A Pilot Study of Voice Therapy Incorporating a Vibration Device Placed at the Larynx for Adults with Vocal Fatigue

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Voice Therapy for Adults with Vocal Fatigue

ABSTRACT

Vocal fatigue, a symptom of prolonged voice use in everyday life, is a common concern among individuals who frequently use their voices in both professional and non-professional capacities. The purpose of this pilot study was to explore the use of vibration therapy as a treatment for vocal fatigue; a preliminary effort to demonstrate the therapeutic value of applying external vibration to the outside of the larynx to treat symptoms of voice misuse or overuse. A volunteer participant who had been experiencing vocal fatigue was recorded before, during, and after receiving a vibration therapy protocol using a Siri vibration apparatus from Lelo. Recordings were analyzed using speech analysis software and then compared on perceptual and acoustic measures. Changes were noted in perceptual measures of voice quality and level of tension. Acoustic measures of overall amplitude of the speech signal and energy of different formants increased following therapy. All changes were maintained, though not at their peak intensity, after a 30-minute rest period. The results of this study provide evidence of the potential therapeutic value inherent in the application of vibration to the outside of the larynx. It is imperative that all possible risks and benefits of such a therapy protocol be thoroughly investigated before it is applied in the field of Speech-Language Pathology to individuals seeking voice therapy.

INTRODUCTION

Vocal fatigue is a common complaint of people who overuse or misuse their voices in both professional and non-professional roles. In order to understand more about how this condition develops and how it can be treated, *vocal fold overuse* and *misuse*, as well as *vocal fatigue*, must first be defined. According to Welham and Maclagan (2002), there is no universally accepted definition of vocal fatigue. Titze (as cited in Welham & Maclagan, 2002) speculates that we are unable to compare it to other types of fatigue in the body because of the unique human process of vocal production, which involves repeated acceleration and deceleration of tissue over time.

For the purposes of this paper, Scherer's definition of vocal fatigue (as cited in Welham & Maclagan, 2002) will be used:

> Vocal fatigue is used to denote negative vocal adaptation that occurs as a consequence of prolonged voice use. Negative vocal adaptation is viewed as a perceptual, acoustic, or physiologic concept, indicating undesirable or unexpected changes in the functional status of the laryngeal mechanism (p. 22).

People who use their voices often in everyday life might complain of vocal fatigue. Certain professionals, such as teachers, members of the clergy, and singers, are at higher risk of developing vocal fatigue than individuals in other professions as a direct result of prolonged voice use in everyday life (Eustace, Stemple, & Lee, 1996). The most common symptoms reported by these individuals are a feeling of vocal tiredness after prolonged use, tightness in the chest and throat, and difficulty talking loudly, especially by the end of the day. Koufman and Isaacson (as cited in Eustace et al., 1996) reported that such vocal fatigue symptoms are most frequently related to *muscle tension dysphonia* (MTD), or abnormal tension in the laryngeal muscles, with or without the presence of lesions. Greene (as cited in Eustace et al., 1996) explains vocal fatigue as a slight “bowing” of the vocal folds caused by weakness in the thyroarytenoid muscle. This bowing often results in incomplete closure of the vocal folds, requiring more effort to achieve full closure and maintain phonation, which in turn leads to more vocal fatigue.

Eustace et al. (1996) conducted a retrospective study in which they compared a set of acoustic and aerodynamic measures of voice for patients who came from a variety of high vocal-risk professions. The primary complaint of all of these patients had been chronic laryngeal fatigue. Of these measures, laryngeal airflow rate for men at comfortable and high-pitch voice frequency levels were found to be above the norms, and maximum phonation time for both men and women at all pitch levels was below the norms. Both of these measures suggest an abnormal glottal chink (opening between the vocal folds). Phonatory function was also evaluated by examining videostroboscopic tapes to determine vocal fold closure. All participants showed some asymmetry in the vocal fold movement, impeding efficient closure. The most commonly occurring abnormalities were an anterior chink, an anterior and posterior chink, or a spindle-shaped chink. These findings suggest that overuse of the voice can lead to physical changes in vocal fold physiology, causing a speaker to exert more effort to achieve closure, and resulting in vocal fatigue.

A similar study was conducted by Stemple, Stanley and Lee (1995), with the goal of obtaining objective measures of voice production, in participants with no previous history of voice disorders or laryngeal pathology, after prolonged voice use in an oral reading task. This experiment allowed the authors to obtain data attributable only to the laryngeal fatigue symptom, without introducing the extraneous variables of other underlying conditions. Acoustic, aerodynamic, and videostroboscopic measures were examined. The videostroboscopic measures revealed a significant difference in vocal fold closure (which presented as anterior glottal chinks or incomplete vocal fold closure) from pre- to post-test in six of 10 participants. The authors proposed that these changes were caused by laryngeal strain from the reading task since there were no other concomitant physical changes. Another important change was the increase in fundamental frequency (F_0) of sustained vowels after the reading task. Subjects had extreme difficulty matching their pre-test lower pitch levels. The authors suggest that the changes brought about by the experimental methods conducted in that study may not compare to those of the severity of the typical patient, which explains the resulting minimal acoustic and aerodynamic changes. The Stemple et al. participants may have been able to override the effects of prolonged voice use simply by increasing their vocal effort; however, if participants were to continue using increased voicing effort over a longer period of time, it could eventually become vocal abuse and may result in pathology similar to that of the patients in the Eustace et al. (1996) study. The Stemple et al. findings are consistent with those of the Eustace et al. study wherein patients complaining of chronic laryngeal fatigue exhibited glottal chinks as a result of laryngeal strain or fatigue.

