Manual Wheelchair Configuration to Improve Efficiency and User Function: A Literature Review and Case Report

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Abstract

Background: Manual wheelchairs serve as reliable assistive technology devices to improve independence, quality of life and access to environment. Frequent and prolonged reliance on these assistive devices for completion of daily activities and functional mobility contributes to a significant increase in the amount of strain placed on the upper extremities secondary to the natural inefficiency and repetitive nature of wheelchair propulsion. Manual wheelchair configuration includes many components that influence system stability and maneuverability. The purpose of this case report is to highlight the impact of manual wheelchair configuration on propulsion efficiency, user function and mobility, and prevention of secondary shoulder complications in an individual with a spinal cord injury. **Case Description:** Patient XYZ was a 49-year-old male referred for a wheelchair clinic evaluation with the presenting diagnosis of chronic paraplegia and subjective report of difficulties with community mobility. The wheelchair was determined to be an improper fit, and the appropriate modifications were made to improve efficiency. **Outcome Measures:** The Wheelchair Use Confidence Scale and Six-Minute Push Test were used to assess the effectiveness of modifications to the manual wheelchair. **Discussion:** With additional knowledge and understanding of the previously established literature, healthcare providers are in a better position to identify and execute appropriate wheelchair modifications. This case report highlights one scenario of effective modifications to improve efficiency, guided by the literature.

Keywords: Manual wheelchair; propulsion; efficiency; wheelchair configuration; mobility

Background

Individuals with spinal cord injury (SCI) often become increasingly reliant on their upper limbs for completion of daily activities and functional mobility depending upon the severity of their injury. A manual wheelchair can serve as a reliable assistive technology device to improve independence, quality of life and access to environment in individuals with significant lower limb impairments. The repetitive nature of frequent and prolonged manual wheelchair propulsion, however, places much higher demands on the user's upper extremities when completing daily activities and functional mobility. Along with the increased frequency of upper limb use comes an increased risk for injury and pain as well as a higher prevalence of shoulder abnormalities which can in turn limit user mobility and function.[11,13] As many as 70% of manual wheelchair users have reported upper extremity pain and injury.[4] Additionally, the natural inefficiency of wheelchair mobility contributes to these functional impairments and associated complications. The mechanical efficiency (power applied to handrim versus movement) of wheelchair use has been reported to be between 2 and 10.5%, in comparison to the 20 to 40% attributed to walking.[10,20]

Despite the manual wheelchair being viewed as one of the more important assistive technology options following spinal cord injury, it is the most frequently reported barrier to participation both within the home and community compared to other associated factors (i.e. physical impairment and environment).[4] Many of the wheelchair-associated problems are attributed to the physical characteristics of the wheelchair, including aspects such as the fit between the device and user.[4,13] Manual wheelchair configuration can have a significant impact on propulsion forces, available range of motion (ROM) within joints of the upper limb, rolling resistance and the balance between system stability and mobility performance. The Paralyzed Veterans of America (PVA) Consortium of Spinal Cord Medicine has published wheelchair prescription guidelines to be used by healthcare professionals in an effort to preserve upper limb function following injury. In addition to these guidelines, there has been more recent evidence discussing the specifics of manual wheelchair configuration to improve mechanics.[16]

Briefly, the wheelchair components that have consistently proven to be most impactful for mobility and function include backrest height, seat position, rear wheel axle position, vertical position and camber of the wheels, listed in no particular order.[1,3] Additionally, stroke pattern for propulsion is another important consideration for preservation of shoulder function, as it can greatly influence the demands placed on the upper limbs.[11] Healthcare professionals play a pivotal role in identifying the appropriate configuration to optimize stability and performance in an effort to minimize mechanical load during use. Thus, the purpose of this case report is to highlight the impact of manual wheelchair configuration on propulsion efficiency, mobility and user function, and prevention of secondary shoulder complications in an individual with a spinal cord injury.

Wheelchair Considerations

The appropriate prescription of a manual wheelchair for optimal performance related to propulsion, maneuverability and control is dependent upon many contributing factors related to the specific configuration of the wheelchair. The available literature investigating the effects of manual wheelchair configuration on mobility has expanded over the years and provides healthcare professionals with increasingly specific recommendations to influence either the stability or mobility of the device. The following review of the evidence serves to justify the reasoning behind the modifications made to Patient XYZ's manual wheelchair.

