Shoulder Pain Prevention Program for Manual Wheelchair Users With Paraplegia: A Randomized Clinical Trial

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Objectives: To compare prevalence of shoulder pain (SP) onset over 3 years for individuals with paraplegia from spinal cord injury who participate in one of two shoulder pain prevention program (SPPP) formats with that of a similar population without intervention, and to compare exercise adherence between two SPPP formats. **Methods:** The randomized clinical trial (compared to historical controls) included a volunteer sample of 100 individuals without SP at study entry. Eighty-seven participants returned for assessments at 18 and 36 months after study entry. Control group included 220 volunteers from a 3-year observational study with identical inclusion criteria. SPPPs included shoulder home exercises and recommendations to improve mobility techniques that are effective in reducing existing SP in this population. Participants were randomly assigned to receive either one instruction session and a refresher session 4 weeks later with a physical therapist or a 4-week series of 2-hour group classes taught by a physical therapist and peer mentor. Prevalence of SP onset at 18 and 36 months and self-reported average weekly exercise frequency were the main outcome measures. **Results:** SP onset was identical in the two SPPPs but was significantly lower at 18 and 36 months in both groups (11% and 24%) compared to controls (27% and 40%, $p < .05$). Self-reported average weekly exercise frequency was similar between intervention groups but was significantly lower during the first 4 months in participants who developed SP compared to those without pain (2.12 ± 1.0 vs. 3.01 ± 1.13, $p < .05$). **Conclusion:** SPPPs reduced SP onset prevalence regardless of instruction format. Exercise adherence was important to the outcome of shoulder pain. **Key words:** *exercise therapy, paraplegia, shoulder pain, spinal cord injury, subacromial impingement*

Introduction

Shoulder pain (SP) is a debilitating secondary condition following spinal cord injury (SCI),[1] with up to 72% of individuals developing pain by 20 years post injury.[2] The most common causes of SP after SCI are subacromial impingement and rotator cuff tendinopathy.[3] These pathologies have been attributed to excessive weight-bearing forces through the upper extremity to compensate for lower limb weakness or paralysis during mobility tasks (pressure relief, transfers, and wheelchair propulsion).[4] SP in wheelchair users with paraplegia substantially compromises independent mobility[5,6] and is associated with reduced quality of life and physical activity.[7]

Conservative treatment of subacromial pain syndrome[8] with shoulder exercise has been documented to reduce SP in this population, although the reported frequency and duration of exercise performance varies widely.[9-12] However, shoulder exercise programs are not completely effective in resolving symptoms in all individuals with SP. Moreover, surgical rotator cuff repair requires prolonged postoperative abstinence from functional mobility tasks, resulting in loss of independence. Given these considerations and the fact that the majority of individuals with paraplegia will experience SP, particularly with life expectancy approaching that of persons without disability,[13] it becomes important to shift focus from SP treatment to prevention of onset.

One SP treatment program in particular, Strengthening and Optimal Movements for

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Painful Shoulders (STOMPS), was used in a randomized control trial for wheelchair users with paraplegia and an average SP duration of 5 years.[14] The STOMPS 12-week program resulted in a three-fold reduction in SP, as documented by Wheelchair User's Shoulder Pain Index (WUSPI) scores, and included recommendations to reduce shoulder demands during mobility tasks and a shoulder muscle flexibility and strengthening exercise program performed three times per week.[14] Reductions in SP in individuals who received the STOMPS intervention were mediated by increased external rotator strength.[14] Reductions in SP mediated improvements in both participation and quality of life.[15] Development of SP over 3 years in manual wheelchair users with paraplegia without pain at entry into a prospective longitudinal study occurred at rate of 40% and was significantly predicted by shoulder adductor weakness.[16] Two of the four STOMPS strengthening exercises address hypertrophy of the shoulder external rotators and adductors.[14] Thus, introducing the STOMPS program as an SP prevention program (SPPP) has the potential to reduce the high prevalence of SP onset in this population and improve participation and quality of life.

