**Title:***Acoustic, respiratory, cognitive and wellbeing comparisons of two groups of people with Parkinson’s disease receiving voice and choral singing group therapy or music appreciation activity: protocol for a randomised controlled trial.*

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ABSTRACT

**Background:** Singing is increasingly regarded as a viable, enjoyable and cost effective means of providing speech and voice therapy for people with Parkinson’s disease (PD). Literature provides evidence that voice and choral singing treatment (VCST) may provide improved vocal intensity, speech intelligibility, prosody and respiration. The objective of this randomised controlled trial (RCT) is to determine how the sophistication of voice production through singing might improve the phonatory and respiratory muscle control systems of people with PD. It is also hypothesised that the group nature of choral singing facilitates social interaction, boosts psychological wellbeing and enhances therapeutic outcomes in people with PD.   
**Method:** This study is a two armed parallel RCT quantitative design. Using a range of internationally recognised approaches to measure aspects of voice, respiration, prosody, wellbeing and cognition it will investigate whether there are significant differences between two groups of people with PD randomised in to one of two groups, one attending a choir and receiving VCST and the other attending an organised social group participating in social and music appreciation activities that will control for the effects of social group participation. The singing group will participate in singing with voice and respiration exercise activities. The non-singing group will receive a placebo music appreciation activity comprised of listening to, and watching, videos of music and singing and discussing it. The frequency of both groups will be one session weekly, for 90 minutes over 9 consecutive weeks. The outcome measures will be voice - amplitude/sound pressure levels (SPL), maximum phonation time in seconds (MPT). Voice quality (Shim & Jitter). Prosody (pitch range). Respiration - spirometric measures of subglottic pressure and peak flow. Functional measures - Cognitive, psychological and psychosocial.

**Discussion:** Results will be disseminated through peer-reviewed journals, international conferences and community reporting. No RCTs have been conducted examining the effects of VCST on a PD population.

**Health and Disability Ethics Committees approved Ethics ref:** 16/NTA/53   
**ANZCTR Trial Registration Number:** ACTRN12616000367448

### **Strengths and limitations of this RCT**

* It examines the effect of group singing, an area currently not investigated using RTC method for people with PD.
* It will enable determination of the effectiveness of the intervention.
* The treatment period is 9 weeks.
* It does not include a follow up, other than the post treatment assessment directly following the intervention.
* Results will inform the design and conduct of subsequent RCTs.

**Introduction**

Current research is recognising and building on our understanding of the ‘alterations’ caused by PD and how they can impact upon social communication skills and on the quality of life (1). PD or idiopathic Parkinsonism is a chronic, progressive neurodegenerative condition. It is more commonly seen in the elderly population with most cases occurring after the age of 50 and affecting 1-2% of people older than 60 years of age (2).

Parkinsonian speech or hypokinetic dysarthria results from an impairment of phonation, articulation, and prosody. The speech characteristics associated with hypokinetic dysarthria are contiguous with a general pattern of hypokinetic motor disorder. That is to say, they are characterised by a marked reduction in amplitude of voluntary movements, slowness of movement, movement initiation and rigidity (3). Other perceptual speech characteristics of hypokinetic dysarthria include mono pitch, mono loudness and reduced stress, all of which represent alterations in the prosodic aspects of speech (4-6). The symptomatology of PD such as hypophonia and dysprosody are well described in the literature, but little is published on how symptoms change over time and if and how phonation and prosody might be improved with therapy.

For successful voice treatment for individuals with PD, the need for focus on problems with sensory perception of effort have to be recognised and re-calibrated (7). It is often observed that when individuals with PD are asked to produce loud speech they increase their ‘habitual’ speech to a level that the listener considers within normal limits or to a pre PD level (8).

Singing in community groups, choirs and choral societies is one of the most wide-spread forms of active musical participation in many western societies and enormous numbers of people regularly come together to sing, motivated primarily by a love of music, the expressive activity of singing itself and sense of community. Group singing may have additional benefits over singing alone due to the additional psychosocial and health benefits associated with social integration. There is considerable research using the World Health Organisation’s ICF (International Classification of Functioning, Disability and Health) framework that shows that social participation and connectedness increase wellbeing and the ability to function wholly as a human being in people who acquire a disability (9).

Singing together is a socially acceptable and creative activity, having intrinsic value and rewards for those who participate (10). As well as the growth in research providing evidence of potential beneficial effects of singing on wellbeing, singing has the potential also to treat speech abnormalities because it directly stimulates the musculature associated with respiration, phonation, articulation and resonance (11). Singing requires breathing to be regulated in order to sustain the notes and glissandos. The result is a higher vocal intensity than when speaking in conversation, which has been suggested increases respiratory muscle strength (12).

Respiration is key in generating voice and is thus an essential factor for singing. Singing involves strong and fast respirations followed by extended, regulated expirations and therefore requires accurate control of breathing. In addition, people who sing are practicing a particular type of respiratory exercise that repeatedly demands diaphragm contractions for full inspirations followed by sustained contractions of expiratory muscles with semi closed vocal folds during expirations (13).