Rear Wheel Configuration

Rear wheel position, also referred to as rear wheel axle position, has been shown to have multiple effects on stability and mobility of a manual wheelchair. Additionally, it has been shown to influence propulsion biomechanics with the correct positioning. The optimal position of the rear wheels is user-dependent, based on perception of stability and ease of function. However, there are objective guidelines for positioning, taking into consideration both the horizontal and vertical positions of the rear wheel. Specific to the horizontal plane, which alters the manual wheelchair's center of gravity, the published PVA guidelines recommend the rear wheel to be positioned as far forward as possible without compromising stability of the user.[16] A more forward rear wheel axle position places the user's center of mass rearward, consequently decreasing the load on the front casters. This alteration in load distribution contributes to decreased rolling resistance and thus increases propulsion efficiency.[10,12] Furthermore, with the wheels forward, push (hand contact) angle and shoulder range of motion increase, which reduces both the push frequency and handrim forces contributing to a minimized risk of injury to the upper extremities.[13] Additional effects of forward rear wheel axle position include smoother joint excursions, decreased muscle effort and a reduction in the wheelchair length, commonly referenced as the footprint of the manual wheelchair. The decreased footprint which reduces rotational inertia allows the wheelchair user to facilitate turning maneuvers with greater ease.[13] However, important considerations of such changes to a wheelchair include a decrease in rearward stability as the center of gravity is moved forward, which contributes to an increased tippiness of the chair. This can become problematic with use on inclines, uneven ground or loading backpacks onto the backrest. Additionally, the amount of forward frame available for transfers is reduced as the wheels are brought forward.

Vertical orientation of the rear wheel axle has a greater influence on manual wheelchair propulsion and associated shoulder strain. More specifically, the vertical distance between the seat and the rear wheels is the primary focus because the vertical position of the wheel is directly linked with rear seat to floor height. Modifications to these two components of the chair are frequently discussed together because an alteration in the seat height results in a relative change to rear wheel axle vertical position and vice versa; as the axle is lowered, the seat is raised, and as the axle is raised, the seat is lowered. The optimal seat height is determined by elbow angle as the user places their hand at the top position of the handrim. In this position, the angle between arm and forearm should be between 100 and 120 degrees of flexion, which strongly correlates to the fingertips contacting the center of the rear wheel axle in a resting position with arms at the user's side.[1] A lower seat height is beneficial to the user because it provides greater access to the pushrim for more efficient propulsion, allowing for an increased push angle and joint protection. Stability of the manual wheelchair is also improved with a lower seat height. Along with these benefits comes an increase in range of motion at the shoulder, which could potentially raise the risk of harm and injury if physiological limits are exceeded. With a seat height that is too low, the user is required to propel with the arm in an abducted position, which may increase the user's risk for shoulder impingement.[7,13,16] Conversely, a seat height that is too high contributes to a smaller push angle that will require a greater push frequency to maintain the same speed, also potentially putting the shoulders at risk for fatigue and injury.[3,13]

Lateral orientation of the rear wheel has a worthwhile effect on user function by influencing the upper extremity position relative to the handrim, width of the wheelchair and lateral stability.[17] The main consideration with this aspect of the manual wheelchair is the degree of camber, or inclination, for the rear wheels. Previously, camber was mainly reserved for wheelchair sports, but it has become increasingly prevalent for daily propulsion due to the apparent benefits.[19] As camber is increased, there is enhanced stability, maneuverability and hand protection up to a certain degree.[13,19] It has been indicated that the optimal angle for rear wheel camber is between three and six degrees to achieve the benefits of increased lateral stability, comfort with propulsion and maneuverability. Additionally, this angle range has been the preference for many manual wheelchair users.[1,13] Specific to optimization of push mechanics, the superior aspect of the wheel should be as close to the person's body as possible. For every two degrees of camber that is added, there is an inch-and-a-half increase in chair width. Therefore, as camber is increased, the width of the chair contacting the ground becomes greater than the width at the point where the hands are in contact with the pushrim, protecting the upper extremities from unnecessary trauma. An increase in camber also contributes to decreased rolling resistance up to nine degrees.[13] However, researchers have evaluated the effects of camber between nine and fifteen degrees and determined that rolling resistance actually begins to increase within this range. The larger camber contributes to increased acceleration required to maintain speed as well as more energy loss as a result of the discrepancy between mechanical work and power flow.[19]

