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Evidenced Based Education Interventions to Preserve Upper Limb Function Among Full Time Manual Wheelchair Users

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Abstract

Full time manual wheelchair users are at high risk for developing upper limb injuries and pain due to their reliance on the upper limbs to perform a wide variety of functional activities of daily living. Critical to survival and living well with a disability, even small decrements in functional mobility can lead to depression, social isolation and reduced quality of life. Treatment strategies to manage pain and injury are often not successful therefore engagement in preventative measures is critical to prevent the disruption of normal activities and performance of necessary social roles. This narrative review highlights key evidenced based training interventions andeducational protocols focused on preventing and managing upper limb pain and injury among full time manual wheelchair users.

1. Introduction:

Full time manual wheelchair users (MWU) rely on their upper limbs (UL) to perform basic activities of daily living (ADLs)such as bathing and dressing and more complex activities including active engagement in family and social life, providing care for family members and occupational pursuits. Unfortunately, UL pain and injury is very common among full timeMWU.Approximately 30-60% MWUworldwide report shoulder pain, 40-60% report wrist pain and 5-16% report pain at the elbow(WHO 2008).Such impairments can have a detrimental effect on an individual's ability to actively engage in necessary and preferred societal roles. Even a small loss of function significantly affects independence.(Pentland and Twomey 1991, Silfverskiold and Waters 1991, Curtis, Roach et al. 1995, Curtis, Drysdale et al. 1999)Among individuals with Spinal Cord Injuries (SCI) affected by UL pain, 26% reported that they need additional help with ADLs and 28% report independence limitations.(Dalyan, Cardenas et al. 1999)UL pain is often cited as one of the major reasons for function decline.(Gerhart, Bergstrom et al. 1993)

As the consequences of UL pain can be severe, researchers have examined numerous strategies to elucidate and rectify the problem. To date, preventative strategies are favored because: 1) the activities contributing to the problem such as manual wheelchair propulsion (MWP) or transferring are difficult if not impossible to avoid(Pentland and Twomey 1991, Pentland and Twomey 1994); and 2) medical treatments like surgery are costly, relatively ineffective, and the associated healing times require significant periods of inactivity. Therefore, it would seem logical to suggest an optimal scenario is one in which UL pain or injury has never occurred in the first place.

In 2005, Boninger, *et a*l(Boninger, Waters et al. 2005) published a set of guidelines for preservation of UL function among wheelchair users (both manual and power)living with SCI. Although the guidelines were developed for individuals with SCI, many of the recommendations are applicable to other full-timewheelchair users.Since publication, the Clinical Practice Guidelines (CPG) for Preservation of Upper Limb Function Following SCI have been widely used and serve as an important resource for clinicians. The recommendationsinclude, but are not limited to, education on effective MWP training, transfer training, exercises to increase strength of the upper extremity musculature and manage pain andappropriate equipment selection. A recent review of the guidelines bySawatzky, *et al*(Sawatzky, DiGiovine et al. 2015)supported the findings and suggests the addition of information regarding equipment, skills and caregivertraining.

The purpose of this paper is to examine education interventions to preserve UL function and prevent the development of pain and injury among full time MWU. Our narrative review highlights intervention studies focused on 1) MWP technique, 2) transfer training, 3) wheelchair skills training and 4) therapeutic exercise. We have attempted to gather studies using a variety of different intervention techniques and examine interventions implemented in different treatment settings including inpatient rehabilitation, outpatient facilities and in the individual's own home. Additionally we have favored inclusion of publications based on use of actual MWUs rather than able bodied subjects when possible.