The suggestion that singing may improve respiratory and voice function is reinforced by a study investigating the effect of two forms of intensive speech treatment, (a) respiration and (b) voice and respiration using the Lee Silverman Voice Treatment programme (LSVT®). Intensive voice and respiration treatment, focusing on increased vocal fold adduction and respiration, is more effective than respiration treatment alone. Correlations between prognostic variables (i.e. stage of disease, speech/voice severity rating, depression, and time since diagnosis) and magnitude of treatment related change indicated these factors did not significantly predict treatment effectiveness (14).

A kinematic and spirometric analysis of respiratory function in PD subjects supports the contention that respiratory exercise might improve respiratory function and voice in someone with PD and that any speech disorder is not related to an abnormality in lung function (3,15). Medical interventions and traditional speech therapy techniques have not been consistently effective in treating voice and speech difficulties severe enough to impair communication and quality of life (16).

LSVT® uses loud phonation and high intensity vocal exercise to improve respiratory, laryngeal, and articulatory function during speech and has been widely reported as having a positive and long-term effect on improvements to amplitude, maximum phonation time (MPT) and fundamental frequency (*F*0) range (7,17-19).

However, with a focus on increased respiratory phonatory effort, LSVT® can adversely affect the voice because it raises vocal pitch and laryngeal muscle tension (20). Also, LSVT® has high administration costs because of the intensity of input and client contact time required. Access to speech and language therapy SLT services and limitations for some people with PD in the extent to which they can take part in activities due to their physical impairments can result in participants dropping out.

Pitch Limiting Voice Treatment (PVLT) is similar to LSVT® in that it is shown to increase loudness, but by setting vocal pitch at a lower level limits the increase in vocal pitch preventing a strained or pressed voicing (20).

Voice therapy techniques using singing as an intervention; music based voice protocols consisting of vocal warm ups and singing exercises, with an emphasis on phonation and breathing have provided promising preliminary results (21,22). An examination of the effects of a Music Therapy Voice Protocol (MTVP) on individuals with PD measuring voice intelligibility, intensity, maximum range, maximum (vowel) phonation time and mean *F0* found that patients with PD showed significant increases in speech intelligibility and in the other acoustic variables, statistically significant increases were found in speech intelligibility and vocal intensity as rated by caregivers after 12-14 sessions (22). Studies investigating VCST with people with PD have shown improvement to voice amplitude, vocal intensity, quality and range as well as singing quality and voice range (22,23).

There are, therefore, compelling reasons to believe that the sophistication of voice production through the process of singing can benefit phonatory and respiratory muscle control systems in a way that established treatments may not. Singing may be beneficial across different clinical populations and, for people with PD it not only provides the potential of improving articulatory movement and increasing amplitude, it also has the potential to engage and perhaps enhance auditory feedback, which has the potential of improving internal perception of the differentiation between that of old ‘habitual’ voice and that of a ‘new normal’ voice. There is encouraging evidence showing exercise involving laryngeal and respiratory mechanisms and increased vocal intensity will produced significant and durable increases in habitual vocal amplitude whether through LSVT®, PVLT, VCST or the Lombard effect (14,20,24).

In addition to voice, there is the associated positive effect that group singing has on the wellbeing, uplift and health of participants (10,25,26).

Two recent studies on the effects of group singing on vocal outcome measures or voice-related QoL had differing outcomes. Shi et al did not find any significant differences for which they have suggested that a variable weekly dosage of the singing sessions were a contributing factor and called for future studies to explore different intensities and frequencies of intervention (27,28). The other study (24) examined the effectiveness of group singing on vocal, respiratory and QoL outcome measures between two groups of people with PD. Participants were assigned to two groups of different dosages (a) low dosage 60 minutes once per week and (b) high dosage 60 minutes twice per week both over 8 weeks. They found no differences on any outcome measure between the low dosage and the high dosage group. Both groups did, however demonstrate significant improvements in phonation time, maximal inspiratory pressure (MIP), maximal expiratory pressure (MEP) and QoL (World Health Organization Quality of Life Questionnaire WHOQOL) (29).

This RCT study seeks to examine the effectiveness of VCST in people with PD by comparing outcomes of two groups – a singing group participating in a 90 minute once a week dosage intervention for 9 weeks and the other attending a music appreciation group. We hypothesise that singing will show improvement in voice amplitude, voice quality, prosody and QoL in the group participating in VCST.

**Objectives**

1. To examine changes to voice and well-being (acoustic and psychosocial) following a group singing intervention in people with PD.
2. To assess the attendance, retention and drop out rates of participants throughout the trial.
3. To explore the participants’ experience of engaging in the activities and outcome measures in order to inform further studies and intervention design and delivery.

**Methods and Analysis**

**Trial Design**

This study is a 9 week (16 hour) two armed, parallel randomised control trial (RCT), quantitative design using a range of internationally recognised approaches to measure aspects of voice, respiration, prosody, wellbeing and cognition. The trial will be reported according to the Consolidated Standards of Reporting Trials for experimental non-pharmacological treatment (30). The trial is registered with the Australian and New Zealand Clinical Trial Registry ACTRN12616000367448 and have been granted ethics approval from the Health and Disability Ethics Committees ref: 16/NTA/53.