Seat Configuration

Seat position plays an important role in manual wheelchair function beyond its previously mentioned positional relationship to the rear wheel axle. Appropriate seating provides trunk support and a stable base to support upper extremity range of motion. The ability for users to reach or complete tasks and activities from the wheelchair is substantially affected by the stability provided to the pelvis and trunk. General principles for seating and positioning in clinical practice are provided by the PVA Consortium of Spinal Cord Medicine and are discussed here. The first priority of seating is to stabilize the pelvis, followed by the lower extremities, and finally the trunk. If deformities are observed, the nature of these abnormalities should be considered; fixed deformities should be accommodated and flexible deformities should be addressed in an attempt to correct them. Without the presence of fixed deformities, it is important to aim for neutral, midline posture with normal lumbar and cervical lordotic curvatures. Seat cushions should provide postural support and appropriate pressure distribution while remaining light weight to avoid the addition of unnecessary propulsion force requirements.[16]

Backrest configuration contributes to the balance between trunk support and shoulder range of motion. A higher backrest provides increased support to the trunk, but it can limit shoulder extension range of motion making initiation of wheelchair propulsion difficult due to limited ability to grip the posterior aspect of the handrim. At the cost of stability, lower backrest heights allow for more free movement of the upper extremities.[12] A lower backrest also has been shown to allow for greater push angle and push time, reducing the push frequency. It is typically recommended that backrest height lies about one inch below the inferior angle of the scapula, taking into consideration the seat cushion height.[3] For users with impaired trunk control, a higher backrest may be of benefit to accommodate postural deficits. Users with intact trunk control are recommended to use lower backrests, aligned with the top of the lumbar spine.[13]

Seat angle, also referred to as seat dump or inclination, can be adjusted to improve the sitting balance and functional reach of the manual wheelchair user. While investigating balance and chair configuration, researchers have established that a chair position in which the entire seat and backrest complex is reclined can impose a posterior tilt of the pelvis, which can contribute to unfavorable posturing and difficulties with overhead reaching. Furthermore, it has been reported that ideal sitting posture includes anterior pelvic tilt and decreased lumbar flexion.[8,13] Hastings et al. compared three wheelchair configurations and found that a manual wheelchair with a lower backrest perpendicular to the floor and a seat with a posterior dump improved sitting posture and function. This configuration placed both the back-to-seat and knee angles at less than 90 degrees and allowed the backrest to serve as a lumbar support to maintain the anterior pelvic position. The findings from this study showed more neutral postural alignment at the neck and shoulder (less head forward and shoulder protraction posturing), a significantly reduced trunk angle indicating more upright positioning and a significantly greater amount of active shoulder flexion, allowing users to reach to a greater height.[8] It is important to note that although this wheelchair configuration is deemed to be ideal, an increase in the seat inclination may make it more difficult to complete transfers into and out of the device. Therefore, completion of a functional evaluation is imperative to assess the influence of seat modifications on mobility. Additionally, the position of the seat can influence the pressure distribution on the seat cushion. While there have not been definitive findings for a seat angle that optimizes pressure distribution, there have been identified trends for changes in pressure distribution with modifications to seat angle. This is a very important concern for healthcare professionals in the management of wheelchair users to prevent secondary complications such as pressure sores. Previous research has demonstrated that a greater seat inclination increases the pressure interface under their thighs rather than the ischial tuberosities or sacrococcygeal region.[13]

