Accepted Manuscript

The effect of singing on respiratory function, voice, and mood following quadriplegia:
A randomized controlled trial

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PII: S0003-9993(12)01060-X

DOI: [10.1016/j.apmr.2012.10.006](https://doi.org/10.1016/j.apmr.2012.10.006)

Reference: YAPMR 55214

To appear in: *ARCHIVES OF PHYSICAL MEDICINE AND REHABILITATION*

Received Date: 19 June 2012

Revised Date: 8 October 2012

Accepted Date: 12 October 2012

Please cite this article as: Tamplin J, Baker FA, Grocke D, Brazzale DJ, Pretto JJ, Ruehland WR, Buttifant M, Brown DJ, Berlowitz DJ, The effect of singing on respiratory function, voice, and mood following quadriplegia: A randomized controlled trial, *ARCHIVES OF PHYSICAL MEDICINE AND REHABILITATION* (2012), doi: 10.1016/j.apmr.2012.10.006.

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Title Page

Running head: Singing training in SCI

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Institution where study was performed:

The Institute for Breathing and Sleep, Austin Health, Melbourne, Australia

Grant and Financial Support: This study was funded by a grant from the Victorian Neurotrauma Initiative (grant no. D066).

Disclaimers: none

Presentation of manuscript material: Presented at the 7th World Congress for Neurorehabilitation in Melbourne, 16-19th May 2012 and the 51st Annual Scientific Meeting of the International Spinal Cord Society in London, 3-5th September 2012.

Financial Disclosure: We certify that no party having a direct interest in the results of the research supporting this article has or will confer a benefit on us or on any organization with which we are associated AND, if applicable, we certify that all financial and material support for this research (eg, NIH or NHS grants) and work are clearly identified in the title page of the manuscript. *J Tamplin, FA Baker, D Grocke, DJ Brazzale, JJ Pretto, WR Ruehland, M Buttifant, DJ Brown, DJ Berlowitz.*

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Clinical Trial Registration Number: ANZCTRN012607000291482 (Australian New Zealand Clinical Trials Registry - www.anzctr.org.au).

Acknowledgements

This project was supported by the Victorian Neurotrauma Initiative. The authors also wish to acknowledge the technical assistance of Darren Tardio (Acoustic Engineer).

Title: The effect of singing on respiratory function, voice, and mood following quadriplegia:

A randomized controlled trial

Abstract

Objectives: To explore the effects of singing training on respiratory function, voice, mood, and quality of life for people with quadriplegia.

Design: Randomized controlled trial

Setting: Large, university-affiliated public hospital, Victoria, Australia.

Participants: Twenty-four participants with chronic quadriplegia (C4-C8, ASIA A & B).

Intervention: The experimental group (n=13) received group singing training 3 times weekly for 12 weeks. The control group (n=11) received group music appreciation and relaxation for 12 weeks. Assessments were conducted pre, mid, immediately post and 6 months post intervention.

Main Outcome Measures: Standard respiratory function testing, surface electromyographic activity from accessory respiratory muscles, sound pressure levels during vocal tasks, assessments of voice quality (Perceptual Voice Profile, Multidimensional Voice Profile), and Voice Handicap Index, Profile of Mood States, and Assessment of Quality of Life instruments.

Results: The singing group increased projected speech intensity ($p=0.028$) and maximum phonation length ($p=0.007$) significantly more than the control group. Trends for improvements in respiratory function, muscle strength and recruitment were also evident for the singing group. These effects were limited by small sample sizes with large inter-subject variability. Both groups demonstrated an improvement in mood ($p=0.002$) which was maintained in the music appreciation and relaxation group after 6 months ($p = 0.017$).

25 **Conclusion:** Group music therapy can have a positive effect on not only physical outcomes,
26 but also can improve mood, energy, social participation and quality of life for an at-risk
27 population such as those with quadriplegia. Specific singing therapy can augment these
28 general improvements by improving vocal intensity.

29

30 **Keywords:** spinal cord injuries, respiratory muscles, singing, voice, mood.

31

32 **List of Abbreviations:** SCI – spinal cord injury; sEMG – surface electromyography; BMI –
33 body mass index; SNIP – sniff nasal inspiratory pressure; MIP – maximal inspiratory
34 pressure; MEP – maximal expiratory pressure; FEV₁ – forced expiratory volume in one
35 second; FVC – forced vital capacity; TLC – total lung capacity; IC – inspiratory capacity;
36 FRC – functional residual capacity; RV- residual volume; SCM - sternocleidomastoid; SPL –
37 sound pressure level.