2. Results:

2.1: Propulsion Training:

Although wheelchairs offer heightened mobility and independence(Boninger, Cooper et al. 1999, Boninger, Baldwin et al. 2000), MWP predispose the UL to high forces repetitively. (Aljure, Eltorai et al. 1985, Bayley, Cochran et al. 1987, Gellman, Chandler et al. 1988, Wylie and Chakera 1988, Davidoff, Werner et al. 1991, Pentland and Twomey 1991, Sie, Waters et al. 1992, Gerhart, Bergstrom et al. 1993, Burnham and Steadward 1994) Since MWU already rely on their UL to perform nearly all activities of daily living, the effects of pain and injury can disrupt daily functioning resulting in marked activity limitations and participation restrictions. (Pentland and Twomey 1991, Gerhart, Bergstrom et al. 1993, Ballinger, Rintala et al. 2000) Accordingly, researches have investigated interventional strategies to reduce the risk of UL pain and injury specifically associated with MWP. The following review involves identification of recent propulsion training interventions emphasizing technique and motor learning modification strategies. Indeed, these investigations have incorporated a diverse range of participant demographics with clinically feasible training modalities including interventions based on combinations of simple education, video, real time feedback, visualization, repetition, and fitness training.

2.1.1: Assessment of Manual Wheelchair Propulsion

Researchers must rely on an array of metrics to describe scenarios which constitute improved or optimized MWP. Outcome measures which serve as a basis for comparison between propulsion training studies most commonly fall under the categories of technique and motor learning. For example, for a given power output, optimal propulsion technique is supported as a scenario involving the minimization ofhandrim forces, braking torques, and stroke frequency(SF) while maximizing contact angle(CA) (angle along the arc of the handrim from contact to release) (Boninger, Koontz et al. 2005, Rice, Impink et al. 2009). Braking torques provide an indication of how smoothly the user initiates contact and release of the handrim. Improved motor learning or motor proficiency has been described in terms of increased variability in the aforementioned technique metrics where fluctuations from stroke to stroke are desirable(Sosnoff, Rice et al. 2015). Additionally, a more advanced learner will exhibit decreased energy expenditure over time for a given task with a constant power output (Sparrow 1983, Sparrow and Newell 1994, Almasbakk, Whiting et al. 2001). Similarly, the high physical strain and low efficiency often associated with handrim propulsion can be quantified in terms of a users' mechanical efficiency (ME) which is calculated as the ratio of power output and energy expenditure(van der Woude, Hendrich et al. 1988, van der Woude, Veeger et al. 1988). Although ME requires significant instrumentation to calculate, it is a useful outcome measure because of its sensitivity to both learning and training, where improved technique may lead to increased ME (Dallmeijer, van der Woude et al. 1999, de Groot, Dallmeijer et al. 2005).

2.1.2: Visual and verbal feedback training

Rice,*et al*(Rice, Pohlig et al. 2013, Dysterheft, Rice et al. 2015, Rice, Rice et al. 2015)has conducted several investigations on full time MWU of varying ages and disabilities based on a similar interventional approach targeting reduced SF and increased CA. Force and moment sensing instrumented wheels were used to capture all propulsion technique metrics across these studies. The training methodology originated utilizing interactive software which allowed MWUs to view and interact with CA and SF feedback in real time during dynamometer propulsion. The first investigation was a non-blinded randomized control trial(RCT) comparing handrim kinetics, CA and SF between three groups (n=27): a control group (CG) that received no training, an instruction only group (IO) that reviewed a multimedia presentation(MMP), and a feedback group (FB) that reviewed the MMP and received visual real time feedback (RTF). Propulsion training was provided three times over three weeks while data was collected at baseline, immediately after training, and 3 months later. Both the FB and IO groups improved aspects of propulsion technique across all surfaces (carpet, tile, ramp) compared to a CG. Both intervention groups (IO & FB) showed long term reductions in peak rate of rise of resultant force and reduced SF with increased CA. Importantly, training with a low cost, instructional video and slide presentation (MMP) was found to be an effective training tool alone as the magnitude of change in technique metrics between intervention groups (IG) was nearly indistinguishable. Consequently, two additional training studies were conducted using the the low tech instructional approach only(Dysterheft, Rice et al. 2015, Rice, Rice et al. 2015). For example, the MMP was provided to 10 adolescent wheelchair users (ages 13-18) during over ground conditions (carpet and tile) to investigate the short-term effects of training on younger MWU. Short term(same day) improvements in SF and CA were observed during all conditions with a trend toward increased peak force when velocity was controlled(Dysterheft, Rice et al. 2015). Similarly, in a separate investigation,non-ambulatory persons living with multiple sclerosis demonstrated propulsion technique improvements compared to a CG 3 months after a single training episode with the MMP on a wheelchair treadmill. After initial training, IG participants were encouraged to use the techniques learned in their home environments until follow up testing. IG participants demonstrated reduced SF and braking torques as well as increased upper limb strength and a trend toward less fatigue compared to a CG three months after training and home use(Rice, Rice et al. 2015).