Accessory Configurations

The caster wheels should also be considered, as they are responsible for turning the wheelchair and influence the rolling resistance.[12] With the horizontal position of the rear wheel more posterior, there is more load placed through the front casters, increasing the rolling resistance. As the rear wheels are brought forward, there is less load through the front casters and a similar decrease in rolling resistance. While weight distribution on the front casters is the most important factor affecting rolling resistance, size of the caster can additionally influence the efficiency of the wheelchair.[12,17] Specifically, the diameter of the caster wheel is inversely related to rolling resistance. Typical caster size is between three and six inches.[3] A smaller caster size increases rolling resistance and thus requires the user to propel with more force to maintain the same velocity. In addition, smaller casters have limited ability to absorb shock and vibrational forces.[13] However, while larger caster wheels have more capacity to handle uneven terrain, the alterations in rolling resistance are minimally different between various caster sizes and thus larger casters are not necessarily beneficial.[3,20]

Leg and foot support and positioning should not be neglected in the configuration process because they have various functional implications related to pressure distribution and wheelchair maneuverability. The center of mass, stability and rolling resistance are all altered, as the horizontal distance between the leg and foot support and the rear wheels is changed. Additionally, the overall length of the chair is influenced by this distance, and in combination with these other factors, the stability and maneuverability of the wheelchair is impacted. The angle of the knees is typically used as a reference for positioning of the foot supports, and most commonly the knees are positioned between 90 and 120 degrees of flexion.[13] As the angle of knee flexion increases, the overall length or footprint of the manual wheelchair is reduced, and it is typically reported that the maneuverability of the wheelchair is improved under such conditions. This increase in maneuverability comes at the cost of stability, particularly as it relates to anterior support with reaching forward, which is a crucial consideration for functional participation. From the perspective of pressure distribution, it is important that the lower extremities are positioned to allow for the thighs to accommodate a substantial amount of the seat interface pressure in an effort to reduce pressure centralizing near the sacrococcygeal region, as previously discussed with seat inclination as well.

One final consideration for manual wheelchair use is the propulsion pattern executed by the user, which is an important aspect of patient management for healthcare professionals to address, as it has strong implications related to shoulder health. It is well established in the literature that reducing forces, rate of force applications and frequency of push strokes is advantageous for shoulder health.[15] Previously discussed in this case report are other aspects of wheelchair configuration that can address these goals (i.e., rear axle position and backrest height). In addition, a long, smooth propulsion pattern can contribute to the accomplishment of these aims. There are four commonly used propulsion strategies: arc, semicircular, single-looping over and double-looping over. Of these, the semicircular pattern is preferred because it is associated with lower stroke frequency, more time spent in the push phase rather than the recovery phase and allows for better biomechanics at the shoulder.[14,15] A study by Tsai et al. acknowledges the benefits of a semicircular pattern but reports from their findings that the single-loop pattern is the most natural and controllable propulsion pattern, especially without wheelchair training.[19] Kwarciak et al. determined in their research that the user's force and cadence preference may influence the most appropriate push stroke pattern. However, their final conclusion aligns with the guidelines provided by the Paralyzed Veterans of America to focus on achieving a longer duration, smooth application of force to the handrim of the wheelchair.[11]

Case Description

A 49-year-old male (referred to as Patient XYZ) was referred to physical therapy for a wheelchair clinic evaluation at a major Midwest medical center to address the need for manual wheelchair modifications. Patient XYZ presented to the clinic with a referring diagnosis of incomplete paraplegia from an injury sustained ten years prior, requesting changes to his manual wheelchair due to difficulty with community mobility. Specifically, the patient expressed concerns with regard to inefficiency and workload with the use of his current chair. Patient XYZ was independent with wheelchair mobility on basic indoor and outdoor surfaces. At the wheelchair evaluation, he indicated he was ambulatory within his home but requires the wheelchair for community distances.

Observation of his sitting posture revealed the following: unremarkable obliquity, a slight right pelvic rotation, mild to moderate posterior pelvic tilt, unremarkable scoliosis and adequate femur support. Patient-specific measurements were also completed at this visit and can be found in Table 1 to the right. Evaluation of his current wheelchair configuration (Wheelchair A) found that his seat-to-floor height and backrest height were appropriate and therefore were not adjusted. His rear seat height, however, was higher than necessary, which limited his rear wheel access. The seat pan was determined to be both too wide and too deep based on patient measurements. While seated upright with his back against the backrest, it was observed that the seat pan was making contact with his knees, which indicated the depth was inappropriate. Additionally, it was noted that both the front rigging and the front casters were unnecessarily large, contributing to excessive weight and size of the chair. The center of gravity was notably too far posterior, which could have been contributing to his perception of inefficient propulsion.