The treatment dosage of 16 hours is designed to match that of the Lee Silverman Voice Treatment – extended version (LSVT-X®) (31) to enable treatment effect size comparison with published data on LSVT (32). Internationally, treatment dosage for LSVT-X® is 2 hours per week for 8 weeks totalling 16 hours, plus a further 30 minutes of homework per day.

**Participants**

Eligible participants will live in the communities of Hamilton (Waikato) and Tauranga (Bay of Plenty), New Zealand (NZ) and will be diagnosed with idiopathic Parkinson’s disease by a Consultant Neurologist and receiving usual PD clinical care. They will have no other neurological disorder other than PD. Symptom severity was assessed according to the Hoehn and Yahr rating scale - Hoehn and Yahr stage 2-3 (33).

Participants will be on stable regimen of anti-Parkinson medication and have no comorbidities such as a stroke, seizures, head trauma or pulmonary disease (COPD) and have not received treatment for depression, alcoholism or drug abuse. They will be non-smokers (more than 5 years not smoking) and will not have received speech and language therapy within 1 year from commencement of the study.

Participants will be prescribed anti-Parkinson (levodopa) medication. To safeguard against On – Off motor fluctuations and to improve the chance that participants will be in an optimum ON phase whilst undergoing assessments, appointments will be arranged to occur no more than two hours after taking their Parkinson’s medication. PD symptoms can vary significantly according to medication levels (34).

Participants will be contacted by phone prior to their appointment to remind them of the appointment and to remind them to take their medications at the correct time. For the same reason, an effort will be made to ensure that scheduled appointment times for both pre and post-treatment assessments occur at the same time of day to avoid fluctuations that may have influenced the outcome measures.

**Recruitment**

Potential PD participants will be recruited from Parkinson’s New Zealand (Waikato) and Bay of Plenty District Health Board databases who have agreed to assist with this study. They will be sent an invitation letter introducing the study, providing key points and a means of replying.

Those who return the signed reply will be contacted by a researcher to confirm their willingness to participate, answer any questions that they may have and ascertain recruitment eligibility. Time will be taken to discuss the trial and what participation in the trial will involve including being randomised in to one of two groups, their required attendance over the 9 week treatment period and the pre and post treatment assessments.

Participants will then be sent a Patient Information Sheet (PIS) in accordance to HDEC guidelines. This letter provides an introduction to the study, key points and a prepaid postal consent form for participants to sign and return.

One month prior to the pre-treatment assessment, consenting participants will receive full details pertaining to the assessment along with four self-reported questionnaires of voice quality, quality of life, anxiety and experience of daily living with PD.

**Pre and Post Treatment assessment**

**Functional assessment**

Four self rating questionnaires will be used to measure general function and symptom severity. Participants and their partners’ perception of voice will be measured using the impairment centred Voice Handicap Index-10 (VHI-10) (35,36), the (VHI-10P) Partner variant (35).

The VHI-10P has the same ten questions as the VHI-10 adjusted to read in the third person enabling perceptual rating of the participant’s voice by the partner. The Voice Handicap Index (VHI) measures voice handicap and is widely used internationally and found to have high reproducibility and excellent clinical validity (37,38) and has proved to be a useful instrument to monitor the treatment efficacy for voice disorders (36). The VHI-10 was designed to be a shortened questionnaire containing 10 statements from the 30-item VHI form. There is no loss of utility or validity of the VHI-10 compared with the VHI for assessing initial patient-based voice handicap evaluation and longitudinal follow-up after treatment (36).

The Depression Anxiety Stress Scale (DASS-21) (39)will enable assessment of participant anxiety, stress and depression.

The Depression Anxiety Stress Scales DASS-21 a short form version of the original DASS developed by Lovibond and Lovibond (40) has been validated in a number of populations such as Hispanic adults, American, British and Australian. It is a screening tool for identifying, differentiating and assessing depression, anxiety, and stress through a 21 item self-completed questionnaire divided into 7 questions in each of the three domains of depression, anxiety and stress.

Quality of life will be measured using the Parkinson’s disease Questionnaire-8 (PDQ-8) (41)**.**

The PDQ-8 is an established assessment and is a short form version of the PDQ-39 which has been validated in the UK and US as well as being translated into 11 other languages. Both measures demonstrate adequate internal consistency, reliability and evidence of cross-sectional validity with patient-reported measures of similar concepts (42). The PDQ-8 is based upon analysis of the original data set on which items for the PDQ-39 were selected. Each of the 39 items of the PDQ were correlated with the dimension total to which they contributed. The most highly correlated item from each dimension have been used to construct the PDQ-8.

The Movement Disorder Society-Revision of the Unified Parkinson’s Disease Rating Scale (MDS-UPDRS) is the most widely used scale for the clinical study of PD and has become the standard scale used in clinical care and research (33). Part I: Non-Motor Aspects of Experiences of Daily Living (nM-EDL) and Part II: Motor Aspects of Experiences of Daily Living (M-EDL) will measure the general function of the participants. These self rating subscales are a basic diagnostic measure of the participant’s self-rated perception of severity of motor difficulties in relation to experiences during activities of daily living.

