

# HEAVY Handed

## Repetitive Strain Injury Among Manual Wheelchair Users

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**W**heelchairs provide mobility for millions of people with physical impairments. However, prolonged manual wheelchair use can lead to pain and repetitive strain injury (RSI) of the upper extremities. The number of manual wheelchair users experiencing pain tends to increase with the time spent using a wheelchair. Although manual wheelchairs have improved tremendously over the past 15 years, many people continue to develop arm pain and injury due to cumulative trauma.

What causes this problem may not be the wheelchair. RSI may be caused by transfers or other activities of daily living. Yet, most clinicians and researchers agree that the wheelchair itself contributes substantially to the development of RSI. We present an overview of the current perspective on repetitive strain injury among manual wheelchair users.

### Incidence of Pain

Prolonged wheelchair use is associated with secondary musculoskeletal and neurologic upper extremity injuries. The shoulder is the most commonly reported site of musculoskeletal injury in manual wheelchair users. Surveys show the prevalence of shoulder pain to range between 31 percent and 73 percent, depending upon the subject group. Prevalence tends to increase over time until 20 years post-injury, then it decreases slightly.

Pentland and colleagues reported on pain complaints, strength and range of motion in 11 women with paraplegia and 11 healthy controls. They found 73 percent of women with paraplegia less than 15 years out from their spinal cord injury experienced shoulder pain during activities. Shoulder pain may be linked to impingement, tendinitis or rotator cuff tears. Studies have shown that people with pain were found to have rotator cuff tears or tendinitis in about 65 percent of the cases and aseptic necrosis of the



Illustrations by Doug Davis

humeral head in 22 percent of the cases. Studies have also reported that patients with greater activity levels had fewer complaints of pain.

Although the shoulder is the most common site of musculoskeletal injury in manual wheelchair users, elbow, wrist and hand pain are also commonly reported. Sie and colleagues reported elbow, wrist and hand pain in 16 percent, 13 percent, and 11 percent of the cases, respectively. In addition, Sie further defined significant pain as that which required analgesia, occurred with two or more aids to daily living, or required cessation of activity.

Using this definition, the prevalence of all upper extremity pain complaints was 20 percent five years post-injury, and 46 percent from 15 to 19 years post-injury. Other studies have shown the prevalence of forearm wrist and hand pain to be between 8 percent and 55 percent.

In all studies on upper extremity pain, the authors believed that the pain was related to overuse of the arm during transfers or wheelchair propulsion, and that traditional work aimed at prevention strategies is needed. The prevalence of carpal tunnel syndrome (CTS) among manual wheelchair users is between 49 percent and 73 percent. Large clinical series have found the incidence of CTS increased with increased duration of wheelchair use.

### Biomechanics

Mechanisms of injury to the rotator cuff have been divided into intrinsic and extrinsic factors. Intrinsic factors relate to anatomy of the tendon itself whereas, extrinsic factors relate to surrounding structures. The most commonly cited intrinsic factor associated with rotator cuff disease is a critical zone for injury at the insertion of the supraspinatus tendon into the humeral head. This critical zone has been found to have smaller veins, capillaries and arteries, and pressure within the joint has been found to be more than two times the typical pressure within the arteries when

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performing a transfer. This increased pressure may further stress the vasculature of the rotator cuff tendon.

Any activity that forces the humeral head further into the glenohumeral joint can cause impingement under the acromioclavicular arch and thus inflammation. During manual wheelchair use, there are forces that tend to drive the humeral head up into the glenohumeral joint. These forces occur during transfer activities and during wheelchair propulsion when a downward force is necessary for propulsion and to create friction against the push-rim.

Another extrinsic factor leading to the impingement and rotator cuff tear or tendinitis is instability of the glenohumeral joint. Instability is thought to relate to a combination of attenuation of supporting structures of the glenohumeral joint, such as the glenoid labrum, and to muscle imbalance. Muscle imbalance, caused by overuse, can lead to abnormal biomechanics and, thus, injury. The most common disparity in strength associated with rotator cuff tear or tendinitis is an imbalance between the internal and external rotators of the shoulder. Burnham was able to demonstrate muscle imbalance in a group of wheelchair athletes and was able to correlate this imbalance to shoulder pain.