Table 1. Patient-Specific Measurements

Hip Width	15.25 inches
Hip Flexion Degree	Within Normal
Inferior Angle: Scapula	22 inches (cushion)
Upper Leg Length	20 inches
Lower Leg Length	20 inches

Due to the previously listed findings, Patient XYZ's manual wheelchair was considered an improper fit, and in combination with the age of the chair, it was determined that he was appropriate for a new manual wheelchair. Assessment of the current wheelchair configuration (Wheelchair A) led to identification of the following necessary adjustments, which can also be found in Table 2: rear seat height, seat width, seat depth, center of gravity, knee angle, caster wheel size and foot position. Patient XYZ completed subjective qualitative measures using the Wheelchair Use Confidence Scale for Manual Wheelchair Users (WheelCon-M) during the initial visit, receiving a score of 58% confidence in his ability to complete functional tasks in his current manual wheelchair. Additionally, as a quantitative measure, he completed the Six-Minute Push Test (6MPT) for a total distance of 1,653 feet, indicating low fitness in the paraplegic population (<1993.2 feet).[6] His rating of perceived exertion after completing the 6MPT was 8/10 at the initial visit.

Table 2. Measurements of Manual Wheelchairs

Dimension (inches)	Wheelchair A	Wheelchair B
Seat to Floor Height	20	19
Rear Seat Height	17	16
Seat Width	17	16
Seat Depth	18	16
Backrest Height	17	16.5
Rear Axle Position	1.5	2

At the conclusion of the initial visit, a new wheelchair (Wheelchair B) was ordered with the necessary modifications as identified throughout the evaluation. Patient XYZ returned to the clinic two months later for fitting and provision of Wheelchair B, and his manual wheelchair was replaced at this time. A second follow-up visit was completed after an additional two months, four months after the evaluation, to reassess the outcome measures completed at the initial visit. This delay in reassessment was intended to allow Patient XYZ to become familiar with the use of his new manual wheelchair.

Outcomes

Follow-up assessments for Patient XYZ were completed across two visits in order to provide enough time for him to get acclimated to the fit of the new manual wheelchair. The first follow-up visit occurred two months after the initial evaluation for provision and fitting of the new manual wheelchair. At this visit, immediate improvements in Patient XYZ's upright sitting posture were observed with all postural variables being considered unremarkable. Additionally, rear wheel access immediately improved with the changes made as Patient XYZ's fingertips were initially two inches above the axle. A second follow-up visit was scheduled for one month after receiving the new manual wheelchair to reassess the outcome measures that were completed at the initial visit. Due to scheduling conflicts, these outcome measures were not reassessed until four months after the initial visit; two months after receiving the wheelchair with modifications.

The Wheelchair Use Confidence Scale is a 65-item self-report questionnaire that serves as a subjective measure to evaluate confidence with manual wheelchair use in six different areas: negotiating the user's physical environment, performing activities in the manual wheelchair, knowledge and problem solving, advocacy, managing social situations, and managing emotions. The stem for each item on the questionnaire is "As of now, how confident are you…" with a 100-point response scale ranging from not confident to completely confident (0-100, respectively). This subjective measure is intended for adults with any physical diagnosis using a manual wheelchair and can be administered across the continuum of care. Confidence with wheelchair use has been found to be a stronger predictor of behavior than actual skills or abilities. Additionally, it has been reported to play a significant role in determining whether or not to perform a behavior, the degree of effort that will be put forth, and the length of time one will persist with a given activity. Summing the rating for each item and dividing by the total number of items (65) results in the final WheelCon-M score. Higher scores represent higher confidence with manual wheelchair use.[16]

The WheelCon-M was found to have high internal consistency, strong retest reliability, support for concurrent validity, construct validity and good responsiveness when evaluated in a population that was not specific to SCI.[16] It is encouraged to use this measure pre- and post-intervention to indicate the extent to which confidence was gained by the user with their manual wheelchair, as in this case report.[16] Interestingly, there was a poor correlation between the WheelCon-M score and social support, which is typically another important consideration in the rehabilitation process. Social support can be provided through both emotional support and physical assistance, and it is hypothesized that the prior positively reinforces the wheelchair user's confidence, while the latter may negatively impact their confidence.[16] The WheelCon-M may clinically serve as a tool to identify areas of lesser confidence and help direct interventions in order to improve confidence during the rehabilitation process. After intervention, however, it is best used as an outcome measure.

