# Strengthening and Optimal Movements for Painful Shoulders (STOMPS) in Chronic Spinal Cord Injury: A Randomized Controlled Trial

Sara J. Mulroy, Lilli Thompson, Bryan Kemp, Patricia Pate Hatchett, Craig J. Newsam, Dee Gutierrez Lupold, Lisa Lighthall Haubert, Valerie Eberly, Ting-Ting Ge, Stanley P. Azen, Carolee J. Winstein, James Gordon; for the Physical Therapy Clinical Research Network (PTClinResNet)

**Background.** Shoulder pain is a common problem after spinal cord injury (SCI), with negative effects on daily activities and quality of life (QOL).

**Objective.** The purpose of this study was to determine the effect of an exercise program and instruction to optimize performance of upper-extremity tasks on shoulder pain in people with paraplegia from SCI.

**Methods/Design.** Eighty individuals with paraplegia from SCI and shoulder pain were randomly assigned to receive either an exercise/movement optimization intervention or an attention control intervention. The exercise/movement optimization intervention consisted of a 12-week home-based program of shoulder strengthening and stretching exercises, along with recommendations on how to optimize the movement technique of transfers, raises, and wheelchair propulsion. The attention control group viewed a 1-hour educational video. Outcome measures of shoulder pain, muscle strength (force-generating capacity), activity, and QOL were assessed at baseline, immediately after intervention, and 4 weeks later.

**Results.** Shoulder pain, as measured with the Wheelchair User's Shoulder Pain Index, decreased to one third of baseline levels after the intervention in the exercise/movement optimization group, but remained unchanged in the attention control group. Shoulder torques, most 36-Item Short-Form Health Survey questionnaire (SF-36) subscale scores, and QOL scores also were improved in the exercise/movement optimization group, but not in the attention control group. Improvements were maintained at the 4-week follow-up assessment.

**Limitations.** Many of the outcome measures were self-reported, and the participant dropout rate was high in both groups. Additional studies are needed to determine whether the results of this study can be generalized to individuals with tetraplegia.

**Conclusions.** This home-based intervention was effective in reducing long-standing shoulder pain in people with SCI. The reduction in pain was associated with improvements in muscle strength and health-related and overall QOL.

S.J. Mulroy, PT, PhD, is Director, Pathokinesiology Laboratory, Rancho Los Amigos National Rehabilitation Center, 7601 E Imperial Hwy, Bldg 800, Room 33, Downey, CA 90242 (USA). Address all correspondence to Dr Mulroy at: smulroy@dhs.lacounty.gov.

L. Thompson, PT, NCS, ATP, is Director, Rehabilitation Therapy Services, Rancho Los Amigos National Rehabilitation Center.

B. Kemp, PhD, is Director, Research Center on Aging With a Disability, Rancho Los Amigos National Rehabilitation Center, and Clinical Professor of Neurology, Keck School of Medicine, University of Southern California, Los Angeles, California.

P.P. Hatchett, PT, DPT, NCS, is Research Physical Therapist, Pathokinesiology Laboratory, Rancho Los Amigos National Rehabilitation Center.

C.J. Newsam, PT, DPT, is Director of Therapy Services, Hollywood Presbyterian Medical Center, Los Angeles, California.

D.G. Lupold, PT, is Research Physical Therapist, Pathokinesiology Laboratory, Rancho Los Amigos National Rehabilitation Center.

L.L. Haubert, PT, MPT, KEMG, is Research Physical Therapist, Pathokinesiology Laboratory, Rancho Los Amigos National Rehabilitation Center.

*Author information continues on next page.*

V. Eberly, PT, NCS, is Research Physical Therapist, Pathokinesiology Laboratory, Rancho Los Amigos National Rehabilitation Center.

T.-T. Ge, PhD, is Biostatistician, Johnson & Johnson Pharmaceutical Research & Development LLC, La Jolla, California.

S.P. Azen, PhD, is Professor, Department of Preventive Medicine, Division of Biostatistics, Keck School of Medicine, University of Southern California.

C.J. Winstein, PT, PhD, FAPTA, is Professor and Director of Research, Division of Biokinesiology and Physical Therapy at the Herman Ostrow School of Dentistry, and Department of Neurology, Keck School of Medicine, University of Southern California.

J. Gordon, PT, EdD, FAPTA, is Associate Dean and Chair, Division of Biokinesiology and Physical Therapy at the Herman Ostrow School of Dentistry, and Department of Neurology, Keck School of Medicine, University of Southern California.

Physical Therapy Clinical Research Network (PTClinResNet) (see list of investigators on page 323).

[Mulroy SJ, Thompson L, Kemp B, et al; for the Physical Therapy Clinical Research Network (PTClinResNet). Strengthening and Optimal Movements for Painful Shoulders (STOMPS) in chronic spinal cord injury: a randomized controlled trial. *Phys Ther.* 2011;91:305–324.]





Upper-extremity (UE) pain is a common secondary complication after spinal cord injury (SCI), with reported prevalence ranging from 30% to 70%.[1–6] Both the incidence and severity of UE pain increase with time postinjury.[5,7,8] The shoulder joint is the most common location of UE pain after SCI,[5] and the etiology is most commonly attributed to chronic impingement syndromes (75%)[6,9] and rotator cuff tears (65%-71%).[9] Without intervention, shoulder pain after SCI is associated with additional losses in function and community mobility.[4,10–12] Lundquist and colleagues[13] identified pain, in general, as the only factor correlated with lower quality-of-life (QOL) scores following SCI. More specifically, Gutierrez et al[14] identified a significant negative correlation between the magnitude of shoulder pain and both physical activity and QOL scores following SCI. These findings highlight the need to identify interventions that can reduce shoulder pain and thereby preserve both UE function and QOL following SCI.

In contrast to people without disabilities, individuals with SCI who develop shoulder pain are unable to rest their arms because they are dependent upon their UEs for both locomotion and typical daily activities. Surgical repair of rotator cuff tears requires complete arm rest for 6 weeks following surgery.[15,16] Therefore, this is not a realistic option for this population because adherence to the postsurgical recommendations would be the equivalent of complete bed rest. More realistic and appropriate for this population is the development of nonoperative, evidence-based interventions for shoulder pain and rotator cuff injury.

Strengthening exercises for the rotator cuff muscles are commonly prescribed for individuals without disabilities who have impingement syndrome prior to considering any shoulder surgical intervention.[17–19] Previous studies have demonstrated that strengthening exercises of the shoulder rotators and scapular stabilizers in adults without disabilities who have chronic inflammation yield improvement and are as clinically effective as surgery, without the high cost associated with surgery.[19–22]

Preliminary evidence suggests that similar stretching and strengthening programs modified for the specific needs of individuals with SCI could be effective in reducing shoulder pain secondary to subacromial impingement syndromes. Three prior studies documented the impact of an exercise program on shoulder pain in individuals with SCI,[23–25] with 2 of the 3 studies reporting a statistically significant decline in shoulder pain following the stretching and strengthening intervention.[24,25] Small sample size,[25] inadequate control groups or lack of randomization,[23–25] and insufficient documentation of the exercise resistance load[23] limit the studies' findings.

Because paralysis of the lower extremities mandates increased demands on the shoulder joints from repetitive weight-bearing activities, individuals who develop shoulder pain after SCI may benefit from an intervention that directly addresses those tasks. Modification of task performance technique to reduce the forces on the shoulder joint and optimize muscle performance has the potential to protect the joint complex while preserving functional ability of the individual. Prior investigations that have detailed the joint motions, forces, and muscle activity patterns during particular UE activities in people with SCI provide guidance for optimizing task performance.[26–33] For example, adjusting the heights of transfer surfaces to

make them level whenever possible will reduce the demands on the muscles of the shoulder and thereby reduce the potential for subacromial joint impingement.[32] Recommendations from laboratory research and clinical studies to preserve upper-limb function after SCI were recently compiled into a clinical guide for practitioners.[34] However, no known controlled studies have investigated the effectiveness of these recommendations on the reduction of shoulder pain in people with SCI.

The primary purpose of the Strengthening and Optimal Movements for Painful Shoulders (STOMPS) trial was to investigate the effect of a home-based exercise program, combined with instruction to optimize performance technique of UE tasks, on shoulder pain in people with SCI. Secondary purposes of the STOMPS trial were to determine the impact of the intervention on physical activity and participation, including health-related and overall self-reported QOL, and to identify whether improvements in pain or function would be maintained for 4 weeks after the end of the intervention. We hypothesized that an intervention of shoulder stretching and strengthening exercises combined with movement optimization training would reduce shoulder pain in people with paraplegia and consequently improve physical activity and participation to a greater extent than an attention control intervention.

## Method

### Design Overview

This prospective randomized controlled trial was approved by the institutional review boards of the University of Southern California, Los Angeles, California, and Rancho Los Amigos National Rehabilitation Center (RLANRC), Downey, California. All participants were assessed by a blinded evaluator before and after the 12-week intervention and at 4 weeks after the end of the intervention (week 16).

### Setting and Participants

Participants were self-selected and volunteered in response to flyers posted at outpatient clinics at RLANRC. Informed consent was obtained, and individuals were screened to determine eligibility. People were candidates for inclusion in the study if they: (1) had postpubescent onset of paraplegia at age 14 years or older, (2) had an SCI of at least 5 years' duration, (3) were between 19 and 75 years of age, (4) had unilateral or bilateral shoulder pain that interfered with at least one functional task (eg, transfers, wheelchair propulsion), (5) used a manual wheelchair for mobility at least 50% of the time, and (6) had the ability to understand informed consent. Individuals were not admitted to the study if any of the following criteria were present: (1) hospitalization within the previous month; (2) cortisone injection to the shoulder within the previous 4 months; (3) fracture within the previous year; (4) shoulder surgery to the painful side within the previous year; (5) diagnosis of complete rotator cuff tear, rheumatoid arthritis, adhesive capsulitis at the shoulder, or complex regional pain syndrome; (6) positive findings on all 3 clinical tests for full-thickness rotator cuff tear (Jobe's Empty Can Test,[35,36] Codman's Drop Arm Test,[37,38] and resisted external rotation[38]); (7) any serious medical conditions; (8) major depression; or (9) alcohol abuse.