Using a similar methodological approach to Rice,*et al*(Rice, Rice et al. 2015), Degroot*et al*(DeGroot, Hollingsworth et al. 2009)in 2009 conducted a pilot investigation to examine differences in propulsion technique in adult MWU (n=9) after training based on verbaland visual feedback. Participants also received video instruction to reduce SF and increase CA, while using a semicircular stroke pattern(Boninger, Koontz et al. 2005). Training and practice involved treadmill propulsion where participants could view the above metric in real-time along with verbal feedback from an experienced investigator. After training, propulsion data was collected during treadmill and over ground propulsion with force and moment sensing instrumented wheels. Participants demonstrate increased CA, decreased SF with increased peak and average forces immediately after training however these changes were not sustained.

Also implementing a practical/clinically feasible approach to training Morgan *et al*(Morgan, Tucker et al. 2015*)*in 2015 conducted a pilot investigation (n=6) based on a motor learning and repetition-based practice for new MWUs with an SCI(mean time with injury 15.3 months). A within subjects design was used with participant acting as their own controls, where 9 training sessions where delivered over three to five weeks (2-3 sessions per week/90min per session). Propulsion patterns and technique were measured with video motion capture and the Wheelchair Propulsion Test(WPT)(Askari, Kirby et al. 2013) during over ground propulsion, 3 times (Pretest 1, Pretest 2, and Posttest) while a WheelMill System(WMS) (Klaesner, Morgan et al. 2014) captured handrim forces during Pretest 2 and Posttest. Training sessions occurred on the WMS, where participants received verbal feedback and were taught to self-identify the need to make corrections through the use of mirrors placed laterally and anteriorly. Additionally, all training sets incorporated 500-700 repetitions which is sufficient to turn a movement into a learned skill(Birkenmeier, Prager et al. 2010). Focus was placed on maximizing contact angle and use of semicircular stroke pattern. Results suggested repetition-based motor learning contributed toward use of improved propulsion patterns and decreased rate of loading at the handrim. In addition to the small sample size, the authors suggest variability in wheelchair configurations, injury level may have contributed to a lack of other significant technique changes.

2.1.3: Practice and repetition training

Other research groups have targeted upper limb preservation strategies utilizing markedly different propulsion training strategies. For example,Leving*et al*(Leving, Vegter et al. 2016) examine the influence of uninstructed variable practice on both technique and motor learning outcomes in 23 able bodied participants. Importantly, this study implemented a training approach without providing feedback or instruction favoring motor exploration as a means to promote learning. The IG received variable practice compared to a CG which incorporated wheelchair basketball with wheelchair skills tasks. These activities require a MWU to adopt variable motor strategies through changing direction and accelerations as well as maneuvering through different patterns. Both groups (IG& CG) were tested at baseline and eight weeks later which yielded a number of interesting findings. The IG demonstrated both improved mechanical efficiency and increased variability (coefficient of variation) in CA and positive work compared to the CG. Both groups demonstrated improved technique (reduced SF with in increased CA) suggesting the CG derived technique benefits from repeat testing without practice. Because the magnitude of change in technique variables were similar between groups with improved ME in the IG, the authors suggest other factors besides technique may have contributed to the lower levels of energy expenditure observed(Leving, Vegter et al. 2016).