Participants will also complete a questionnaire to evaluate any perceived personal changes owing to group participation, to determine opinion of the study process and the experience of their participation in the group activity (43). Participants will rate their agreement with 23 social and personal dimensions of wellbeing regarding group participation. A Likert rating 5-point scale will be used to assess the degree of agreement with each statement within the questionnaire, *with 1 representing strongly disagree and 5 representing strongly agree*. Participants will complete the questionnaire after the nine week treatment period and returned along with the self-reported questionnaires listed above.

**Administered Assessment – Cognition**

The Addenbrookes Cognitive Examination-III (ACE-III NZ)(44) will be administered and scored by a research assistant who is trained in accordance with the ACE-III administration manual. The ACE-III is scored on a scale from 0-100 Cut-off scores (88 and 82) are suspicious of dementia. It assesses five cognitive domains: Attention (18 points), Memory (26 points), Verbal Fluency (14 points), Language (26 points) and Visual-spatial (16 points).

Currently there is no data with regard to a minimum time before retesting with the ACE-III. Neuroscience Research Australia (NeuRA) suggests that a duration of 6 months would be acceptable with 12 months advisable. The short 9 week test re-test interval could result in participants remembering elements in the memory domain of the ACE-III. To counter this potential problem, participants will complete two regional versions – (**A** NZ) pre-treatment & (**B** NZ) post-treatment. The ACE-III has been validated as a reliable cognitive screening tool in EOD and its cognitive domains are found to correlate significantly with standardised neuropsychological tests used in the assessment of attention, language, verbal memory and visuospatial function and compared very favourably with its predecessor, the ACE-R, with similar levels of sensitivity and specificity. The two tests correlated significantly (r p = 0.99, p < 0.01).

**Table 1.**

*Table of measures*

|  |  |
| --- | --- |
| **Self-Reported Assessments** | |
| Voice | **VHI-10** + **VHI-10 (P)** Voice Handicap Index (Partner) |
| Quality of life | **PDQ-8** Parkinson’s disease quality of life Scale |
| Depression Anxiety | **DASS-21** Depression Anxiety Stress Scales |
| ADLs/functional  Motor and Non-Motor | **MDS-UPDRS** Patient self-evaluation questionnaire  **Part I:**  **Non-Motor Aspects of Experiences of Daily Living (nM-EDL)**  *Sleep, daytime sleepiness, pain and other sensation, urinary problems, constipation problems, lightheadedness on standing, and fatigue.* **Part II:**  **Motor Aspects of Experiences of Daily Living (M-EDL)**  *Speech, swallow, handwriting, dressing, hygiene, falling, salivating, turning in bed, walking, transfers.* |
| Participant Questionnaire  (Post treatment only) | To determine participant view on the process, the experience of their participation in the group activity. |
| **Research Assistant Administered Assessment** | |
| Mild Cognitive Impairment (MCI) | **ACE-III (NZed A&B)** Addenbrookes Cognitive Examination  memory/organisation/spatial awareness |

**Instrumental Assessment**Voice quality, amplitude, affective prosody and stability will be measured acoustically and data extracted from spontaneous and elicited utterances with participant voices from both groups measured individually. The recordings (44.1 kHz sampling rate, 16 bit) are to be captured using an AKG C577L (Harman International, Austria) head mounted condenser microphone connected to a 24-bit/96kHz audio interface preamp (M-Audio Mobile Pre USB) and recorded digitally on to a Dell Latitude E6540 Laptop computer using Sona-Speech II**™** Software (KayPENTAX)and saved as .nsp and .wav files. In accordance with AKG guidelines, the microphone will be placed at a distance of 1 cm behind the corner of the participant’s mouth.

**Acoustic Analysis**

Acoustic analysis of all the speech samples is to be completed using Sona-Speech II™ Software (KayPENTAX). Sona-Speech extracts acoustic parameters e.g. pitch, amplitude, and spectral characteristics during speech/voice production. The Real Time Pitch (RTP) application captured and edits voice samples taken from the reading and spontaneous conversation tasks.

The particular parameters extracted for the purpose of this study are described below. Results of the acoustic analyses will be examined to determine changes over time and to compare findings to normative data such as that reported in the published data (45).

Explanations of the dependent variables described here are based on measures presented in Sona-Speech II™ KayPENTAX - Issue F.

The research assistant’s voice and all other extraneous ‘noises’ will be removed from the samples before analysis generates a wide selection of values that included Mean Fundamental Frequency (*F0*) in Hertz (Hz) (Mean*F0*), Standard Deviation (SD), Variance in Fundamental Frequency (v*F0*), phonatory *F0* range in semi-tones (STR) and Standard Deviation Semitone (SDS).

**Comfortable Sustained Phonation**Measurements of comfortable sustained phonation (CSP) will be captured using The Multi-Dimensional Voice Programme (MDVP) during a sustained open vowel /a/. The participant will be instructed to take a deep breath and produce a sustained /a/ at a comfortable pitch and loudness for as long as comfortable (about 7 seconds). The captured sustained /a/ sample will be edited so that phonation at onset and offset are excluded to leave a ‘mid’ three second sample captured for spectral analysis.