CTS is generally thought to be caused by compression of the median nerve within the carpal tunnel. Extremes of wrist flexion and extension have been shown to greatly increase the pressure within the carpal tunnel, more so in patients with CTS. Thickening of the flexor tendon sheaths secondary to repetitive motion has also been implicated as a cause for compression of the median nerve.

High repetition is more important than high force in the development of CTS, and anatomic or congenital factors are also important. CTS is commonly bilateral. Exposure to vibration is also a strong risk factor for CTS. Part-time use of a power wheelchair can reduce the high repetition involved in manual wheelchair propulsion. Positioning within the manual wheelchair or modification of the user stroke may be able to reduce forces—the amount and type of wrist motion as well as the amount of vibration that occurs when the hand strikes the wheel.

## SMARTWheel

We have developed tools for analyzing manual wheelchair propulsion that are analogous to the force platform analysis systems for gait. A significant component of this research was the development of a force-and-moment sensing wheel, or SMARTWheel, which when used on common wheelchair types, has proven to be a reliable force-and-moment measurement system for wheelchair propulsion.

The SMARTWheel is a modified manual wheelchair wheel that measures and records the forces and moments applied to the push-rim by the hands of the wheelchair user. It employs an array of sensors and a microprocessor to sense the forces and moments and transmit them to a personal computer. The

SMARTWheel can be mounted to a variety of wheelchairs, which allows it to be used to assess an individual's personal wheelchair.

Computerized motion analysis is used in conjunction with the SMARTWheel to provide detailed analyses of the biomechanics of the wrist, elbow and shoulder during wheelchair propulsion. The information can be used to examine the strain borne by the joints of the upper extremities.

## Selecting a Wheelchair

With the lightweight wheelchair revolution came choice. Most people who have used a manual wheelchair for mobility for more than 10 years have spent a substantial amount of time in a classic hospital-type wheelchair. These wheelchairs are typified by their high weight and poor performance. The prolonged use of hospital-type wheelchairs may contribute to the high incidence of repetitive strain injury among manual wheelchair users with many years of experience.

Hospital-type wheelchairs are also much heavier than the ultralight wheelchairs designed for active use by individuals. 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 repetitive strain injury. Hospital-type wheelchairs incorporate high backrest and rear axle positions that are aft of the wheelchair user's hip joints. This often causes the wheelchair user to employ awkward arm movements in order to effectively maneuver the wheelchair.

No single manual wheelchair meets the needs of all wheelchair users. However, some desirable features may minimize the risk of developing repetitive strain injury. The risk of developing RSI may be reduced by lowering the amplitude and the frequency of the push-rim forces. This can be accomplished by selecting wheelchairs with lower resistance to motion. Pneumatic tires, when properly inflated, generally have lower rolling resistance over a variety of surfaces than do solid semi-pneumatic or foam-filled

tires. Standard manual wheelchair tires require about 65 psi tire pressure. If the wheelchair is used primarily indoors or on finished surfaces (e.g., well-groomed sidewalks, paved paths), then high pressure tires using about 120 psi can make pushing the wheelchair easier.

All wheelchair wheels roll better with sealed ball bearings in their hubs and caster spindles. Wheelchair users should always select the highest quality bearings available, and should replace them every few years, depending on the environment and amount of use. Spoked wheels are typically lighter than plastic Mag wheels, and roll more easily (because of their increased stiffness).

Selection of the wheelchair frame can also reduce the risk of developing repetitive strain injury. Light weight is desirable. There is no need to push around more weight than is necessary to make the wheelchair perform all of the necessary functions. More weight means more force, and more force can mean higher risk for RSI. However, weight is not a substitute for quality. Poor quality can eliminate any benefits of light weight. The wheelchair must fit properly. The shoulder is more stable when the arms are in the anatomically neutral position. The shoulder



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will remain more neutral during propulsion when the wheels are close to the body. This may be accomplished by ordering the wheelchair seat width to be close to the distance between the person's greater trochantors. Seat angle and height and backrest height are also important, but are not as easily related to RSI. These parameters should be selected to provide the user a fluid stroke.

## Positioning in a Wheelchair

There are a variety of wheelchairs to choose from, and most include a number of adjustable or selectable features. The basis for providing people with optional or adjustable features is to provide some degree of flexibility or customization. If the factory settings for the adjustable features are used, then most consumers will not benefit from the enhanced feature of lightweight wheelchairs. Proper positioning in the wheelchair is, perhaps, the most important intervention for the prevention of repetitive strain injury among manual wheelchair users. Positioning can reduce the forces required to propel the wheelchair, and can place the arms in positions for which they are better suited to the task.