38 Cervical spinal cord injury (SCI) can cause loss of function in respiratory muscles and
39 subsequently decreases inspiratory and expiratory muscle strength – the degree of
40 dysfunction being dependent upon the level and completeness of the injury. Resultant
41 reductions in chest wall compliance, ineffective cough, and increased respiratory tract
42 infections^{1,2} are a major cause of illness and death.³ Respiratory dysfunction can also
43 decrease voice projection and phonation length.⁴ Further, health-related quality of life for
44 people with SCI is significantly lower than that of the general population⁵⁻⁷ and depression is
45 common.⁸⁻¹⁰

46

47 Respiratory muscle training improves respiratory muscle strength and endurance in
48 quadriplegia.¹¹⁻¹⁷ Although training is effective, patients consider it cumbersome, boring and
49 without immediate reward.¹⁸ Furthermore, function declines again when training ceases.¹²

50

51 In able-bodied people, inspiration is performed by contraction of the diaphragm, expiration is
52 essentially passive, and the accessory respiratory muscles are only used during exertion or for
53 high-effort vocal tasks.^{13, 19-21} In quadriplegia, accessory respiratory muscles
54 (sternocleidomastoid for inspiration and pectoralis major for expiration) are commonly
55 recruited at rest,^{2, 22} and to a greater degree during exertion.²³ The act of singing places
56 significant demands on the respiratory system, requiring strong, fast inspirations, extended,
57 regulated expirations, and recruitment of accessory respiratory muscles.²⁴ Therefore, singing
58 may have positive effects on respiratory function in this population.²⁵ We also postulated that
59 singing training may aid people with quadriplegia to develop effective breathing strategies
60 that would improve respiratory and vocal function.

61

This study aimed to investigate the effect of a group therapeutic singing intervention on a range of outcomes for people with quadriplegia. We hypothesized that in order to sing and to speak loudly, people with quadriplegia would increase recruitment of accessory respiratory muscles and that the deep, controlled breathing used during singing would train the respiratory muscles, improving respiratory function and voice. As music therapy has positively affected mood in other clinical populations²⁶⁻³¹ we also examined mood and quality of life outcomes.

Methods

Participants

A randomized, controlled trial design was used to assess the effect of singing on respiratory, voice, mood, and quality of life outcomes for participants with C4-C8 quadriplegia. Thematic analysis of post-study participant interviews also contributed qualitative data. Participants (> 1 year post injury) were recruited from the Victorian Spinal Cord Service (Victoria, Australia). All were English speaking, in stable general health and able to travel for the assessments. Exclusion criteria were a history of speech disorder, psychiatric disorder, neurological impairment or respiratory disease prior to injury. Stratified, block randomization was performed (using a computer-generated sequence) with allocation concealed using sealed, opaque envelopes. Randomization was stratified by previous tracheostomy history, as this has been linked to abnormal phonation and impaired laryngeal function for this population.⁴ All persons involved in recruitment, data collection and analysis were blinded to group allocation. Attempts were made to blind participants by concealing which intervention was the experimental condition. The project was approved by the institutional Human Research Ethics Committee and all applicable institutional and governmental regulations concerning the ethical use of human volunteers were followed.

87

88 **Measurements**

89 All participants participated in pre, mid, post, and 6-month follow up assessment sessions

90 consisting of: (i) respiratory function tests, (ii) vocal assessment, including surface

91 electromyographic (sEMG) activity from accessory respiratory muscles, and (iii)

92 questionnaires. No participant wore abdominal binders or other aids likely to affect lung

93 function during assessment or training. Respiratory function tests were conducted according

94 to the guidelines of the American Thoracic Society^{32, 33} and modified to incorporate the95 limitations associated with SCI.^{34, 35} Ventilatory function and upper airway function were

96 assessed using maximal inspiratory and expiratory flow-volume loops using an EasyOne

97 spirometer^a. Static lung volumes were measured by inert-gas dilution using a P.K Morgan98 M8 rolling seal spirometer with a helium analyser.^b Respiratory muscle strength was assessed

99 by measuring maximal inspiratory pressure, maximal expiratory pressure and sniff nasal

100 inspiratory pressures³⁶ using a portable MicroRPM respiratory pressure meter.^c in accordance101 with ATS/ERS guidelines.³² To ensure that subjects were performing the tests well, maximal

102 respiratory pressure measurements were repeated at least 6 times within each session, with

103 the best two values matching to within 10%. All assessments were made by the same