Vocal fatigue is usually treated by speech-language pathologists through therapy aimed at identifying and practicing more efficient vocal fold closure and voice use behaviours. These therapies are similar to therapy of a variety of types aimed to effect change either by teaching new physiological behaviours, or extinguishing ones that have already been learned or acquired.

One successful way to achieve this effect is through verbal input. For example, Yue and Cole (1992) conducted a study that demonstrated the effectiveness of verbal instruction on increasing motor performance of the fifth finger. Participants were given the verbal instructions to imagine the performance of a skilled movement of the fifth finger, without demonstrating any actual motor activation. The authors' goal was to determine whether or not imagined muscle contractions would increase the strength of voluntary contractions of the same muscles. Participants who were given verbal instructions to imagine producing muscle contractions yielded similar results to those of participants who trained using effortful, voluntary muscle contractions. Those results showed that verbal input can effectively change human physiological behaviour. That study serves as an example of how verbal input can result in changing human physiological behaviours.

Several studies describe therapy designed to change specific vocal fold behaviour through verbal instruction. For example, McNeill (2006) reviewed studies that demonstrate the effectiveness of specialized voice training for adjusting the F_0 of transgendered individuals. Among such studies, for instance, Soderpalm, Larsson, and Almquist (2004) found an increase in the F_0 of male-to-female transgendered individuals, as well as decreased vocal fatigue, following voice therapy, suggesting that verbal input (i.e., instructions given verbally) can elicit changes in vocal fold behaviour.

A study conducted by Andrews, Shrivastav and Yamaguchi (2000), examining the influences of cognitive cueing (generating mental images through verbal instruction) on laryngeal motor patterns, provides another example of such a phenomenon. Nine typical and four voice-disordered speakers produced three readings of a set of eight sentences. For each of the eight sentences, participants were asked to imagine or feel a situation described by cognitive cues as they read. For example, before reading the sentence “The submarine sank to the bottom of the sea”, participants were provided with verbal instructions, such as “Think about the surface of the water. Start your voice there and show me how the submarine goes down.” The sentences were analyzed using C-Speech speech analysis software for sentence duration and variability in F_0. All subjects showed greater variability in F_0 during cued renditions of sentences, demonstrating that generating a mental image before reading encouraged them to vary the pitch as they read. Surprisingly, the voice-disordered speakers produced significantly higher F_0 variability on cued trials compared to the typical speakers. The authors postulated that this discrepancy could be explained by the fact that the typical speakers were all trained singers who might already naturally produce more pitch variability in un-cued sentences and thus display less difference between cued and un-cued renditions. Sentence duration differed in both groups, as all subjects increased the duration of the utterances in response to the additional cognitive demand placed on them by the mental imagery cues.

Tse, Masters, Whitehill, and Ma (2012) conducted a study to show that verbal instructions given in the form of an analogy would elicit more dramatic changes in intonation (i.e., pitch variation) from speakers reading a short passage than would explicit verbal instruction. Twenty participants assigned to the analogy group were given verbal instructions using the analogy of a boat on a sea for three different conditions: producing minimum pitch change like that of a calm sea, producing moderate pitch change like that of a moderate sea, and producing maximum pitch change like that of a choppy sea. Instructions were accompanied by a simplistic drawing. Twenty different participants assigned to the explicit verbal instruction group were given instructions for the same three conditions (e.g., "Read aloud with no pitch variation. That is, speak without changes in the highness or lowness of your voice.") The analogy group showed no greater changes in intonation than the explicit instructions group; both groups showed changes across conditions compared to baseline. These findings suggest that verbal instructions in any form can bring about changes in how an individual might behave vocally.

Speech-language pathologists sometimes attempt to elicit physiological behavioural change using other modalities, such as visual or tactile sensation. In a preliminary study by McGarr, Head, Friedman, Behrman, and Youdelman (1986), both tactile and visual approaches were shown to be effective when providing speech training to students with hearing impairments. The participants in this study attended a school for the deaf where they received speech training as part of the regular curriculum. The speech training of the experimental groups was additionally supported by either frequency contour feedback presented visually (visual group), or F_0 feedback presented through a tactile sensory aid (tactile group). A control group had no additional sensory input. The groups were compared on measures of average voice pitch and pitch contours, both of which are typically inappropriate in this population. All groups showed improvement on these measures post-treatment; however, the control group showed much less improvement than the experimental groups. Of the experimental groups, the visual group showed most improvement on the average voice pitch measure, and the tactile group showed most improvement on the pitch contours measure. These results suggest that the use of other modalities, in addition to verbal instructions, can also be an effective way to bring about changes in vocal physiological behaviour. While this study had a small sample size requiring that the results be interpreted with caution, the findings are nevertheless compelling.

Thus far, the evidence presented shows that both verbal instructions only and verbal instructions plus sensory input can be used effectively to change vocal behaviour. Can sensory input in isolation change specific vocal fold behaviour in the same way? The Lee Silverman Voice Treatment (LSVT) is designed to increase reduced vocal loudness in patients with Parkinson's Disease (PD). LSVT is delivered in a high intensity regime, where words, phrases and sentences are repeatedly practiced with a high level of physical effort in an attempt to increase the speaker's sensory awareness of loudness, and by association, the loudness level at which he/she speaks. There is a heavy focus on training the respiratory and phonatory systems together. Clinicians are to rely mainly on modeling (i.e., demonstrating use of a loud voice) rather than giving verbal instructions (Fox, Morrison, Ramig, & Sapir, 2002). In a randomized control trial study by Smith, Ramig, Dromey, Perez and Samandari (1995), patients with PD received either respiratory effort treatment only (control group), or vocal effort treatment in addition to respiratory effort treatment (experimental group). Videostroboscopic examination revealed differences in vocal fold adduction following LSVT in the experimental group compared to the control group, suggesting that the sensory input provided by the LSVT component of therapy effectively produced a change in specific vocal fold behaviour.