### Randomization and Interventions

Once determined eligible for inclusion into the study, participants were enrolled. Decentralized randomization to 1 of 2 intervention groups was implemented by the Data Management Center of the

## The Bottom Line

### What do we already know about this topic?

Shoulder pain is a common problem for patients after spinal cord injury (SCI). Untreated, shoulder pain may lead to additional losses in function and community mobility. Preliminary evidence suggests that shoulder strengthening and stretching exercises may reduce shoulder pain in patients after SCI.

### What new information does this study offer?

This randomized controlled trial demonstrated that a 12-week home exercise program, paired with instruction to optimize movement performance, will result in a significant and persistent reduction in shoulder pain as well as significant improvements in muscle strength and in health-related and overall quality of life.

### If you're a patient, what might these findings mean for you?

Chronic shoulder pain after SCI can be markedly reduced by using a relatively simple home exercise program coupled with assessment and modification of performance technique for several upper-extremity weight-bearing activities.


**Figure 1.**
Stretching exercises for (A) anterior shoulder joint structures, (B) posterior shoulder joint structures, and (C) upper trapezius muscle.

Physical Therapy Clinical Research Network (PTClinResNet) referencing a computer-generated randomization list. Allocation was concealed until the time of intervention assignment. All of the enrolled and randomized participants received 2 payments of $50 as incentive for participation, the first issued at the baseline visit and the second at the 4-week postintervention visit. At the end of the final assessment, all participants were offered the opportunity to receive the intervention administered to the other intervention group.

**Exercise/movement optimization group.** Participants received instruction by a physical therapist in a 12-week shoulder home exercise program (HEP) and in strategies to optimize transfers, depression raises, and wheelchair propulsion technique. A binder with written instructions and picture illustrations for all stretches and exercises, as well as the necessary exercise equipment of elastic bands and a dumbbell, were provided. Participants were asked to maintain a Physical Activity Calendar to note any adverse responses to the HEP and to track adherence to the exercise program.

The shoulder HEP consisted of a stretching phase, a warm-up phase, and a resistive shoulder exercise phase, all to be performed 3 times per week for 12 weeks (eAppendix 1; available at ptjournal.apta.org). The stretching phase included stretches for the anterior and posterior joint capsules and surrounding musculature, plus the upper trapezius muscle (Fig. 1). The warm-up phase included 4 non-resisted active movements. The resistive exercise phase consisted of the identical 4 exercises performed during the warm-up phase; however, performance instructions promoted either hypertrophy or endurance. The physical therapist established a stan-

dardized level of resistance at the initial intervention visit according to the ability of the participant and based upon guidelines by the American College of Sports Medicine.[39] The level of resistance was manipulated by adjusting the color and length of the Dura-Band resistive bands* or the weight of the hand weight. The bands were selected to achieve an 8-repetition maximum resistance level for the hypertrophy protocol or a 15-repetition maximum resistance for the endurance protocol.[40,41] The muscle hypertrophy exercises targeted shoulder external rotation and diagonal extension with adduction motions, and muscle endurance exercises included humeral elevation in the scapular plane and scapular retraction (Fig. 2). Participants were instructed to perform 3 sets of 8 repetitions for each hypertrophy exercise and 3 sets of 15 repetitions for the endurance exercises, with a 1- to 2-minute rest interval between sets (eAppendix 1).

Participants returned for strength (force-generating capacity) and technique performance reassessment 4 weeks into the intervention to: (1) reassess appropriate levels of resistance to meet the intended 8- and 15-repetition maximum intensity for the hypertrophy and endurance exercises, respectively, with adjustment as needed; (2) ensure that exercises were being performed appropriately; and (3) indirectly measure adherence to the exercise protocol based upon their familiarity with and ability to perform the exercises. At the end of the 12-week intervention, participants were allowed to keep the exercise equipment and were told they could continue the exercises, stop them, or restart the exercises if the shoulder pain recurred.

* For You Inc, 1773 Pine Hollow Rd, McKees Rocks, PA 15136.

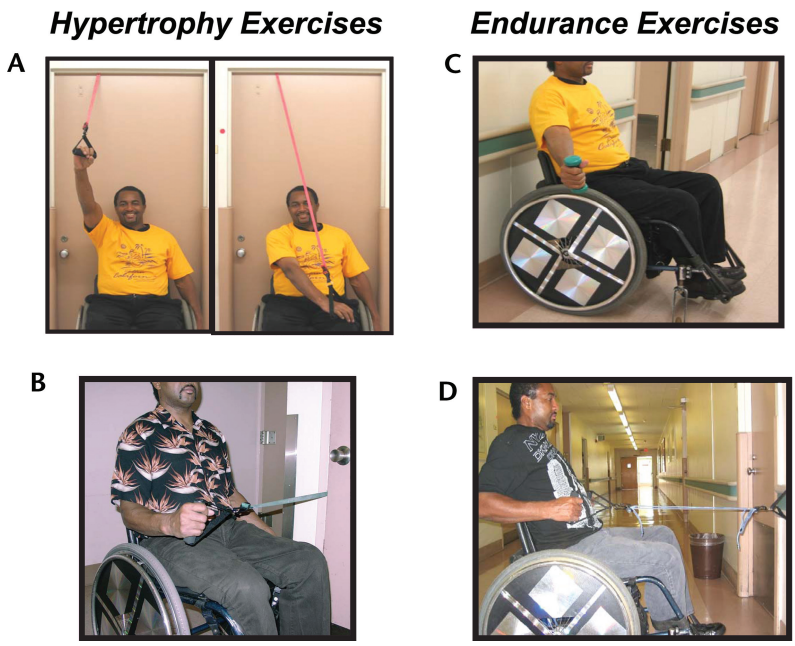


**Figure 2.**
Muscle strengthening exercises. Hypertrophy exercises using an 8-repetition maximum resistance for (A) shoulder adduction and (B) shoulder external rotation. Endurance exercises using a 15-repetition maximum resistance for (C) shoulder elevation in the scapular plane and (D) scapular retraction.

Movement optimization recommendations were aimed at reducing the risk of shoulder injury. All participants were provided with a list of 10 recommendations to improve performance and efficiency of transfers and depression raises and a list of 9 recommendations to optimize wheelchair propulsion (eAppendix 2; available at ptjournal.apta.org) and received verbal reinforcement of the concepts. The transfer and raise maneuver recommendations focused primarily on modification of the height of the transfer surface or positioning of the hand, arm, and trunk. Recommendations for optimal wheelchair propulsion performance focused on propulsion technique and energy conservation. Participants were asked to demonstrate performance of those activities that provoked shoulder pain. The intervention physical therapist assessed their task performance observationally and emphasized those specific recommendations (eAppendix 2) for the related activities.

**Attention control group.** The attention control intervention was designed as a sham intervention to give participants time and attention from a clinician. Participants randomly assigned to this group viewed a 1-hour instructional video emphasizing shoulder anatomy, mechanisms of injury, and general concepts in managing shoulder pain. A handout on the video and an educational brochure regarding general shoulder care were provided to all attention control group participants. The information was intentionally general and did not contain recommendations to change behavior.

## Outcomes and Follow-up

All measurements were conducted by physical therapists who were trained to perform standardized assessment procedures (required

to score >90% on a standardization score sheet that included all components of each procedure) and kept blinded to group assignment. Outcome measures for each participant were assessed by the same physical therapist at baseline, at the end of the 12-week intervention, and again at 4 weeks after the end of the intervention. We used the World Health Organization's *International Classification of Functioning, Disability and Health* (ICF) model as a theoretical framework for selecting our outcome measures.[42] The primary outcome measure was the presence and severity of shoulder pain (in the body function and structures domain of the ICF), as measured by the Wheelchair User's Shoulder Pain Index (WUSPI).[43] The WUSPI is an aggregate index of participant-reported intensity of shoulder pain during 15 different activities, including transfers, activities of daily living, and mobility, performed from a wheelchair. The questionnaire utilizes a series of visual analog scales (VASs) consisting of 10-cm lines anchored by "no pain" and "worst pain ever experienced," with a maximum total score of 150. The WUSPI has been shown to be both reliable and valid for people with SCI.[44]

Secondary outcome measures within the ICF domain of body function and structures included a single-item VAS (0–10 cm) for rating shoulder pain[45] and measures of shoulder strength. Muscle strength was assessed by measuring maximal force production with a Micro-FET handheld dynamometer[†] (HHD) during resisted isometric contractions of the following shoulder motions: elevation in the plane of the scapula, adduction, internal rotation, and external rotation. Measurement of shoulder muscle force production using an HHD has been shown to be highly reliable in people with SCI, with intraclass correlation coefficients for intrarater reliability from .89 to .96.[46] Torque values were calculated by multiplying the maximal forces by the distance of the lever arms used for resistance.

Secondary outcome measures assessing the ICF domain of activities included self-selected wheelchair propulsion speed over a 25-m distance and the Physical Activity Scale for Individuals With Physical Disabilities (PASIPD).[47] The PASIPD assesses how physically active a person has been in the previous week and was designed for people who have a disability. It covers leisure-time activities, household activities, and work-related demands.[47]

The ICF domain of participation was addressed by measuring community involvement and QOL using the Social Interaction Inventory (SII) (formerly called the Community Activities Checklist),[48] the 36-Item Short-Form Health Survey (SF-36) questionnaire,[49] and the Subjective Quality of Life Scale (SQOL).[48] The SII is a 16-item questionnaire that asks people to indicate how many times during the previous 7 days they engaged in a range of specified social activities, with a possible range of scores from 0 to 84.[48] Its test-retest reliability is .87 over a 3-week interval, and it has proven to be a valid outcome measure for interventions designed to improve functioning among people with a disability, including those with an SCI.[50] The SF-36 is one of the most widely used health status evaluation tools and has been proven valid.[49] The instrument consists of 36 questions that require respondents to rate items related to 8 conceptual areas, including general health, ability to perform certain physical tasks, level of pain, emotional state, and limitations in usual activities. The SQOL was developed to assess a person's self-reported rating of overall QOL.[48] The SQOL uses a 7-point Likert scale with a low rating of 1 and a high rating of 7. Descriptors anchor the low end ("Life is very distressing"), the high end ("Life is great"), and the middle ("Life is so-so"). Participants are asked to make an overall rating of their current life, taking everything into account. It has shown both good validity and reliability and has been shown to correlate negatively with measures of depression and positively with measures of life satisfaction.[51]

## Statistical Analyses

Power analysis using a repeated-measures analysis of variance (ANOVA) design (power=80%, with a one-tailed $P$ value of .05) determined that 30 participants for each intervention group were required to detect a significant difference in change of WUSPI scores between groups with a medium effect size (d=0.65, effect size=between-groups difference in mean change scores divided by the pooled standard deviation). To compensate for expected attrition, we planned to enroll 40 participants per group.