104 experienced operator. Lung function results were compared with able-bodied predicted

105 values for spirometry,³⁷ lung volumes,³⁸ MIP/MEP,³⁹ and SNIP.⁴⁰

106 During the vocal assessment audio data was collected simultaneously with sEMG

107 measurement of accessory respiratory muscle function during vocal tasks. These sEMG

108 signals from sternocleidomastoid, pectoralis major and diaphragm muscles were amplified

109 using the Micro1401 data acquisition system and Spike2 software^d. Audio signals were110 recorded using a calibrated Ono Sokki MI-1211 Type 1 condenser microphone^f positioned at

a distance of 30cm from the participant's mouth and analysed using an EASERA software analyser^g.

⁴¹The audio recordings from the vocal assessment were used to measure sound pressure level (SPL) and assess voice quality both subjectively (Perceptual Voice Profile⁴²) and objectively using computer analysis (Multidimensional Voice Profile on the Visipitch IV). Questionnaires included: the Voice Handicap Index (VHI)⁴³, the Profile of Mood States (POMS)⁴⁴, the Assessment of Quality of Life (AQoL),⁴⁵ and a musical background questionnaire. Post-study music participation questionnaires and participant interviews were completed at the 6-month follow-up assessment. The affect grid⁴⁶ was completed before and immediately after each treatment session. This provided a measure of any immediate effects on pleasure and arousal (scored from 1-9 on a grid).

Assessment Protocol

For the vocal assessment each participant was seated in a soundproofed room. An investigator directed participants through a protocol consisting of phonatory exercises, standardised reading passages and familiar songs. Participants selected a song to sing using the karaoke game SingstarTM which scores performance based on pitch and timing accuracy. Sound pressure level (SPL) and sEMG (quantified as area under the curve) analyses were conducted on the following three conditions: "Rainbow Passage"⁴⁷ with and without background noise, loud versus soft vowels, and speech versus singing (Happy Birthday). Background noise was delivered to each participant via headphones and was standardised to the SPL recorded during normative speaking.

Intervention

The experimental group participated in a therapeutic group singing intervention. Training intensity was one hour at least thrice weekly for 12 weeks. Neurologic music therapy techniques: oral motor and respiratory exercises and therapeutic singing⁴⁸ were employed in the singing protocol. All participants in the experimental group followed the same set intervention protocol⁴⁹. The control group participated in group music appreciation and relaxation for 12 weeks. Receptive music therapy techniques employed included: song lyric discussion, musical games, and music-assisted relaxation.

Analysis

The sEMG data were rectified and smoothed with a 0.1 second moving window.⁵⁰ To give an area under the curve measure corrected for time, background amplitude (defined as the size in microvolts of the average baseline activity between events in the absence of phonation) was multiplied by task completion time and subtracted from the total area under the curve. An acoustic engineer extracted temporal and SPL data from the vocal recordings. Perceptual voice assessments were conducted by a speech pathologist using the Perceptual Voice Profile.⁴² Recordings were de-identified during analyses. Normally distributed data are summarized as mean (standard deviation) and analysed using repeated measures ANOVAs. Non-normally distributed data are summarised as median (interquartile range) and analysed using non-parametric analyses. Intention-to-treat analysis was used with missing data imputed using the last-observation-carried-forward method.

Results

Demographic and Attendance Data

Twenty-four participants with quadriplegia (5 women) were recruited with an average age of 45 (95% CI 39-51, range 27-70). Participants were screened for eligibility and recruited

based on their ASIA score on discharge from hospital. However, the ASIA score on initial assessment for this study often differed from the hospital discharge score due to length of time since discharge and functional improvement made in that time. For example, participant 23 was recruited with a lesion level of C6B, however upon assessment was found to be at T1 level. As this participant had already consented and been assessed, and our sample size was small, we decided to include him in the study. Level of injury on assessment for all participants thus ranged from C4-T1 and is presented in Table 1.

Insert Table 1 about here.

Demographic information is presented in Table 2. As anticipated, both groups show a typical profile of respiratory muscle involvement with a reduced vital capacity and an elevated residual volume compared to reference values for an able-bodied population.

Insert Table 2 about here.

All participants rated music as important in their lives and listened to music daily. Half had played an instrument and most sang rarely or occasionally when alone. Of the 16 sessions, both groups attended a mean of 12 (3.5) sessions. One intervention participant dropped out prior to commencement. One control and two intervention participants dropped out halfway.

Insert Figure 1 about here.