Adherence to an SPPP for an extended duration and when asymptomatic presents a unique challenge. Although a short duration program like STOMPS was successful in reducing existing SP with a limited number of visits, adopting a long-term exercise program purely for prevention of potential symptoms can be more challenging to sustain. Given these potential barriers to program effectiveness, the traditional two-session STOMPS delivery method may be inadequate to promote long-term adherence and success as an SPPP. An enhanced STOMPS delivery method including more sessions with the physical therapist might improve adherence and, subsequently, SPPP effectiveness for three reasons. First, it would allow more practice of the exercises and movement optimization techniques as well as education of participants regarding program benefits. Second, increased physical activity behaviors have been documented for interventions delivered by peer mentors in a systematic review by Ginis and colleagues.[17] Thus, using a peer mentor, in addition to a physical therapist, to deliver the intervention could facilitate adoption of the exercise program into participants' lives. Finally, because telephone-based support provided by trained peers has been shown to be effective to increase engagement in physical activity, calls from peer mentors might promote adherence.[18]

The purpose of this study, in manual wheelchair users with paraplegia and without SP, was two-fold: (1) to assess the effectiveness of the STOMPS program as a prevention tool by comparing prevalence of SP onset from subacromial pain syndrome over 3 years in individuals who were instructed in a STOMPS[11] SPPP versus those in a historical control group (controls) who did not receive the intervention, and (2) to compare the effectiveness of two different STOMPS[11] SPPP implementation formats, traditional or enhanced STOMPS, in reducing SP onset under these circumstances. We hypothesized that either format would significantly decrease SP prevalence over 3 years compared to no intervention and that individuals receiving the enhanced STOMPS format would be more adherent to exercise program performance than those in the traditional STOMPS group.

Methods

Trial design and settings

Recruitment included snowball sampling (flyers, word of mouth) from outpatient clinics for this 3-year, single-blind, randomized clinical trial. After each participant reviewed and signed an institutional review board–approved informed consent form, a physical therapist performed screening to rule out shoulder pain and pathology before study entry. Participants were evaluated at study entry (baseline) and then randomized into one of two groups; participants in both groups received instruction in an SPPP delivered via a traditional or an enhanced STOMPS format. The program for both groups included shoulder exercises and education in optimizing shoulder function during daily activities and mobility tasks from the STOMPS protocol.[14] SP onset was assessed at 18 and 36 months by a masked evaluator.

Prevalence of SP onset in participants from the SPPP study was compared to that of a historical control group (controls) from a prospective cohort study previously completed in our lab.[19-21]

Recruitment, screening, enrollment (inclusion/exclusion criteria), and assessment (baseline, 18 month, 36 month) of controls were similar to those of the intervention trial.

Participants

Individuals 18 years and older with paraplegia (American Spinal Cord Injury Association Impairment Scale [AIS] A, B, C) from SCI were eligible to participate. Inclusion criteria were (a) SCI duration of 2 to 20 years at baseline,[2,22] (b) manual wheelchair user for more than 50% of locomotion, (c) free of SP indicated by WUSPI Index Score of 12 or less,[15,18,19,20,23] and (d) able to comprehend the informed consent in English or Spanish. Participants were excluded if they had (a) SCI from transverse myelitis, (b) serious medical conditions, (c) cervical radiculopathy, adhesive capsulitis, rotator cuff and/or bicipital tendinopathy (positive Hawkins-Kennedy test,[24] painful arc in shoulder abduction or flexion,[25] empty can test,[26,27] resisted external rotation,[25] Codman's drop arm test[28,29] or Speed's test[24] as indicated on clinical exam by a physical therapist),[21,30] (d) history of shoulder surgery and/or fracture or orthopedic or neurologic disorders impacting arm function,[16] or (e) participated in the control trial.

Settings and locations where data were collected

Screening and assessment as well as exercise interventions in the SPPP were conducted at the Pathokinesiology Laboratory at Ranch Los Amigos National Rehabilitation Center in Downey, CA. Participants additionally performed the SPPP at home.

Randomization (sequence generation)

A random numbers chart with a total of 120 numbers, either "1" or "2," was generated.[31] Following screening, enrollment, and (masked) baseline evaluation, participants were sequentially assigned a random number on the chart, indicating the participant's designated intervention group (1 = traditional STOMPS; 2 = enhanced STOMPS). Randomization was blocked by groups of five such that if one intervention group block became full with five participants, subsequent enrollees were forced into the opposite intervention group until it was then capped at five enrollees.

Interventions

Both SPPP groups (traditional STOMPS, enhanced STOMPS) received resistive tubing exercise kits (Bodylastics, Boca Raton, FL), a hand weight, and instruction in an SPPP that consisted of shoulder exercises and stretches to be performed three times per week (avoiding performance on consecutive days), along with movement optimization instruction.[14] Both groups also received instruction during their last training session on progressing resistance to facilitate strength gains and discontinuing an exercise and contacting researchers if SPPP performance elicited pain.