Statistical analyses were conducted at the .05 significance level using SPSS (version 12.0).[‡] Data were screened for normality using the Shapiro-Wilks test. Demographic and medical history characteristics were compared between the exercise/movement optimization and attention control groups using ANOVAs for means and chi-square or Fisher tests for proportions.

Primary analyses of the outcome measures (WUSPI, VAS, shoulder torque, PASIPD, SII, SF-36, and SQOL) were conducted using data from the baseline and immediate postintervention assessments. Because our

[†] Hoggan Health Industries, 8020 South 1300 West, West Jordan, UT 84088.

[‡] SPSS Inc, 233 S Wacker Dr, Chicago, IL 60606.

primary purpose was to establish the effects and functional impact of our intervention, we elected to complete the primary analyses on the evaluable participants (ie, those participants who completed the intervention and returned for the immediate postintervention assessment). Repeated-measures ANOVA models were used to determine the interaction effects of intervention group and time (baseline versus immediate postintervention). A one-sided test was used because we hypothesized that there would be greater improvement in the exercise/movement optimization group than in the attention control group and we considered results of no difference or in the opposite direction as lack of support for our hypothesis. When a significant interaction between group and time was identified, *post hoc* comparisons were conducted to determine whether the changes over time were significant within each intervention group. Similar analyses were conducted to evaluate the difference in shoulder pain outcomes in response to the exercise/movement optimization intervention between participants who demonstrated specific pain-inducing activities and those who did not and to evaluate the persistence of the treatment effects at 4 weeks for all outcomes in both intervention groups. In the latter case, each outcome variable was compared over time between the immediate postintervention assessment and the final assessment 4 weeks later.

We also report the results of an intention-to-treat (ITT) analysis of all randomized participants across the 3 assessment times using a mixed linear model analysis to accommodate missing values. The means at each time interval using the ITT analysis include values from all participants regardless of whether they completed the invervention or subsequent outcome assessments. Intervention group and time were included in the model as fixed effects, and the intercept of the dependent variable at baseline across participants was the random effect.

### Role of the Funding Source

Funding for this randomized controlled trial was provided by the Foundation for Physical Therapy as part of the first clinical research network, PTClinResNet, and by the National Institute on Disability and Rehabilitation Research as part of the Rehabilitation Research and Training Center (RRTC) on Aging With a Disability.

## Results

### Participant Recruitment, Retention, and Demographics

Eligible participants were recruited from outpatient clinics at RLANRC from March 2004 to December 2005. Figure 3 shows the consort flow diagram. Among the 127 individuals screened for eligibility, a total of 80 participants (40 per intervention arm) were eligible for randomization and gave written informed consent. Table 1 summarizes the demographic and clinical characteristics for the 80 randomized participants, stratified by intervention assignment. No statistically significant baseline differences were found between the intervention groups except for race ($P=.03$) and high versus low paraplegia (T2–T7 versus T8 and below) ($P=.01$). Greater percentages of participants in the exercise/movement optimization group were African American (20%) and had high-level paraplegia (T2–T7) (67%) than in the attention control group (5% and 40%, respectively). Overall, 57 (71%) of the participants were men, and the average (SD) age was 45.0 (11.2) years. Sixty-four of the 80 participants had motor complete (AIS A or B)[52] spinal injuries. The average (SD) durations of SCI and shoulder pain were 20 (11) years and 66 (80) months, respectively. The majority of participants in both groups (83%) exhibited positive clinical signs for subacromial impingement.[38,53,54]

### Adverse Events and Adherence

Of the 80 participants who were randomized into an intervention group, 9 (11%) withdrew from the study prior to receiving the intervention (5 in the exercise/movement optimization group and 4 in the attention control group) (Fig. 3). One participant in the exercise/movement optimization group developed a pressure ulcer, and 1 participant in the attention control group withdrew because of unexplained weight loss. The remaining 7 participants were lost to follow-up. An additional 13 participants (16%) withdrew from the study before completing the 12-week intervention period (9 in the exercise/movement optimization group and 4 in the attention control group). Of the 9 participants who withdrew from the intervention in the exercise/movement optimization group, 6 were lost to follow-up, and 3 dropped out and cited reasons of: (1) a perception that the exercises were causing neck pain, (2) renewal of outpatient physical therapy sessions following a fall in the community unrelated to the study, and (3) an infected spider bite. Reasons for withdrawal in the attention control group were: 3 participants were lost to follow-up, and 1 participant developed a deep vein thrombosis. Six additional participants in the attention control group withdrew from the study after completing the immediate postintervention assessment but prior to the 4-week follow-up assessment. Five of the 6 participants were lost to follow-up, and 1 individual died from aortic dissection. No significant differences in demographics or baseline outcome measures existed between participants who withdrew and those who completed the immediate postintervention evaluation.

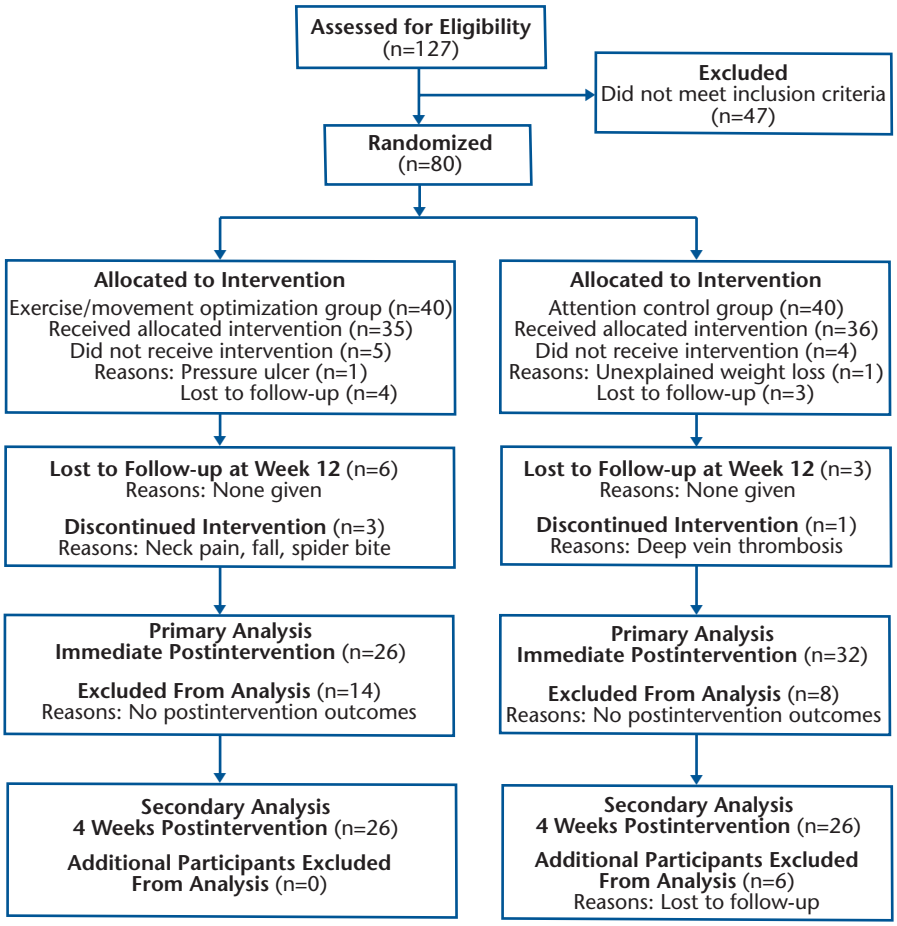


**Figure 3.**
CONSORT flow diagram for the Strengthening and Optimal Movements for Painful Shoulders (STOMPS) trial.

Adverse events (AEs) were monitored and reported according to the protocol approved by the Data Monitoring and Safety Committee. There were 27 cumulative AEs that occurred in 23 participants. The proportion of participants experiencing any AE was similar in the exercise/movement optimization group and the attention control group: 12 (30%) and 11 (28%), respectively. Two AEs (increased neck pain and elbow abrasion) were related to the study and occurred in the exercise/movement optimization group. The remaining 25 AEs were not related to the study, and 9 were considered serious. Serious, non–study-related AEs associated with the exercise/movement optimization group were: a breast biopsy and lumpectomy, bladder surgery, wrist surgery secondary to carpal tunnel syndrome, a pressure ulcer requiring hospitalization, and a kidney infection requiring hospitalization. The exercise program was interrupted temporarily for 2 participants who had serious non–study-related AEs. The remaining serious AEs occurred after the intervention was completed (n=2) or was the reason for withdrawal (n=1). Serious, non–study-related AEs associated with the attention control group were: a death due to aortic dissection, abdominal surgery and gall bladder removal, bilateral shoulder pain following a wheelchair-related accident in the home, and a femur fracture requiring bracing following a fall.

Non–study-related, nonserious AEs in the exercise/movement optimization group were: a fall (n=2), a leg ulcer (n=1), starting smoking (n=1), a spider bite developing into an abscess (n=1), a bladder infection (n=1), wrist pain (n=1), and a urinary tract infection (n=1). Non–study-related, nonserious AEs in the attention control group were: shoulder pain (n=1), a fall (n=3), an emergency cholecystectomy (n=1), a deep vein thrombosis (n=1), unexplained weight loss (n=1), and migraine and neck pain (n=1).

Four people (out of 26) in the exercise/movement optimization group were unable to demonstrate adequate performance of the exercises at the reassessment 4 weeks after

beginning the intervention. Two of 4 participants who required additional instruction in exercise performance demonstrated an increase in resistance for the 8- and 15-repetition maximum levels in all 4 exercises, indicating at least partial adherence. One participant increased resistance in only 1 of 4 exercises, and the other person did not increase the resistance in any of the exercises, indicating likely nonadherence to the exercise program.