Respiratory function

Respiratory muscle strength generally improved in both groups over time. There was a significant effect of group on sniff nasal inspiratory pressure (SNIP) due to baseline differences, $t(-18.78)-2.12$, $p=0.049$. No significant differences between any time periods were observed for the control group. Maximal expiratory pressure (MEP) did not show any significant main effects, but there were trends towards improvement in the intervention group, with the control group remaining relatively stable.

Insert Table 3 about here.

For the spirometric variables, there was a significant effect of time on FEV₁/FVC (forced expiratory volume in one second as a percentage of forced vital capacity) scores for the overall cohort, $F(2.70, 45.81) = 3.31$, $p=0.032$, but no group or interaction effects. There were also significant time versus group interactions for two of the lung volume variables: total lung capacity (TLC), $F(3,48)2.84$, $p=0.048$ and inspiratory capacity (IC), $F(3,48)3.50$, $p=0.022$, but no main effects. Post hoc t-tests revealed no significant differences between the groups for TLC change, but a significant decrease in IC between post-test and 6 month follow-up for the intervention participants ($p=0.008$) and non-significant trends for the pre to post increase ($p=0.068$). There were no significant differences between any other time points.

Effect size calculations were conducted to determine the size of any clinically significant changes in respiratory function. These calculations revealed a medium effect⁵¹ for the between-group difference in mean change for MEP ($d=0.57$), IC ($d=0.66$), and functional residual capacity (FRC, $d=0.73$) from pre to post assessment. A small effect was seen for FEV₁ ($d=0.39$), MIP ($d=0.24$), and SNIP ($d=0.20$). In the intervention group only, some respiratory function variables were positively correlated with attendance: FEV₁/FVC ($r=0.749$, $p=0.013$), TLC ($r=0.757$, $p=0.018$), and IC ($r=0.792$, $p=0.011$).

Surface Electromyography

The sEMG results showed substantial variation in measurements across the study cohort and thus were normalized, expressing the results as percentage change between vocal conditions (soft-loud and speech-singing), and analysed using the Wilcoxon Signed Ranks Test. Between-subject changes were analysed using the Mann-Whitney U Test^{15, 52}.

Insert Table 4 about here.

There were no significant between-group differences in the sEMG area under the curve data for the soft versus loud condition. The pre-post change in sternocleidomastoid (SCM) activation from speech to singing was significantly different between groups ($p=0.015$). The 98% pre-post change in SCM activation from speech to singing were statistically significant for the intervention group only ($p=0.007$).

Voice

To account for baseline differences in sound pressure level (SPL), individual results were normalized by subtracting soft from loud or speaking from singing (Table 5).

Insert Table 5 about here.

A significant time versus group interaction was observed for normal versus projected speech $F(3,51)3.28$, $p=0.028$. Post hoc t tests attributed this to intervention group pre-post increases, paired $t(9)-3.674$, $p=0.005$. Independent sample t -tests revealed a significant difference between groups from pre-post assessment, $t(18)=-3.339$, $p=0.004$. For the loud versus soft condition, there were trends towards an effect of time, $F(3,51) 2.30$, $p=0.088$, but no significant group or interaction effects. Post hoc t -tests revealed a significant pre-post increase in decibel change scores for the intervention group, paired $t(9)-2.512$, $p=0.033$ There were no statistically significant results in the spoken versus sung condition, however paired sample t -tests revealed a significantly higher SPL for singing than speech for both groups at each assessment period. The intervention group increase in SPL from low to high demand vocal tasks got larger over time for all vocal tasks. Large effect sizes were noted for the between-group differences in pre-post change on the projected speech ($d=0.98$) and loud vocalization ($d=0.85$).

Outcomes of singing post SCI

There was a significant effect of time in the maximum phonation length task, $F(3,51)4.10$, $p=0.011$ (Table 5). Post hoc t-tests revealed a significant pre-post ($p=0.012$) increase in mean maximum phonation time for the intervention group. There was also a significant decrease between post and follow-up assessments ($p=0.007$) where the five second improvement made during the training period was mostly lost when training ceased. Baseline cohort voice quality data revealed higher (worse) than normal scores (Multidimensional Voice Profile, Perceptual Voice Profile), but no statistically significant changes in voice quality for either group. There were trends towards an improvement in singing assessed through improvement in Singstar scores for the intervention group with a statistically significant main effect of time, $F(3,13)12.009$, $p=0.000$ and trends towards a significant time versus group interaction also, $F(3,13)2.842$, $p=0.084$. Post hoc t tests revealed a significant difference between groups on the pre-post change scores, $p=0.025$.