van der Scheer*et al*(van der Scheer, de Groot et al. 2015*)*conducted anonblinded RCT on long term inactive MWUs with SCI(N=29) to investigate the effects of low intensity wheelchair training on propulsion technique during treadmill propulsion with an instrumented force and moment sensing wheel attached. Similar to the previous investigation, no direct feedback or technique training was utilized. Propulsion technique parameters (CA, SF peak force push time), and ME were examined at baseline and then 8,16& 42 weeks from baseline. Only the IG (exercise group) received 16 weeks of low intensity training through steady state treadmill propulsion, twice a week for 30 mins per session. Differences in technique, ME, and peak PO were not found between groups however a near significant reduction in SF was observed in the exercise group. The authors present a number of feasible explanations and suggestions based on findings including; 1) the existence of responders and non-responders to training as evidence by the exercises groups' substantial variance in propulsion technique over time; 2) The possibility that low intensity/frequency training were below a critical threshold required for shifting to a more optimal propulsion technique(Rice, Impink et al. 2009); 3) Participants' technique were already optimal under their current capacity and wheelchair configuration; and 4) low-intensity wheelchair training may require the additional modalities like bio feedback for long term users to adopt more optimal technique.

2.1.4: Multifaceted Education approach to training

Rice*et al(*Rice, Smith et al. 2014) in 2014 conducted a single blinded RCT on new MWU with SCI(n=37) investigating the effects of a structured education program based on the CPG for Preservation of Upper Limb Function(Boninger, Waters et al. 2005). Participants in acute inpatient rehabilitation were educated according to either a structured protocol based on the CPG (IG)(Boninger, Waters et al. 2005)or the standard of care (CG) at the same rehabilitation facility. Training was provided during daily therapy sessions utilizing a multifaceted, interactive approach which included paper-based handouts, pictures, and videos, as well as instruction based on various motor learning techniques(delayed knowledge of results, blocked practice, etc). Data was collected at discharge, 6 months and 1 year post discharge using a force and moment sensing instrumented wheel to evaluate over ground propulsion. IG participants demonstrated various technique improvements including reduced SF on tile surface at discharge, and use of a larger CA during ramp propulsion across all time points.

2.2: Transfer Training

The ability to effectively transfer is an important skill for full time MWUs to master.(Nyland, Quigley et al. 2000) Transfers, defined as movement to/from a wheelchair to a goal surface, are needed to perform essential activities of daily living such as getting in and out of bed, getting on or off a toilet seat or shower chair, etc. Learning how to master both basic and complex transfer skills has been rated as highly important by full time MWUs.(Fliess-Douer, Vanlandewijck et al. 2012) Maintenance of transfer skills across the lifespan has also been associated with increased life expectancy.(Nyland, Quigley et al. 2000) Performing a transfer is a complex skill: the user must place him/herself in a position of instability to allow for movement but must also appropriately control the movement to prevent falls.(Gagnon, Koontz et al. 2009) In addition, during a transfer a significant amount of force is placed on the shoulder, a joint designed for mobility, not stability(van Drongelen, van der Woude et al. 2005). As a result, leaning how to perform a transfer correctly is essential for the health and safety of a full time WCU.

2.2.1: Assessment of Transfer Training

Transfer skills are evaluated by both examining the quality of a transfer and evaluating kinetic and kinematic variables. Transfer quality can be evaluated using the Transfer Assessment Instrument (TAI)(Tsai, Rice et al. 2013). The TAI breaks down a transfer into small components and examines if the participant performs those components in a manner consistent with the CPG for preservation of upper limb function(Boninger, Waters et al. 2005) and other pertinent research findings associated with advantageous transfer skills(Campbell and Koris 1996, Finley and Rodgers 2004). A score between 0 (poor quality) and 10 (high quality) is reported.The biomechanics of transfers are also evaluated to examine changes in key variables such asresultant joint forces and moments at the shoulder, elbow and wrist and joint position as a result of training.