Kosztyla-Hojna et al. (2012) produced a study (originally written in Polish and translated to English for the purposes of this current study) that targeted the use of physical sensation in the form of vibration in order to change vocal fold behaviour. The authors explored the use of vibratory stimulation therapy (VST) in conjunction with pharmacological treatment to improve the voice quality of patients with hyperfunctional occupational dysphonia (HOD). HOD is characterized by excess muscle tension in both extrinsic and intrinsic laryngeal muscles during phonation causing pain, dryness, clavicular breathing, "hard voice adjustment", poor perceptual judgment of voice quality, low maximum phonation time (MPT), restricted range of the singing voice, and atypical values for $F_{0,}$ jitter, shimmer, and noise-to-harmonics ratio (NHR). The participants were adults who used their voices as a tool in their professions (i.e., school teachers and university professors). Half the participants, placed in the control group, were treated pharmacologically (an inhaled mixture of Dexavenu and Afleganu in a saline solution, as well as menthol, ethereal oils and a benzodiazepine to relax muscle tension) for their voice dysfunction, while the other half, placed in the experimental group, received VST in addition to the pharmacological treatment. In general, more participants in the experimental group improved on acoustic measures, such as MPT, F_0, jitter, and noise-to-harmonics ratio, than did the control group. The experimental group also showed reduced muscle tension, improved voice quality (perceptually), and no longer used clavicular breathing patterns post-treatment. However, the details of how the vibrator was used were limited. The duration and frequency of use were specified (15 minutes, twice daily, for 21 days), but the frequency of vibration and the placement of the vibratory device are unknown. The study may also have been more convincing had they included a third experimental control group that received no pharmacological treatment (i.e., only VST), to determine how effective VST may be on its own.

Is there reason to believe that vibration of the larynx alone would yield positive results for voice misuse or abuse? Vibration is a method often used in physical therapy to stimulate electrical activity in large muscle groups. A study conducted by Herrero et al. (2011) investigated the effects of physical sensation in the form of whole-body vibration (WBV) on muscular electrical activity and peak blood flow velocity. The eight participants in this study all had spinal cord injury and used wheelchairs. All of the participants were assessed in eight different sessions. The first two sessions were held in the same week separated by at least 48 hours and they consisted of familiarizing the participants with the testing treatments and vibration stimulus. The other six sessions were held on Monday, Wednesday and Friday of the following two weeks. Every participant was assigned a random WBV treatment for each of the six sessions. The six different WBV treatments consisted of three different combinations of frequency (either 10, 20 or 30 Hz) and two protocol types ("constant" [WBV applied for three consecutive minutes] or "fragmented" [three WBV cycles of one minute separated by one minute of rest]). Herrero et al. did not explain why those particular frequencies were chosen. The participants were placed on a tilt table with a vibration platform beneath the feet. Surface electromyography activity measures were recorded for two muscles in the front of the thigh (vastus medialis and vastus lateralis). Following both the constant and fragmented protocols, the EMG measure was higher than baseline values in both thigh muscles at all frequencies. Measures of peak blood flow velocity in the leg increased when vibrated at 20 and 30 Hz. The increased leg blood flow velocity was maintained above basal values one minute after the 30 Hz stimulus was no longer present. In addition, the authors noted that WBV increases metabolic demand measured by oxygen uptake as vibration frequency increases, suggesting that vibration applied to large muscle groups causes them to become active. The implications of Herrero et al.'s study are twofold: 1) It provides evidence that vibration elicits change in the physiological functioning of muscles, and 2) It invites the question as to whether applying vibration directly to the muscles of the larynx would result in physiological benefits leading to perceptible voice improvement.

According to Kutty and Webb (2010), misuse of the vocal folds, as well as other sources of trauma or injury, primarily affect the vocal mucosa, the external layer of the vocal folds composed of lamina propria and epithelium. The vocal mucosa, superficial to the thyroarytenoid muscles, is the primary vocal fold component that vibrates during phonation. Damage to it can cause changes to fibroblasts and extracellular matrix (ECM), components of the lamina propria, resulting in vocal scarring. Vocal scarring often results in symptoms such as reduced vocal amplitude or dysphonia, and increased required effort to sustain phonation. In Kutty and Webb's study, human fibroblasts were encapsulated in a hydrogel environment designed to simulate the viscoelastic properties of human vocal mucosa. One group of samples was vibrated at 100 Hz in a two seconds on/two seconds off pattern, four hours per day for up to ten days, while another group was left static for the same period. This stimulation pattern simulates a voice use pattern in typical conversation for a prolonged period of time. For instance, a man might speak for approximately two seconds, phonating at 150 Hz, pause for two seconds while the interlocutor speaks, then speak again for two seconds. Compared to the static controls, vibration applied to the simulated mucosa samples caused an increase in expression of genes for proteins involved in the production of ECM (such as decorin and fibromodulin). It was also noted that the number of living cells remaining in the static group was greater after 10 days than that of the vibration group. The implication here is that applying vibration to scarred vocal folds could cause the tissue to express genes that allow it to restore the ECM composition, effectively reducing scarring and improving vocal quality, but there is a possibility of some cell death occurring in the process. Kutty and Webb's study provides important evidence to support the need for further research into cellular changes that could be brought about by the application of an external vibration source on the vocal folds. Taken together, the Kosztyla-Hojna et al. (2012) findings that vibratory stimulation therapy plus pharmacological treatment yielded acoustic and perceptual improvements in the voice and the Kutty and Webb findings that vibration resulted in cellular changes in simulated vocal mucosa samples compelled us to develop a hypothesis that vibration therapy may have the potential to not only elicit change in vocal fold behaviour, but also in vocal fold physiology.

