.188$). A significant positive correlation was seen between height from the shoulder to axle of WC (inches) and cross-sectional area (CS) of median nerve at carpal tunnel inlet ($r = 0.517$, $P = 0.0001$).

CONCLUSION: The height of the axle with respect to the shoulder is important to limit the stress on the wrist to the minimum, thus preventing the median nerve compression.

Keywords:

Median nerve, ultrasound, wheelchair

Introduction

Median nerve compression (carpal tunnel syndrome [CTS]) is one of the most common entrapment neuropathies in the general population with a prevalence of as high as 44%–66% among those with spinal cord injury.[1,2] The reason being increased weight bearing, repeated stress, and deloading of the wrist joint in such patients, which alters the volume and configuration of the carpal tunnel.

Apart from the anatomical factors that promote median nerve compression, certain factors such as age and gender of the patients, manual wheelchair (WC) use, duration of use, and its ergonomics, may affect the occurrence and severity of median nerve compression.[3]

The symptoms of median nerve compression comprise of numbness, tingling, and weakness of hands.[4] In addition, it decreases the quality of life of such patients as they are already suffering from the lower limb paralysis. The treatment is

How to cite this article: Shukla A, Gaur AK, Shenoy A, Mhambre A. A cross-sectional study to evaluate the manual wheelchair-related factors associated with median nerve compression by ultrasonography. J Orthop Spine 2020;8:57-64.

initially conservative involving rest, pain killers, and less weight-bearing on the wrist joint, which, if not properly followed, leads to the progressive compression, demanding surgery to release the transverse carpal ligament for the management.[5] Again, WC users are reluctant to undergo surgery due to the loss of independence.

Considering the seriousness of the condition and the usual progressive deterioration of median nerve compression due to lower limb paralysis, few researchers have studied and fortunately found a significant association WC ergonomics with wrist injuries.[6-18]

For nerve entrapment, although diagnosis is important, the determination of severity is very useful because it may influence the treatment approach. Thus, earlier screening may help detect changes in the median nerve in such patients and provide ample time for effective conservative treatment without the risk of significant compression in manual WC users (MWU) with spinal cord injury.

Peripheral nerve ultrasonography (USG) is an emerging promising diagnostic tool for entrapment neuropathies these days. Its noninvasiveness, no radiation, readiness to use, cost-effectiveness, and the ability for dynamic examination makes it the choice of investigation in screening purposes in musculoskeletal conditions.

Based on a recent study conducted, the normalized data of median nerve cross-sectional area (CS) for the Indian population for CTS in patients were 0.09 cm^2 at the level of the distal radioulnar joint (sensitivity 68% and specificity 68.64%), 0.10 cm^2 at the level of the inlet of the carpal tunnel (sensitivity 78% and specificity 77.97%), and 0.08 cm^2 at the level of the outlet of the carpal tunnel (sensitivity 72% and specificity 55.93%).[6]

Thus, we conducted this study to know the prevalence of median nerve compression among patients with SCI who have been using WC for >6 months. USG, as a modality, was used to assess median nerve compression and its severity. We also determined the relationship of median nerve compression with parameters such as weight of WC, height of shoulder from the axle of WC, and the duration of WC use.

Materials and Methods

A cross-sectional study was done in the Department of Physical Medicine and Rehabilitation, at a tertiary care hospital, Mumbai, from December 2016 to September 2018. The study was started after the approval of the institutional ethical committee.

A total of 50 patients were enrolled in the study after informed consent. The sample size was based on the study of Asheghan *et al*.,[3] who observed that the prevalence of CTS was 71.4% among long-term MWU. Taking this value as reference, the minimum required sample size with a 12.5% margin of error and 5% level of significance is 50 patients. Hence, total sample size taken is 50.[3]

We included the patients of either sex, aged 20–70 years, with Spinal cord injury (D2 or below) were independent manual WC ambulators for >6 months. Any patient with age <20 or >70 years, Paraplegics with diabetes, renal impairment, thyroid disorders, obesity, connective tissue disorders and with any brachial plexus injury, Paraplegics who have already taken treatment for the CTS or are taking treatment and patients with any medical problems relating to upper extremities; were excluded from the study.

