Research Article

Community exercise for individuals with spinal cord injury with inspiratory muscle training: A pilot study

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Context/Objective: Respiratory disorders are a common cause of rehospitalization, and premature death in individuals with spinal cord injuries (SCI). Respiratory training combined with community exercise programs may be a method to reduce secondary complications in this population.

Objective: The present study explores the inclusion of inspiratory muscle training (IMT) in an existing community exercise program.

Design: Case series.

Setting: Community.

Participants: Participants ($N = 6$) completed the exercise program. Five were male and one was female; four reported incomplete injuries, and two reported complete injuries; four had cervical injuries, and two had thoracic injuries. The average age was 33 years ($SD = 18.6$) and time since injury was 7 years ($SD = 4.0$).

Interventions: Participants completed an 8-week program, once-per-week for 4 h that included a circuit of resistance training, aerobic exercise, trunk stability, and education. IMT was completed as a home exercise program.

Outcome Measures: Transfer test, T-shirt test, four-directional reach, four-directional trunk strength, weekly training diaries, and a subjective interview.

Results: Twenty-eight training logs were collected. All measures improved: transfer test (mean = -14.62 , $SD = 7.00$ s), T-shirt test (mean = -7.83 , $SD = 13.88$ s), four-directional reach (mean = 3.75 , $SD = 8.06$ in) and hand-held dynamometer (mean = 6.73 , $SD = 8.02$ kg). Individuals reported a positive impact of the program.

Conclusions: This pilot study demonstrated community exercise with IMT use may have positive impact on functional measures for people with SCI who are vulnerable to respiratory compromise. Continued education may increase successful health outcomes.

Trial Registration: NCT03743077.

Keywords: Spinal cord injury, Community program, Exercise, Respiratory training, Daily function

Introduction

Spinal cord injury (SCI) has become increasingly prevalent,¹ with motor vehicle accidents, falls, and violence

as common causes.² As medical technology advances and care improves, the population of individuals living with SCI is increasing, with increasing life expectancies compared to previous decades.³ Despite this, these individuals are considered to be at risk for secondary health conditions which can become fatal.^{4,5} Respiratory disorders are among these secondary risks; they are common and treatable causes for

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rehospitalization for people with SCI.^{2,6,7} Thus, prevention of respiratory compromise is critical to these individuals. Interventions to decrease risk for respiratory complications include exercise⁸ and inspiratory muscle training (IMT).⁹

Exercise programs for individuals with SCI can improve muscle strength, cardiopulmonary fitness, power,^{8,10–12} physical capacity, and body composition.¹² Length of stay has been decreasing for inpatient rehabilitation,¹³ thereby creating a need for improved community exercise options throughout the lifespan. Decreased length of stay may lead to inadequate education or training needed for optimal functioning, and limits patients' knowledge of, and access to resources for successful community reintegration.^{13–15} Patients are often overwhelmed during initial rehabilitation; as a result, education on community reintegration and long-term health management may be ineffective due to decreased readiness to receive education.^{16,17} Consequently, the risk for secondary complications and rehospitalization may increase,^{4,5,7} resulting in a need to bridge the gap between rehabilitation and community resources. Community-based programs for those with neurological conditions have been shown to have a positive impact on functional goals,^{15,18} self-esteem,¹⁵ quality of life,^{14,15} leisure activity,^{15,18} and decreasing depressive symptoms.¹⁸ Previous retrospective study of a community-based exercise program, specifically the Spinal Mobility X class (SMX), has shown a positive effect on function and quality of life for people with SCI.¹⁹

In addition to regular exercise, IMT can provide additional benefit for individuals with SCI.^{8,9,15} To decrease risk for respiratory complications, resistive respiratory training (RRT) can be included in an exercise program to potentially decrease secondary health complications.²⁰ RRT has been shown to be effective when included in inpatient rehabilitation for improving respiratory function in patients with SCI,^{21,22} and other neuromuscular disorders.^{23–25} This is important, as people with impaired neuromuscular control of respiratory muscles have more difficulty maintaining pulmonary hygiene.^{26–28} Changes that occur with SCI can impact inspiratory and expiratory neuromuscular control resulting in altered inspiration mechanics,^{28,29} paradoxical breathing patterns,^{30,31} and increased reliance on accessory muscles.^{31,32} Impaired efficiency of respiration increases the risk for respiratory complications^{13,22,32} supporting the need for continued RRT through the continuum of care. IMT specifically targets inspiratory muscles, providing progressive resistance to the diaphragm, intercostals, and accessory muscles to improve lung volume utilization,^{33–35} and can improve

cardiovascular health, blood pressure regulation,³⁴ and overall respiratory health.^{36–39}

Previous literature has shown both exercise^{8,15} and IMT^{9,20,33} have positive benefits for people with SCI, however, there has been little investigation into the combined effects of exercise and IMT, as well as use of the IMT at the community level. Therefore, the aims of this pilot study were to (1) to examine compliance with IMT as a home program added to an existing community exercise program and (2) to compare changes in four functional outcome measures before and after the SMX program with home IMT.