Traditional STOMPS group

Traditional STOMPS participants partook in two 45-minute training sessions with a physical therapist, 4 weeks apart, to learn the SPPP. The first session included instruction in and performance of the three STOMPS shoulder stretches (anterior and posterior shoulder joint musculature and upper trapezius) and four strengthening exercises.[14] Three of the strengthening exercises were performed with the resistive tubing (shoulder depressors and external rotators for three sets of eight repetitions and scapular retractors for three sets of 15 repetitions). The fourth exercise (scapular plane shoulder elevation for three sets of 15 repetitions) was performed with a hand weight (STOMPS; see **Figure 2**).[14] Movement optimization instruction included discussion of a list of nine recommendations to reduce shoulder injury risk during wheelchair propulsion and 10 techniques to optimize transfers and depression raises.[14] Movement and exercise techniques and resistances were reviewed and modified as appropriate during the second program session.[14]

Enhanced STOMPS group

Individuals in the enhanced STOMPS group participated in four weekly 2-hour group classes with instruction in and performance of the shoulder exercises and education on shoulder protection during daily activities and practice, led by a physical therapist and peer mentor assistant with SCI. Weekly movement optimization education classes included a 45- to 60-minute PowerPoint presentation with discussion and practice of (a)

barriers to exercise performance and STOMPS shoulder exercise training (eAppendix A); (b) car transfers and wheelchair loading techniques (eAppendix B); (c) pressure relief, transfers and overhead activity techniques (eAppendix C); and (d) wheelchair propulsion techniques and assessment with a Smartwheel (Smartwheel; Out-Front, Pasco, WA, USA) (eAppendix D). In addition, enhanced STOMPS participants received booster phone calls from peer mentors at 3 and 6 months after baseline and then every 6 months thereafter to discuss barriers to shoulder exercise performance and potential solutions (eAppendix E).

Outcomes

Eighteen- and 36-month assessments for both SPPP and control participants included completion of the WUSPI, an Interim SP Questionnaire (eAppendix F), and a clinical shoulder exam. For the SPPP, the two physical therapists who performed the 18- and 36-month evaluations were blinded to participants' intervention groups. SP onset was determined by an increased WUSPI Index score of at least 10 points from baseline at 18 or 36 months.[16] Additionally, SP onset was documented when individuals reported an SP episode on the Interim SP questionnaire that was symptomatically consistent with subacromial impingement from overuse (based on the pain onset, location, and symptom description) and lasting at least 1 week at an intensity of greater than 3 out of 10. The presence or absence of shoulder pain over the first 18 months and cumulatively over the 3-year study period was used to stratify participants into pain and no-pain groups at each time point. Both intervention groups received a telephone call from their peer mentor or study staff every 6 to 8 weeks following baseline to document self-reported frequency of shoulder exercise performance during the last week and to encourage exercise performance.

Sample size

We estimated the sample size required to attain 80% statistical power for our two primary analyses using nQuery Advisor Study Planning Software. We assumed a type I error rate of 5% for all calculations. Our comparison cohort of 199 participants had a prevalence of SP onset over 3 years of 38%. We estimated that a clinically important effect of the SPPP would decrease the prevalence rate of SP onset by one-half, to 19%, resulting in an odds ratio of 0.382. Thus, a sample of 60 participants would be necessary in the SPPP to achieve at least 80% power to detect this odds ratio for the chi-square analysis. With a sample size of 60 participants (30 each in traditional and enhanced STOMPS), we would have sufficient power (80%) to detect an effect size of 0.73 for differences in weekly shoulder exercise performance between SPPP groups.

Statistical methods

Descriptive statistics were determined for the demographic variables, as well as SP onset and self-reported exercise frequency. Parametric assumptions (normality/skewness, homogeneity of variance) were examined for continuous demographic data and study measures. Chi-square tests were utilized to compare frequency of categorical baseline demographics between SPPP and control participants. They were additionally used to compare the frequency of SP onset by 18 and 36 months between SPPP and control participants and within the SPPP between the two interventions (traditional and enhanced STOMPS).

Independent *t* tests compared continuous baseline characteristics between SPPP and control subjects and within SPPP participants in traditional and enhanced STOMPS groups. Self-reported exercise frequency data were not normally distributed; therefore Mann-Whitney *U* tests compared self-reported frequency of weekly exercise performance between traditional and enhanced STOMPS for three time periods: 0-4 months (early adherence); 12-18 months and 18-36 months (long-term adherence). Mann-Whitney *U* test was also utilized to compare ordinal baseline characteristics between SPPP and control groups and within the SPPP in traditional and enhanced STOMPS participants. A secondary analysis was conducted using Mann-Whitney *U* tests to compare self-reported frequency of weekly shoulder exercise performance for the three periods (0-4 months, 12-18 months, and 18-36 months) between SPPP participants who developed pain at both 18 months and 36 months and those who remained pain-free. Bonferroni corrections were applied to account for multiple comparisons.