In summer of 2012, David Ley, a professor of voice pedagogy in the Department of Drama at the University of Alberta, began working with a friend who had been experiencing vocal fatigue for over three weeks. His friend had two job opportunities lined up in which she would be required to use her voice professionally. Given the fatigued state of her voice, she would have had to turn the jobs down. She sought Ley's help. Ley's many years of experience in voice pedagogy allowed him to perceive in this actor's voice the signs of laryngeal tension that so often accompany vocal overuse and misuse. She exhibited hoarse voice quality and tension in her larynx. Ley began developing an idea that a small, powerful, hand-held vibration device placed on the larynx might help reduce tension associated with vocal stress. Ley was ultimately able to find the appropriate vibration device at an adult retail store. After one session using the vibration device, both Ley and the actor perceived a noticeable release of tension in her throat and an improvement in her voice quality. Ley continued to explore the effects of this vibration device on improving vocal quality. He discovered an additional use of the vibration device: varying vocal placement. He has found it useful for the professional voice user interested in exploring the various ways to project the voice.

The initial feedback Ley received from numerous students and colleagues was that it had never before felt so easy to make sound. In working with professional singers, Ley found that after using the vibration device they had more vocal range and richer resonance. Positive anecdotal evidence continued to accumulate along with Ley's conviction that he had found a way to help individuals with vocal fatigue to "find their voices, find a way to be heard". Having experienced great success using the device informally with many different voice users, Ley took the next step of bringing his observations to the Department of Speech Pathology and Audiology at the University of Alberta to begin a pilot study with the aim of better understanding the mechanisms underlying this voice therapy technique, and of extending this evidence from anecdotal to measured.

This pilot study sought also to further investigate the implications of application of vibration to the larynx for voice treatment in the field of Speech-Language Pathology. The authors sought to examine how changes in specific vocal fold behaviour can be targeted via sensory input (sensation), with the end goal of developing a clinical voice therapy that relies solely on sensory input to produce results. The aim was to explore the use of vibration therapy as a successful treatment for vocal fatigue. The authors' intent was to provide the reader with a suitable foundation for future experiments and further research in this area.

METHODS

Participant

One of the authors of this paper, SP, volunteered to participate in a brief, preliminary trial to demonstrate a protocol using the vibratory device selected by David Ley. The participant was a 25-year-old female who had been working with children five days per week in an early-education setting (clinical practicum) for six weeks prior to the trial date. During that time, there were multiple weekly periods of hour-long, continuous voice usage. In the week prior to the trial date she began experiencing sore throat and nasal congestion, further contributing to a strained vocal quality, which had developed over the course of the clinical practicum. The strained vocal quality was noted both physically by the participant, and perceptually by two listeners. David Ley and a second student researcher conducted the therapy and testing with SP.

Apparatus

The requirements for an appropriate vibration device included: small dimensions; a smoothly rounded and convex shape that would conform nicely to the thyroid lamina of the larynx; and the option to choose different frequency settings. Most vibration devices used in therapy-related settings are suited for vibration of large muscle groups and, therefore, the dimensions of these devices were inappropriate for placement on the delicate structure of the larynx. An appropriate and discreet vibration device named Siri, manufactured by the company Lelo, was found by David Ley at an adult retail store. This device fit all the necessary requirements envisioned by Ley. The manufacturer specifies that it weighs 0.16 pounds (2.56 ounces), measures 9.6 cm x 4.5 cm x 3.7 cm, contains a rechargeable battery, and has a continuum of frequency settings up to a maximum of 120 Hz, which falls generally within the range of normal human vocal frequency. A disadvantage of the continuous frequency mechanism of this vibration device is that frequency selection is not precise. The device is designed with up and down arrows to increase or decrease the frequency; however the specific frequency of vibration is not indicated.

The software program used to record and acoustically analyze speech samples was the KayPENTAX Computerized Speech Lab Model (CSL) 4500-Multi-Speech Module by STR-SpeechTech Limited, Version 3.2.0.

Procedure

Pre-Therapy. The participant was recorded reading a short standardized passage ("Grandfather Passage"). Next, the participant was recorded while producing three repetitions of "mmm-ah", sustained for approximately four seconds each. All recordings in this trial were taken at a mouth-to-microphone distance of three finger-widths. The sample was analyzed using Multispeech software. The analysis produced visual representations in the form of waveform and spectrogram to show amplitude and range of resonant frequencies (formants) in the speech sample, respectively. (The "Grandfather Passage" was recorded twice, before and after therapy. Three repetitions of "mmm-ah" were recorded before, during, and after therapy.)

Therapy. The participant's thyroid notch was located, and the vibration device placed to one side so that a flat side of the device was flush with the thyroid lamina (see Figure 1). The vibration device was set to approximately 60% of its maximum frequency (or approximately 70 Hz). A researcher massaged the laryngeal region in large circular patterns, reaching the medial and lateral portions of the thyroid lamina, as well as the area superior to the thyroid cartilage and the inferior portion of the thyroid cartilage where it meets the cricoid cartilage. The participant then began humming musical triads while the researcher continuously massaged the thyroid lamina for approximately two minutes on each side. Massaging continued while the participant produced three repetitions of “mmm-ah”. That is, recordings were made of the device on and vibrating at approximately 70 Hz plus the participant phonating simultaneously. The participant’s perceptions of voice quality and physical state were again recorded.