The detailed demography, clinical details, and the WC ergonomics (height of the shoulder from the axle of WC, weight of the WC) were noted. The height of the shoulder from the axle was measured as depicted in Figure 1 and weight of WC was measured using a weighing hoist available in the ward of the institute. Assessment of spinal cord injury patient neurological level was made using ASIA (American Spinal Injury Association) impairment scale (AIS). USG of the bilateral median nerve was done at three levels: (1) at the level of distal radio-ulnar joint, (2) at the level of the inlet of carpal tunnel, and (3) at the level of the outlet of the Cross-sectional area The participant was asked to sit relaxed with outstretched hand, and the ultrasound was done. The procedure was carried out for both hands and observations were recorded [Figure 2].

The median nerve was considered to be thickened if any one of the following was increased:

1. CS of the median nerve at distal radio ulna joint was ≥ 0.09 cm^2
2. CS of the median nerve at CT inlet was ≥ 0.10 cm^2
3. CS of the median nerve at CT outlet was ≥ 0.08 cm^2

Figure 1: Method showing estimation of height of the shoulder from wheelchair axle. Height obtained from Figure 1b is subtracted from height obtained from Figure 1a

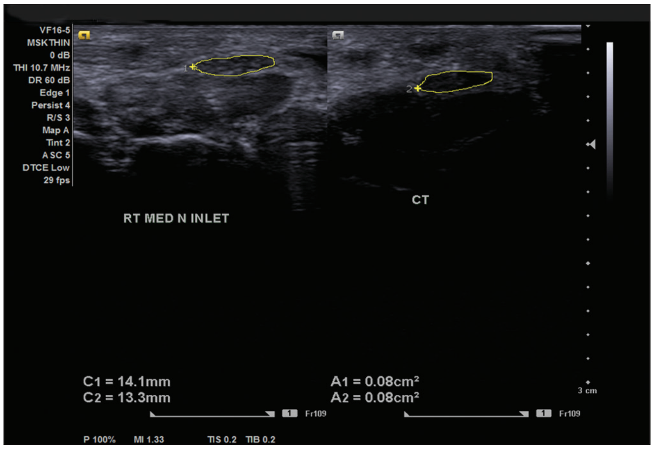

Figure 2: Right median nerve at inlet and at carpal tunnel

Statistical analysis

Categorical variables were presented in number and percentage (%), and continuous variables were presented as mean ± standard deviation and median. The normality of data was tested using Kolmogorov–Smirnov test. If the normality was rejected, then non parametric test was used. Quantitative variables were compared using the Mann–Whitney test (as the data sets were not normally distributed) between the two groups. Spearman rank correlation coefficient was used to find the correlation of WC characteristics with CS of the median nerve at CT inlet, outlet, and distal radio ulna joint. A value of $P < 0.05$ was considered statistically significant. The data were entered into MS EXCEL spreadsheet and analysis was performed using the Statistical package for the social sciences (SPSS) version 21.0 IBM manufacturers, Chicago, USA.

Results

In this study, there were 80% of males and 20% of females. In the majority of the patients (66.00%), AIS Grade A injuries were present, followed by Grade C in 18.00%, and Grade B in 16.00%. Duration of injury in most of the cases (52.00%) was between 1 and 5 years, followed by ≤1 year in 44.00%, and between 5 and 10 years in 4.00% of cases. The level of injury in the majority (66.00%) was D2–D10, followed by D11–L1 in 30.00%, and L2–L5 in 4.00% of cases. The demographic and clinical characteristics of the study patients are shown in Table 1.