Results

Participant flow diagram

For the trial investigating the SPPP, in-person or telephone eligibility screens were conducted for 348 individuals (**Figure 1**). Of those screened, 248 failed to meet inclusion/exclusion criteria. One hundred people meeting inclusion criteria were enrolled and completed baseline evaluation. Of those enrolled, 48 participants were randomized into the traditional STOMPS and 52 into the enhanced STOMPS. Eighty-six participants returned for follow-up assessment at 36 months.

In the controls, 327 individuals were screened for eligibility. Of these, 107 were excluded and 220 enrolled (**Figure 2**). Of those included, 203 participants completed their 18-month evaluation and 199 completed the 36-month assessment.

Recruitment

Subject enrollment started in May 2012 and closed in July 2014. Testing was completed in August 2017.

Baseline data

Demographic and baseline characteristics of participants in the SPPP (n = 100) were largely similar to controls (n = 220) (**Table 1**). SPPP participants, however, had a significantly shorter SCI duration compared to controls (6.8 ± 5.0 years vs. 10.1 ± 6.2 years; $p < .05$) (**Table 1**). SPPP participants additionally had significantly greater body weight and body mass index (BMI) compared to controls (80.9 ± 23.7 kg vs. 74.4 ± 16.1 kg and 26.2 ± 7.1 kg/m^2 vs. 24.6 ± 5.3 kg/m^2, respectively; $p < .05$). In those participants with SP onset by the 36-month evaluation in both SPPP and control groups, demographics were similar overall, except that the SPPP had a significantly greater proportion of participants with high (T2-T7) versus low paraplegia (T8-L3) than controls (65% vs. 39%, respectively; p = .031) and tended to be younger (31.1 ± 8.2 years vs. 35.7 ± 9.6 years, respectively; p = .052) (**Table 2**). Within the SPPP (n = 100), baseline characteristics were similar in both treatment groups (traditional and enhanced STOMPS) (**Table 3**).

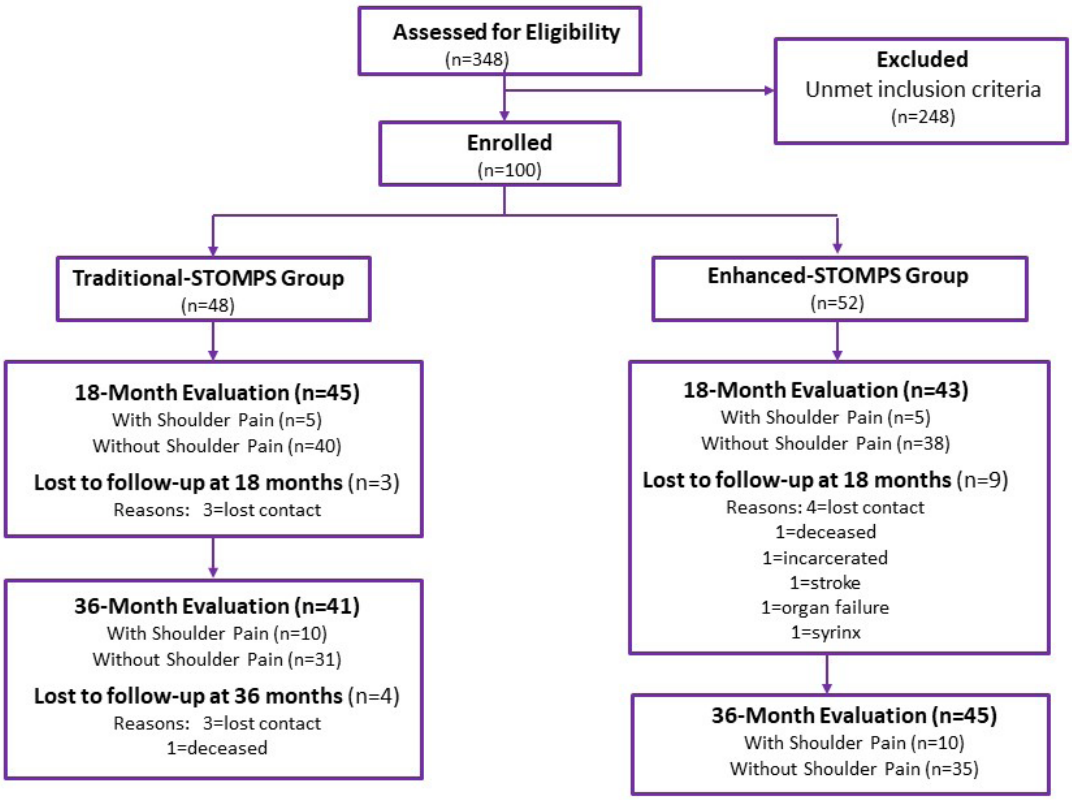

Figure 1. Shoulder Pain Prevention Program (SPPP) study flow diagram.