## Outcomes at Baseline and Immediately Postintervention

**Movement optimization.** Of the 35 participants who received the exercise/movement optimization intervention, 17 individuals demonstrated specific activities that provoked shoulder pain and received instruction from the intervention therapist in how to modify their movement performance technique to reduce stress on the shoulder. Transfers were modified in 12 participants, with specific recommendations to avoid internal rotation of the shoulder, to keep hands on transfer surfaces, to lead with the painful arm, to lean the trunk forward, and to use a stool for an intermediate surface when the target transfer surface was significantly higher or lower than the wheelchair. Wheelchair propulsion technique or setup was modified in 6 participants, with specific recommendations to move the rear wheel axle forward, to avoid inclines, and to consider a lightweight wheelchair.

**Table 1.**
Baseline Demographic and Medical History Characteristics Stratified by Randomization Groups (N=80)[a]

| Variable | Exercise/Movement Optimization Group (n=40) | Attention Control Group (n=40) | P[b] |
|---|---|---|---|
| Demographics | | | |
| Sex: male | 31 (78%) | 26 (65%) | .22 |
| Age (y) | 47 (9) | 47 (12) | .16 |
| Latino or Hispanic | 21 (53%) | 23 (57%) | .65 |
| Race | | | **.03** |
| Black or African American | 8 (20%) | 2 (5%) | |
| White | 18 (45%) | 19 (48%) | |
| Unspecified or other | 14 (35%) | 19 (48%) | |
| Medical history | | | |
| Neurological classification of SCI[52] | | | .49 |
| AIS A | 25 (62%) | 25 (62%) | |
| AIS B | 9 (23%) | 5 (13%) | |
| AIS C | 3 (8%) | 5 (13%) | |
| AIS D | 1 (2%) | 1 (2%) | |
| Unknown | 2 (5%) | 4 (10%) | |
| High paraplegia (T2–T7) | 27 (67%) | 16 (40%) | **.02** |
| Low paraplegia (T8 and below) | 13 (33%) | 24 (60%) | |
| Duration of spinal injury (y) | 17.9 (9.2) | 22.3 (11.8) | .07 |
| Duration of shoulder pain (mo) | | | |
| Right side | 66 (69) | 65 (94) | .95 |
| Left side | 71 (61) | 61 (97) | .65 |
| Special tests | | | |
| Empty Can Test | 24 (60%) | 20 (50%) | .37 |
| Drop Arm Test | 2 (5%) | 1 (3%) | .51 |
| Resisted external rotation | 22 (55%) | 18 (45%) | .31 |
| Hawkins-Kennedy Test | 18 (45%) | 19 (48%) | .92 |
| At least one of above tests | 32 (80%) | 34 (85%) | .56 |
| Speed's test | 18 (45%) | 10 (25%) | .07 |

[a] Values are mean (SD) for continuous variables, frequency (%) for categorical variables. Chi-square test was used for categorical variables, and one-way analysis of variance was used for continuous variables. AIS=American Spinal Injury Association Impairment Scale, SCI=spinal cord injury.
[b] Values in bold type were significant at $P<.05$.

**Bodily function.** The primary outcome measure of WUSPI scores and secondary outcome measures of single-item VAS scores, shoulder torques, PASIPD scores, wheelchair propulsion speed, and SII, SF-36, and SQOL scores are summarized in Table 2. Data are reported as mean and standard deviation. Analysis of the WUSPI scores identified a significant interaction between intervention group and time ($P<.001$). Shoulder pain, as measured with the WUSPI, was reduced at the immediate postintervention assessment in the exercise/movement optimization group to approximately one third of the baseline values (from 51.2±33.0 to 14.9±14.0, $P<.001$), but was unchanged for those in the attention control group (from 45.4±38.8 to 45.6±38.2) (Fig. 4). The single-item VAS measure of overall shoulder pain also was reduced to one third of baseline values in the exercise/movement optimization group (from 5.1±2.8 to 1.4±1.6, $P<.001$), but was not significantly reduced for those in the attention control group (from 4.7±2.7 to 4.2±2.7) (Tab. 2).

Those participants in the exercise/movement optimization group who received specific instruction to modify their performance technique of an UE activity had higher scores on the WUSPI at baseline than those who did not receive specific instruction (68.1±28 versus 38.6±30, $P=.04$). Pain levels on the WUSPI were similar, however, at the immediate postintervention assessment, regardless of whether specific movement optimization instruction was received (16.1±14 versus 14.8±14, $P=.81$).

For the shoulder torque measurements, strength gains were significantly greater in the exercise/movement optimization group than in the attention control group for all 4 motions tested ($P<.01$ to .05). In addition, although the magnitudes of the strength gains were moderate (18%–32% improvement from baseline), all muscle groups demonstrated a statistically significant increase in maximal torque production following the intervention in the exercise/movement optimization group ($P>.05$).

**Activity and participation.** Physical activity (PASIPD scores) and wheelchair propulsion speed were not significantly changed after the intervention in either group (Tab. 2). Community activity, as measured with the SII, showed a significant interaction between group and time, with a greater increase for the exercise/movement optimization group than for the attention control group ($P<.03$). Although the average SII scores increased 8.6±32.8 points in the exercise/movement optimization group, the improvements were not consistent and, consequently, *post hoc* testing did not show a statistically significant improvement ($P=.06$). Overall SQOL scores increased 10% following the intervention for participants in the exercise/movement optimization group (4.8±1.3 to 5.3±0.9, $P=.04$), but were unchanged for those in the attention control group (5.0±1.4) at both baseline and immediate postintervention assessments. All of the SF-36 subscales except for general health and vitality demonstrated a statistically significant interaction between participant group and time, with improvement in scores for participants in the exercise/movement optimization group and no change for the attention control group (Tab. 3). The largest improvements were seen in the SF-36 subscales of bodily pain (+7.4, SD=11.6), role-physical (physical limitations in fulfilling life roles) (+5.8, SD=8.2), and social functioning (+5.5, SD=10.2) ($P<.05$).

### Outcomes at 4-Week Postintervention Follow-up

The reduction in shoulder pain for participants in the exercise/movement optimization group was maintained at the 4-week postintervention follow-up assessment (Tab. 3, Fig. 4). For participants in the attention control group, the high levels of shoulder pain recorded at the immediate postintervention assessment were not significantly reduced at the 4-week follow-up assessment (Tab. 3). Community activity levels, overall SQRL scores, and SF-36 scores also were unchanged in both groups from the immediate postintervention assessment to the 4-week follow-up evaluation (Tab. 3).

Approximately half of the participants in the attention control group requested and received the exercise/movement optimization intervention at the end of the 4-week follow-up assessment. This intervention was documented only anecdotally because it was not a formal part of the STOMPS trial, and no follow-up assessment was planned.

### Intention-to-Treat Analysis

Results of the ITT analysis of all 80 randomized participants across the 3 assessments were similar to those of the primary analysis, which included only participants who completed the intervention. In the ITT analysis, greater improvement was seen in the exercise/movement optimization group than in the attention control group for isometric shoulder torques (except for external rotation) and scores on the WUSPI, single-item VAS, PASIPD (physical activity), SQOL, SF-36 physical component score, and SF-36 subscales of bodily pain, role-physical, and social functioning (Tab. 4). There were no significant differences between groups in response to the intervention using the ITT analysis for the external rotation torque, wheelchair propulsion speed, the SII, the SF-36 mental component score, and the remaining SF-36 subscales.

## Discussion

We demonstrated a marked reduction in shoulder pain levels in individuals with SCI using a relatively simple home exercise intervention coupled with assessment and modification of performance technique for several UE weight-bearing activities. Consequently, this study provides the only evidence from a randomized controlled trial for the effectiveness of an intervention that includes exercise in reducing chronic shoulder pain in individuals with SCI. The magnitude of the pain reduction is particularly noteworthy, given that the participants' average duration of shoulder pain was greater than 5 years (65.7 months). Moreover, the extent of pain reduction demonstrated in this study is more than 2 times greater than the estimate of a minimal clinically important reduction of chronic pain in patients treated for rotator cuff disease (1.4 cm on a 10-cm VAS).[55]

**Table 2.**
Mean Change in Outcomes From Baseline (Preintervention) Assessment to Immediate Postintervention Assessment Based on 2-Group Analysis of Evaluable Data[a]

| Outcome Measure | Exercise/Movement Optimization Group (n=26) | Attention Control Group (n=32) | Interaction Between Group and Time | |
|---|---|---|---|---|
| | | | *P*[b] | Effect Size |
| WUSPI | | | | |
| Preintervention | 51.2 (33.0) | 45.4 (38.8) | | |
| Postintervention | 14.9 (14.0) | 45.6 (38.2) | **<.001** | −1.2 |
| Change | **−36.3[c] (34.7)** | **0.2 (28.3)** | | |
| 95% CI | −48.5 to 23.7 | −11.2 to 11.2 | | |
| Single-item VAS | | | | |
| Preintervention | 5.1 (2.8) | 4.7 (2.7) | | |
| Postintervention | 1.4 (1.6) | 4.2 (2.7) | **<.001** | −1.2 |
| Change | **−3.7[c] (3.3)** | **−0.5 (2.1)** | | |
| 95% CI | −2.3 to 5.0 | −1.3 to 1.9 | | |
| Shoulder torque (N·m) | | | | |
| Adduction | | | | |
| Preintervention | 60.5 (31.8) | 61.0 (33.2) | | |
| Postintervention | 74.2 (28.3) | 63.3 (19.0) | **.05** | 0.48 |
| Change | **14.3[c] (20.0)** | **2.3 (28.8)** | | |
| 95% CI | 3.5 to 23.9 | −6.9 to 11.4 | | |
| Elevation (scapular plane) | | | | |
| Preintervention | 37.3 (22.5) | 42.3 (20.5) | | |
| Postintervention | 49.3 (21.8) | 44.7 (21.1) | **.01** | 0.69 |
| Change | **12.0[c] (17.3)** | **2.4 (9.5)** | | |
| 95% CI | 6.5 to 17.6 | −2.5 to 7.4 | | |
| Internal rotation | | | | |
| Preintervention | 33.2 (16.7) | 33.7 (14.6) | | |
| Postintervention | 41.7 (19.3) | 32.8 (13.5) | **.01** | 0.69 |
| Change | **8.5[c] (16.2)** | **−0.9 (10.7)** | | |
| 95% CI | 3.1 to 12.9 | −5.8 to 4.0 | | |
| External rotation | | | | |
| Preintervention | 25.8 (9.9) | 26.3 (11.2) | | |
| Postintervention | 30.5 (12.2) | 25.7 (11.3) | **.03** | 0.53 |
| Change | **4.7[c] (8.5)** | **−0.6 (11.2)** | | |
| 95% CI | 0.7 to 8.8 | −4.2 to 3.0 | | |
| PASIPD | | | | |
| Preintervention | 13.8 (12.6) | 16.2 (11.2) | | |
| Postintervention | 15.3 (9.0) | 14.9 (9.8) | .16 | 0.27 |
| Change | 1.5 (12.2) | −1.3 (8.9) | | |
| 95% CI | −2.9 to 5.7 | −5.1 to 2.5 | | |