The Six-Minute Push Test (6MPT) is an adaptation of the frequently used Six-Minute Walk Test (6MWT) in clinical settings for non-ambulatory populations. Administration of this outcome measure parallels that of the 6MWT including the standardized pretest script instructing participants to propel as far as possible on the course, allowing for slowing or stopping at any point during testing. Feedback is similarly provided during the testing period, as it would be during completion of the 6MWT.[6,18] The 6MPT demonstrates reliability in populations of both tetraplegia and paraplegia, demonstrates acceptable test-retest reliability, and results appear to have the ability to discriminate between persons with high and low aerobic fitness, regardless of injury level. However, for those with injuries above the T10 level, this outcome measure can be considered a maximal test of aerobic capacity. Clinically, this outcome measure can also be used as a screening tool for low fitness in persons with spinal cord injury. A 6MPT distance below the threshold values of 445 meters (1459.97 feet) for tetraplegia and 604 meters (1981.63 feet) for paraplegia, identifies an individual with low fitness.[6]

At Patient XYZ's second follow-up visit, the Wheelcon-M was administered to evaluate the change in confidence levels with use of the manual wheelchair following modifications. Upon reassessment, his final score of 86 indicated 86% confidence in his ability to complete functional tasks in the current manual wheelchair. This signifies a 28% increase in his confidence after a two-month trial period with his new manual wheelchair. The Six-Minute Push Test was also reassessed during the second follow-up, and Patient XYZ was able to propel his new manual wheelchair a total distance of 1,932 feet. While the distance covered during the second assessment was an improvement of 279 feet from his previous total of 1,653 feet, Patient XYZ remained in the category of low fitness, as determined by previously established literature.[6]

Using the modified category-ratio version of the Borg Scale for assessment, Patient XYZ stated his rating of perceived exertion to be an 8/10 at completion of the 6MPT during both the initial and final visit. The modified 11-point scale ranges from 0 (nothing at all) to 10 (very, very hard) as a measure of training intensity and outcomes for exercise. This measure has been deemed appropriate for use with any individual capable of exercising and parallels the physiological variables associated with exercise. There is established reliability and validity for the use of this scale to monitor and prescribe exercise intensity with a variety of populations, with the exception of a stroke. However, there is not established test-retest reliability and validity specific to physiologic measures. Another important consideration with the use of this assessment is that pain may influence a patient's score, and it is recommended to make note of this potential influence in the clinical setting.[2]

For evaluation of push stroke and efficiency as a result of the wheelchair modifications, videos and photos were taken throughout the 6MPT. Push stroke specifically was measured observationally by comparing the photos at the initial and final visits, looking at initial contact and release point of the handrim during propulsion. At the initial evaluation, Patient XYZ demonstrated a propulsion pattern with initial contact at the 10:00 position of a clock face and a release point at the 2:00 position of a clock face. During the final visit, the propulsion pattern was altered to a 9:00 and 3:00 position for initial contact and release point, respectively. It can be concluded from these observations that the patient was executing longer push strokes and demonstrating increased time in contact with the handrim, which is advantageous to shoulder health as previously discussed. Comparison of push stroke pattern with the use of Wheelchair A and B can be seen in Figure 1 below.