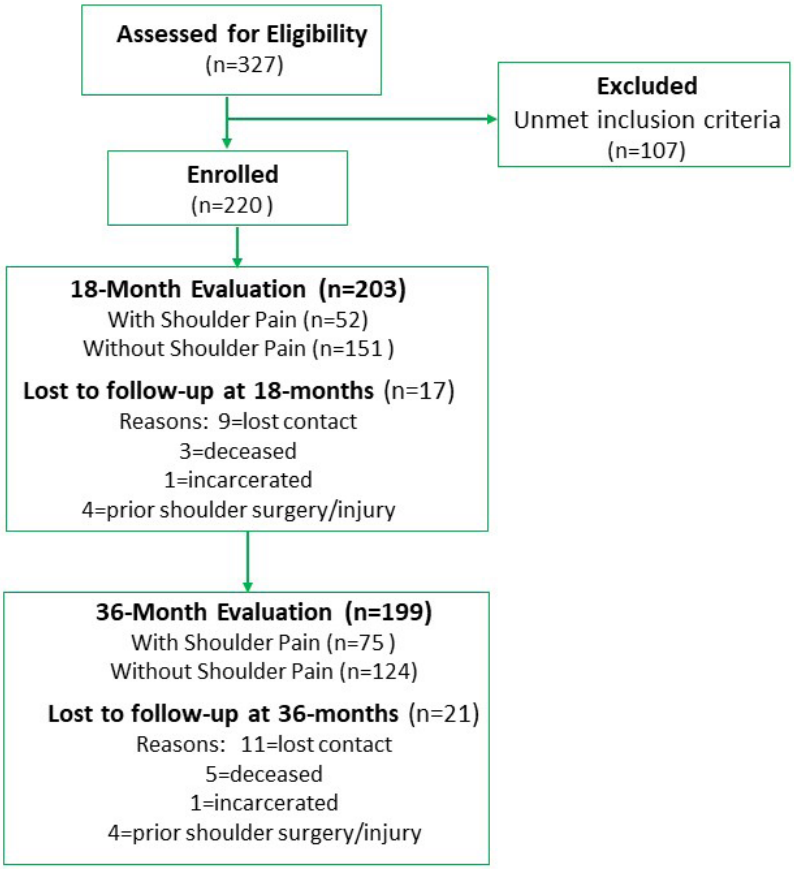

Figure 2. Historical control group (controls) study flow diagram.

Outcomes and estimation

Frequency of SP onset at 18 months was significantly reduced by 56% in SPPP compared to controls (11.4% vs. 25.6% frequency of SP onset, respectively; $p = .006$). The odds of SP onset by 18 months for individuals who did not participate in the SPPP was 2.7 times greater (95% CI, 1.3-5.6). At 36 months, cumulative SP onset was significantly reduced by about 40% in the SPPP compared to control participants (23.3% vs. 37.7% frequency of SP onset, respectively; $p = .018$) (**Table 4**). The odds of SP onset by 36 months for individuals who did not participate in the SPPP were 2.0 times greater (95% CI, 1.1-3.6).

For SPPP participants, prevalence of SP onset was statistically similar at 18 and 36 months between traditional and enhanced STOMPS (11.1% vs. 11.6% [$p = .94$] and 24.4% vs. 22.2% [$p = .812$], respectively) (**Table 5**). Further, self-reported weekly frequency of shoulder exercise performance was not significantly different between the two SPPP intervention groups at any of the three time periods ($p > .05$) (**Table 6**).

Average self-reported weekly frequency of shoulder exercise performance during the first 4 months, however, was significantly greater in those who remained pain-free. Pain-free participants at 18 months reported performing an additional bout of weekly shoulder exercise during the first 4 months of the program compared to those with SP onset (median 3.0 [IQR = 2.5-3.4] vs. 2.0 [IQR = 0.9-2.3] sessions per week, respectively [$p = .012$]) (**Table 7**). Self-reported weekly frequency of shoulder exercise during the first 4 months was also significantly greater for those who remained pain-free at 36 months compared to those who developed pain (median 3.0 [IQR = 2.5-3.5] vs. 2.0 [IQR = 1.5-3.0] times per week, respectively [$p = .007$]) (**Table 7**).

Harms

No harms or unintended effects occurred owing to the traditional and enhanced STOMPS interventions.