The MDVP analysed values of Average Fundamental Frequency (Ave Fo), Standard Deviation of Fundamental Frequency (STDFo), Relative Average Perturbation (RAP), Shimmer %-Shim (Shim), Noise to Harmonic Ratio (NHR), Voice Turbulence Index (VTI), Fundamental Frequency Variation (vFo), Peak-to-Peak Amplitude Variation (vAm) and Soft Phonation Index (SPI).

Description of the captured data samples are based upon fundamental frequency (*F0*) measurement, obtained by extracting fundamental frequency from the speech sample as the lowest audio frequency with the highest intensity, less harmonic content, calculating *F0* variation both as *F0* standard deviation *F0SD, vF0* variation range (difference between minimum and maximum *F0*) in Hz and Standard Deviation (Semitone). The measure of variability in the data will be expressed in semitones reflecting the spread of the data, or the average amount by which the data deviates from the harmonic mean.

**Affective Prosody – Reading**A task to elicit prosody will consist of a given reading passage: *The Rainbow Passage*. The Rainbow Passage is a standard and commonly used means of eliciting a sample of connected speech. The participants will read the passage from a pre-prepared printed and laminated sheet whilst being recorded.

**Affective Prosody - Spontaneous Conversation**Although picture description tasks are widely used and one of the simplest means of eliciting speech and obtaining diagnostic speech samples for evaluation, results are often predictable in content and are relatively brief. However, discourse typically generated through picture descriptions has led some researchers to question whether such tasks elicit sufficient language and present sufficient cognitive-linguistic spontaneity to reveal ‘normal’ speech-language production, as it is not representative of most communicative interactions (46). For this reason, ‘natural’ spontaneous conversation is chosen over picture description for this study. Spontaneous conversation was elicited through a set questions asked by the researcher e.g. *How was that for you? What do you think of the assessments so far? What do you have planned for the weekend?*

**Aerodynamic Analysis**Instrumental analysis of the aerodynamic component of vocal function is obtained using the KayPENTAX Phonatory Aerodynamic System (PAS) Model 6600 (KayPENTAX Corp, Lincoln Park, NJ). The PAS captured phonatory acoustic/aerodynamic data (frequency, sound pressure, airflow, and air pressure) of voice signals.

The PAS program uses a variety of macros to configure graphics and to execute pre-programmed clinical protocols to capture the data and display an analysis of results. A menu of protocolsprovide the macros, which are the recommended method of performing the program operations of which there are seven pre-defined protocols - Vital Capacity, Air Pressure Screening, Maximum Sustained Phonation, Comfortable Sustained Phonation, Variation in Sound Pressure Level, Voicing Efficiency and Running Speech.

Of the seven pre-defined protocols provided by the PAS, three are chosen for this study and are detailed below.

Before testing starts, all participants will be given the PAS external module to handle. This will enable them to become familiar with the device and learn how it feels when held against their face. After familiarisation, the participants will receive training on how to use the external module and given time to practice the three different protocols.

If required the attending research assistant will hold the mask to ensure adequate seal. Specifically, with the left hand on the participant and the right hand holding the mask to the face to ensure a firm seal with no leaks. Carefully attention will be paid to the intra-oral pressure tube and the mouth to monitor location and lip closure.

The computer monitor will be placed behind the participant to enable observation of the data recording as well as the intra-oral pressure tube to check if it becomes occluded because of saliva or misplacement. A comfortable seated position for all speech and respiratory tasks will be ensured for all participants.

**Maximum Sustained Phonation**Maximum Sustained Phonation (MSP) is a widely used traditional measure of respiratory integrity and laryngeal valving efficiency. The maximum volume of air exhaled on a sustained phonatory task is called phonation volume, which is the product of MSP and flow and is thus directly related to vital capacity (47).

The PAS MSP protocol captures measurements of pitch, sound pressure level (volume), and airflow during a sustained open vowel /a/. The participant will be instructed to press and seal the mask of the PAS firmly against the face so the nose and the mouth are both covered and instructed to take a deep breath and produce a sustained /a/ with constant pitch and loudness for as long as possible.

Every effort will be made to ensure that the sample was representative of the overall phonation and to avoid such effects as straining at the termination of phonation (48).

MSP will be assessed twice on each test occasion, at the beginning and at the end of the assessment process as the last task of eight tasks listed below.

**Vital Capacity**Vital capacity is a measure of the maximum amount of air potentially available for use in respiration or phonation and is the maximum volume air that can be expired following a maximum inspiration and is, therefore, respiratory volume necessary for speech and/or singing tasks. The participants will be instructed to inhale maximally, hold their breath briefly while placing the mask of the PAS firmly against the face, and then exhale maximally. This process is repeated three times with the best of the three data used.

Data captured using this protocol includes, Expiratory Airflow Duration, Peak Expiratory Airflow (PEF) and Expiratory Volume (FVC).

**Subglottic Pressure - Aerodynamic Resistance**Common in the clinical evaluation of the aerodynamics of voicing is subglottal pressure, which refers to the amount of pressure required below vocal cords (glottis) to force them open. It is not possible to directly measure the air pressure below the glottis, but it is possible to calculate the pressure indirectly.