Methods

This study was approved by Columbia University's IRB (Protocol – AAAQ8226).

Participants

This was a prospective pilot study. Participants were recruited on a voluntary basis from the SMX class. The SMX class was completed at The Axis Project (New York, NY), a community-based organization that provides leisure and exercise opportunities for individuals with disabilities. The SMX class was specifically for individuals with SCI and included participants with varied age, time since injury, and injury levels. All participants in the SMX class were offered participation in this study. Volunteers for the study signed an informed consent. Participants were included in the study if they had a SCI, ASIA levels A–D. Participants were excluded if they had any other neurological condition other than SCI, could not complete a single repetition using the IMT device, could not transfer independently, or if there were any conditions limiting participation in exercise including but not limited to orthopedic, cardiac, or pulmonary conditions. Consenting participants themselves reported level of injury, complete versus incomplete, ASIA level, age, and time since injury.

Interventions

Spinal mobility X class

The SMX class was held at the Axis Project once per week for eight consecutive weeks. Each four-hour class was comprised of three circuits: strengthening, aerobic training, and spinal mobility. The spinal mobility technique includes closed chain exercises targeting proximal musculature activation, with progressive resistance and varying support surfaces to increase postural control.

Inspiratory muscle training

Participants were trained in the use of a Threshold IMT (Threshold IMT[®], Respironics, Parsippany, New

Jersey). The IMT device provides consistent pressure for inspiratory muscle strength and endurance training, regardless of speed of breath. The calibrated device is marked every 2 cm H₂O from 7 to 41. Physical therapy student researchers were trained in the administration of the IMT devices and set the initial training level at less than or equal to 2 cm H₂O below the one repetition maximum level for each subject, such that they could complete ten breaths without symptoms of hyperventilation. The training goal was to achieve thirty breaths, over two sessions a day, five days a week, over the training period. This training protocol has been shown to be feasible and effective in the COPD population,^{40,41} and SCI.^{9,20} Participants were given weekly training diaries noting training resistance, perceived rate of exertion, adverse responses, and number of breaths completed. If a training diary was forgotten a verbal report was recorded by a student researcher. All participants received their own trainer and resistance was progressed weekly.

Measures

A subjective survey was administered during pre- and post-testing to serve as a measure of the combined IMT and exercise. Five questions were asked related to daily activity challenges, which tasks participants needed to improve, previous RRT, perceived understanding of exercise, and ability to clear secretions.

Pre- and post-data were obtained for four measures: transfer test, t-shirt test, four-directional reach test, and four-directional trunk strength. The same researcher completed pre- and post-tests for the four-directional reach and four-directional trunk strength tests.

The transfer test is a timed test which had subjects transfer from their wheelchair to a mat table, to the supine position, and return, and was adapted from Chen *et al.*⁴² The transfer test was created to assess postural stability that was similar to daily mobility tasks that a person with SCI would perform.⁴² Currently, there are no minimal detectable change (MDC) values for this test, as it was adapted for this pilot study. Any decrease in time of transfer can indicate meaningful change, as it indicates more efficient task performance. Subjects were allowed to complete the transfer in any manner they chose. Transfers to and from the mat were timed separately. Times were recorded in seconds and summed for total transfer time. Timing began when a subject was instructed to go and stopped when the subject was fully supine. Timing for the reverse transfer was completed with the same procedure. Each transfer direction was only completed once. For safety, two researchers were present to assist the subject if needed.

The t-shirt test was adapted from two studies that investigated assessment tools for measuring postural stability for people with SCI.^{43,44} The t-shirt test measured time to don and doff a t-shirt. Currently, there are no MDC values for this measure, as it was adapted for this pilot study. Subjects were seated on the mat table without back support, with legs and feet supported. A standard height table was positioned directly in front of the subject with an XXL unisex t-shirt placed flat and face-down on the table. Timing started when the subject first touched the shirt and ended when the subject had donned the shirt, and said, “done”. The process was reversed for taking the t-shirt off. For safety, two researchers were positioned to assist the subject if needed. Each subject performed the test twice. Times for donning and doffing were added for a total time, with shorter times indicating better performance, and the best trial was recorded.

