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REVIEW ARTICLE

Effect of Vocal Exercise on Respiratory Function and Voice Quality in Patients with Cervical Spinal Cord Injury: A Mini-review

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Objectives: This study reviewed the effect of vocal exercise on patients with cervical spinal cord injury (SCI). **Methods:** An electronic search of the Cochrane Central Register of Controlled Trials (CENTRAL), MEDLINE, and Embase databases was conducted for relevant studies published between 1980 and 2022. The review included studies that used randomized controlled trials to examine the effects of vocal exercise on people with cervical SCI. **Results:** We screened 1351 articles, of which 4 studies were eligible for inclusion. Vocal exercises were conducted two or three times a week for 12–24 weeks. Random sequences were adequately generated in all studies. All studies used respiratory function as the main outcome, and three studies used vocal quality as an outcome. In all studies, there were no dropouts other than those caused by unexpected illness. Vocal exercises were reported to have a positive effect on respiratory function in all studies and on voice quality in three studies. Meta-analysis was not possible because of the heterogeneity of the studies. **Conclusions:** Vocal exercise for SCI is a sustainable method that does not require special equipment or skills. More studies with large sample sizes are needed to confirm the effects of vocal exercises in patients with cervical SCI.

Key Words: rehabilitation; spinal cord injury; training; vocal exercise

INTRODUCTION

Cervical spinal cord injury (SCI) is a devastating disease that alters the quality of life. The worldwide incidence of cervical SCI is approximately 50 people per million.[1)] Traffic trauma and falls are often the causes of cervical SCI. The average age at injury is 40 years, and incomplete or complete quadriplegia is common among patients with cervical SCI.[1)] Respiratory dysfunction is a major cause of morbidity and mortality in patients with cervical SCI and is of particular concern as a severe consequence of cervical SCI.[2)] The complication rate of respiratory failure among patients hospitalized for cervical SCI has been reported to be approximately 60%.[3)] Respiratory dysfunction is characterized by low lung volume and a weak cough secondary to respiratory muscle weakness in cervical SCI.[4)] Weak respiratory muscles result in reduced lung volume, increased frequency of respiratory tract infection, and reduced chest wall compliance.[5,6)] Additionally, respiratory dysfunction can negatively affect vocal quality by reducing vocal loudness and decreasing phonation length.[7,8)]

Voice exercise improves respiratory muscle strength, endurance, and flexibility and includes warm-up, rhythm, pitch games, and singing exercises.[9)] Singing requires strong and fast inhalations, long and regulated exhalations, and accessory respiratory muscle mobilization, which are used for respiratory training.[10)] Therefore, singing may have a positive impact on respiratory function and voice quality in people with cervical SCI.[11,12)] In addition, it is likely that vocal exercises are more sustainable than regular exercises. Furthermore, vocal exercises are easier to monitor than regular respiratory exercises because of their acoustic character. Vocal exercise does not require special equipment or skills, which makes it easy to introduce in rural areas where human

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medical resources are limited.

Several clinical trials have examined the effect of vocal exercises on people with cervical SCI. A previous study reported that vocal intonation therapy was effective in improving respiratory dysfunction and vocal quality in patients with cervical SCI.[13] However, there are no reviews related to vocal exercises for cervical SCI that have assessed the findings of available trials. Furthermore, studies on vocal exercise have tended to include small sample sizes. Therefore, a review of trials is needed to evaluate the effect of vocal exercise. This study aimed to investigate the effect of vocal exercise on patients with cervical SCI. However, we expected that the number of included articles would be limited, and meta-analysis would be challenging. We considered the topic to be inappropriate for a rigorous systematic review, leading to the preparation of this mini-review with qualitative descriptions.

MATERIALS AND METHODS

This mini-review used conventional systematic review methodology. The discussion provides a mostly qualitative description of the observed trends.

Search Strategy

The databases MEDLINE, Cochrane Central Register of Controlled Trials (CENTRAL), and Embase were searched from January 1980 to March 2022. The review protocol, including the search strategy, was registered at Figshare before the review was started.[14] We used search terms that were related to the spinal cord (spine, spinal, spinal cord), injury (fracture, trauma, injure, damage, contusion, trauma, ischemia), vocal exercise (voice, vocal, sing, acoustic, sound, rhythmic, melody, harmony, music, musical), and paralysis caused by spinal cord injury (paraplegia, paraparesis, quadriparesia, tetraplegia, tetraparesis, SCI). In addition, the reference lists of the included studies were searched to identify other relevant trials.