Mood and Quality of Life

A main effect of time (all participants improved) was found for the POMS Total Mood Disturbance, $F(3,51)2.799$, $p=0.049$, depression, $F(3,51)3.222$, $p=0.030$, and fatigue subscale scores, $F(3,51)3.246$, $p=0.029$.

Insert Table 6 about here.

There were no significant changes in quality of life (AQoL) or perceived vocal handicap (VHI) for either group. However, there was a significant improvement in pleasure scores on the affect grid from pre to post session, $F(1,21)46.597$, $p<0.001$. A significant group effect for the change in arousal, $F(1,21)9.472$, $p=0.006$, and a significant time versus group interaction, $F(1,21)8.325$, $p=0.009$ were observed; the intervention group became more and the control group less aroused.

Insert Table 7 about here.

259

260 **Thematic Analysis of Participant Interviews**

261 The post-study interviews revealed high levels of reported enjoyment and engagement in the
262 sessions and all participants recommended the groups to others. A number of themes were
263 shared by both groups: 1) encouraged social engagement, 2) positive effect on mood, 3)
264 increased energy, and 4) increased relaxation. Themes unique to the intervention included: 1)
265 singing is a positive/pleasurable experience, 2) singing increased confidence, 3) the singing
266 groups were motivating, 4) singing was challenging/confronting at times, 5) singing was an
267 independent/accessible activity, and 6) changes occurred to their voice. Themes unique to the
268 control group included: 1) reconnected people with their music, 2) expanded musical
269 horizons, 3) music-assisted relaxation was beneficial, 4) music used therapeutically at home
270 now, 5) increased participants' awareness of the importance of music in their life, and 6)
271 break in routine/diversion. Participants from both groups felt that their program of music
272 therapy had been more than a pleasant distraction, and had changed the way they would use
273 music in the future. In addition, 80% of the intervention group noticed changes to their voice
274 and breathing and had developed new techniques to improve their voice.

275

276 **Discussion**

277 Group music therapy in quadriplegia was well received and improved mood and quality of
278 life, but singing training did not show any clear, physiological improvement in respiratory
279 strength and function. This study was designed to assess the intervention across multiple
280 functional domains. We observed trends towards improvement in the intervention group and
281 specific post-hoc differences consistent with a benefit. However, it is likely that a number of
282 factors combined to diminish the observed statistical power of the study; random baseline
283 demographic differences, small participant numbers, large between-subject variability and an

active control group. Specifically, the observed statistical power for the key variable of SNIP, given our group mean difference of 6, standard deviation of 17 and 24 participants, was only 12%. If this effect size was replicated in any future trial, 254 participants would be required to show a difference at 80% power.

Respiratory function did not significantly improve however there was an overall trend, with significant pairwise, post-hoc differences on key variables, particularly respiratory pressures. Notably, TLC, FEV₁/FVC and IC were all positively correlated with attendance for the intervention group and we speculate that this reflects a dose-response effect where participants who trained more regularly showed greater improvement. The sEMG data provide further evidence for a training effect, albeit a submaximal one, as the intervention group increased recruitment of accessory neck (SCM) and chest (pectoralis major) muscles when changing from a low effort to a high effort vocal task.

The intervention group increased SPL over a number of conditions and significantly increased maximum phonation time. Controlled expiration was a therapeutic target in the intervention group and these vocal improvements (intensity and endurance) represent improved expiratory function. People with quadriplegia may also make greater use of respiratory system recoil pressure by using larger inspiratory volume to achieve louder and longer vocalisations.⁵³ Our preliminary findings suggest that either or both of these strategies may have been employed in the intervention group. Additionally, half of the intervention participants reported singing more, and three quarters were still practising the vocal exercises at the six-monthly review. This supports the assumption that singing may be better incorporated into daily routines than traditional respiratory muscle training.

The high baseline Multidimensional Voice Profile cohort data confirm previous findings that quadriplegia diminishes voice quality; in particular causing a perception of roughness and breathiness.^{4, 54} Furthermore, our blinded, subjective Perceptual Voice Profile data provide novel support to this finding.