*(Continued)*

**Table 2.**
Continued

| Outcome Measure | Exercise/Movement Optimization Group (n=26) | Attention Control Group (n=32) | Interaction Between Group and Time | |
|---|---|---|---|---|
| | | | *P*[b] | Effect Size |
| Wheelchair propulsion speed (m/s) | | | | |
| Preintervention | 1.5 (0.4) | 1.6 (0.4) | | |
| Postintervention | 1.5 (0.3) | 1.6 (0.4) | .45 | 0.14 |
| Change | 0.0 (0.2) | 0.0 (0.2) | | |
| 95% CI | −0.1 to 0.1 | −0.1 to 0.1 | | |
| Social Interaction Inventory | | | | |
| Preintervention | 44.8 (24.4) | 46.9 (35.1) | | |
| Postintervention | 53.3 (30.6) | 40.8 (16.6) | **.03** | 0.48 |
| Change | **8.6 (32.8)** | **−6.1 (28.7)** | | |
| 95% CI | −2.3 to 19.5 | −15.9 to 3.7 | | |
| Subjective Quality of Life Scale | | | | |
| Preintervention | 4.8 (1.3) | 5.0 (1.4) | | |
| Postintervention | 5.3 (0.9) | 5.0 (1.4) | **.04** | 0.51 |
| Change | **0.5[c] (0.7)** | **0.0 (1.2)** | | |
| 95% CI | 0.1 to 0.8 | −0.4 to 0.3 | | |
| SF-36 subscales | | | | |
| Physical function | | | | |
| Preintervention | 29.5 (7.8) | 28.7 (8.5) | | |
| Postintervention | 32.1 (7.2) | 28.4 (6.5) | **.05** | 0.44 |
| Change | **2.6[c] (7.2)** | **−0.3 (6.0)** | | |
| 95% CI | 0.0 to 5.1 | −2.7 to 2.0 | | |
| Role–physical | | | | |
| Preintervention | 41.4 (6.4) | 43.9 (11.8) | | |
| Postintervention | 47.2 (9.0) | 41.1 (9.0) | **.01** | 1.45 |
| Change | **5.8[c] (8.2)** | **−2.8 (1.9)** | | |
| 95% CI | 1.7 to 9.8 | −6.5 to 0.9 | | |
| Bodily pain | | | | |
| Preintervention | 39.1 (10.0) | 41.0 (9.2) | | |
| Postintervention | 46.5 (8.1) | 41.4 (10.3) | **.02** | 0.61 |
| Change | **7.4[c] (11.6)** | **0.4 (11.5)** | | |
| 95% CI | 2.9 to 11.9 | −3.7 to 4.5 | | |
| General health | | | | |
| Preintervention | 47.7 (8.6) | 46.5 (12.7) | | |
| Postintervention | 49.5 (8.5) | 46.0 (9.7) | .16 | 0.27 |
| Change | 1.8 (8.2) | −0.5 (9.1) | | |
| 95% CI | −1.6 to 5.2 | −3.6 to 2.2 | | |
| Physical Component Score | | | | |
| Preintervention | 35.7 (8.6) | 36.2 (9.4) | | |
| Postintervention | 40.0 (6.6) | 35.7 (7.3) | **.02** | 0.57 |
| Change | **4.3[c] (7.9)** | **−0.5 (8.8)** | | |
| 95% CI | 0.8 to 7.6 | −3.5 to 2.5 | | |

*(Continued)*

**Table 2.**
Continued

| Outcome Measure | Exercise/Movement Optimization Group (n=26) | Attention Control Group (n=32) | Interaction Between Group and Time | |
|---|---|---|---|---|
| | | | *P*[b] | Effect Size |
| Role–emotional | | | | |
| Preintervention | 44.8 (11.8) | 45.6 (12.1) | | |
| Postintervention | 48.6 (11.1) | 44.5 (11.4) | **.04** | 0.46 |
| Change | **3.8 (12.3)** | **−1.1 (8.6)** | | |
| 95% CI | −0.4 to 7.9 | −4.8 to 2.7 | | |
| Mental health | | | | |
| Preintervention | 48.2 (12.0) | 49.0 (11.8) | | |
| Postintervention | 52.4 (8.4) | 46.8 (12.6) | **.03** | 0.54 |
| Change | **4.2[c] (11.8)** | **−2.2 (11.9)** | | |
| 95% CI | 0.0 to 8.6 | −6.4 to 2.0 | | |
| Vitality | | | | |
| Preintervention | 51.5 (7.6) | 49.9 (10.4) | | |
| Postintervention | 53.9 (9.2) | 48.3 (11.6) | .07 | 0.39 |
| Change | 2.4 (11.1) | −1.6 (9.4) | | |
| 95% CI | −1.7 to 6.4 | −5.3 to 2.0 | | |
| Social functioning | | | | |
| Preintervention | 44.9 (8.7) | 43.7 (14.2) | | |
| Postintervention | 50.4 (8.6) | 42.4 (13.4) | **.01** | 0.61 |
| Change | **5.5[c] (10.2)** | **−1.3 (12.2)** | | |
| 95% CI | 1.0 to 9.9 | −5.4 to 2.7 | | |
| Mental Component Score | | | | |
| Preintervention | 52.7 (12.4) | 52.5 (13.5) | | |
| Postintervention | 56.3 (10.4) | 50.6 (14.1) | **.04** | 0.47 |
| Change | **3.6 (12.2)** | **−1.9 (11.3)** | | |
| 95% CI | −1.1 to 8.2 | −6.0 to 2.3 | | |

[a] Data are mean (SD) unless otherwise indicated. WUSPI=Wheelchair User's Shoulder Pain Index, VAS=visual analog scale, PASIPD=Physical Activity Scale for Individuals With Physical Disabilities, SF-36=36-Item Short-Form Health Survey questionnaire, postintervention=immediately after 12-week intervention, 95% CI=95% confidence interval.
[b] *P* values for between-group comparison were obtained from the interaction of treatment group and time using a repeated-measures analysis of variance. Values in bold type were significant at $P<.05$
[c] Within-group *P* values were significant at $P<.05$ with *post hoc* testing using a paired *t* test.

Although the exercise/movement optimization intervention significantly reduced shoulder pain levels, participants in this group did not demonstrate increases in the physical activity or community activity measures (wheelchair propulsion speed, PASIPD scores, and SII scores). This finding is contrary to our hypothesis and what would be expected, given the findings of Gutierrez and colleagues,[14] who documented a significant correlation between shoulder pain levels and both physical activity and community activity scores. However, the improvement seen in health-related QOL, particularly in scores on the role–physical and social functioning subscales of the SF-36, suggests that the reduction in shoulder pain allowed individuals to more successfully complete their social and life role activities. This discrepancy in results might reflect differences between outcome measures in the quantification of activity. Both the PASIPD and the SII measure the frequency of performing specific activities (prespecified by the test designer), whereas the SF-36 permits the respondent to assess social activities and life roles in general to reflect those that are pertinent.

The results of our randomized controlled trial generally are consistent with the few studies in the literature that investigated the impact of an

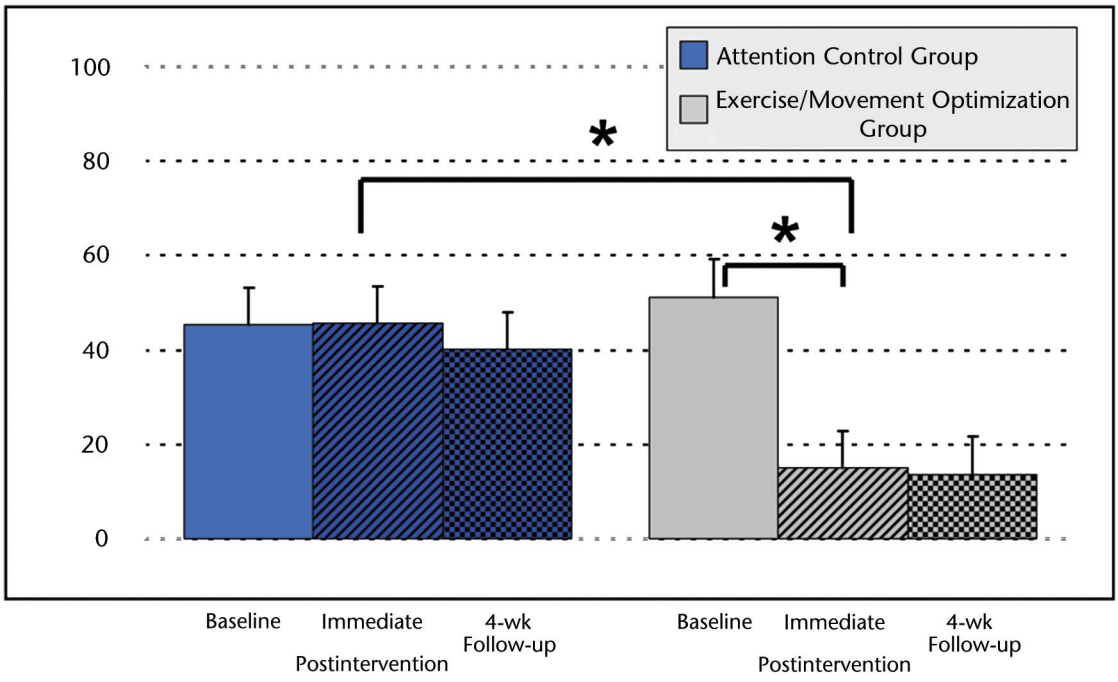


**Figure 4.**
Bar graphs of shoulder pain as measured by Wheelchair User's Shoulder Pain Index (WUSPI) scores (mean±SD) over time (baseline, immediate postintervention, 4-week follow-up) by group (attention control group: blue bars; exercise/movement optimization group: gray bars). There was a statistically significant interaction between intervention group and time (baseline to immediate postintervention, $P<.001$) and a statistically significant reduction in the exercise/movement optimization group (baseline to immediate postintervention, $P<.001$). There were no changes in WUSPI scores for the attention control group at any time interval. Reduction in WUSPI scores was maintained at the 4-week follow-up assessment. Asterisk indicates $P<.0001$.

exercise program on shoulder pain in individuals with SCI.[23–25] The similarities and differences in muscle strengthening protocols between this study and prior investigations are worth noting. Our goal was to develop an exercise program that was effective, required minimal equipment, and was brief enough to minimize the added burden on participants who already have heavy self-care demands. The rotator cuff muscles were the primary focus of our strengthening protocol in this trial, which was most similar to that used in the study by Curtis and colleagues.[23] The primary difference in protocols between the 2 studies was that strengthening exercises were performed 3 times per week in the STOMPS trial and daily in the study by Curtis et al. In addition to possible overtraining with daily exercise, the more modest reduction in shoulder pain seen in the study by Curtis and colleagues was likely related to mild levels of initial shoulder pain, with only 50% of participants having shoulder pain at entry into the study.