Median nerve compression was present in 12 (24%) patients. The median nerve compression was right-handed in four patients, left handed in two patients, and bilateral in six patients. All of the patients were right hand dominant. The median nerve was thickened in 8% cases at the distal radio ulna joint and in 20% of cases at CT outlet as per the diagnostic cutoffs [Table 2a].

Table 1: Distribution of demographic and clinical characteristics

Demographic and clinical characteristics	Frequency (%)
Gender	
Female	10 (20.00)
Male	40 (80.00)
AIS	
A	33 (66.00)
B	8 (16.00)
C	9 (18.00)
Duration of injury	
≤1 year	22 (44.00)
Between 1 and 5 years	26 (52.00)
Between 5 and 10 years	2 (4.00)
Level of injury	
D2-D10	33 (66.00)
D11-L1	15 (30.00)
L2-L5	2 (4.00)

AIS: American Spinal Injury Association impairment scale

The comparison of normal and involved hand could be made only for six patients who had unilateral median nerve thickness. It was observed that the involved hand had significantly more thickness of the median nerve at CT outlet than the normal hand (0.08 vs. 0.07, $P = 0.043$) [Table 2b].

As compared to individuals without median nerve compression, those with median nerve compression had significantly more weight of WC (kg) (19.42 ± 2.02 vs. 18.74 ± 7.38, $P = 0.023$); comparable mean duration of WC use (months) (31 ± 21.78 vs. 20.9 ± 20.02, $P = 0.114$); and comparable height between the shoulder and axle of WC (inches) (28.17 ± 2.86 vs. 27.16 ± 2.32, $P = 0.188$) [Table 3].

There was nonsignificant positive correlation of duration of WC use (months) with CS of median nerve at CT inlet ($r = 0.082$, $P = 0.5721$); with CS of median nerve at CT outlet ($r = 0.259$, $P = 0.0688$); and with CS of median nerve at the distal radioulnar joint ($r = 0.021$, $P = 0.8832$).

There was a significant positive correlation of height between the shoulder and axle of WC (inches) with CS of the median nerve at CT inlet ($r = 0.517$, $P = 0.0001$). There was nonsignificant positive correlation of height between the shoulder and axle of WC (inches) with CS of median nerve at CT outlet ($r = 0.109$, $P = 0.4524$); and with CS of median nerve at distal radio ulna joint ($r = 0.146$, $P = 0.3106$).

There was nonsignificant positive correlation of weight of WC (kg) with CS of median nerve at CT inlet ($r = 0.115$, $P = 0.4283$); with CS of median nerve at CT outlet ($r = 0.144$, $P = 0.3171$); and with CS of median nerve at distal radio ulna joint ($r = 0.078$, $P = 0.5882$). This is shown in Table 4.

Table 2a: Distribution of Cross-sectional area of median nerve at various levels in total study population

CS of median nerve	Right hand (%)	Left hand (%)	Either hand (%)
CS of median nerve at distal radio ulna joint			
Normal (<0.09 cm²)	46 (92.00)	49 (98.00)	46 (92.00)
Thickened (≥0.09 cm²)	4 (8.00)	1 (2.00)	4 (8.00)
CS of median nerve at CT inlet			
Normal (<0.10 cm²)	50 (100.00)	50 (100.00)	50 (100.00)
CS of median nerve at CT outlet			
Normal (<0.08 cm²)	44 (88.00)	43 (86.00)	40 (80.00)
Thickened (≥0.08 cm²)	6 (12.00)	7 (14.00)	10 (20.00)

CS: Cross-sectional area, CT: Carpal tunnel

Table 2b: Comparison of Cross-sectional area of median nerve between normal and involved hand in patients with unilateral median nerve thickness (*n*=6)