Study Selection

This review included studies with adult participants (aged >18 years) who had sustained a cervical SCI regardless of the severity. For interventions, studies that examined structured singing training or voice training were included. Vocal exercises could be performed individually or as part of a group facilitated by a singing leader. Additionally, inpatient and outpatient programs were included. In the case of interventions combining one or more components of vocal exercise, such as instrumental and singing training, singing was required to form the majority of the intervention. For controls, studies that used no intervention, usual care, or alternative interventions were included. Studies that used randomized controlled trials, quasi-randomized, or cluster randomized trials were included. Studies that used crossover trials were excluded.

Outcomes

The primary outcomes related to respiratory function were vital capacity (VC), forced expiratory volume 1 (FEV1), forced vital capacity (FVC), total lung capacity (TLC), inspiratory capacity (IC), and residual volume (RV). The secondary outcomes related to voice function were speech intensity, voice quality (Perceptual Voice Profile and Multidimensional Voice Profile), Voice Handicap Index, sound pressure level (SPL), and other original voice function assessment scales.

Data Extraction and Quality Evaluation

The procedure for selecting studies for the review was independently completed by two researchers (YK and SH). One researcher (YK) extracted the data, and the other (SH) independently checked the data extraction forms for accuracy and completeness. Any discrepancy in selecting studies and extracting data was resolved by discussion and decision of a third researcher (RM). The risk of bias was independently assessed by two authors using the Cochrane Risk of Bias Tool version 1.[15] Any disagreements between the two authors about the risk of bias and the quality of evidence about the included studies were resolved with discussion.

Strategy for Data Synthesis

We subjectively determined the degree of heterogeneity between studies and investigated whether a meta-analysis could be performed.

RESULTS

A total of 1351 articles were screened, and 6 potentially relevant studies were identified. Of these 6 studies, 4 (80 participants) met the study inclusion criteria (**Fig. 1**).[16–19] **Table 1** shows the details of each study.

Study Characteristics

All eligible studies included patients with cervical SCI.[16–19] All studies included adults only, with sample sizes ranging from 18 to 26 participants.