The strengthening exercises used by Nawoczenski and colleagues[24] focused primarily on scapular muscles using electromyographic-guided exercise prescription, but also included an exercise for the shoulder external rotator muscles. The magnitude of shoulder pain reduction documented in the study by Nawoczenski et al was similar to that found in the STOMPS trial. In contrast, Nash and colleagues[25] utilized a gym-based circuit resistance training program with exercises designed for overall strength and power building as part of a general fitness program. On average, the participants in their study had less-severe initial shoulder pain than those in the STOMPS trial (initial WUSPI score of 32 versus 48, respectively). Based on our clinical experience, individuals with moderate to severe shoulder pain do not tolerate typical power-building exercises with UE weight bearing, such as dips, at least initially, until their pain levels have subsided. Therefore, at least some of the participants enrolled in the STOMPS trial who initially had greater pain severity may not have been able to tolerate the protocol proposed by Nash et al.[25]

One unique characteristic of the intervention tested in the STOMPS trial was the inclusion of the movement optimization component. The goal of this portion of the intervention was to reduce both the forces transmitted to the shoulder joint and the magnitude of demands on the

**Table 3.**
Mean Change (SD) for Outcomes From Immediate Postintervention Assessment to 4-Week Follow-up Assessment Based on 2-Group Analysis of Evaluable Data[a]

| Outcome Measure | Exercise/Movement Optimization Group (n=26) | Attention Control Group (n=26) | Interaction Between Group and Time *P*[b] |
|---|---|---|---|
| WUSPI | | | .34 |
| Postintervention | 14.9 (14.0) | 45.4 (37.3) | |
| 4-wk follow-up | 14.0 (15.2) | 39.3 (33.5) | |
| Change | −0.9 (34.7) | −6.1 (28.3) | |
| Subjective Quality of Life Scale | | | .56 |
| Postintervention | 5.3 (0.9) | 4.9 (1.4) | |
| 4-wk follow-up | 5.5 (0.9) | 4.9 (1.4) | |
| Change | 0.2 (0.9) | 0.0 (1.2) | |
| Social Interaction Inventory | | | .33 |
| Postintervention | 53.3 (30.6) | 40.5 (16.6) | |
| 4-wk follow-up | 46.7 (22.9) | 40.0 (13.9) | |
| Change | −6.6 (27.0) | 0.5 (12.3) | |
| SF-36 subscales | | | |
| Physical function | | | .27 |
| Postintervention | 32.1 (7.2) | 28.9 (6.8) | |
| 4-wk follow-up | 31.0 (7.1) | 29.7 (8.7) | |
| Change | −1.1 (5.9) | 0.8 (6.0) | |
| Role–physical | | | .36 |
| Postintervention | 47.2 (9.0) | 42.2 (9.3) | |
| 4-wk follow-up | 46.3 (9.0) | 42.8 (9.0) | |
| Change | −0.9 (9.2) | 0.6 (1.9) | |
| Bodily pain | | | .93 |
| Postintervention | 46.5 (8.1) | 41.0 (9.2) | |
| 4-wk follow-up | 47.4 (9.6) | 41.4 (10.3) | |
| Change | 0.9 (9.2) | 0.4 (11.5) | |
| Physical Component Score | | | .73 |
| Postintervention | 40.0 (6.6) | 36.4 (7.4) | |
| 4-wk follow-up | 39.2 (7.2) | 36.3 (8.0) | |
| Change | −0.8 (7.9) | −0.1 (8.8) | |
| Role–emotional | | | .76 |
| Postintervention | 48.9 (11.1) | 45.4 (10.9) | |
| 4-wk follow-up | 49.7 (11.7) | 47.4 (12.1) | |
| Change | 0.8 (12.3) | 2.0 (8.6) | |
| Mental health | | | .47 |
| Postintervention | 52.4 (8.4) | 47.1 (12.8) | |
| 4-wk follow-up | 52.4 (10.2) | 48.5 (12.1) | |
| Change | 0.0 (11.8) | 1.4 (11.9) | |

*(Continued)*

**Table 3.**
Continued

| Outcome Measure | Exercise/Movement Optimization Group (n=26) | Attention Control Group (n=26) | Interaction Between Group and Time *P*[b] |
|---|---|---|---|
| Social functioning | | | |
| Postintervention | 50.4 (8.6) | 41.7 (14.2) | .06 |
| 4-wk follow-up | 47.0 (10.7) | 44.9 (10.8) | |
| Change | −3.4 (13.4) | 3.2 (12.2) | |
| Mental Component Score | | | |
| Postintervention | 52.7 (12.4) | 52.5 (13.5) | .33 |
| 4-wk follow-up | 56.3 (10.4) | 50.6 (14.1) | |
| Change | 3.6 (12.2) | −1.9 (11.3) | |

[a] Data are mean scores (SD) unless otherwise indicated. Postintervention=immediately after 12-week intervention, WUSPI=Wheelchair User's Shoulder Pain Index, SF-36=36-Item Short-Form Health Survey questionnaire.
[b] *P* values for between-group comparisons were obtained from the interaction of treatment group and time using a repeated-measures analysis of variance.

stabilizing muscles of the shoulder by providing evidence-based instruction to modify the technique used to perform activities that provoked shoulder pain. Participants who demonstrated a UE activity that provoked shoulder pain and received specific instruction to optimize task performance had baseline shoulder pain levels that were nearly twice as severe as those of participants who did not demonstrate a specific UE task. The intervention was effective despite the high levels of shoulder pain, and shoulder pain levels were similar in the 2 groups at the end of the 12-week intervention. The combination of improved muscular capacity through strengthening and decreased demands by modification of movement techniques likely reduced the risk of ongoing subacromial impingement during those activities performed on a daily basis after SCI for mobility and function. Because the 2 components of the intervention were not tested separately, however, it is not possible to determine the individual contributions of the exercise program and movement optimization instruction to the reduction of shoulder pain.

There are several limitations associated with the STOMPS trial. All of the outcomes except for isometric torques and wheelchair propulsion speed were self-reported measures, which could have been susceptible to bias from participants' expectations regarding treatment effectiveness or desire to please researchers. We do not believe this was a primary factor affecting outcomes because both interventions were presented to participants equally as potentially effective treatments, the magnitude of the changes in the experimental group was large, and outcomes unlikely to be improved with decreased shoulder pain did not change (eg, general health subscale of the SF-36). We also had a large dropout rate in both groups, but this loss was directly related to the intervention in only one participant. Participant dropout is not uncommon in research studies that require multiple visits over time for individuals with SCI, who face secondary medical complications and transportation difficulties.[56] The ITT analysis, however, confirmed the robustness of our findings despite the high dropout rate.

Among participants in the exercise/movement optimization group who completed the 12-week intervention and immediate follow-up evaluation, adherence to the exercise program was high, with only 2 participants (6%) noted as likely nonadherent. Because the exercise intervention was primarily a home-based program, however, measurement of adherence was indirect. We also did not document whether participants actually changed their movement performance after receiving the recommendations. Additionally, participants were allowed to continue the exercise component of the intervention after the 12-week period, so the 4-week follow-up assessment likely included outcomes from participants who continued performing the exercises as well as from those who stopped the program after 12 weeks. This instruction is reflective of clinical practice, however, where clients would be expected to continue the changes in movement technique and might choose to continue the shoulder exercises. Finally, additional studies would be needed to determine whether the results of this study can be generalized to individuals with tetraplegia, who have shoulder muscle weakness due to level of injury that may not respond to exercise.

**Table 4.**
Mean Change in Outcomes Over 3 Time Intervals—Preintervention, Immediately After 12-Week Intervention, and 4 Weeks Postintervention—Based on 2-Group Intention-to-Treat Analysis of All Data[a]

| Outcome Measure | Exercise/Movement Optimization Group[b] | Attention Control Group[c] | Interaction Between Group and Time *P*[d] |
|---|---|---|---|
| WUSPI | | | **<.001** |
| Preintervention | 53.7 (35.4) | 46.3 (37.3) | |
| Postintervention | 14.9 (14.0) | 45.6 (38.2) | |
| 4-wk follow-up | 13.7 (15.3) | 40.1 (32.8) | |
| Single-item VAS | | | **<.001** |
| Preintervention | 5.3 (2.7) | 4.8 (2.7) | |
| Postintervention | 1.4 (1.6) | 4.2 (2.7) | |
| 4-wk follow-up | 1.4 (1.5) | 3.9 (2.8) | |
| Shoulder torque (N·m) | | | |
| Adduction | | | **.05** |
| Preintervention | 57.6 (28.7) | 59.3 (31.4) | |
| Postintervention | 74.2 (28.3) | 63.3 (19.0) | |
| 4-wk follow-up | 75.0 (28.9) | 63.9 (19.2) | |
| Elevation (scapular plane) | | | **.03** |
| Preintervention | 38.4 (21.2) | 40.4 (19.8) | |
| Postintervention | 49.3 (21.8) | 44.7 (21.1) | |
| 4-wk follow-up | 51.4 (22.5) | 48.7 (18.7) | |
| Internal rotation | | | **.05** |
| Preintervention | 34.4 (16.3) | 32.8 (13.8) | |
| Postintervention | 41.7 (19.3) | 32.8 (13.5) | |
| 4-wk follow-up | 42.6 (15.1) | 38.5 (14.7) | |
| External rotation | | | .09 |
| Preintervention | 27.1 (10.8) | 25.3 (10.3) | |
| Postintervention | 30.5 (12.2) | 25.7 (11.3) | |
| 4-wk follow-up | 28.6 (8.8) | 29.7 (7.6) | |
| PASIPD | | | **.03** |
| Preintervention | 15.7 (12.2) | 16.7 (11.2) | |
| Postintervention | 15.3 (9.0) | 14.9 (9.8) | |
| 4-wk follow-up | 19.0 (15.4) | 13.7 (6.1) | |
| Wheelchair propulsion speed (m/s) | | | .70 |
| Preintervention | 1.5 (0.4) | 1.5 (0.4) | |
| Postintervention | 1.5 (0.3) | 1.6 (0.4) | |
| 4-wk follow-up | 1.4 (0.3) | 1.5 (0.4) | |
| Social Interaction Inventory | | | .14 |
| Preintervention | 45.7 (24.2) | 45.4 (32.8) | |
| Postintervention | 53.3 (30.6) | 40.8 (16.6) | |
| 4-wk follow-up | 46.7 (20.7) | 40.0 (13.9) | |
| Subjective Quality of Life Scale | | | **.05** |
| Preintervention | 4.8 (1.3) | 5.0 (1.4) | |
| Postintervention | 5.3 (0.9) | 5.0 (1.4) | |
| 4-wk follow-up | 5.4 (1.0) | 4.9 (1.4) | |