The four-directional reach test was adapted from the Functional Reach Test,⁴⁵ and the Modified Functional Reach (mFR) as applied to the SCI population.^{46,47} This test measured the distance the subject could reach in anterior, posterior, and lateral directions without loss of balance. The MDC for the mFR changes with injury level: C5-6 5.16 cm (2.03 in), T1-4 4.63 cm (1.82 in), T10-12 4.10 cm (1.61 in).⁴⁶ Because this outcome measure was adapted from the mFR, the same MDC values are used to determine meaningful change. Subjects were seated on the mat table without back support, with legs and feet supported. Four directions were tested: anterior, posterior, lateral left and right. Excursion in centimeters was measured from a visual marker on the wrist crease against a meter stick affixed to a board held at shoulder height by a researcher. For each direction, the right arm was designated the measured arm, except when reaching left, the left arm was used (see Fig. 1). Subjects were asked to reach as far as possible while maintaining their balance for thirty seconds. Measurements for excursion and time to maintain position were recorded by an additional researcher observing excursion along with the board. For safety, two researchers were positioned to assist subjects if needed. Seated trunk excursion has been shown to be reliable and effective in measuring postural control in people with stroke,⁴⁸ and SCI.^{47,49}

Four-directional trunk strength was assessed using a hand-held dynamometer (HHD), with testing adapted from Larson *et al.*⁵⁰ which found the use of HHD to assess postural stability for people with SCI has high intra- and interrater reliability.⁵⁰ Currently, there are limited MDC values for trunk strength, and limited investigation of HHD use with those with SCI. MDC

Figure 1 Modified Functional Reach (mFR) Test diagram. The subject was seated on a mat table with hips and knees at 90 degrees, and feet flat on the floor. For each direction, the right arm was designated the measured arm, and had a visual marker at wrist (red line) to measure reach. When reaching to the left the left arm was the measured arm. Excursion in each direction was measured in centimeters against a board with a meter stick affixed at shoulder height (blue line). Four directions were tested: anterior (1), lateral left (2), lateral right (2), and posterior (3).

values for trunk strength HHD for individuals with chronic stroke are: flexion 8.34 kg, extension 7.32 kg, lateral flexion 6.48 kg (average MDC of assessment of each side).⁵¹ These MDC values were used to determine meaningful change in the present study. Subjects were seated on the mat table without back support, with legs and feet supported. Trunk strength was measured in flexion, extension, and lateral directions. The researcher applied force to the trunk by placing the HHD in four locations: anterior, mid-sternum; posterior, thoracic spine, midway between the superior and inferior angles of the scapula; right and left lateral, lateral aspect of the acromion process. Force was applied perpendicular to the subject's trunk and graded to allow time for the participants to respond. The instructions given to the participants were: "hold, do not let me move you." The test was concluded when the participant was displaced 2.5 cm (1 in) in the direction in which force was applied (visually estimated by linear trunk movement). The peak force registered by the HHD was recorded. Subjects had two practice trials, and three recorded trials. A 15-second rest period followed each trial. For safety, two researchers were positioned to assist patient if needed.

Data analysis

Descriptive statistics were completed for all data collected. Mean difference for each subject for each outcome measure between pre- and post- was calculated; transfer test times were summed for total transfer time; the best T-shirt test trials were summed for total test time; best trials for HHD for each direction were summed (HHD Sum); and MFR trials in each direction were averaged, then summed (MFR Sum). Results were compared to MDC values when available.

Results

Demographics

Ten individuals with SCI consented to the study. Four participants did not complete the study. Subject 2 and 9 did not complete post-test data due to hospitalization. Subject 6 and 10 reported they did not use the IMT, therefore changes would not reflect the aim of the study and their data were excluded. Six participants completed the training and were included in the analysis. Five of the participants were male and one was female; four had incomplete injuries, and two had complete injuries; four had cervical level injuries, and two had thoracic. The average age was 33 years (SD = 18.6 years) and time since onset of injury was 7 years (SD = 4.0, see Table 1). Pre and post measures were obtained for all participants who completed the training. Twenty-eight IMT training logs were collected from the participants. Subject 3 and 5 reported completing the most training.