Discussion

The current study showed that the STOMPS program is a valuable SP prevention approach, in addition to its effectiveness for reducing ongoing SP in wheelchair users with paraplegia.[14] The reduction of SP onset was substantial, by close to 60% at 18 months and nearly 40% at 36 months, despite no formal input from the physical therapist after the fourth week to progress the strengthening exercises. In the future, investigation of additional in-person sessions with the physical therapist every 3 to 6 months to review and progress shoulder strengthening exercises might reveal a more substantial reduction in SP development over 36 months.

Occurrence of SP development in control participants at 18 and 36 months was similar to that reported in other studies of individuals with paraplegia.[32,33] Demographically, there were some significant differences between the SPPP and control participants at study entry. SPPP participants were significantly heavier than controls by about 10%, which was reflected additionally in their greater BMI (7%). Collinger and colleagues found that body weight was a significant positive predictor of higher shoulder joint forces during manual wheelchair propulsion in individuals with paraplegia,[34] which could contribute to earlier development of shoulder pathology in heavier individuals. Conversely, duration of SCI was significantly less in the SPPP participants compared to controls. SCI duration has been positively associated with SP development and pathology in the literature.[2,3] While it is possible that this greater body weight in the SPPP may have increased the risk for SP onset, the shorter injury duration may have conversely somewhat reduced the risk. Within participants who developed SP over 36 months, a significantly greater proportion of those in the SPPP group (65%) had high paraplegia than controls (39%) but they also tended to be about 4 years younger. Even though these demographic differences are interesting, Mulroy and colleagues found no association of these and other demographic variables with SP onset over 3 years in a similar population.[16]

This investigation found that a traditional STOMPS format entailing two sessions with a physical therapist was as effective in reducing SP onset as an enhanced STOMPS intervention including additional staff (a peer mentor), twice as many sessions, and more than double the duration per session. Moreover, adherence to exercise performance was similar in the two intervention groups at each time period assessed. These findings are critical considerations in a national healthcare environment with continuously rising costs,[13] because implementation of an effective SPPP utilizing substantially fewer resources is beneficial for recipients, providers, and payers. Because both SPPPs failed to completely eliminate SP onset over 36 months and exercise adherence decreased over time, in-person sessions with the physical therapist every 3 to 6 months may be beneficial to review exercise technique and progress resistance to maintain and/or facilitate strength gains over the long term.

Finally, our randomized control trial documented that, regardless of intervention group, self-reported average weekly frequency of exercise performance was significantly greater in the first 4 months in participants who remained pain-free. Specifically, those who remained pain-free at 18 and 36 months reported performing an additional session of weekly exercise during the first 4 months, compared to those who developed SP, whereas longer term exercise frequency was not significantly different for those with and without SP development at 18 and 36 months. Potentially, this early and reportedly more frequent exercise adherence was protective over the study duration because those with significantly increased adherence with an additional session per week had lower rates of SP onset. The possibility also exists that individuals who remained free of SP were more adherent to exercise performance owing to other factors, such as motivation, mood, etc. It is also not surprising that exercise performance dwindled over the 36-month study. Exercise adherence is challenging; adherence with any long-term exercise program is reported to be approximately 35% in the nondisabled population and 63% in the second 8-week session of a home-based functional electrical stimulation (FES) cycling program in individuals with SCI.[35] Although a shoulder exercise program is quite different than FES cycling, both studies investigated adherence to home-based, unsupervised exercise programs and showed a decline in adherence over time.

Limitations

One limitation of this study was the utilization of a historical versus simultaneous control group for

Table 1. Baseline demographics of Shoulder Pain Prevention Program (SPPP) and historical control group (control) participants

Demographics	**SPPP (*n* = 100)**	**Control (*n* = 220)**
Age at baseline, years	34.0 ± 9.7	35.5 ± 9.2
Height, cm	175.3 ± 9.5	173.8 ± 9.5
Bodyweight, kg	80.9* ± 23.7	74.4 ± 16.1
Body mass index	26.2* ± 7.1	24.6 ± 5.3
Duration of injury, years	6.8* ± 5.0	10.1 ± 6.2
Level of injury (T2-L3) (T2=2, T3=3, T4=4,…T12=12; L1=13; L2=14; L3=15)	7.0 (4.0, 10.0)	8.0 (4.0, 12.0)
High paraplegia (T2-T7) (vs. low paraplegia, T8-L3)	53%	42%
Gender, % female (national average in SCI = 22%)[13]	13.0%	10.9%
Race (%)		
Asian/Pacific Islander	5%	3.6%
Black	22%	17.7%
White	48%	61.8%
American Indian, unknown, > one race	25%	16.8%
Ethnicity, % Hispanic	65%	66.4%[a]
Baseline Wheelchair User's Shoulder Pain Index Score	0.0 (0.0, 0.8)	0.0 (0.0, 1.9)[b]