2.2.2: Transfer Training Programs

We reviewed 3 papers examining transfer training among full timeMWUs. In 2013, Rice, *et al*(Rice, Smith et al. 2013) evaluated the impact of a structured education protocol used by an Occupational and Physical Therapist to instruct individuals with new SCIsusing both manual and power wheelchairs in inpatient rehabilitation on transfer skills in manner consistent with the recommendations of the CPG for Preservation of Upper Limb Function.(Boninger, Waters et al. 2005)The study intervention was implemented during standard treatment times in inpatient rehabilitation and utilized a variety of different adult education strategies to educate both the treating clinicians and the study participants(Winstein 1991, Immink and Wright 2001, Magill 2001, Ste-Marie, Clark et al. 2004). The education materials included paper based handouts that provided highly detailed information on transfer skills specific to the participant's needs and an educational video that the participant could take home with him/her after rehabilitation. After implementation of the intervention, no significant differences were found in the general population of study participants, however among participants performing assisted pivot transfers,transfer quality significantly improved (p = 0.026), as measured by the TAI in IG participants compared to CG participants who received standard therapy services. Of note, some power wheelchair users were included in this population. In 2016, Tsai, et al(Tsai, Boninger et al. 2016)evaluated the impact of a personalized transfer training program on full time MWUs who initially presented with low TAI scores, indicating poor transfer quality. During the intervention program, the training clinician focused on the areas of deficits that the study participant presented with,utilized a block practice strategy and diminished the feedback provided as study participants became more confident in their skills. After receiving training, TAI scores increased from 6.31 ± -.98 to 9.92 ± 0.25. Participants also showed significant improvements on key kinetic variables associated with injuries including a reduction in shoulder resultant force on both the leading and trailing arm and a decrease in rates of rise of shoulder resultant force and moment on the leading side. Finally, a study performed by Rice, *et al(*Rice, Dysterheft et al. 2016*)*in 2016 evaluated the impact of a transfer training intervention among full time pediatric MWUs. The intervention consisted of an educational video describing the various components of a transfer. Participants were given the opportunity to ask questions about the transfer instructions and practice the newly learned skills. Participants were also given feedback on their practice performance. After implementation of the intervention, the TAI scores of the IG were significantly higher (9.06 ± 1.01) compared to the CG (7.15 ± 1.67), $p = 0.030$, d = 1.385 who did not receive any training.

2.3: Wheelchair skills training

Sawatzky, *et al(*Sawatzky, DiGiovine et al. 2015*)* emphasized the need to teach full time MCUs wheelchair skills in order to minimize the impact of detrimental forces on the upper extremity during mobility andimprove community participation.Wheelchair skills include the ability of an individual to maneuver their wheelchair to perform activities of daily living and move from point A to point B. Such skills can range from very simple items such as propelling or driving a wheelchair over a smooth surface or more complex tasks including performance of wheelies and ascending and descending curbs. Wheelchair skills are most frequently evaluated using the wheelchair skills test (WST)(Kirby, Swuste et al. 2002). The WST is a validated outcome measure that assesses both simple and complex skills performed by manual and powerwheelchair users. The tool evaluates both the participant's ability to perform a specific skill and how safe they are performing the skill. Participants receive a final score as a percentage of their performance of applicable items. Higher scores indicate higher skill levels. Recently, a questionnaire version (WST-Q) of the WST has been developed that has been found to be highly correlated to the WST(Rushton, Kirby et al. 2012). The WST-Q is self-administered tool and provides additional breakdown of scores related to the participant's capacity to perform the skills, confidence in performance and how often the skills are performed.