The improvement in mood (POMS and thematic analysis data) experienced by both groups in this study was not surprising as all participants experienced a group music therapy intervention promoting social interaction and positive musical experiences. Slow, deep breathing has been shown to reduce tension and anxiety⁵⁵ and the controlled, deep breathing used in the therapeutic singing intervention may have reduced anxiety and stress via this mechanism. The development of interpersonal connections through group singing is related to the sense of belonging to a group and shared experiences of musical peak moments and catharsis.⁵⁶ The reported high incidence of social isolation and depression in the quadriplegic population^{10, 57} was evident with POMS depression scores almost double the healthy adult population and Total Mood Disturbance scores three times higher.⁵⁸ Both groups decreased their Total Mood Disturbance scores from pre to post assessment, suggesting that group music therapy may play a positive role in managing negative mood for this population.

Feelings of pleasure were significantly higher after music therapy sessions, supporting previous findings that group singing creates “a sense of happiness, positive mood, joy, elation, and feeling high”.⁵⁹ Having enjoyable intervention sessions not only aids motivation and improved attendance, but also provides important social and emotional outcomes and thereby enhances the feasibility of this type of intervention. Participants from both groups expressed that they felt reconnected to their own music, either through singing more, or through exploring and listening to music more. A greater self-awareness and consciousness

of the significance of music in life was described, together with its fundamental link to health and quality of life. Thus, music was engaged as a health-promoting resource.⁶⁰ Participants in both groups experienced opportunities for community reintegration, and for developing self-confidence and social skills to facilitate increased independence. Being a part of a group provided social support and friendship, which are natural antidotes to social isolation and depression, both common following SCI.^{10, 56, 57} However, further research is required to test alternative models for music therapy delivery given the logistical barriers that prevented willing individuals from participating.

Study Limitations

The primary study limitation is the limited statistical power as detailed previously. By chance, all five women were randomized to the control condition and this may have contributed to baseline differences in respiratory variables. We speculate that the inclusion of an active control group, rather than a “no therapy” arm diminished the effect size. Had there been no change in the control arm, the observed power would have been almost five times higher (54% versus 12%).

Conclusions

The thematic analysis of participant-reported experiences indicated that group music therapy is perceived as a necessary, acceptable, practical, and effective treatment modality by people with quadriplegia. Whilst we observed at best modest changes in response to group music therapy in the wide range of measurements conducted, we did detect changes and trends significant enough to suggest that this intervention would be an effective, sustainable treatment option in quadriplegia. It is also apparent that if this possibility is to be effectively tested and translated, new models of participation are required. These treatment models might

include internet-based group singing or greater participation by people with quadriplegia in predominantly able-bodied choirs.

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Suppliers

- a. OPS Medical, LLC, 8055 Ritchie Hwy, Suite 103, Pasadena, MD 21122, USA.
- b. Micro Medical Ltd, PO Box 6, Rochester, Kent ME1 2AZ, England.
- c. Compumedics Sleep Pty Ltd, 1 Marine Parade, Abbotsford, Victoria, 3067, Australia.
- d. Cambridge Electronic Design Ltd, 4 Science Park, Milton Road, Cambridge, Cambridgeshire, CB4 0FE, England.
- e. Ambulatory Monitoring, Inc. 731 Saw Mill River Road, Ardsley, New York 10502-0609, USA.
- f. VIPAC Engineers & Scientists Ltd, Victorian Technology Centre, 275 Normanby Road, Port Melbourne, Victoria, 3207, Australia.
- g. SDA Software Design Ahnert GmbH, Arkonastraße 45-49, 13189, Berlin, Germany.

CONSORT Flow Diagram

Table 1. Distribution of lesion level and completeness between intervention and control groups

	C4		C5			C6		C7		C8		T1
ASIA level	A	B	A	B	C	A	B	A	B	A	B	B
<i>Recruitment score</i>												
Intervention	3		4			2	4					
Control	2		5			2	2					
<i>Assessment score</i>												
Intervention	1		4			4			1	1	1	1
Control	1				1	5	1	1	2			

Table 2 Demographic information for intervention and control groups

	Intervention	Control
Age (years)	44 (15)	47 (13)
Time since injury (years)	13 (7)	8 (6)
BMI (kg/m ²)	24 (4)	28 (15)
Speech SPL (dBA)	69 (4)	68 (3)
FEV ₁ (% predicted)	63 (15)	63 (16)
FVC (% predicted)	64 (19)	62 (17)
MEP (% predicted)	80 (10)	75 (26)
MIP (% predicted)	52 (23)	77 (28)
SNIP (% predicted)	76 (26)	40 (23)
TLC (% predicted)	81 (12)	77 (12)
FRC (% predicted)	86 (16)	79 (19)
RV (% predicted)	137 (33)	118 (35)

Data expressed as mean (standard deviation). Abbreviations: BMI – body mass index; SPL – sound pressure level; dBA – A-weighted decibels; FEV₁, Forced expiratory volume in 1 second; FVC, Forced vital capacity; MEP, Maximum expiratory pressure; MIP, Maximum inspiratory pressure; SNIP, Sniff nasal inspiratory pressure; TLC, Total lung capacity; FRC, Functional residual capacity; RV, Residual volume.