The position of the rear axle probably has the greatest effect on the performance of the wheelchair. If the rear-wheel axles are positioned behind the center of gravity, then more weight will be placed on the front casters. This causes the wheelchair to be harder to turn and have a higher tendency to turn down a side slope, and it makes the chair harder to push. If the rear axles are placed in front of the center of gravity, the wheelchair and rider will have a tendency to rotate backwards (i.e., do a wheelie). Each wheelchair user needs to find the rear axle position that makes the individual feel secure. However, many people err on the side of additional static stability without weighing the risk that the extra effort to push the chair creates for pain or injury due to repetitive strain.

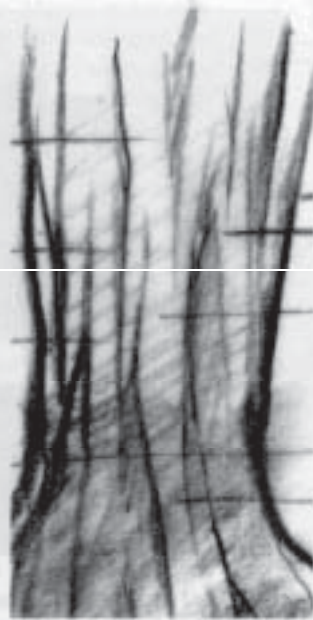
A fundamental property of all push-rim-propelled manual wheelchairs is that seating position and the location of the rear wheels are coupled. In other words, as the seating position is adjusted or as the rear wheels are adjusted, the propulsion of the wheelchair changes. This requires some trade-offs. For efficient pushing, the elbows should be bent at an angle of about 120 degrees when the hands are resting on the top of the push-rims. The wheelchair user should be able to comfortably reach the front and back of the push-rim at axle height. In order to obtain this position, the wheels need to be adjusted fore and aft, the wheels or seat need to be adjusted vertically, and the camber on the wheels needs to be adjusted. The camber adjustment should be set so that the arms are unrestricted over the entire propulsion phase. The primary goals are to reduce the forces and moments required to push the wheelchair, and to increase the angle over which the user can apply force to the push-rim comfortably.

Using a longer propulsion angle lowers the maximum amount of force or moment that needs to be applied to the push-rim, and also reduces the frequency of the strokes. Increasing the seat angle some can help to hold the rider in a secure seating position while pushing.

## Power or Manual

Some people have chronic pain while using a manual wheelchair, which persists despite conventional therapies. Other people, because of their anatomical structure, past activities or genetic makeup will develop chronic pain during manual wheelchair propulsion. Wheelchair users and their clinical partners have an important balance to maintain between cardiovascular health, prevention/reduction of pain from musculoskeletal or neurologic injury, and personal autonomy. A combination of manual mobility and powered mobility may be an acceptable compromise for some people. Although current manual wheelchairs are often easier to transport and, in many cases, easier to maneuver than a power wheelchair, they may not offer the same degree of independence for wheelchair users with chronic arm pain.

The use of a power wheelchair or scooter while participating in excursions may reduce the frequency of pain episodes, allow joint structures to recover, and provide greater opportunity for social interaction. The manual wheelchair would still be used in the home and office. This could help people to avoid the downward spiral of restricting their mobility due to chronic pain, sometimes reaching the point where they no longer leave home. A factor inhibiting the transition of manual wheelchair users to power wheelchairs is the stigma associated with their use. This may be alleviated with the introduction of new power wheelchairs, especially if manufacturers develop power wheelchairs designed for this segment of the market.



## Perspective on the Future

Many studies have clearly identified that repetitive strain injury is a potential problem for a high percentage of manual wheelchair users. Unfortunately, the linkage between wheelchair setup and selection and the development of arm pain has not been clearly established. Therefore, consumers and clinicians must apply their knowledge of wheelchair propulsion and wheelchairs with some consideration for the long term impact of manual wheelchair mobility.

Scientists and clinicians are investigating answers to why and how people develop RSI through manual wheelchair propulsion. This should lead to methods to position wheelchair users so that they are less likely to develop pain or repetitive strain injury. Research may also lead to new wheelchair designs that provide greater mobility with less effort. Part-time use of powered mobility may become an attractive alternative for some people who are currently manual wheelchair candidates.

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