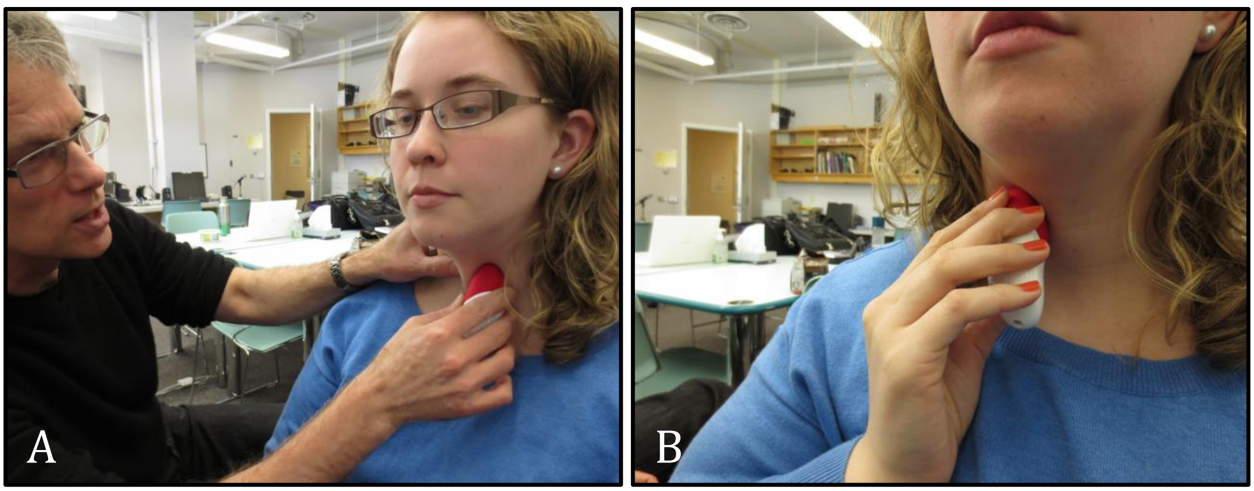

Figure 1. *A.* Locating the thyroid lamina. *B.* Placement of the vibration device on the thyroid lamina.

Post-therapy. Immediately following application of the vibration device, the participant again recorded the “Grandfather Passage” and three repetitions of “mmm-ah”. This time recordings were made of the participant phonating and the vibration device off. The sample was analyzed as described above.

Vocal Placement. This step is optional for specific populations (e.g., singers, actors, etc.) interested in varying their vocal placement. The vibration device can be placed on areas such as the cheekbone, forehead, or occipital bone at the back of the head to provide the speaker with a physical target for vocal resonance. In this trial, the vibration device was set to 100% of its maximum frequency (or 120 Hz) and placed on the participant's maxilla bone, medial to the zygomatic bone (i.e., cheekbone) (See Figure 2). The participant practiced humming triads for a total of two minutes, with the vibration device placed on each side of the face. The participant again recorded her perceptions of voice quality and physical state. After a 30-minute rest period, which involved some casual conversation, she was recorded producing three repetitions of "mmm-ah" (i.e., recordings were of the participant phonating and the vibration device off), and the sample was analyzed, as described above.

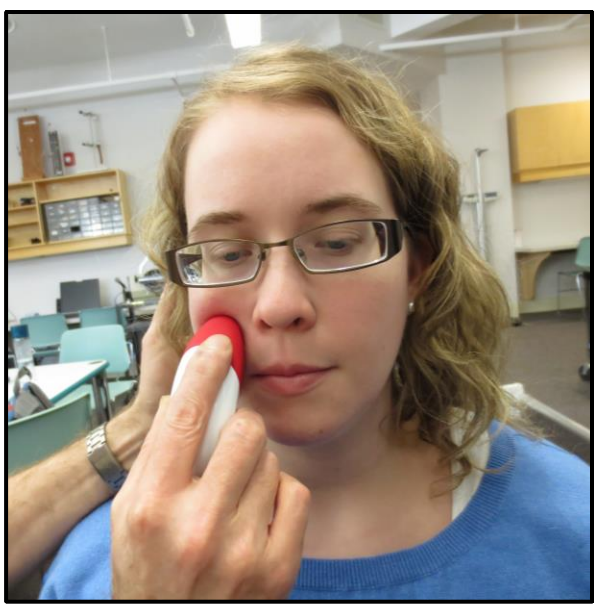

Figure 2. Placement of the vibration device on the maxilla bone.

RESULTS

Perceptual Reports

Before the therapy protocol was administered, the participant stated that her throat felt sore and dry, and she could feel tension in her larynx. She was experiencing nasal congestion and post-nasal drip as a result of a cold. The participant felt the need to clear her throat every 2-3 sentences. She described her voice quality as “crackly” at the end of words, and she claimed that it took effort for her to initiate and maintain phonation. The listeners' observations were consistent with the participant's description (i.e., mild hoarseness, glottal fry at the end of words). During the administration of the therapy protocol, the participant noted that her voice was beginning to feel “looser”, and that it took less effort to begin phonating. Following the therapy protocol, the participant reported that the “crackly” voice quality was no longer present, and she no longer felt tension in the larynx. Her throat felt relieved, and more hydrated (i.e., more saliva was present), despite not having consumed any liquid during the therapy and assessment period. She described her voice as “more powerful, fuller and louder”, and that it took much less effort for her to initiate and maintain phonation. The two researchers noted that her voice quality sounded clearer, and was no longer hoarse. Following the vocal placement step of therapy, the researchers perceived the participant's voice as noticeably louder. After a 30-minute rest period, SP had maintained this improved voice quality, and although loudness was reduced compared to measures taken immediately following therapy, it was increased compared to baseline.

Recordings of the “Grandfather Passage” provided a connected speech sample as additional perceptual data demonstrating the changes noted above in the participant's voice quality, pre- versus post-therapy. To hear the recordings, please visit http://hdl.handle.net/10402/era.22532**.**

Acoustic Measures

"Mmm-ah" recordings (available at http://hdl.handle.net/10402/era.22532) were analyzed using Kay PENTAX Multi-speech software to produce visual representations of amplitude and resonant frequency ranges. The results are displayed in Figures 3 and 4, respectively.