CS of median nerve	Normal hand (*n*=6)	Involved hand (*n*=6)	Total	*P*	Test performed
CS of median nerve at distal radio ulna joint					
Mean±SD	0.06±0	0.07±0.02	0.06±0.01	0.363	Paired *t*-test; *t*=1
Median (IQR)	0.06 (0.06-0.06)	0.07 (0.055-0.07)	0.06 (0.06-0.07)		
Range	0.06-0.07	0.05-0.09	0.05-0.09		
CS of median nerve at CT outlet					
Mean±SD	0.07±0.01	0.08±0.01	0.07±0.01	0.043	Paired *t*-test; *t*=2.697
Median (IQR)	0.07 (0.062-0.07)	0.08 (0.08-0.088)	0.07 (0.068-0.08)		
Range	0.06-0.07	0.06-0.09	0.06-0.09		

*CS of median nerve at CT inlet was not compared since all patients had normal median nerve thickness at that level. SD: Standard deviation, CT: Carpal tunnel, IQR: Interquartile range, CS: Cross-sectional area

Table 3: Association of wheelchair characteristics with median nerve compression

Median nerve compression	No (*n*=38)	Yes (*n*=12)	*P*
Duration of WC use (months)			
Mean±SD	20.9±20.02	31±21.78	0.114
Median (range)	12.5 (3-84)	23 (6-66)	
IQR	9-18	13-51	
Height between the shoulder and axle of WC (inches)			
Mean±SD	27.16±2.32	28.17±2.86	0.188
Median (range)	27 (20-30)	28 (22-33)	
IQR	26-29	27-30	
Weight of WC (kg)			
Mean±SD	18.74±7.38	19.42±2.02	0.023
Median (range)	14-60	16-22	
IQR	16-18	18-21.500	

WC: Wheelchair, IQR: Interquartile range, SD: Standard deviation

Discussion

WCs provide mobility for millions of people with physical impairments. However, prolonged manual WC use can lead to pain and repetitive strain injury (RSI) of the upper extremities. The number of MWU experiencing pain tends to increase with the time spent using a WC. Although manual WCs have improved tremendously over the past 15 years, many people continue to develop arm pain and injury due to cumulative trauma. The problem may not be only due to WC, but RSI may be caused by transfers or other activities of daily living. Yet, most clinicians and researchers agree that the WC itself contributes substantially to the development of RSI.[3]

A common overuse disorder is CTS. CTS is a disorder that affects the median nerve at the wrist, resulting in numbness, tingling, and weakness in the hands. It is the most common entrapment neuropathy with a prevalence ranging from 1.5% to 2.7% in the general population.[7] Since MWU rely heavily on the upper extremities for mobility, a greater focus should be placed on the prevention of this overuse syndrome rather than treatment. To achieve this, there needs to be a better understanding of the pathophysiology of CTS, specifically median nerve characteristics related to WC propulsion. USG provides the means necessary to study the median nerve characteristics and physiologic changes associated with WC propulsion.[8]

Thus, this study was conducted to know the median nerve compression in MWU after spinal cord injury. We analyzed the subject characteristics and WC factors that could be potential risk factors for causing swelling and thereby, compression of the median nerve and resulting in CTS. We found a significantly higher weight of the WC among the patients with median nerve compression. On correlation analysis, a significant positive correlation of height between the shoulder and axle of WC (inches) and CS of the median nerve at CT inlet was also determined.

In this study, the majority of the patients (80%) were male. The male predominance has been seen in other studies as well. In the study by Hogaboom *et al*.,[9] majority of the patients were male (37 males and 3 females) and in another study by Asheghan *et al*.,[3]

Table 4: Correlation of wheel chair characteristics with cross-sectional of the median nerve at carpal tunnel inlet, outlet, and distal radioulnar joint

Correlation matrix	CS of the median nerve at CT inlet	CS of the median nerve at CT outlet	CS of the median nerve at distal radio ulna joint
Duration of WC use (in months)			
Correlation coefficient	0.082	0.259	0.021
P	0.5721	0.0688	0.8832
N	50	50	50
Height between shoulder and axle of WC (inches)			
Correlation coefficient	0.517	0.109	0.146
P	0.0001	0.4524	0.3106
N	50	50	50
Weight of WC (kg)			
Correlation coefficient	0.115	0.144	0.078
P	0.4283	0.3171	0.5882
N	50	50	50