Table 3 Respiratory function results across the study period for intervention and control groups expressed as mean (standard deviation)

Respiratory Function Variables	Treatment Condition	Pre	Post	6 month Follow Up
FEV ₁ (L)	Intervention	2.54 (0.49)	2.57 (0.64)	2.62 (0.56)
	Control	2.30 (0.83)	2.27 (0.90)	2.41 (0.89)
FVC (L)	Intervention	3.26 (0.85)	3.11 (0.78)	3.15 (0.85)
	Control	2.85 (1.05)	2.71 (1.01)	2.89 (1.01)
FEV ₁ /FVC (%) ⁺	Intervention	79.71 (10.71)	83.01 (9.78)	84.63 (11.03)
	Control	81.29 (7.83)	83.10 (9.23)	82.97 (9.24)
MEP (cm/H ₂ O)	Intervention	73.31 (30.29)	86.60 (37.96)	94.22 (45.14)
	Control	92.55 (35.63)	91.20 (35.04)	98.18 (39.25)
MIP (cm/H ₂ O)	Intervention	83.54 (23.07)	88.90 (20.39)	89.89 (23.37)
	Control	77.09 (26.38)	75.30 (26.68)	82.64 (32.87)
SNIP (cm/H ₂ O) ^{*+}	Intervention	63.69 (26.42)	78.80 (17.89)	79.56 (23.47)
	Control	41.70 (17.65)	52.70 (22.70)	55.82 (22.95)
TLC (L) [#]	Intervention	5.56 (0.76)	5.35 (0.98)	5.25 (0.66)
	Control	4.86 (1.54)	4.80 (1.56)	4.92 (1.56)
VC (L)	Intervention	2.79 (0.78)	2.96 (0.89)	2.83 (0.88)
	Control	2.46 (0.97)	2.49 (0.89)	2.54 (0.76)
IC (L) [#]	Intervention	2.24 (0.40)	2.44 (0.59)	2.24 (0.54)
	Control	2.04 (0.78)	1.95 (0.75)	2.08 (0.62)
FRC (L)	Intervention	3.32 (0.62)	2.91 (0.72)	3.01 (0.62)
	Control	2.81 (1.13)	2.85 (1.10)	2.83 (1.22)
RV (L)	Intervention	2.77 (0.36)	2.40 (0.45)	2.43 (0.61)
	Control	2.40 (0.96)	2.31 (0.97)	2.38 (1.08)

* = significant main effect of group, + = significant main effect of time [#] = significant time versus group interaction. Abbreviations: L, Litres; FEV₁, Forced expiratory volume in 1 second; FVC, Forced vital capacity; MEP, Maximum expiratory pressure; MIP, Maximum inspiratory pressure; SNIP, Sniff nasal inspiratory pressure; TLC, Total lung capacity; VC, Vital capacity; IC, Inspiratory capacity; FRC, Functional residual capacity; RV, Residual volume.

Table 4 Percentage change in sEMG AUC between vocal conditions for intervention and control groups, expressed as median (interquartile range).

<i>% change in sEMG AUC</i>	<i>Treatment Condition</i>	<i>Pre</i>	<i>Post</i>
Soft to Loud			
SCM	Intervention	20 (-9, 115)	70 (13, 160)
	Control	105 (23, 170)	47 (14, 103)
Pectoralis	Intervention	17 (-15, 32)	26 (6, 122)
	Control	50 (20, 112)	46 (16, 109)
Diaphragm	Intervention	6 (-9, 33)	4 (-8, 18)
	Control	14 (0, 60)	18 (-3, 56)
Speech to Singing			
SCM	Intervention	38 (4, 100)	136 (67, 271)
	Control	14 (-13, 76)	30 (7, 78)
Pectoralis	Intervention	137 (-8, 225)	83 (52, 127)
	Control	31 (-6, 122)	82 (19, 236)
Diaphragm	Intervention	42 (15, 97)	82 (53, 118)
	Control	30 (18, 49)	35 (10, 104)

Abbreviations, sEMG = surface electromyography; AUC = area under the curve; SCM = sternocleidomastoid.