Note: Values are given as mean ± *SD* or median (25%, 75%).
[a]*n* = 214
[b]*n* = 219
*$p < .05$.

comparison of SP prevalence with the intervention groups. Although it may have been scientifically ideal to randomize SPPP enrollees into an intervention or control group, the observational prospective study was carried out prior to conceptualization of the intervention trial. Further, it was impractical from a recruitment and management perspective to add an additional control group to the intervention study, given the large number of participants this would require. This limitation was mitigated, however, by utilization in the SPPP of the same inclusion and exclusion criteria and evaluations as those used in the previous controls and performance of baseline evaluations by the same experienced physical therapists. In addition, individuals who had participated in the control study were excluded from the prevention study, even if they remained pain-free.

Another aspect of this study to consider includes the fact that formal assessments of SP occurrence were performed only at the 18- and 36-month visits. Although participants who reported an episode of SP between formal assessments (during phone calls from study staff and/or peer mentors) were administered a WUSPI and Interim SP Questionnaire via telephone to document the episode, it is possible that some volunteers in both the control and SPPP groups neglected to report a resolved episode of SP. Thus, the actual prevalence of SP onset may have been higher in both groups at both 18- and 36-month assessments. To

Table 2. Baseline demographics in the Shoulder Pain Prevention Program (SPPP) and historical control group (control) participants who developed shoulder pain by 36 months

Demographics	**SPPP (*n* = 20)**	**Control (*n* = 75)**
Age at baseline, years	31.1* ± 8.2	35.7 ± 9.6
Height, cm	176.4 ± 8.1	173.1 ± 9.6
Bodyweight, kg	74.3 ± 22.6	75.6 ± 16.8
Body mass index	23.8 ± 6.8	25.2 ± 5.5
Duration of injury, years	8.3 ± 6.5	8.5 ± 6.1
Level of injury (T2-L3) (T2=2, T3=3, T4=4,…T12=12; L1=13; L2=14; L3=15)	5.5 (4.0, 10.3)	10.0 (5.8, 12.0)
High paraplegia (T2-T7) (vs. low paraplegia, T8-L3)	65%**	39%
Gender, % female (national average in SCI = 22%)[13]	5%	16%
Race		
Asian/Pacific Islander	10.0%	4.0%
Black	20.0%	13.3%
White	35.0%	65.3%
American Indian, unknown, > one race	35.0%	17.3%
Ethnicity, % Hispanic	60%	61.1%[a]
Baseline Wheelchair User's Shoulder Pain Index Score (WUSPI)	0.0 (0.0, 0.8)	0.0 (0.0, 2.3)[b]
Highest WUSPI score	40.0 (15.3, 72.6)	31.0 (13.3, 48.8)[b]

Note: Values are given as mean ± *SD* or median (25%, 75%).
[a]*n* = 214
[b]*n* = 219
*.05 < *p* < 1.0
**$p < .05$

address this issue, future studies could specifically inquire into incidents of SP during calls between formal assessments and additionally request that participants contact investigators if they have a bout of SP between contacts.

Next, the proportion of females in both the control (11%; **Table 1**) and SPPP groups (traditional = 16.7%, enhanced = 13%; **Table 3**), although not significantly different between groups, was slightly lower than the proportion of females sustaining new injuries in the United States (22%).[12] Because women with SCI have been found to have higher levels of SP[7] as well as more prevalent radiographic evidence of shoulder degenerative changes than men,[36] it is possible that the rate of SP onset in both the control and SPPP groups was lower than it would have been in a more representative sample.

A final limitation of this study was that average weekly exercise adherence was measured via self-report. It is possible that participants inaccurately reported the frequency of weekly exercise performance; however, there is no reason to suspect that reporting errors would differ in those with and without SP onset. Future studies, however, could

Table 3. Baseline demographics of Shoulder Pain Prevention Program (SPPP) participants: traditional STOMPS and enhanced STOMPS groups