Subglottal pressure is measured when the participant produces successive /pa/ /pa/ /pa/ with lips closed around an intra-oral pressure tube within the PAS external module. At that moment of production of /pa/ the pressure in the oral cavity is the same as the subglottic pressure. Voicing Efficiency is, therefore, the ratio of acoustic power to aerodynamic power, calculated as the ratio of vocal intensity to the product of the airflow and subglottal pressure.

Measurements taken using the Voicing Efficiency protocol will be used to describe participants’ glottal behaviour. This protocol calculates laryngeal - subglottal pressure and glottal resistance parameters related to voicing efficiency during the production of successive /pa/ /pa/ /pa/ utterances.

The participants will be instructed to press the mask firmly against their face so that the nose and the mouth are covered with the intra-oral tube placed between the lips.

The participants will repeat the utterance /pa/ /pa/ /pa/ seven times on a single breath into the mask of the external module once data capture is initiated. Rate of repetition is set at 2 syllables per second which will be modelled using a digital Yamaha PR7TM metronome.

Data captured using this protocol includes, Maximum Sound Pressure Level (MAXDB), Mean Sound Pressure Level (MEADB), Mean Sound Pressure Level During Voicing, (PHODB), Mean Pitch (MEAP), Pitch Range (RANP), Expiratory Airflow Duration (FET100), Peak Air Pressure (PAP), Mean Peak Air Pressure (MPAP), Peak Expiratory Airflow (PEF), Target Airflow (TARF), Expiratory Volume (FVC), Mean Airflow During Voicing (MFPHO), Aerodynamic Power (APOW), Aerodynamic Resistance (ARES), Acoustic Ohms (AOHM), and Aerodynamic Efficiency (AEFF).

**Instrumental Acoustic Assessments**

The singing group and control participants will undergo identical assessment tasks as set out in the assessment guidelines and listed in Table 2 over.

**Table 2** V*oice and respiratory data capture tasks in the sequence in which they will be administered and by application.*

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| **PAS** |
| Task 1. **Maximum Phonation Time -** (MPT1) sustained /a/ |
| Task 2. **Vital Capacity** - Expiratory Volume |
| Task 3. **Subglottic Pressure** - Aerodynamic Resistance |
| **SonaSpeech** |
| Type 4. **Pitch Range** - (Glissando) /a/ |
| Task 5. **Comfortable Sustained Phonation** (CSP) /a/ - voice quality (shimmer, jitter) |
| Task 6. **Reading** - Rainbow Passage. |
| Task 7. **Spontaneous conversation** |
| **PAS** |
| Task 8. **Maximum phonation time** - (MPT2) sustained /a/ |

**Sound Pressure Levels**Voice/speech levels will be measured using a sound level meter (SLM) (CEL-246 Digital Integrating Sound Level Meter Class 2, Casella) mounted on a tripod and placed 50 cm from, and directly in line with, the participant’s mouth, with participants seated in a quiet room for the sample capture.

Calibration will be performed before each session using the CEL-110/2 Acoustic calibrator. To enable accurate measurement of the participant’s voice levels while they speak, all instruction will be given before the start of each recording. The SLM provides two acoustic values to be included in the analyses: a slow C-weighted sound level (Lceq); and a maximum sound level (Lmx). C-weighted readings are used because their minimally filtered qualities gave the most accurate representations of the sound levels.

‘C’ weighting is one of the standard frequency correction curves (or weightings) applied to sounds in a measurement device to simulate the hearing capability of the human hearing mechanism. The C weighting is most often used for the measurement of transient or impulsive noise levels. It is specified in certain noise standards for the response of the meter to peak noise measurements since it has a defined characteristic unlike the linear (or un-weighted) frequency weighting. All edited and analysed data will be recorded on to an Excel spreadsheet for further analysis.

**Randomisation**The participants who consent to participate in the study will be randomly assigned to one of two groups; a choir (experimental) receiving voice and choral singing therapy (VCST) and a group (control) participating in music appreciation activities to control for the effect of social group participation. To ensure concealment of intervention allocation, the randomisation was undertaken by a trained clinician and coordinator at the Bay of Plenty Clinical Trials Unit (BOPCTU) using computer-generated randomisation software with a 1:1 allocation ratio.

**Blinding**Following randomisation, the participants and the research assistant will be blinded to the intervention allocation at the time of the pre-treatment (baseline) assessments. The participants will be informed of their treatment allocation after completing the pre-treatment assessment on attending their respective treatment groups one week later. The research assistant will also be blinded to the intervention allocation at the time of the post-treatment assessments as participants will be informed not to tell the researcher what intervention group they attended.

**Intervention**Eligible participants will be randomly assigned to participate in one of two groups: Voice and Choral Singing Therapy (VCST) and Music Appreciation (control) for 105 minutes per week over 9 continuous weeks. A speech and language therapist (SLT), who is also an experienced musician and accompanied by a pianist will lead the VCST sessions.