Vocal exercises for SCI were conducted for 12 weeks

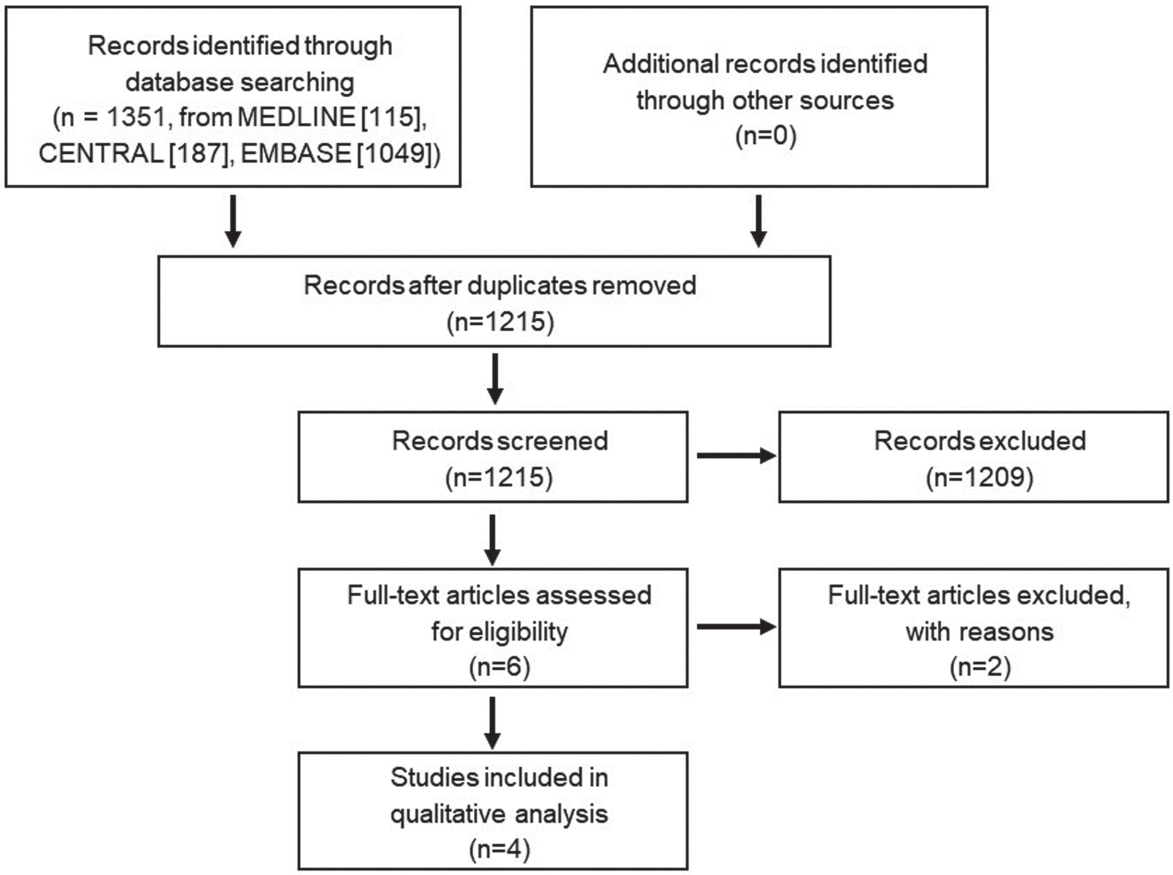

Fig. 1. Flow diagram of the screening process.

in three of the four studies[16,18,19] and for 24 weeks in one study.[17] Vocal exercises were conducted five times a week in two studies[18,19] and three times a week in the other two studies.[16,17] Vocal exercise included singing training in two studies[16,17] and respiratory and vocal exercise in the other two studies.[18,19]

In three studies, some form of evaluation of the quality of participants' voices was included as an outcome.[16–18] The quality of voice was assessed using several methods, including SPL and sustained note length. The voice turbulence index was measured in only one study, which assessed the relative amounts of periodic and aperiodic energy in the voice.[17] The FEV1, FVC, FEV1/FVC, TLC, VC, IC, and RV were measured in three studies.[17–19] SingStar scores were measured in only one study as an outcome based on pitch and timing accuracy in a singing game.[16] In this study by Tamplin et al.,[16] which focused on voice quality, voice intensity increased only in the voice exercise group, and maximal enunciation length increased 1.5-fold compared to the control group. In another study by Tamplin et al.,[17] voice quality tended to improve in the voice exercise group. In studies that focused mainly on respiratory function, Li et al.[18,19] showed that, compared with controls, vocal exercises improved VC, TLC, IC, RV, FEV1, and FVC by about 1.3- to 1.5-fold and improved FEV1/FVC by 1.2-fold.

Risk of Bias

All studies reported the methods used for random sequence generation (**Table 2**). Two studies did not report allocation concealment,[18,19] and the same two studies did not perform blinding of study participants.[18,19] No studies included blinding of outcome assessors, and all studies were judged to have an unclear risk of bias in this respect. No studies had dropouts other than those caused by unexpected illness. Therefore, the potential for bias caused by incomplete outcome data was judged as low in all studies. Study protocols were not available for one of the included studies. Therefore, selective reporting bias was judged as unclear for that study.[18] The available information did not reveal any other potential for bias.

Vocal exercise was reported to have a significant positive effect on respiratory function in all studies. The details of