Demographics	**Traditional STOMPS (*n* = 48)**	**Enhanced STOMPS (*n* = 52)**
Age at baseline, years	32.6 ± 9.3	35.3 ± 10.0
Height, cm	175.9 ± 10.1	174.7 ± 8.9
Bodyweight, kg	80.2 ± 24.8	81.5 ± 22.8
Body mass index	26.0 ± 7.5	26.6 ± 6.8
Duration of injury, years	6.3 ± 4.8	7.2 ± 5.1
Level of injury (T2-L3) (T2=2, T3=3, T4=4,…T12=12; L1=13; L2=14; L3=15)	7.0 (4.0, 10.0)	8.0 (4.0, 10.8)
High paraplegia (T2-T7) (vs. low paraplegia, T8-L3)	58.3%	48.1%
Gender, % female (national average in SCI =22%)13	16.7%	13.0%
Race		
Asian/Pacific Islander	10.4%	0%
Black	16.7%	26.9%
White	47.9%	48.1%
American Indian, unknown, > one race	25.0%	25.0%
Ethnicity, % Hispanic	62.5%	67.3%
Baseline Wheelchair User's Shoulder Pain Index Score	0.0 (0.0, 0.8)	0.0 (0.0, 0.8)

Note: Values are given as mean ± *SD* or median (25%, 75%). STOMPS = Strengthening and Optimal Movements for Painful Shoulders.

utilize an activity monitor or inertial measurement unit device to more objectively document shoulder exercise performance.

Conclusion

The current investigation documents the effectiveness of the STOMPS shoulder exercise program[14] as a preventative measure to reduce the prevalence of SP onset by 38% to 56% over 3 years in manual wheelchair users with paraplegia. Additionally, a traditional STOMPS format requiring two one-on-one sessions totaling approximately 1.5 hours was equally successful in reducing SP development as an enhanced STOMPS intervention requiring more than double the staff and hours and produced self-reports of similar adherence to exercise performance. Individuals who reported performing their SPPP an additional session weekly (three versus two times per week) during the first 4 months were protected from developing SP over 3 years. The documented reduction in exercise performance in both intervention groups after the first 4 months, as well as the reduced effectiveness in preventing SP onset between 18 and 36 months, suggests that a STOMPS program that includes additional in-person sessions with the physical therapist to review technique and progress exercise resistance after the first 4 months, possibly every 3 to 6 months, could improve the effectiveness of the SPPP.

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Table 4. Prevalence of shoulder pain (SP) onset at 18 months and cumulatively at 36 months in Shoulder Pain Prevention Program (SPPP) and control group (Control) participants

Prevalence of SP	SPPP	Control
Prevalence of SP onset at 18 months	11.4%* (n = 88)	25.6% (n = 203)
Prevalence of cumulative SP onset by 36 months	23.3%* (n = 86)	37.7% (n = 199)

*Significantly different than control, $p < .05$.

Table 5. Prevalence of shoulder pain (SP) onset at 18 months and cumulatively at 36 months in Shoulder Pain Prevention Program (SPPP) participants: traditional STOMPS and enhanced STOMPS groups

Prevalence of SP	Traditional STOMPS	Enhanced STOMPS
Prevalence of SP onset at 18 months	11.1 (n = 45)	11.6 (n = 43)
Prevalence of cumulative SP onset by 36 months	24.4 (n = 41)	22.2 (n = 45)

Note: STOMPS = Strengthening and Optimal Movements for Painful Shoulders.

Table 6. Average self-reported frequency of weekly shoulder exercise performance for Shoulder Pain Prevention Program (SPPP) participants: traditional STOMPS versus enhanced STOMPS

Weekly exercise frequency	Traditional STOMPS (n = 41)	Enhanced STOMPS (n = 43)
0 to 4 months	3.0 (2.2, 3.2)	2.5 (2.0, 3.5)
12 to 18 months	2.0 (1.0, 3.0)	1.5 (0.5, 2.5)
18 to 36 months	1.8 (0.7, 2.6)	1.8 (0.8, 2.5)

Note: Values are given as median (25%, 75%). STOMPS = Strengthening and Optimal Movements for Painful Shoulders.

Table 7. Average self-reported frequency of weekly shoulder exercise program performance for individuals with no pain (NP) versus shoulder pain (SP) onset at 18-month evaluation and cumulatively at 36-month evaluation

Self-reported average weekly exercise frequency	NP at 18-month evaluation (n = 73)	SP onset at 18-month evaluation (n = 8)	NP at 18-month evaluation and 36-month evaluation (n = 61)	SP onset cumulatively by 36-month evaluation (n = 17)
0 to 4 months	3.0* (2.5, 3.4)	2.0 (0.9, 2.3)	3.0* (2.5, 3.5)	2.0 (1.5, 3.0)
12 to 18 months	2.0 (0.9, 3.0)	1.0 (0.1, 2.1)	2.0 (1.0, 3.0)	1.3 (0.2, 2.3)
18 to 36 months	1.8 (0.7, 2.6)	1.3 (1.1, 2.1)	1.8 (0.8, 2.5)	1.3 (0.5, 2.4)

Note: Values are given as median (25%, 75%).
*Significantly different than SP onset at 18-month evaluation, $p < .05$.

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