CT: Carpal tunnel, CS: Cross-sectional area, WC: Wheelchair

and Kim *et al*.,[10] all study patients were male. Males usually have more weight than females and thus have more strength of propulsion. This can be interpreted in two ways: (1) Women can be at a greater risk of upper limb injury from WC propulsion than men because women have lower strength of propulsion,[11] (2) Due to the paradox that the user's weight is related to the push rim forces applied and to median nerve function – thus heavier body weight is associated with increased shoulder loading and thus forces required during WC propulsion causing more injury. Hence, men usually experience more median nerve injury, as was seen in various studies.[12] (3) Weight of the person may affect push rim biomechanics in MWU.[13]

In our study, 52% of the patients had an injury for 1–5 years and 44% had the injury for less than a year. No significant association between the time of injury and median nerve compression was seen in our study. Even in a research study on compressive mononeuropathies of the upper extremity in chronic paraplegia by Davidoff *et al*.,[7] 31 patients with a mean time since the injury of 9.7 years (range 1–28 years), were studied. The researchers of that study concluded that there was no association between the prevalence of compressive mononeuropathies and the age of the patient or time since the onset of the injury. In the study by Hogaboom *et al*.,[9] average age, weight, and duration of injury of the sample were 42.2 ± 13.2 years, 80.7 ± 23.4 kg, and 15.4 ± 10.9 years, respectively, which was much higher than our study. In contrast, in the study by Asheghan *et al*.,[3] a significant difference in the median duration of injury based on the severity of the syndrome ($P < 0.001$), and a significant trend in the time since injury for the severity (P [one-tailed] <0.001) were seen. The variation of this study from other studies could be due to less time follow-up in our study or due to patients with less time of injury being included in our study.

The mean duration of WC use in patients with median nerve compression and without median nerve compression was 31 ± 21.78 and 20.9 ± 20.02 months, respectively. There was no significant association between median nerve compression and duration of WC use ($P > 0.05$). When each observation separately analyzed, a positive correlation exists between the duration of WC use and median nerve at CT outlet left hand, ($r = 0.311$). In contrast, other studies showed a significant association between the duration of WC use and symptoms. In a study by Impink *et al*.,[14] subjects with CTS symptoms had a significantly ($P = 0.022$) greater duration of WC use (17.1 year) compared with the asymptomatic participants (9 years). Even in the study by Kim *et al*.,[10] on average, CTS participants used WC longer than normals (25 years in CTS participants and 14.5 in normal; $P = 0.014$). This is in line with previous research suggesting that a longer duration of disability, and thus WC use, is a risk factor for the development of CTS.[15]

In this study, most of the patients (66%) had injury at the level of D2–D10 and only 4% had injury at L2–L5. Although it was due to a strict inclusion criterion that we included only those patients who had injury below D2, and thus, they were the most common. Hence, based on the inclusion criteria followed by different studies, it varied accordingly. In a cross-sectional multicenter study by Yang *et al*.,[16] most of the patients had midlevel paraplegia with lesions, especially at the level of T12. The injury level may not affect the median nerve injury as all the patients in our study were paraplegic with the level if injury below T2 and the exact level shall not change the force generated by hands to any extent.

In this study, only 12 patients (24%) had median nerve compression and 76% patients had no median nerve compression, accounting for a prevalence of 24% on following the USG cutoffs. This study followed the cutoffs laid down by Chandy *et al*.,[6] 0.09 cm^2 at the level proximal to the inlet, 0.10 cm^2 at the inlet, and 0.08 cm^2 at the tunnel outlet with sensitivities of 68%, 78%, and 72%, respectively, and specificities of 68.64%, 77.97%, and 55.93%. In this study, 8% of the patients had ≥0.09 cm^2 area at the distal radioulnar joint and 20% had ≥0.08 cm^2 area at CT outlet. No patient crossed the cutoff at CT inlet. The median nerve compression was right handed in four patients, left handed in two patients, and bilateral in 6 patients and there was no significant association between median nerve compression and the hand dominance since all of the patients were Right hand dominant.