Figure 3 depicts waveforms produced at five different time points throughout the trial. The waveforms show that the amplitude of the participant's voice production remained fairly constant throughout the therapy process, with a slight increase post-therapy (Figure 3 *C*). A large increase in amplitude can be seen following the additional vocal placement step (Figure 3 *Vocal Placement*). Some of this increased amplitude was maintained after the 30-minute rest period (Figure 3 *After 30 minute rest*). The reader is cautioned that no measures of respiration or airflow were taken, but the mouth-to-microphone distance was kept constant and the participant reported that she was not aware of an increase in vocal effort.

Figure 4 shows spectrograms produced at the same five time points throughout the trial. The pre-therapy and post-therapy spectrograms show that the prominence of higher resonant frequencies (formants) increased following application of the vibration device (Figure 4 *C*). Following the additional vocal placement step (Figure 4 *Vocal Placement*), a large increase in energy can be seen at all frequencies, particularly at the formants above the fundamental frequency. After the 30-minute rest period (Figure 4 *After 30 minute rest*), there remained some additional energy at all formants compared to baseline. During the therapy protocol,

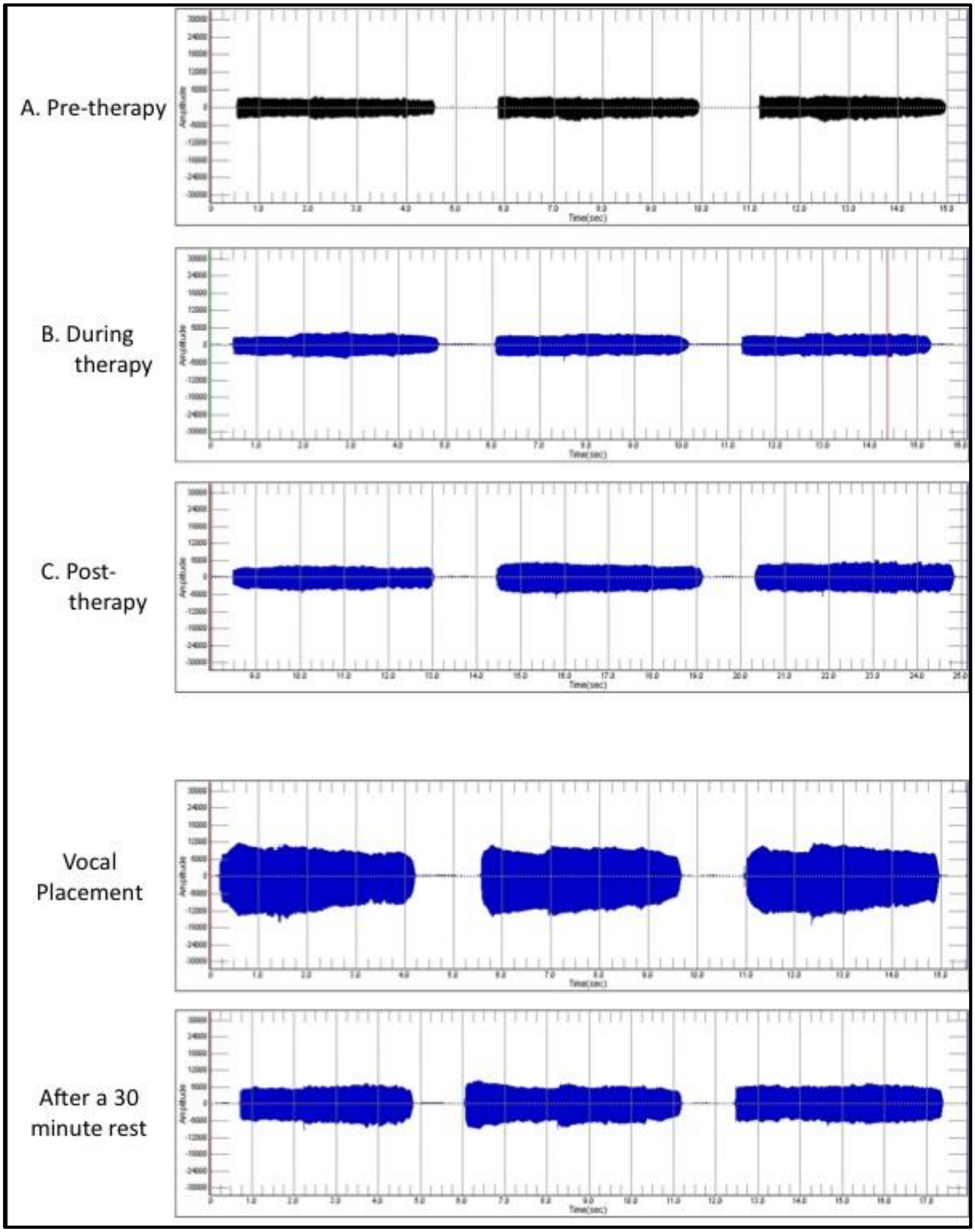

Figure 3. Waveforms produced at all stages of the therapy trial show differences in the amplitude of the participant's productions of "mmm-ah".