Table 5 Group mean (standard deviation) voice results

	<i>Treatment Condition</i>	<i>Pre</i>	<i>Post</i>	<i>Follow-up</i>
Normal-Projected SPL [#] (dBA)	Intervention	5.9 (4.0)	7.0 (4.8)	8.1 (5.0)
	Control	8.9 (3.8)	7.2 (2.7)	8.6 (4.0)
Soft-Loud SPL ⁺ (dBA)	Intervention	14.8 (5.9)	17.9 (9.3)	15.4 (7.9)
	Control	16.6 (4.3)	18.5 (4.1)	18.5 (4.1)
Spoken-Sung SPL (dBA)	Intervention	5.1 (2.7)	5.4 (4.0)	5.2 (4.1)
	Control	3.4 (3.0)	2.8 (3.3)	3.3 (4.0)
Sustained note length (seconds)	Intervention	13.2 (4.6)	18.2 (7.0)	15.3 (6.8)
	Control	11.6 (4.0)	11.8 (5.6)	11.8 (4.4)
Singstar scores	Intervention	3994 (1442)	5589 (2499)	5738 (2443)
	Control	3968 (1639)	4054 (2179)	4894 (1933)

[#] = significant group-time interaction, + = significant main effect of time. Abbreviation: SPL, sound pressure level;; dBA, decibels A-weighted.

Table 6 Profile of Mood States mean (standard deviation) scores

Profile of Mood States Scores	Treatment Condition	Pre	Post	Follow-up
Tension	Intervention	10.1 (5.0)	9.0 (4.2)	7.9 (3.4)
	Control	8.4 (7.2)	4.8 (3.3)	7.4 (8.5)
Depression ⁺	Intervention	15.9 (11.3)	12.7 (11.2)	13.2 (12.9)
	Control	11.0 (11.7)	5.6 (5.9)	9.6 (11.7)
Anger	Intervention	11.7 (7.4)	9.7 (7.5)	13.6 (11.6)
	Control	9.8 (11)	6.5 (7.2)	8.9 (10.6)
Fatigue* ⁺	Intervention	11.5 (5.1)	8.6 (5.6)	10.3 (4.5)
	Control	9.7 (7.6)	5.2 (3.9)	6.1 (6.6)
Confusion	Intervention	8.3 (5.9)	7.1 (5.2)	7.8 (5.6)
	Control	7.1 (5.4)	5.3 (4.8)	7.0 (6.6)
Vigour*	Intervention	13.7 (6.3)	14.6 (3.8)	13.2 (5.6)
	Control	19.0 (5.0)	20.9 (3.2)	19.2 (6.5)
Total Mood	Intervention	43.8 (34.2)	32.5 (34.3)	38.4 (39.6)
Disturbance ⁺	Control	27 (42.5)	6.5 (24.3)	19.7 (46.2)

* = significant main effect of group, + = significant main effect of time. When completing the POMS, participants indicate the degree to which 65 adjectives describe their mood during the past week using a 5-point scale ranging from 0 (not at all) to 4 (extremely). The subscale score ranges are: Tension (0-36), Depression (0-60), Anxiety (0-48), Fatigue (0-28), Confusion (0-28) and Vigour (0-32). A total score is derived by summing each of the six subscales, with vigor weighted negatively. The possible range of Total Mood Disturbance scores is -32 to 200. Higher scores indicate greater mood disturbance.

Table 7 Mean (standard deviation) affect grid scores

<i>Affect Grid Scores</i>	<i>Treatment Condition</i>	<i>Pre session</i>	<i>Post session</i>
Pleasure	Intervention	5.7 (0.8)	6.9 (1.0)
	Control	5.7 (1.1)	6.8 (0.8)
Arousal	Intervention	5.7 (0.8)	6.5 (1.1)
	Control	5.3 (0.8)	4.9 (1.0)

Possible scores range from 1-9, where 9 indicates maximum pleasure or arousal

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Title:

Effect of Singing on Respiratory Function, Voice, and Mood After Quadriplegia: A Randomized Controlled Trial

Date:

2013-03-01

Citation:

Tamplin, J., Baker, F. A., Grocke, D., Brazzale, D. J., Pretto, J. J., Ruehland, W. R., Buttifiant, M., Brown, D. J. & Berlowitz, D. J. (2013). Effect of Singing on Respiratory Function, Voice, and Mood After Quadriplegia: A Randomized Controlled Trial. ARCHIVES OF PHYSICAL MEDICINE AND REHABILITATION, 94 (3), pp.426-434. <https://doi.org/10.1016/j.apmr.2012.10.006>.

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