In this study, USG was chosen as the entity to diagnose and label median nerve compression, and no patient in the study had physical symptoms for the same. Even the study by Impink *et al*.,[14] used USG to study median nerve characteristics. One of the common median nerve characteristics associated with CTS is the flattening of the nerve. In this study, the flattening ratio was not calculated, as it did not show any significant correlation with the presence of the disease. In their study also, neither baseline relationships nor significant relationships with changes in flattening ratios were found.[17] They did see a positive trend between age and change in flattening ratio, suggesting that the median nerves of older participants may be more likely to flatten in response to activity. The lack of significant findings is most likely caused by the fact that the flattening is typically noted at the level of the hook of the hamate, and no images were collected at this level because of limitations of the ultrasound equipment and time constraints associated with this study design. Kim *et al*.,[10] also used USG in their study, and they also found that CSA of the median nerve was greater in CTS participants than in normal subjects at 0.5 cm and 1 cm proximal to distal wrist crease (DWC), DWC, 1 cm, 2 cm, 3 cm, and 3.5 cm distal to DWC. Sarría *et al*.,[18] and Nakamichi and Tachibana[19] reported similar ultrasonographic findings in general CTS patients. Abe reported similar ultrasonographic findings in disabled persons with CTS.[20] In contrast, in a study by Yang *et al*.,[16] 126 manual WC-users with chronic paraplegia underwent physical examination specific for CTS. The questionnaire had not been validated specifically for use in persons with spinal cord injury. Their results indicated that 78% of patients had electrophysiologic evidence of median mononeuropathy. In addition, they reported that those with physical examination findings were more likely to have a longer duration of injury ($P = 0.003$). In another study by Hogaboom *et al*.,[9] The transfer assessment instrument (TAI) was completed to quantify transfer ability. Median nerve CSA at the level of the pisiform (PCSA) and swelling ratio (SR), transfer quality, and skills was assessed through the TAI. They showed that PCSA increased after repeated transfers ($P < 0.025$). Participants who used safe hand positions had a lower baseline SR ($P < 0.01$). Participants with a higher body weight had a lower baseline SR provided they performed higher quality transfers. Participants who scooted to the front of the seat before transferring (TAI item 7; $P < 0.05$) and who weighed more ($P < 0.05$) exhibited greater increase in PCSA in response to transfers.

Although electrodiagnostic test is considered as the gold standard for diagnosis of CTS, USG provides a simple noninvasive means of visualizing peripheral nerve pathology.[6] USG is useful in CTS diagnosis, providing anatomic images of the median nerve, neighboring structures, and mass-occupying space in the carpal canal. The advantages of USG are that it is low cost, takes a shorter duration to perform the investigation compared to nerve conduction studies, and it is more commonly available, besides it is painless and noninvasive; and gives dynamic images. The US is operator dependent but shows high reproducibility after adequate training of the operators.[6]

In this study, the mean height between shoulder and axle of WC in patients with median nerve compression was and without median nerve compression was 28.17 ± 2.86 and 27.16 ± 2.32 inches, respectively. There was no significant association between median nerve compression and height between shoulder and axle of WC ($P > 0.05$). Even in the study by Kim *et al*.,[10] between CTS subjects and normals, there was no significant difference in height and WC propelling time. It has been previously noticed in few studies that lower but optimal seat height (rather than high seat height) may reduce strain on the upper limb and improve efficiency (e.g., improve push time) as well as reducing the range of motion demands at the wrist.[21]

The mean weight of WC in patients with median nerve compression was and without median nerve compression was 19.42 ± 2.02 and 18.74 ± 7.38 kg, respectively. A significant association between median nerve compression and mean weight of WC was seen ($P < 0.05$). When analyzed separately, a positive correlation exists between the weight of WC and median nerve at CT inlet of both hands, the median nerve at CT outlet of the right hand, and at the distal radio-ulna joint. Higher sample size could have given more discreet results. There could not be any relationship established between the WC weight and duration of WC use in patients with median nerve compression.