*(Continued)*

**Table 4.**
Continued

| Outcome Measure | Exercise/Movement Optimization Group[b] | Attention Control Group[c] | Interaction Between Group and Time *P*[d] |
|---|---|---|---|
| SF-36 subscale | | | |
| Physical function | | | |
| Preintervention | 29.9 (8.2) | 28.4 (8.4) | .28 |
| Postintervention | 32.1 (7.2) | 28.4 (6.5) | |
| 4-wk follow-up | 31.0 (7.1) | 29.7 (8.7) | |
| Role–physical | | | |
| Preintervention | 41.2 (7.9) | 42.6 (12.1) | **.01** |
| Postintervention | 47.2 (9.0) | 41.1 (9.0) | |
| 4-wk follow-up | 46.3 (9.5) | 42.8 (10.8) | |
| Bodily pain | | | |
| Preintervention | 37.6 (9.6) | 40.6 (9.3) | **.01** |
| Postintervention | 46.5 (8.1) | 41.4 (10.3) | |
| 4-wk follow-up | 47.4 (9.6) | 41.9 (8.5) | |
| General health | | | |
| Preintervention | 47.5 (8.6) | 45.3 (12.3) | .62 |
| Postintervention | 49.5 (8.5) | 46.0 (9.7) | |
| 4-wk follow-up | 48.8 (7.8) | 45.2 (8.8) | |
| Physical Component Score | | | |
| Preintervention | 35.2 (8.1) | 35.4 (9.4) | **.05** |
| Postintervention | 39.9 (6.5) | 35.7 (7.3) | |
| 4-wk follow-up | 39.2 (7.2) | 36.3 (8.0) | |
| Role–emotional | | | |
| Preintervention | 44.1 (11.2) | 45.5 (12.9) | .15 |
| Postintervention | 48.9 (11.1) | 44.5 (11.4) | |
| 4-wk follow-up | 49.7 (10.7) | 47.4 (12.1) | |
| Mental health | | | |
| Preintervention | 49.1 (10.3) | 48.3 (11.9) | .07 |
| Postintervention | 52.5 (8.4) | 46.8 (12.6) | |
| 4-wk follow-up | 52.4 (10.2) | 48.5 (12.1) | |
| Vitality | | | |
| Preintervention | 50.2 (7.4) | 49.6 (10.8) | .07 |
| Postintervention | 53.9 (9.2) | 48.3 (11.6) | |
| 4-wk follow-up | 55.5 (7.4) | 49.7 (11.0) | |
| Social functioning | | | |
| Preintervention | 44.3 (8.3) | 43.2 (14.7) | **.05** |
| Postintervention | 50.4 (8.6) | 42.4 (13.4) | |
| 4-wk follow-up | 47.0 (10.5) | 44.9 (10.8) | |
| Mental Component Score | | | |
| Preintervention | 52.5 (10.7) | 52.2 (13.8) | .12 |
| Postintervention | 56.6 (10.4) | 50.6 (14.1) | |
| 4-wk follow-up | 56.6 (11.3) | 54.5 (11.4) | |

[a] Data are mean (SD) unless otherwise indicated. WUSPI=Wheelchair User's Shoulder Pain Index, VAS=visual analog scale, PASIPD=Physical Activity Scale for Individuals With Physical Disabilities, SF-36=36-Item Short-Form Health Survey questionnaire, postintervention=immediately after 12-week intervention.
[b] Preintervention: n=40; postintervention: n=26; 4-week follow-up: n=26.
[c] Preintervention: n=40; postintervention: n=32; 4-week follow-up: n=26.
[d] *P* values for between-group comparison were obtained from the interaction of treatment group and time using a repeated-measures analysis of variance. Values in bold type were significant at $P<.05$.

## Conclusions

The STOMPS trial is the first to document the efficacy of a home exercise program paired with instruction to optimize movement performance techniques for activities that involve UE weight bearing. Together, they create a comprehensive intervention that was effective in reducing long-standing shoulder pain in people with SCI. The significant reduction in pain following the exercise/movement optimization intervention was accompanied by significant improvements in muscle strength and health-related and overall self-reported QOL. These positive results were maintained for at least 4 weeks after the active intervention period.

Dr Mulroy, Ms Thompson, Dr Kemp, Dr Newsam, Ms Haubert, Ms Eberly, Dr Ge, Dr Azen, Dr Winstein, and Dr Gordon provided concept/idea/research design. Dr Mulroy, Dr Kemp, Dr Hatchett, Dr Ge, and Dr Azen provided writing. Dr Mulroy, Dr Newsam, Ms Lupold, Ms Haubert, and Ms Eberly provided data collection. Dr Mulroy, Dr Hatchett, Dr Ge, Dr Azen, and Dr Gordon provided data analysis. Dr Mulroy, Dr Hatchett, Dr Newsam, Ms Lupold, Ms Haubert, Ms Eberly, Dr Winstein, and Dr Gordon provided project management. Dr Kemp, Dr Winstein, and Dr Gordon provided fund procurement. Dr Mulroy provided facilities/equipment. Dr Mulroy and Dr Gordon provided institutional liaisons. Ms Thompson, Dr Kemp, Dr Hatchett, Dr Newsam, Ms Haubert, Ms Eberly, Dr Azen, Dr Winstein, and Dr Gordon provided consultation (including review of manuscript before submission).

The authors acknowledge the Physical Therapy Clinical Research Network (PTClinResNet). The principal investigator was Carolee J. Winstein, PT, PhD, FAPTA, and the co-principal investigator was James Gordon, PT, EdD, FAPTA (both at University of Southern California, Los Angeles, California). Project principal and co-principal investigators were: David A. Brown, PT, PhD (Northwestern University, Chicago, Illinois); Sara J. Mulroy, PT, PhD, and Bryan Kemp, PhD (Rancho Los Amigos National Rehabilitation Center, Downey, California); Loretta M. Knutson, PT, PhD, PCS (Missouri State University, Springfield, Missouri); Eileen G. Fowler, PT, PhD (University of California, Los Angeles, Los Angeles, California); and Sharon K. DeMuth, PT, DPT, Kornelia Kulig, PT, PhD, and Katherine J. Sullivan, PT, PhD (University of Southern California). The Data Management Center was located at University of Southern California and is directed by Stanley P. Azen, PhD. The 4-member Data Safety and Monitoring Committee were: Nancy Byl, PT, PhD, FAPTA, Chair (University of California, San Francisco, San Francisco, California), Hugh G. Watts, MD (Shriners' Hospital for Children—LA Unit, Los Angeles, California), June Isaacson Kailes, MSW (Western University of Health Sciences, Pomona, California), and Anny Xiang, PhD (University of Southern California).

Parts of this protocol and data were presented at the American Spinal Injury Association Instructional Course; May 2005; Dallas, Texas; the Combined Sections Meeting of the American Physical Therapy Association; February 23–27, 2005; New Orleans, Louisiana; the Combined Sections Meeting of the American Physical Therapy Association; February 14–18, 2007; Boston, Massachusetts; and the California Physical Therapy Association Annual Conference; October 21–22, 2004; Anaheim, California.


This study was supported by grants from the Foundation for Physical Therapy (American Physical Therapy Association) to establish the PTClinResNet and the National Institute on Disability and Rehabilitation Research through the Research and Rehabilitation Training Center on Aging With a Disability (grant H133B081002). The PTClinResNet is a clinical research network to evaluate the efficacy of physical therapist practice.

Trial registration: ClinicalTrials.gov Identifier: NCT00461474.

*This article was submitted May 21, 2010, and was accepted October 31, 2010.*

DOI: 10.2522/ptj.20100182

## References

1 Burnham RS, May L, Nelson E, et al. Shoulder pain in wheelchair athletes: the role of muscle imbalance. *Am J Sports Med*. 1993;21:238–242.

2 Curtis KA, Drysdale GA, Lanza RD, et al. Shoulder pain in wheelchair users with tetraplegia and paraplegia. *Arch Phys Med Rehabil*. 1999;80:453–457.

3 Pentland WE, Twomey LT. Upper limb function in persons with long term paraplegia and implications for independence: part I. *Paraplegia*. 1994;32:211–218.

4 Pentland WE, Twomey LT. Upper limb function in persons with long term paraplegia and implications for independence: part II. *Paraplegia*. 1994;32:219–224.

5 Sie IH, Waters RL, Adkins RH, Gellman H. Upper extremity pain in the postrehabilitation spinal cord injured patient. *Arch Phys Med Rehabil*. 1992;73:44–48.

6 Bayley JC, Cochran TP, Sledge CB. The weight-bearing shoulder: the impingement syndrome in paraplegics. *J Bone Joint Surg Am*. 1987;69:676–678.

7 Subbarao JV, Klopfstein J, Turpin R. Prevalence and impact of wrist and shoulder pain in patients with spinal cord injury. *J Spinal Cord Med*. 1995;18:9–13.