Figure 1. Handrim Contact in Wheelchair A (Left) and Wheelchair B (Right)

Discussion

This case report intended to highlight the impact of manual wheelchair configuration on propulsion efficiency, mobility and user function and prevention of secondary shoulder complications in an individual with a spinal cord injury. A wheelchair user's capacity for efficient manual wheelchair propulsion significantly contributes to their independence and level of function.[9] The highly repetitive nature of the propulsion and increased reliance on the upper extremities for task completion after injury sets individuals up for a greater risk of pain and injury.[15] The shoulder and wrist continue to be the most frequently reported joints experiencing pain and injury across various populations of manual wheelchair users.[19] Through reconfiguration of the manual wheelchair setup, the user can be placed at a biomechanical advantage in order to improve stability and maneuverability during propulsion. It has been reported that as much as 68% of evaluated manual wheelchairs were not suitable for their users and may be the result of prescription errors.[5,13] With additional knowledge and understanding, healthcare providers are in a better position to identify the need for modifications to a manual wheelchair when inefficiency of use or improper fit become a concern. Furthermore, these potential limitations can be avoided during the wheelchair prescription process by following the recommendations established in the literature and working with the user to determine the appropriate balance between stability and mobility.

To summarize, the modifications made to Patient XYZ's manual wheelchair were selected with the intention to improve efficiency, function and comfort following identification of improper fit during an initial visit. Adjustments were completed to reduce both the seat width and seat depth for a more appropriate fit contributing to comfort. The backrest height seemed appropriate, and the patient had expressed it was at the preferred height, providing him with support. The rear seat height was lowered to improve rear wheel access because, according to the established recommendations, his fingertips were too high. The rear wheels were also brought forward in order to improve the efficiency of propulsion, as previously discussed, moving the center of mass rearward. Both a smaller caster size and a smaller front rigging were selected to reduce rolling resistance and the size of the chair, respectively. Footplate position was modified to reduce the footprint of the manual wheelchair by flipping the footplate backwards, which is useful for Patient XYZ as he completes his transfers by standing. Lastly, his feet were moved back slightly, decreasing the knee angle, which further reduced the footprint of the manual wheelchair. His seat cushion was unchanged, per Patient XYZ's request. Following all of these changes, there were immediate improvements noted in sitting posture and rear wheel access. The final follow-up visit took place two months after receiving his new wheelchair, four months after the initial evaluation. At this visit, outcome measures were reassessed and Patient XYZ demonstrated a 28% increase in his confidence score, a nearly 300-foot increase in his 6MPT distance, and no change to his rating of perceived exertion. It is worthwhile to note that while a 28% increase in confidence may not be a large change, his rating of confidence with the new manual wheelchair was 86% after just a few weeks of use, compared to 58% confidence rating with his original chair, despite having ten years of experience using it for community mobility. Lastly, an improvement in his push stroke pattern was observed by increasing the length of time in contact with the handrim.

The Wheelchair Use Confidence Scale and the Six-Minute Push Test are both appropriate outcome measures to be used within the clinic to provide subjective and objective data respectively, to evaluate the effectiveness of intervention or modifications to a manual wheelchair. Both of these measures are clinically feasible, simple to administer and can serve multiple purposes. In addition to measuring a change in confidence level after intervention, the WheelCon-M can be used across the continuum of care to direct rehabilitation interventions towards areas that the user may be less confident in as they transition to the use of a manual wheelchair.[16] Likewise, in addition to the distance covered pre- and post-intervention, the 6MPT can also provide a clinician with a screening tool for physical fitness. The distance covered within the duration of the assessment is also able to be utilized as a screening tool to identify individuals that are considered to have low fitness levels, and thus the rehabilitation plan can be adjusted accordingly. As previously discussed, the Borg Rating of Perceived Exertion Scale is a useful tool for the clinic to measure fatigue during an activity.

Improving the efficiency of manual wheelchair use can be a challenging task requiring consideration of multiple components to identify an appropriate configuration for the delicate balance between stability and mobility. The amount of literature related to the configuration and management of manual wheelchairs has increased in previous years and can guide healthcare professionals in the identification and completion of necessary modifications to improve maneuverability. This case report was created to summarize the multitude of configuration options and provide a specific patient example to highlight the effectiveness of these changes and their impact on a patient's function and perceived quality of life. As previously discussed, manual wheelchairs are naturally an inefficient method of primary mobility but are extensively relied on for completion of daily tasks and navigation of the environment. While this report provided an example specific to spinal cord injury, the information included can be applied to the vast majority of manual wheelchair users to address relevant limitations. Therefore, it is important for physical therapists and other healthcare professionals to understand the potential influence these modifications can have on propulsion efficiency, function and the prevention of secondary shoulder complications, which are all valuable aspects of the care and management for this population.

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