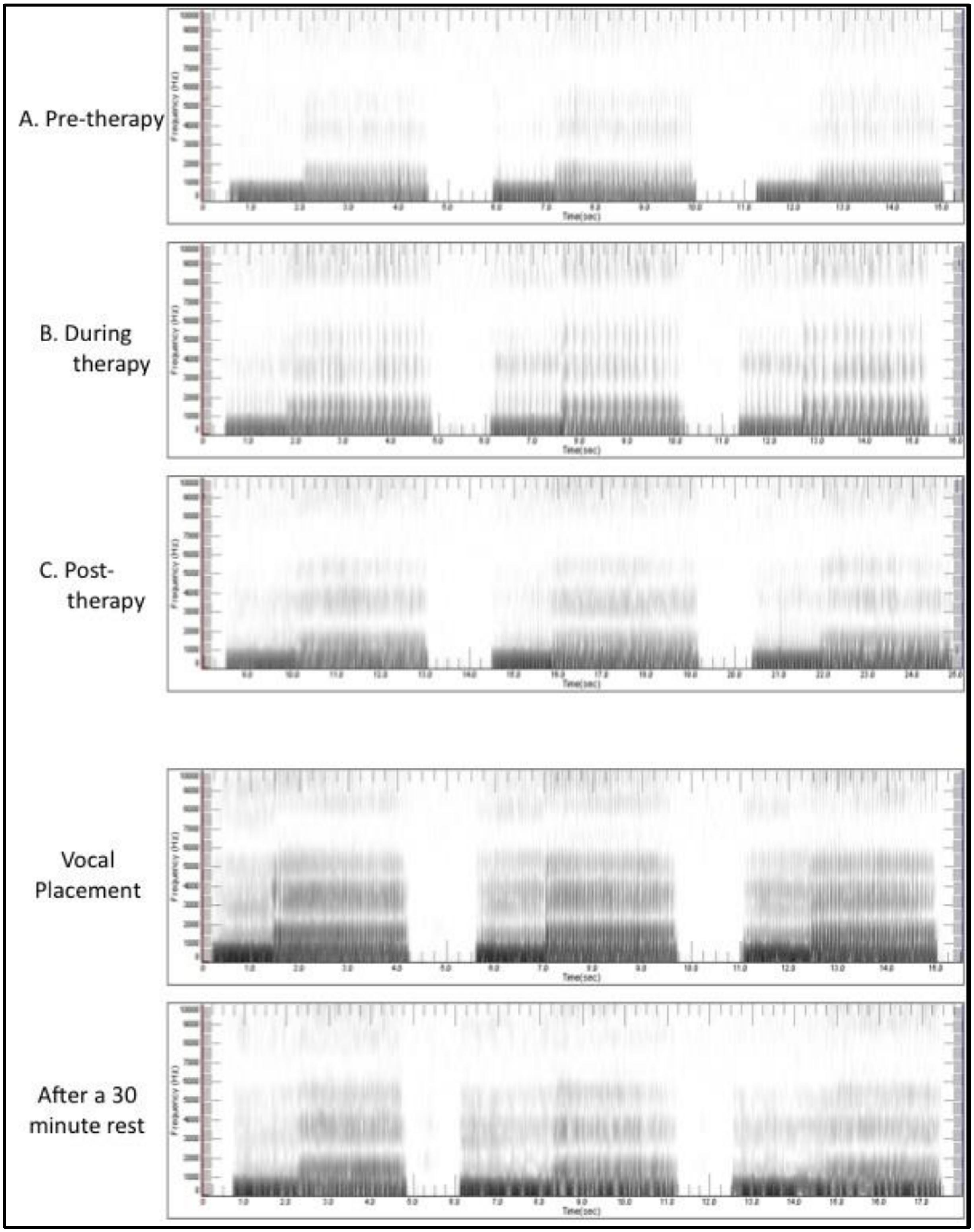

Figure 4. Spectrograms produced at all stages of the therapy trial show differences in intensity of higher formants during the participant's productions of "mmm-ah".

when the vibration device was applied directly to the larynx while recording, the energy in the formants above the fundamental frequency increased (Figure 4 *B*). This increased energy level was likely the result of the vibration device being in physical contact with the outside of the larynx during that step of the experimental procedure. To be specific, the vibrator was "on" and vibrating at approximately 70 Hz WHILE the participant was phonating in Figure 4 B (vibrating at approximately 70Hz) and Figure 4 "Vocal Placement" (vibrating at approximately 120Hz), but the vibrator was off when the participant phonated in Figure 4 A, C, "Vocal Placement", and "After a 30-minute rest".

DISCUSSION

The pilot investigation presented here was intended to demonstrate whether or not there was an effect of a voice therapy protocol, applying external vibration to the outside of the larynx, on the voice of a person experiencing vocal fatigue. This was an initial preliminary effort to show the effectiveness of this method. Robey and Schultz's "5 Phases of Treatment Research" (1998) describes the status level of the kind of research used in this study: "Phase 1: Pre-efficacy", a study conducted in order to acquire evidence to suggest that a treatment has therapeutic value. A study in "Phase 1: Pre-efficacy" uses small sample sizes and/or case studies, as was the case here. Using a different term, Ebell et al.'s "Strength of Recommendation Taxonomy (SORT)" (2004) classifies the level of evidence generated by this trial as "Level III", evidence such as expert opinion, case series, case reports, bench research, and clinical experience. Ley's informal experimentation with the vibration device on himself and other voice users, which yielded perceptible (e.g., audible, physical) changes in voice quality, has contributed to a robust hypothesis of the potential therapeutic value of this treatment. The authors sought to provide evidence in the form of expert opinion, a case study, anecdotal testimony, and an overview of previous related research as a foundation for future experiments and further research in vibration therapy treatment for vocal fatigue. The next stage of research, according to Robey and Shultz, would be "Phase 2: Pre-efficacy", an investigation of why the treatment works and who the ideal candidates are. A study in "Phase 2: Pre-efficacy" also uses small sample groups and case studies, but is more hypothesis driven.