8 Gellman H, Sie I, Waters RL. Late complications of the weight-bearing upper extremity in the paraplegic patient. *Clin Orthop Relat Res*. 1988;233:132–135.

9 Escobedo EM, Hunter JC, Hollister MC, et al. MR imaging of rotator cuff tears in individuals with paraplegia. *AJR Am J Roentgenol*. 1997;168:919–923.

10 McCasland LD, Budiman-Mak E, Weaver FM, et al. Shoulder pain in the traumatically injured spinal cord patient: evaluation of risk factors and function. *J Clin Rheumatol*. 2006;12:179–186.

11 Ballinger DA, Rintala DH, Hart KA. The relation of shoulder pain and range-of-motion problems to functional limitations, disability, and perceived health of men with spinal cord injury: a multifaceted longitudinal study. *Arch Phys Med Rehabil*. 2000;81:1575–1581.

12 Gerhart KA, Bergstrom E, Charlifue SW, et al. Long-term spinal cord injury: functional changes over time. *Arch Phys Med Rehabil*. 1993;74:1030–1034.

13 Lundqvist C, Siösteen A, Blomstrand C, et al. Spinal cord injuries: clinical, functional, and emotional status. *Spine (Phila Pa 1976)*. 1991;16:78–83.

14 Gutierrez DD, Thompson L, Kemp B, Mulroy SJ. The relationship of shoulder pain intensity to quality of life, physical activity, and community participation in persons with paraplegia. *J Spinal Cord Med*. 2007;30:251–255.

15 Goldstein B, Young J, Escobedo EM. Rotator cuff repairs in individuals with paraplegia. *Am J Phys Med Rehabil*. 1997;76:316–322.

16 Popowitz RL, Zvijac JE, Uribe JW, et al. Rotator cuff repair in spinal cord injury patients. *J Shoulder Elbow Surg*. 2003;12:327–332.

17 Lyons PM, Orwin JF. Rotator cuff tendinopathy and subacromial impingement syndrome. *Med Sci Sports Exerc*. 1998;30:S12–S17.

18 Michener LA, Walsworth MK, Burnet EN. Effectiveness of rehabilitation for patients with subacromial impingement syndrome: a systematic review. *J Hand Ther*. 2004;17:152–164.

19 Haahr JP, Ostergaard S, Dalsgaard J, et al. Exercises versus arthroscopic decompression in patients with subacromial impingement: a randomised, controlled study in 90 cases with a one-year follow-up. *Ann Rheum Dis*. 2005;64:760–764.

**20** Haahr JP, Anderson JH. Exercises may be as efficient as subacromial decompression in patients with subacromial stage II impingement: 4–8 years' follow-up in a prospective, randomized study. *Scand J Rheumatol*. 2006;35:224–228.

**21** Brox JI, Staff PH, Ljunggren AE, Brevik JI. Arthroscopic surgery compared with supervised exercises in patients with rotator cuff disease (stage II impingement syndrome) [erratum in: *BMJ*. 1993;307:1269]. *BMJ*. 1993;307:899–903.

**22** Brox JI, Gjengedal E, Uppheim G, et al. Arthroscopic surgery versus supervised exercises in patients with rotator cuff disease (stage II impingement syndrome): a prospective, randomized, controlled study in 125 patients with a 2 1/2 year follow-up. *J Shoulder Elbow Surg*. 1999;8:102–111.

**23** Curtis KA, Tyner TM, Zachary L, et al. Effect of a standard exercise protocol on shoulder pain in long-term wheelchair users. *Spinal Cord*. 1999;37:421–429.

**24** Nawoczenski DA, Ritter-Soronen JM, Wilson CM, et al. Clinical trial of exercise for shoulder pain in chronic spinal injury. *Phys Ther*. 2006;86:1604–1618.

**25** Nash MS, van de Ven I, van Elk N, Johnson BM. Effects of circuit resistance training on fitness attributes and upper-extremity pain in middle-aged men with paraplegia. *Arch Phys Med Rehabil*. 2007;88:70–75.

**26** Kulig K, Newsam CJ, Mulroy SJ, et al. The effect of level of spinal cord injury on shoulder joint kinetics during manual wheelchair propulsion. *Clin Biomech (Bristol, Avon)*. 2001;16:744–751.

**27** Newsam CJ, Rao SS, Mulroy SJ, et al. Three dimensional upper extremity motion during manual wheelchair propulsion in men with different levels of spinal cord injury. *Gait Posture*. 1999;10:223–232.

**28** Perry J, Gronley JK, Newsam CJ, et al. Electromyographic analysis of the shoulder muscles during depression transfers in subjects with low-level paraplegia. *Arch Phys Med Rehabil*. 1996;77:350–355.

**29** Mulroy SJ, Gronley JK, Newsam CJ, Perry J. Electromyographic activity of shoulder muscles during wheelchair propulsion by paraplegic persons. *Arch Phys Med Rehabil*. 1996;77:187–193.

**30** Reyes ML, Gronley JK, Newsam CJ, et al. Electromyographic analysis of shoulder muscles of men with low-level paraplegia during a weight relief raise. *Arch Phys Med Rehabil*. 1995;76:433–439.

**31** Powers CM, Newsam CJ, Gronley JK, et al. Isometric shoulder torque in subjects with spinal cord injury. *Arch Phys Med Rehabil*. 1994;75:761–765.

**32** Gagnon D, Nadeau S, Noreau L, et al. Electromyographic patterns of upper extremity muscles during sitting pivot transfers performed by individuals with spinal cord injury. *J Electromyogr Kinesiol*. 2009;19:509–520.

**33** Boninger ML, Koontz AM, Sisto SA, et al. Pushrim biomechanics and injury prevention in spinal cord injury: recommendations based on CULP-SCI investigations. *J Rehabil Res Dev*. 2005;42(3 Suppl 1):9–19.

**34** Paralyzed Veterans of America Consortium for Spinal Cord Medicine. *Preservation of Upper Limb Function Following Spinal Cord Injury: A Clinical Practice Guideline for Health-care Professionals*. Washington, DC: Paralyzed Veterans of America; 2005.

**35** Jobe FW, Moynes DR. Delineation of diagnostic criteria and a rehabilitation program for rotator cuff injuries. *Am J Sports Med*. 1982;10:336–339.

**36** Kim E, Jeong HJ, Lee KW, Song JS. Interpreting positive signs of the supraspinatus test in screening for torn rotator cuff. *Acta Med Okayama*. 2006;60:223–228.

**37** Codman EA. *The Shoulder*. Brooklyn, NY: Medical Publishers Inc; 1934:12–13.

**38** Park HB, Yokota A, Gill HS, et al. Diagnostic accuracy of clinical tests for the different degrees of subacromial impingement syndrome. *J Bone Joint Surg Am*. 2005;87:1446–1455.

**39** American College of Sports Medicine position stand: the recommended quantity and quality of exercise for developing and maintaining cardiorespiratory and muscular fitness in healthy adults. *Med Sci Sports Exerc*. 1990;22:265–274.

**40** Baechle TR, Earle RW, Wathen D. Resistance training. In: Baechle TR, Earle RW, eds. *Essentials of Strength Training and Conditioning*. 2nd ed. Champaign, IL: Human Kinetics Inc; 2000:406–416.

**41** Newsam CJ, Leese C, Fernandez-Silva J. Intratester reliability for determining an eight-repetition maximum for three shoulder exercises using elastic bands. *J Sport Rehabil*. 2005;14:35–47.

**42** *Towards a Common Language for Functioning, Disability and Health: ICF*. Geneva, Switzerland: World Health Organization; 2002.

**43** Curtis KA, Roach KE, Applegate EB, et al. Development of the Wheelchair User's Shoulder Pain Index (WUSPI). *Paraplegia*. 1995;33:290–293.

**44** Curtis KA, Roach KE, Applegate EB, et al. Reliability and validity of the Wheelchair User's Shoulder Pain Index (WUSPI). *Paraplegia*. 1995;33:595–601.

**45** Melzack R. The short-form McGill Pain Questionnaire. *Pain*. 1987;30:191–197.

**46** May LA, Burnham RS, Steadward RD. Assessment of isokinetic and hand-held dynamometer measures of shoulder rotator strength among individuals with spinal cord injury. *Arch Phys Med Rehabil*. 1997;78:251–255.

**47** Washburn RA, Zhu W, McAuley E, et al. The Physical Activity Scale for Individuals With Physical Disabilities: development and evaluation. *Arch Phys Med Rehabil*. 2002;83:193–200.

**48** Kemp BJ, Ettelson D. Quality of life while living and aging with a spinal cord injury and other impairments. *Top Spinal Cord Inj Rehabil*. 2001;6:116–127.

**49** Ware JE Jr, Sherbourne CD. The MOS 36-Item Short-Form Health Survey (SF-36), I: conceptual framework and item selection. *Med Care*. 1992;30:473–483.

**50** Kahan JS, Mitchell JM, Kemp BJ, Adkins RH. The results of a 6-month treatment for depression on symptoms, life satisfaction, and community activities among individuals aging with a disability. *Rehabil Psychol*. 2006;51:13–22.

**51** Kemp BJ. Quality of life, coping and depression. In: Kemp BJ, Mosqueda L, eds. *Aging With a Disability*. Baltimore, MD: The John Hopkins University Press; 2004:48–67.

**52** *International Standards for Neurological Classification of Spinal Injury, Revised 2002*. Chicago, IL: American Spinal Injury Association; 2002.

**53** Kelly SM, Brittle N, Allen GM. The value of physical tests for subacromial impingement syndrome: a study of diagnostic accuracy. *Clin Rehabil*. 2010;24:149–158.

**54** Michener LA, Walsworth MK, Doukas WC, Murphy KP. Reliability and diagnostic accuracy of 5 physical examination tests and combination of tests for subacromial impingement. *Arch Phys Med Rehabil*. 2009;90:1898–1903.

**55** Tashjian RZ, Deloach J, Porucznik CA, Powell AP. Minimal clinically important differences (MCID) and patient acceptable symptomatic state (PASS) for visual analog scales (VAS) measuring pain in patients treated for rotator cuff disease. *J Shoulder Elbow Surg*. 2009;18:927–932.

**56** Hicks AL, Martin KA, Ditor DS, et al. Long-term exercise training in persons with spinal cord injury: effects on strength, arm ergometry performance and psychological well-being. *Spinal Cord*. 2003;41:34–43.