Singing Group: Sessions will comprise of two components. The first component will consist of a 15 minute warm up routine that will include non-singing exercises targeting oro-facial and neck muscles, laryngeal movement, breathing exercises and postural alignment exercises. The warm up routine will also consist of simple vocalisations that include ascending/descending five-note scales, ascending/descending octave scales and ascending/descending arpeggios and glissandi. This will be followed by the second component; 90 minutes of singing separated by a 15 minute refreshment break. Nine consecutive weekly sessions over a period of nine weeks will give a total of 16 hours treatment**.**

The singing group will also be required to undertake a home voice maintenance programme for 30 minute each day (except for the day of the treatment) with compliance monitored using a homework diary**.** The home voice maintenance programme is an abridged version of the warm up routine, which also includes two songs.

A pianist playing a digital piano and the choir leader who will play guitar and tenor ukulele will provide music for the singing group. The choir leader will orchestrate the choir to create an atmosphere of fun and direct movement such as crescendo, diminuendo and tempo and, importantly, the dynamic required for driving ‘vitality’ or intensity.

VCST is the vehicle that will facilitate phonatory and respiratory exercise. The songs, therefore, are the ‘terrain’ for which the phonatory and respiratory muscle control systems will navigate. For obvious reasons, the choice of song, the duration and intensity of how it is delivered impacts significantly on the level of the exercise and therapeutic outcome. Too slow and on level terrain is likely to see no benefit, whilst too fast and on steep, uneven, terrain could be harmful.

The singing group will draw upon a pre-arranged repertoire of 9 different song lists each comprising 15 songs. This enables a 9 week rotation of the lists and by doing so reduces the potential risk of repetition, boredom and reduced motivation. Songs have been chosen that are well known and with consideration given to enjoyment, tempo and how the ‘terrain’ will facilitate an increase in respiratory and phonatory effort and improve parameters of laryngeal mobility and the respiratory and phonatory involvement required to sing them. However, to remove strain and over reaching, the piano will be transposed four chromatic steps to adjust the pitch to be a major third lower.

Careful attention will be paid at all times to the singing group’s posture when exercising and singing. Everyone will sit on comfortable padded seating, feet flat on the floor, sitting up straight with good symmetry and with arms unfolded resting on thighs. Attaining good posture will be helped greatly by the use of a digital projector connected to a laptop. This enables a large projection on to a facing wall of all song lyrics as well as the exercise regime.

Music appreciation Group (Control) Activity: The music appreciation activity will comprise of two segments. The first will involve listening to music and watching YouTube video recordings of songs. The viewed songs will be those used by the singing group and will be categorised by genre and decade of release. A facilitator will lead a discussion with the group after they have watched song videos, however no singing will take place. The group members will also be encouraged to bring influential or prominent music to the sessions considered by them as very pleasurable or that captured an important lifespan event.

The music will generate discussion around personal music preferences, group consensus and reminiscences of past memories associated with the music and the era from which the music is derived.

The second segment will involve a music quiz in which the participants will divide themselves into two teams to answer music related questions. As with the first segment, the questions will be categorised into genre and the decade in which the music was released.

Throughout the session, participants will be free to help themselves to morning tea and biscuits and have the opportunity to socialise.

**Outcome Measurements**Participants will be contacted by phone prior to their pre-intervention assessment appointment to remind them of the need to take their medications at the correct time. For the same reason, an effort will be made to ensure that scheduled appointment times for the post-intervention assessment occur at the same time of day to avoid fluctuations that may influence the outcome measures.

To capture data from all participants, the outcome measures will be administered over four days in the week prior to the interventions commencing (baseline) and over four days in the week after the 9 week intervention period. Outcome measures will be a combination of self-reported questionnaires, cognitive assessment and voice and respiratory data.

Baseline outcome measures will be administered by a skilled and blinded research assistant. Participants will also be blinded to their intervention at baseline. They will be asked not to disclose their intervention group to the assessor at the post intervention assessment. The assistant will log if instances of unblinding occur.

**Primary Outcome 1 - Voice amplitude**

Voice/speech levels will be measured using a sound level meter (SLM) (CEL-244 Digital Integrating Sound Level Meter Class 2, Casella).

Three acoustic values:

1. Slow, C-weighted sound level (LCS)

2. Average, C-weighted sound level (Lceq)

3. Maximum sound level (Lmx)

Time point 1 Baseline and end of intervention (9 weeks)

**Primary outcome 2 - Voice quality (jitter, Shim) Comfortable Sustained Phonation**

Voice samples captured for voice quality will be edited and analysed using the Multi Dimensional Voice Programme.

Programme (MDVP). Spectral analysis will include:

1. Average Fundamental Frequency (Ave F0)

2. Relative Average Perturbation (RAP)

3. Shimmer %-Shim (Shim)

4. Fundamental Frequency Variation (vF0)

As well as these data, further data analysis of prosody will include:

1. Mean Fundamental Frequency (MeanF0) in Hertz (Hz)

2. Standard Deviation (SD)

3. Variance in Fundamental Frequency (vF0)

4. Semi-tones (STR)

5. Standard Deviation Semitone (SDS)

The recordings and spectral analysis using (44.1 kHz sampling rate, 16 bit) will be captured using an AKG C410 (Harman International, Austria) head mounted condenser microphone connected to a 24-bit/96kHz audio interface with preamp (M-Audio Mobile Pre USB) and recorded digitally. Acoustic analysis of all the speech samples will be completed using Sona-Speech II 'Trademark' Software (KayPENTAX).