2.3.1: Wheelchair Skills Training Programs

Our review found that the majority of the literature utilized all or some of the components of the Wheelchair Skills Program (WSP) developed by Kirby, *et al*(Kirby, Smith et al. 2016). The WSP is an evidenced-based training program to teach wheelchair skills(Lindquist, Loudon et al. 2010) that was initially developed by the Nova Scotia Rehabilitation Centre(MacPhee, Kirby et al. 2004).The WSP involves a "circle of education" in which both assessment and training are included in the program. The program utilizes the WST(Kirby, Swuste et al. 2002) to examine deficits in wheelchair skills and uses the WSP to enhance such skills. The program itself breaks wheelchair skills down into various modules focused on functional activities. Some examples of the modules include: Understanding the functionality of the wheelchair, moving the wheelchair around on smooth level surfaces and navigating environmental challenges. An in-depth description of the program is available at http://www.wheelchairskillsprogram.ca/eng/. This literature review highlights representative publications that have examined the use of the program in various treatment settings.In 2004, MacPhee, *et al(*MacPhee, Kirby et al. 2004) examined the use of the WSP among MWU admitted to an inpatient rehabilitation facility for their initial course of therapy. Wheelchair skills of IG participants who were exposed to the WSP were compared to CG participants who received typical wheelchair skill training during inpatient rehabilitation. After completion of the study, the IG showed a 25% improvement in their wheelchair skills compared to an 8% increase among the CG. In 2005, Best, *et al*(Best, Kirby et al. 2005) examined the efficacy of the program among community-based MWUs. Participants allocated to the IG received an average of 4.5 hours of training in 3-5 one hour sessions. A combination of blocked and random practice strategies were utilized during the sessions. CG participants did not receive skills training and were contacted by the trainer three times during the intervention period. After completion of the intervention period, the IG showed a 24% improvement in wheelchair skills compared to a 4.5% improvement in the CG.In 2016, Worobey, *et al*(Worobey, Kirby et al. 2016)evaluated the use of a group based instructional intervention among full time MWUwith SCI living in the community. IG participants received six weekly 90-minute group sessions with six to ten people in each group over a period of 6-8 weeks. Skills described in the WSP were implemented and participants were given an opportunity to practice their skills and receive feedback from a trainer. CG participants attended two, one hour general education classes focusing on aging with SCI, weight management and nutrition. After completion of the intervention period, IG participants showed significant improvements in the WST-Q capacity advanced score (p = 0.02) but not in the WST-Q capacity or WST-Q performance scores. Finally, in 2016, Best, *et al*(Best, Miller et al. 2016) examined the effect of a peer-led training program (enhanced wheelchair training program, WheelSee) to improve wheelchair skills, life-space mobility and satisfaction with participation. The WheelSee intervention was conducted by a peer trainer who had over 15 years of manual wheelchair experience. The WheelSee program was conducted over six sessions in which participants identified goals important to their specific circumstances and targeted practice was completed based on the participant's own goals. In addition, the program also provided instruction on how participants could problem solve community mobility issues, advocate for themselves, manage social situations and control emotions. The CG had no contact with the research team during the intervention period. After completion of the WheelSee program, IG participants reported significantly higher wheelchair-use self-efficacy (d = 1.4) and also scored significantly higher on the WST capacity (d = 1.3) and performance tests (d = 1.0) compared to the control group.

2.4: Exercise

Active engagement in a structured exercise program is important for MWUs to maintain adequate strength to perform necessary activities of daily living. Regular exercise programs can not only prevent pain and injury but also help reduce existing pain and improve propulsion technique (Rodgers, Keyser et al. 2001). The CPG for Preservation of Upper Limb functionrecommends that wheelchair usersshould "incorporate resistance training as an integral part of an adult fitness program. Training should be individualized and progressive, should be sufficient intensity to enhance strength and muscular endurance, and should provide stimulus to exercise all major muscle groups to pain-free fatigue.(Boninger, Waters et al. 2005)" Therecent review of the CPG by Sawatzky, *et al*(Sawatzky, DiGiovine et al. 2015)continues to promote engagement in an exercise program.