In another study by Beekman *et al*.,[22] it was stressed that lighter WCs improve the efficiency of propulsion for all users (speed and distance traveled) and may particularly assist people with tetraplegia. Even in the study by Cowan *et al*.,[23] it was concluded that lighter WCs require less force to propel, which is important to reduce the force required for the upper limb for propulsion.

The additional weight requires greater forces to be generated at the push-rims. The higher forces must be generated by joint structures and can contribute to a higher incidence of RSI. Thus, the selection of the WC frame can also reduce the risk of developing RSI. Lightweight is desirable. There is no need to push around more weight than is necessary to make the WC perform all the necessary functions. More weight means more force, and more force can mean higher risk for Median nerve injury. However, weight is not a substitute for quality. Poor quality can eliminate any benefits of the lightweight. Thus, a good quality lightweight manual WC shall be preferred to minimize the median nerve injury.

This study has some implications for the management of patients with chronic paraplegia. Hospital-type WCs (Heavier) cause RSI when used in the long term. Application of light WCs with lower rolling resistance and educating patients on how to prevent cumulative trauma may decrease the risk of the injury. Furthermore, we recommend periodic USG evaluation of patients for CTS, especially in the presence of other local or systemic risk factors. The concurrence of other risk factors such as diabetes, obesity, and daily activity may cumulatively increase the probability of CTS, and further research studies are required to investigate these issues.

The study suffered from few limitations. This study had a small sample size (50) owing to the fact it has been carried out in a single center, and within 18-months duration time, also electrodiagnostic studies were not included in the determination of median nerve compression in Spinal cord injury patients. This was due to resources constraint as well to the fact that the study focused on USG as noninvasive screening tool to determine median nerve compression.

The age and the weight of the patients were not taken in to account although they comprise important confounding factors. Meanwhile, it should be emphasized that we were trying to investigate importantly the WC-related factors. The study did not address movement pattern difficulties and WC ergonomic defects. Furthermore, the impacts of other risk factors, including diabetes on the development of CTS, were not studied. Although USG examination was done for all patients using WC for >6 months, some cases of early median nerve injury may have been missed on physical examination.