Time point 3 Baseline and at end of intervention (9 weeks).

**Primary outcome 3 – Comfortable Sustained Phonation time**

Voice samples captured for CSP will be edited and analysed using the Multi Dimensional Voice Programme.

The recordings (44.1 kHz sampling rate, 16 bit) will be captured using an AKG C410 (Harman International, Austria) head mounted condenser microphone connected to a 24-bit/96kHz audio interface with preamp (MAudio Mobile Pre USB) and recorded digitally. Acoustic analysis of all the speech samples will be completed using Sona-Speech II 'Trademark' Software (KayPENTAX).

Time point 2 Baseline and at end of intervention (9 weeks).

**Primary outcome 4 – Pitch Range (glissando)**

Voice samples captured for pitch range Pitch Range will be edited and analysed using the Sona-Speech – Real Time Pitch.  
The recordings (44.1 kHz sampling rate, 16 bit) will be captured using an AKG C410 (Harman International, Austria) head mounted condenser microphone connected to a 24-bit/96kHz audio interface with preamp (MAudio Mobile Pre USB) and recorded digitally. Acoustic analysis of all the speech samples will be completed using Sona-Speech II 'Trademark' Software (KayPENTAX).  
Time point 2 Baseline and at end of intervention (9 weeks).

**Primary outcome 5 – Reading Prosody**

Voice samples captured for pitch range R P will be edited and analysed using the Sona-Speech – Real Time Pitch.  
The recordings (44.1 kHz sampling rate, 16 bit) will be captured using an AKG C410 (Harman International, Austria) head mounted condenser microphone connected to a 24-bit/96kHz audio interface with preamp (MAudio Mobile Pre USB) and recorded digitally. Acoustic analysis of all the speech samples will be completed using Sona-Speech II 'Trademark' Software (KayPENTAX).  
Time point 2 Baseline and at end of intervention (9 weeks).

**Primary Outcome 6 - Average Phonatory Flow Rate, Vital capacity, Subglottal pressure and Maximum sustained phonation.**

Instrumental analysis using the KayPENTAX Phonatory Aerodynamic System (PAS) Model 6600 (KayPENTAX Corp, Lincoln Park, NJ).   
The PAS captures phonatory acoustic/aerodynamic data (frequency, sound pressure, airflow, and air pressure) of voice signals.  
Time point 3 Baseline and at end of intervention (9 weeks).

**Secondary outcome 1 - Voice VHI-10 + VHI-10P**

Using the Voice Handicap Index

Time point 1 Baseline and at end of intervention (9 weeks).

**Secondary outcome 2 - Quality of Life**

Using Parkinson’s disease quality of life Scale PDQ-8

Time point 2 Baseline and at end of intervention (9 weeks).

**Secondary outcome 3 - Depression Anxiety**

Using Depression Anxiety Stress Scales DASS-21

Time point 3 Baseline and at end of intervention (9 weeks).

**Secondary outcome 4 - Cognitive Impairment**

Using the Addenbrookes Cognitive Examination ACE-III (NZed) Two NZ variants

Time point 4 Baseline and at end of intervention (9 weeks).

**Secondary outcome 5 - ADLs/functional Motor and Non-Motor**

Using the MDS-UPDRS Patient self-evaluation questionnaire

Part I: Non-Motor Aspects of Experiences of Daily Living (nM-EDL)

Part II: Motor Aspects of Experiences of Daily Living (M-EDL)

Time point 5 Baseline and at end of intervention (9 weeks).

**Secondary outcome 6 - Participant questionnaire**

To determine participant views on enjoyment, engagement, meaningfulness of participation. Questionnaire adapted from Fogg & Talmage (43).

Following the completion of the intervention participants will be asked to complete a reflections questionnaire with questions about the activity, impact on self, health and emotions using Likert scale measures. There will also be the opportunity for the participants to provide qualitative responses, comments and examples at the end of each Likert scale.

Time point 6 End of intervention

**Sample size and analysis**

It is estimated that a sample size n=32 participants is required to have 80% power to detect a 4 dB difference in the primary outcome measure – SPL (n=32 participants total divided between a singing intervention and the music appreciation intervention). To account for an anticipated attrition rate of 15% - 20%, participant numbers will be approximately 48 (24 per group).

To compare the differences between groups, we will use the general linear model (GLM) controlling for covariates. If assumptions of normality are violated non-parametric analyses will be conducted. We will also describe the demographics of the sample using ANOVA. For secondary outcomes GLM measures will be used. Analyses will be conducted on an intention-to-treat basis.

**Dissemination**

To date there are no RCT studies that examine VCST treatment effects on people with PD that combine measures of voice, respiration and well-being. This study will help redress the balance and offers comparative data and design ideas for further studies in this field along with ideas around intervention. Results will be disseminated through publications in peer-reviewed journals and conference presentations as well as community service led articles in relevant publications, e.g. Parkinson’s Society.

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