The exercise programs we have selected are focused on prevention of UL pain and increasing ULstrength among full time MWU. UL limb strength was evaluated either using assessment tools such as dynamometers or examining the amount of weight a participant could lift. Shoulder pain and function was assessed using validated outcome measures such as the Wheelchair Users Shoulder Pain Index(Curtis, Roach et al. 1995) (WUSPI) and the Shoulder Rating Questionnaire(L'Insalata, Warren et al. 1997) (SRQ).

We have attempted to highlight a variety of studies using various exercise protocols in diverse treatment settings. As a result of the barriers(Rimmer, Riley et al. 2004)MWU often face when attempting to engage in a community based exercise programs, we have broken our review of the interventions into home and community based programs to help clinicians chose a program that will best fit the needs and match the resources available to their individual clients.

2.4.1: Home Based Programs

In 2006, Nawoczenski, *et al*(Nawoczenski, Ritter-Soronen et al. 2006)evaluated the impact of an individualized home-based program to stretch and strengthen scapular musculature. The program was individualized to study participants based on their ability to effectively activate specific muscles. If an individual was unable to activate a specific muscle, modifications were made to the program. After completion of the eight-week program, study participants in the IG showed a significant improvement in WUSPI scores (p = 0.002) and SRQ scores ($p < 0.001$). Control group participants showed no significant changes at the posttest assessments. In 2011, Mulroy, *et al*(Mulroy, Thompson et al. 2011) examined the effect of a home-based program designed to optimize performance of upper-extremity tasks on shoulder pain among MWU with paraplegia from SCI. The program consisted of a 12 week shoulder strengthening and stretching exercises and instructions on how to optimize transfer skills, pressure reliefs and wheelchair propulsion skills. All materials necessary to complete the HEP were provided to the study participants including written instructions, dumbbells and resistance bands. The stretching program focused on stretching the anterior and posterior joint capsules, surrounding musculature and the upper trapezius muscles. The strengthening program focused on shoulder external rotation and diagonal extension with adduction motions. This combination exercise and functional mobility program resulted in significant reductions in WUSPI scores ($p<0.001$) and improvements in shoulder strength($p<0.05$) among IG study participants. No changes were seen among CG participants who watched a generalized 1 hour instructional video on management of shoulder pain. The improvements seen at the end of the 12 week program were maintained among IG participants at a four week follow up assessment. The reduction in shoulder pain was also related to increased social participation and improved quality of life scores(Kemp, Bateham et al. 2011). In 2014, Froehlich-Grobe, *et al(*Froehlich-Grobe, Lee et al. 2014)evaluated the impact of a home-based behavior intervention among inactivewheelchair user with sufficient upper arm mobility for arm-based exercise. Of note, the study was not restricted to only MWU, however the number of power wheelchair users involved was not reported. The study examined the difference between those receiving anintensive home based exercise support program vs. a self-guided program. The supportive program consisted of a one day educational workshop where an individualized exercise plan was developed, goals established and plans to prevent relapse were discussed. Participants were also contacted by phone to support exercise efforts. The CG had minimal contact with investigators except for follow up phone calls to review exercises sent to study participants through the mail. After completion of the program, the IG spent significantly more time exercising compared to the CG ($t = 10.6$, $p = 0.00$), however, no significant between-group differences were found inpeak aerobic capacity and maximal strength.Similarly, van Straaten, *et al*(Van Straaten, Cloud et al. 2014)evaluated the effects of a high-intensity supportive exercise program focused on the rotator cuff and scapular stabilizers. After completion of the 12-week program, WUSPI scores significantly decreased ($p = 0.014$)and SRQ scores significant increased ($p <0.001$). In addition, the isometric strength of the serratus anterior ($p = 0.04$) and scapular retractors ($p = 0.003$) significantly increased.