In the current trial, vibration therapy elicited changes in the perceptual (both physical and audible) and acoustic characteristics of the participant's voice. The participant reported that her voice felt less tense and was easier to use, and two researchers reported that it sounded healthier and less hoarse. Visual representations of basic acoustic analyses showed evidence to support that the therapy procedure elicited changes in the participant's vocal loudness and resonance. The perceptual changes were more marked than were the acoustic changes, and all effects were maintained, though not at peak intensity, after a 30-minute rest period.

The "*optional*" vocal placement step of the protocol proved to be a major contributor to the acoustic changes observed, suggesting that this step may be as important for relieving stress on the vocal folds as the laryngeal massage portion. The authors postulate that this adjusted placement generated such an effect by reducing the effort required by the vocal folds while the speaker produced a more amplified speech signal using the resonant features of the head to full advantage. Further research may reveal that the vocal placement step should in fact be included in the therapy protocol for all voice clients, not only those seeking to adjust the placement of their vocal resonance.

The participant in this trial reported all the same symptoms as the participants in the aforementioned study by Eustace et al. (1996). The voice therapy protocol used in the current trial alleviated all of these symptoms, as reported by the participant. The perceptual and acoustic vocal changes demonstrated here support the concept that sensory input alone can elicit change in specific vocal fold behaviour. No verbal instruction was used to adjust vocal behaviours in this therapy protocol, only the physical sensation of vibration on different areas of the head and neck. These findings are consistent with the research of McGarr et al. (1986); Fox et al. (2002); Smith et al. (1995); and Kosztyla-Hojna et al. (2012). The studies of Herrero et al. (2011), and Kutty and Webb (2010) served as evidence that vibration has an impact on muscles at the gross and cellular levels. Taken together, this evidence provides a basis for further investigation of the effects that vibration has on the muscles of the larynx at the macro and cellular levels.

Of course vibration applied to muscles may be a potential source of risk to clients when using this type of therapy (Kutty & Webb, 2010), and merits very careful consideration in research. Very little is known about the mechanism underlying the apparent benefit of this voice therapy method, and it requires further attention for the safety of recipients, and for the viability of the technique.

Many variables can be manipulated in future experiments using this vibration device: physical placement of the device; variations in frequency of vibration of the device; duration of vibration treatment; frequency of treatment; etc. In addition, a variety of dependent variables should be studied: perceptual, acoustic and physiological measures. A closer look at the impact of vibration on the mucosal wave produced during phonation is also necessary.

This vibration therapy technique has the potential to benefit many different kinds of voice users, including people who use their voices artistically or functionally in the workplace for prolonged periods of time in everyday life. Such populations include singers, actors, teachers, lecturers, clergymen, and people who work and communicate regularly in noisy environments. Individuals who are interested in further investigating the effects of vibration therapy treatment for vocal fatigue should consider these populations when determining the parameters of their investigations.

It is evident from the results of the trial presented here that vibration therapy has an effect on the perceptual and physical voice characteristics of a person who is experiencing vocal fatigue symptoms. It would be in the interest of the field of Speech-Language Pathology, as well as numerous groups of voice users who experience vocal fatigue, to investigate more deeply the underlying mechanism of these effects. In the same way, it will be important to uncover and eliminate any negative or adverse effects that may result from this type of therapy protocol. Future studies are endorsed in order to develop and test increasingly fine-tuned vibration training protocols built on those used in this study (see *Appendix* for a more detailed description of the LELO Voice Vibration Protocol developed by David Ley). The development of a thoroughly investigated vibration therapy technique may prove an important breakthrough for both providers and recipients of voice therapy.

APPENDIX

<u>LELO Voice Vibration Protocols for Investigation</u>
For tension arising from or contributing to vocal fatigue, try the following steps:

For tension in the jaw:

Apply the vibrator to the masseter muscle while gently and slowly opening and closing the jaw. Micro movements are all that is needed so the jaw does not need to open more than a quarter of an inch. Follow the same procedure a) with the vibrator on the tendon of the temporalis muscle, just above the front of the ear, and b) with the vibrator underneath the front of the cheekbones to relax the pterytgoid muscles.

For tension in the tongue:

Apply the vibrator just above the hyoid bone to release tension in the hyoglossus. It can also be applied under the jaw to relax the mylohyoid and genioglossus muscles.

For laryngeal tension:

Gently massage with the vibrator the area between the hyoid bone and thyroid cartilage. Move from the center around the side of the thyroid cartilage.

For stimulation of the vocal folds:

Apply the vibrator to the thyroid lamina just underneath and to the side of the thyroid notch while humming. One may hum on one note or explore using gentle arpeggios or humming through scales up and down in pitch. Apply as much pressure on the vibrator as necessary in order to hear a distinct buzzing or jittery quality to the sound. Apply the vibration to one side for one to two minutes and then move the vibrator to the other side. For this exercise, one may set the vibrator at a slightly lower speed until accustomed to the sensation, at which point one could explore humming with the vibrator running at different speeds to determine which frequency is the most effective for the voice.

For placement of the voice:

Place the vibrator just underneath the zygomatic process of the maxilla, on the bottom of the cheekbones, about an inch from the nose. Hum for around two minutes on either side.

Now place the vibrator on the frontal bone at the top of the forehead approximately one inch ventral to the point where the frontal and parietal bones meet. To find that point, move the vibrator from the top of the forehead back three or four inches to the top of the head. In between those points, one should find a spot that feels slightly more vibrant and where one may feel some vibration on the lips.

To round out the sound a bit and reinforce some lower tones, adding a bit more resonance from the back of the mouth, hum at a slightly lower pitch while pressing the vibrator on to the bottom of the occipital bone at the back of the head. This is not recommended for anyone who is experiencing vocal fatigue or who has trouble maintaining forward placement, as it may draw the placement back towards the throat.

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