Table 1. Characteristics of included studies

Study	Country	Participants	Number (I/C)	Intervention (I)	Control (C)	Assessment
Tamplin et al.[16]	Australia	Participants (>1 year after SCI) with C4–8 quadriplegia who were in stable general health and able to travel for assessment (>1 year after injury)	24 (13/11)	Singing intervention with neurologic music therapy techniques (comprising oral motor and respiratory exercises and therapeutic singing) for 1 h at least three times a week for 12 weeks.	Group music appreciation and relaxation, including song lyric discussion and musical games for 12 weeks.	Respiratory function tests, vocal assessment, including surface electromyographic activity from accessory respiratory muscles, and questionnaires.
Tamplin et al.[17]	Australia	Participants (at least 1 year after SCI) who were in good health and able to travel. Exclusion criteria included a preexisting history of speech disorder, respiratory disease, psychiatric disorder, or neurologic impairment.	12 (6/6)	Training using oral motor and respiratory exercises and therapeutic singing three times a week for 6 months.	Music sharing, song lyric discussion, musical games, and music-assisted relaxation.	Vocal assessment, including sound pressure level and assessing voice quality, subjectively using the Perceptual Voice Profile and objectively using computer analysis.
Li et al.[18]	China	Hospitalized patients with SCI diagnosed with a B or C level of injury according to the American Spinal Injury Association classification. SCI duration of at least 3 months. 18–70 years old. Able to sit for more than 30 min.	18 (9/9)	Oral motor respiratory exercise and vocal intonation therapy by a music therapist for 30 min per session, five sessions a week for 12 weeks.	Routine respiratory function training, including breathing control and pursed-lip breathing supervised by a respiratory therapist for 30 min per session, five sessions a week for 12 weeks.	Respiratory function tests, vocal assessment, questionnaires.
Li et al.[19]	China	Hospitalized patients with SCI diagnosed with a B or C level of injury according to the American Spinal Injury Association classification. SCI duration of at least 3 months. 18–60 years old. Absence of postural hypotension. Tolerance for sitting for 30 min. Stable medical treatment.	26 (13/13)	Vocal respiratory training by a music therapist for 30 min per session, five sessions a week for 12 weeks.	Respiratory control exercises, pursed-lip abdominal breathing, and respiratory physiotherapy for 30 min per session, five sessions a week for 12 weeks.	Respiratory function test.

Table 2. Risk of bias in included studies

Bias	Study			
	Tamplin et al.[16]	Tamplin et al.[17]	Li et al.[18]	Li et al.[19]
Random sequence generation	Low risk	Low risk	Low risk	Low risk
Allocation concealment	Low risk	Low risk	Unclear	Unclear
Blinding of participants and personnel	Low risk	Low risk	High risk	High risk
Blinding of outcome assessment	Unclear	Unclear	Unclear	Unclear
Incomplete outcome data	Low risk	Low risk	Low risk	Low risk
Selective reporting	Low risk	Low risk	Unclear	Low risk
Other bias	Low risk	Low risk	Low risk	Low risk

voice exercise varied from study to study, with some studies intervening with a music therapist and others not. The control group received routine respiratory function therapy in some studies and group vocal exercise in other studies. A meta-analysis was impossible because of this high variability in the intervention and control groups.

DISCUSSION

Recently, research on the effects of vocal exercise has increased.[20] In a Cochrane review of general respiratory training for SCI, dropout rates were as high as 8% to 73% in half of the 11 studies.[21] In rehabilitation, vocal exercise is one of the alternative tools to improve respiratory training adherence.[22] A previous study reported that group vocal exercises for cervical SCI have significant psychological and social benefits.[13] In addition, an interesting brain-imaging study showed that vocal exercises improve the respiratory neural plasticity of the cervical SCI.[19] Researchers are increasingly focusing on the clinical implications of vocal exercises for cervical SCI.

Although the dropout rates were low in the studies discussed in this review, further studies are needed to investigate the effects of vocal exercise on respiratory training adherence for cervical SCI. Recently, face-to-face interventions have become more difficult because of the COVID-19 pandemic, and vocal exercises using virtual reality technologies have been implemented.[22] Online virtual reality platforms for delivering therapeutic group singing interventions for people with cervical SCI are now being developed.[23] Given that virtual reality technology can intervene remotely, we believe that it could be easily utilized in rural areas.

To the best of our knowledge, this study is the first review of the effects of vocal exercise on patients with cervical SCI. However, this mini-review has the limitation that unpublished studies are not included.

Currently, there is insufficient evidence to conclude on the effects of vocal exercise on patients with SCI. However, vocal exercise for cervical SCI is considered a sustainable method that can be used to improve respiratory function and voice quality. More research with a larger number of patients in unified intervention and control groups is needed to identify the relationship between vocal exercise and improved respiratory function for patients with cervical SCI.

CONFLICTS OF INTEREST

The authors have no conflicts of interest to declare.

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