2.4.2: Community Based Programs

In 2007, Nash *et al*(Nash, van de Ven et al. 2007) examined the effect of circuit resistance training among MWUswith T5-T12 paraplegia. In this pre/post assessment study, MWUs participated in a16-week circuit resistant training programthat was conducted three times a week for approximately 40-45 minutes per session. Participants first warmed-up using arm ergometry and engaged in resistance training (weight lifting) and high-speed, low-intensity endurance activities (arm cracking). After completion of the program, WUSPI scores significantly decreased (31.8 ± 23.5 to 5.0 ± 7.7, $p = 0.008$). In 2010, Valent, *et al*(Valent, Dallmeijer et al. 2010)evaluated the impact of using an add-on hand cycle that was mounted to the front of a handrim propelled wheelchair to increase upper extremity strength in participants receiving inpatient rehabilitation.The IG group participated in 35-45 minute sessions of handcycling two times per week during inpatient rehabilitation. The training periods varied from 9 to 39 weeks based on the participant's length of stay in inpatient rehabilitation. Participants initially cycled for approximately 1-2 minutes and received a 3-4 minute rest. As the program progressed, the period of cycling increased and the rest time decreased. CG participants were matched based on level of injury, age, gender and motor completeness of lesion from a group of inpatient rehabilitation patients who received standard care. After the end of the participant's inpatient rehabilitation stay, IG participants showed significant improvements in left elbow flexion ($p = 0.037$), and bilateral internal and external rotators of the shoulder musculature ($p = 0.00 – 0.01$). No significant differences however were observed between groups.

Finally, Troy, *et al*(Troy, Munce et al. 2015) and Wilbanks, *et al*(Wilbanks, Rogers et al. 2016) examined the influence of using rowing techniques to increase shoulder strength and reduce pain amongMWU. Troy, *et al*(Troy, Munce et al. 2015) examined the effect of using an upper body rowing ergometer compared to a standard arm crank ergometer. Participants in both the standard arm crank ergometer and the upper body rowing ergometer groups exercised 3 days per week, 30 minutes per day for 12 weeks. After completion of the program, the upper body rowing ergometer group increased their peak power output (Cohen's d range = 0.66-1.33), however no differences were observed between the two groups based on muscle strength. Wilbanks, *et al*(Wilbanks, Rogers et al. 2016)evaluated the effectiveness of a 6 week functional electrical stimulation (FES) assisted rowing intervention. MWU performed FES assisted rowing for 30 minutes, 3 days per week for six weeks. After completion of the program, no significant differences were found in upper extremity strength, however WUSPI scores decreased by 10.5 ± 4.4 points (p<0.05).

3. Conclusion

Preservation of UL function and pain prevention among full time MWU is critical to promote high levels of quality of life and community participation. Fortunately, a wealth of intervention studies have been completed on which clinicians can base their treatment recommendations. We did however note several limitations in the existing literature. First, we noted that several of the intervention studies were performed in strictly controlled laboratory settings. Although control is often required in the early phases of investigation, interventions must be practical and clinically feasible to maximize their reach and effect amongst clinicians and end users alike. Further investigation of these protocols in clinical and community based settings are needed. We also noted the lack of studies focused on transfer training. Although a narrative review was performed, a systematic search was conducted to capture a wide variety of transfer training studies. Our results yielded three studies, although aspects of transfer training have been integrated into a few of the wheelchair skills and exercise program reviewed.Further, in-depth evaluations of transfer training techniques are neededto inform treatment recommendations of clinicians. Finally, much of the research performed on actual wheelchair users involved small sample sizes with relatively uniform demographic characteristics. Research performed on more diverse populations of wheelchair users will be necessary to fully examine the efficacy of interventional programs which seek to offer validated treatment recommendations for clinicians who provide care to a variety of MWU.Despite the limitations, a wide variety of evidenced based interventional studies are available to clinicians. Utilization of these interventions are an important endeavor to prevent the development of UL pain and injury and enhance quality of life and community participation among full time MWU.

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