Participant survey

None of the participants reported adverse effects due to the respiratory training in the collected diaries or in the surveys. Individual reflections regarding components of the study were commented on in the post-intervention survey. Subjects reported various improvements such as:

"It normally takes 30 min to transfer chair to couch and I am able to do it in 10 min now."

Subject 4

"I feel more stamina- don't fatigue as easily."

Subject 1

"[I] can't tell a difference because I don't get secretions, but lung capacity is better." Subject 5

Table 1 Subject demographics.

subject	Level	C/I	AIS	Yrs post	Age	Sex	# logs
1	C5	I	D	5	24	F	5
2*	T6	unknown	unknown	25	50	M	0
3	C3	I	D	2	71	M	6 [†]
4	C6	I	B	9	27	M	5
5	C6	I	B	13	27	M	6
6*	T9	C	unknown	2	37	M	1
7	T5	C	unknown	9	23	M	4
8	T4	C	unknown	4	23	M	1
9*	T9	I	unknown	27	37	M	0
10*	T3	C	unknown	20	23	F	0

Level = injury level, C = complete injury, I = incomplete injury, ASIA = ASIA level as reported by participant, yrs post = years post injury, F = female, M = male, # logs = the total number of diaries turned in. Subjects self-reported injury level, complete versus incomplete, AIS classification, and years post injury. Subject 2 and 9 did not complete post-test data as they were hospitalized, subject 6 and 10 did not use the IMT, changes would not reflect the aim of the study therefore their data was excluded. Level of injury, complete versus incomplete, AIS level, age and time since injury were self-reported by subjects.

*Indicates data removed from analysis secondary to dropout.

[†]Indicates participant provided additional 3 verbal logs when physical log misplaced.

Additional self-reported benefits of IMT included:

“When I used the breather I think it helped with going to the bathroom.” Subject 8

“[I feel] stronger on the device. [Did] not translate [into] a change in activities.” Subject 3

“[I feel] happier, stronger, ADLs became easier. [I can] take deeper breaths so more energy after this training.” Subject 5

“[I am] using more resistance because of the device” Subject 7

Outcome measures

Mean difference for all measures across subjects indicates overall improvement in all four functional outcome measures (Fig. 2). All subjects improved in the time to complete the transfer test, mean -14.62 s (SD = 7), except subject 5, who reported excessive fatigue, noting that his aide had not been present to assist him earlier in the day. The t-shirt test results showed subjects overall improved, mean -7.83 s (SD = 13.89). Subject 4 did not improve, with increased time on the post-test, however, he noted increased fatigue as he had performed aerobic exercise just prior to testing. Subject 3 (pre/post diff = -26.33 s) and subject 7 (pre/post diff = -18.69 s) showed greatest improvement in the t-shirt test. Four-directional trunk strength assessment showed the least change pre- and post-interventions in all four directions, mean 6.73 kg (SD = 8.02). Subject 7 showed the most improvement in the anterior and left directions (pre/post diff = 4.6 kg; pre/post diff = 2.5 kg, respectively). The multi-directional reach test demonstrated the greatest

improvement in the anterior and posterior directions, mean 3.75 in (SD = 8.07), with subject 3 (pre/post diff = 11 in anterior; pre/post diff = 5 in posterior) demonstrating the greatest improvement.

Discussion

This pilot study demonstrated that combining IMT with a community exercise program can be a positive intervention strategy for individuals with chronic SCI. The effects of IMT and exercise on function were determined qualitatively through the training diaries and the pre- and post-surveys. Objective measures improved by the majority of the participants.

Compliance with respiratory training was mixed. Those with tetraplegia have greater potential for respiratory compromise and could achieve greater improvements from IMT than those with thoracic injuries due to decreased innervation of respiratory muscles.^{27–30} Our findings support that subjects who reported higher level injuries also reported greater compliance with the IMT. Subject 1 and 3, who had cervical level injuries, reported the greatest compliance with IMT and improved most in the functional measures. Conversely, participants with thoracic injuries perceived little benefit of IMT and had poorer reported compliance (Table 1). This discrepancy may have been due to incomplete or ineffective education on respiratory health during rehabilitation, with the added barrier of few community resources for health promotion.^{16,17}

The improvements from pre- to post-intervention were the greatest with the transfer and t-shirt tests. Improvements in these tasks' efficiency may positively impact day to day life as these tasks are completed daily. The results are supported by the subjective

Figure 2 Results by subject, by outcome measure, pre- and post-intervention. Data were removed from subject 4, and subject 5 for the T-shirt Test (TST) and the Timed Transfer Test (TTT) respectively. Results for multidirectional reach (MFR) and four direction trunk strength (HHD) have all subjects included in analysis.

responses that time to complete tasks had decreased. The subjects who decreased their times the greatest were individuals with cervical level injuries, who would have decreased hand function and would typically take longer with these tasks. Therefore, the decrease in time is particularly important for task efficiency, and clinically relevant as these were individuals considered to have chronic injuries living in the community.