Conclusion

A significant association was seen between the weight of the WC and increased median nerve compression, and thus, caution should be maintained while selecting the manual WC. Owing to the positive significant correlation, we also conclude that the height of the axle with respect to the shoulder is important. The height must be appropriate to limit the stress to the minimum, thus preventing the median nerve compression.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1. Sei IH, Waters RL, Adkins RH, Gellman H. Upper extremity pain in post rehabilitation spinal cord injury patient. Arch Phys Med Rehabil 1992;73:44-8.
2. Gellman H, Sie I, Waters RL. Late complications of the weight-bearing upper extremity in the paraplegic patient. Clin Orthop Relat Res 1988;233:132-5.
3. Asheghan M, Hollisaz MT, Taheri T, Kazemi H, Aghda AK. The prevalence of carpal tunnel syndrome among long-term manual wheelchair users with spinal cord injury: A cross-sectional study. J Spinal Cord Med 2016;39:265-71.
4. Practice parameter for carpal tunnel syndrome (summary statement). Report of Quality Standard Subcommittee of the American Academy of Neurology. Neurology. 1993;43:2406-9.
5. Jackson DL, Hynninen BC, Caborn DN, McLean J. Electrodiagnostic study of carpal tunnel syndrome in wheelchair basketball players. Clin J Sport Med 1996;6:27-31.
6. Chandy BR, Betty M, Magimairaj HP, Thomas BP, Tharion G. Ultrasound: A screening tool for carpal tunnel syndrome. IJPMR 2015;26:102-8.
7. Davidoff G, Werner R, Waring W. Compressive mononeuropathies of the upper extremity in chronic paraplegia. Paraplegia 1991;29:17-24.
8. Altinok MT, Baysal O, Karakas HM, Firat AK. Sonographic evaluation of the carpal tunnel after provocative exercises. J Ultrasound Med 2004;23:1301-6.
9. Hogaboom NS, Diehl JA, Oyster ML, Koontz AM, Boninger ML. Ultrasonographic median nerve changes after repeated wheelchair transfers in persons with paraplegia: Relationship with subject characteristics and transfer skills. PM R 2016;8:305-13.
10. Kim DK, Kim BS, Kim MJ, Kim KH, Park BK, Kim DH. Electrophysiologic and ultrasonographic assessment of carpal tunnel syndrome in wheelchair basketball athletes. Ann Rehabil Med 2017;41:58-65.
11. Boninger ML, Dicianno BE, Cooper RA, Towers JD, Koontz AM, Souza AL. Shoulder magnetic resonance imaging abnormalities, wheelchair propulsion, and gender. Arch Phys Med Rehabil 2003;84:1615-20.
12. Collinger JL, Boninger ML, Koontz AM, Price R, Sisto SA, Tolerico ML, *et al*. Shoulder biomechanics during the push phase of wheelchair propulsion: A multisite study of persons with paraplegia. Arch Phys Med Rehabil 2008;89:667-76.
13. Boninger ML, Cooper RA, Baldwin MA, Shimada SD, Koontz A. Wheelchair pushrim kinetics: Body weight and median nerve function. Arch Phys Med Rehabil 1999;80:910-5.
14. Impink BG, Boninger ML, Walker H, Collinger JL, Niyonkuru C. Ultrasonographic median nerve changes after a wheelchair sporting event. Arch Phys Med Rehabil 2009;90:1489-94.
15. Stevens JC. AAEM minimonograph #26: The electrodiagnosis of carpal tunnel syndrome. American Association of

Electrodiagnostic Medicine. Muscle Nerve 1997;20:1477-86.

16. Yang J, Boninger ML, Leath JD, Fitzgerald SG, Dyson-Hudson TA, Chang MW. Carpal tunnel syndrome in manual wheelchair users with spinal cord injury: A cross-sectional multicenter study. Am J Phys Med Rehabil 2009;88:1007-16.
17. Tanaka S, Wild DK, Seligman PJ, Behrens V, Cameron L, Putz-Anderson V. The US prevalence of self-reported carpal tunnel syndrome: 1988 National Health Interview Survey data. Am J Public Health 1994;84:1846-8.
18. Sarría L, Cabada T, Cozcolluela R, Martínez-Berganza T, García S. Carpal tunnel syndrome: Usefulness of sonography. Eur Radiol 2000;10:1920-5.
19. Nakamichi K, Tachibana S. Ultrasonographic measurement of median nerve cross-sectional area in idiopathic carpal tunnel syndrome: Diagnostic accuracy. Muscle Nerve 2002;26:798-803.
20. Abe M. Ultrasound measurement of the median nerve for carpal tunnel syndrome of the non-handicapped and the handicapped. J Phys Ther Sci 2004;16:107-14.
21. Kotajarvi BR, Sabick MB, An KN, Zhao KD, Kaufman KR, Basford JR. The effect of seat position on wheelchair propulsion biomechanics. J Rehabil Res Dev 2004;41:403-14.
22. Beekman CE, Miller-Porter L, Schoneberger M. Energy cost of propulsion in standard and ultralight wheelchairs in people with spinal cord injuries. Phys Ther 1999;79:146-58.
23. Cowan RE, Nash MS, Collinger JL, Koontz AM, Boninger ML. Impact of surface type, wheelchair weight, and axle position on wheelchair propulsion by novice older adults. Arch Phys Med Rehabil 2009;90:1076-83.