The multidirectional reach improved in all subjects except subject 8. Given the greater impact on trunk stability of those with higher-level injuries,^{44,49} improvements were the greatest in the two individuals with cervical injuries. Sliwinski *et al.*,¹⁹ found a positive change in functional reach improves postural control and seated balance, skills that are vital for individuals with SCI.¹⁹ With the exception of subject 8, all subjects improved beyond the MDC values for mFR used for comparison in this study. These results show meaningful

change and indicate improvement in postural control and sitting balance.

All subjects improved in the HHD from pre- to post-intervention but did not surpass the MDC values used for comparison in this study. Though changes were small, Gagnon *et al.*,⁴⁷ showed increased trunk strength and reaching ability together can facilitate wheelchair propulsion, both propulsion velocity, and ability to perform dynamic tasks.⁴⁷ This is a vital skill for people with SCI as it is often their primary means of mobility. Therefore, even small improvements in reach and trunk strength together may clinically indicate improved efficiency for wheelchair propulsion and daily tasks such as transfers and dressing.

Though previous literature supports using IMT to improve respiratory health,^{20,33} the lack of compliance with IMT with some participants may have been due to incomplete understanding of the purpose and benefits of RRT. IMT has been shown to positively affect lung

function which can last even after training stops,³⁷ improving secretion management,^{27,37} chronic activity-related dyspnea, and physiological response to aerobic exercise.³⁸ Although subject 3 had the greatest self-reported compliance and improved in the objective measures, he did not attribute functional improvements to the IMT training, but he stated that he would continue the IMT.

The disparity between subject beliefs and extensive literature supporting IMT shows a further need to explore education methods for people with SCI on the importance of lifetime respiratory health. Previous studies have shown a patient-centered approach with training in self-efficacy and peer-to-peer mentorship can improve receptiveness to education and discussion of management of secondary conditions. However, it appears education needs to continue even after discharge from rehabilitation and needs to include community centers and community health care professionals to increase knowledge of SCI in order for individuals to access appropriate care.^{16,17}

Given the lack of community programs and resources for this population, this small study offers a positive addition to the literature. This study supports continued community programs and education for individuals with SCI since life expectancy is increasing,³ and the consequences of aging and inactivity can have a negative impact on function.^{4,52}

Limitations

As this was a preliminary pilot study, there are several limitations to our findings. This includes a small convenience sample, lack of control group, and a heterogeneous population of subjects. The use of volunteers may have affected the results, as a volunteer bias may have influenced compliance in the exercise program and IMT training. In addition, subjects self-reported injury level and classification; many were not aware of the difference between motor and sensory incomplete. Being in a community setting, and unable to perform a full AIS assessment, classification of each subject was unable to be verified other than by self-report. Because of these limitations, it is difficult to generalize our findings with confidence to the overall SCI population.

Conclusion

This prospective study was the first of its kind to consider the use of IMT in combination with a community exercise program and supports the use of IMT with an exercise program for those with chronic SCI living in the community. Overall, subjects reported positive impacts in daily life and improved across all functional

outcome measures. These results do not indicate whether the improvements were a result of the exercise program or the IMT, as all subjects received both interventions. With increased education and expansion of these types of programs, compliance with an IMT program may increase.

Future research

This study revealed a need for expanded education regarding lifetime respiratory health as these individuals are living longer,³ increasing the likelihood of rehospitalization,^{4,5} and they have greater barriers to accessing community care specific to their condition.^{13–15} The four outcome measures were selected because of the potential to impact daily functional change, however, there is a lack of validated outcome measures that adequately assess function in this population. Measuring multidirectional reach and trunk strength using dynamometry in the SCI population have not been extensively validated and it is unknown how improvements translate to function. Future controlled studies should investigate outcome measure validity, as well as cervical versus thoracic injuries as separate subgroups.

Disclaimer statements

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Conflicts of interest The authors report no conflict of interest.

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