

Vibrational Therapies for Vocal fatigue

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Background

Vibration is commonly used to relax tension in the limb and trunk muscle. Vibration used directly on the muscle concerned and vertical vibration used on the whole-body through a foot platform have been reported in the literature to be useful to release muscle tension.

Aim

The present study investigated the effect of indirect whole-body vibration (WBV) and direct localized peri-laryngeal vibration (LPV) on the phonatory functions of non-dysphonic individuals with vocal fatigue.

Methods

Forty-four subjects (mean age=21.67 years) with normal voice, were randomly assigned to either the WBV group, the LPV group, or the Control (sham hand-held vibratory device) group. They performed karaoke singing for at least 95 minutes. They then received either WBV through a Turbosonic vibratory machine, LPV with a Novofan vibrator, or a sham vibrator for 10 minutes. The highest pitch produced, and self-reported vocal fatigue score were taken before singing, after singing, and after the intervention. Data were analyzed separately for the gender subgroups.

Results

All subject groups showed significant reduction of vocal function (highest pitch production, and vocal fatigue score) after singing. Following the vibrational interventions, both the WBV and LPV groups showed significantly recovery in highest pitch production and the perception of vocal fatigue ($p<0.002$) than the Control groups.

Conclusion

Vibrational therapy, whether it is localized vibration on the peri-laryngeal muscles, or whole-body vibration, is more effective than voice rest *per se* in relieving vocal fatigue. Vibrational methods are recommended for treating vocal fatigue.

Impact of vocal fatigue

Vocal fatigue is frequently experienced by professional voice users, like teachers^{1,2}, performing artists^{3,4} and telemarketers⁵. It is a reduction in the vocal function that occurs following prolonged voice use⁶. People with vocal fatigue often report an “increased sense of vocal effort with prolonged voice use”⁷. Commonly reported vocal fatigue symptoms include sense of discomfort (soreness, pain, tightness) in the laryngeal area⁷, increased voicing effort⁸, difficulty in voice projection⁶, reduced pitch range and deterioration in voice quality or hoarseness^{7,9,10}. Furthermore, it is common that such changes are not easily noticed or detected by other listeners or instrumental measures^{7,10} since vocal fatigue is a subjective percept and is not easily identified or quantifiable. However, such fatigue can be severe enough to result in reduced work attendance¹¹, job dissatisfaction¹² and stress or anxiety¹³.

Physiology of vocal fatigue

Physiological changes associated with vocal fatigue has been postulated to be related to excessive thyrohyoid muscle tension¹⁴, and extra-/peri-laryngeal muscle tension during prolonged phonation^{7,13}. Mechanical stress on the mucosal membrane of the vocal folds during phonation is also postulated to be another cause of vocal fatigue¹³. Prolonged exposure to such mechanical stress could lead to deformation and structural damage in the laryngeal mucosa and contributes to the development of vocal fatigue^{13,15}. Change in the tissue viscosity following prolonged phonation reduces the lubricating and shock-absorbing functions of the vocal folds, which has been contended as another contributing factor to vocal fatigue^{7,16-19}. It has also been shown that increased muscular activities causes blood vessel constriction that leads to a reduction in blood circulation²⁰. Whether this applies to the intrinsic muscles or not is still unclear, but it has been hypothesized that blood vessel constriction would reduce the efficiency of oxygen supply to the muscles and lactic acid waste removal from the muscles⁶.

Vibrational exercises as a treatment for vocal fatigue

Localized vibration on the throat area is one form of vocal fatigue relief technique used by some singers and performers (e.g. the Vibrant Voice Program promoted by Ley²¹). Ley²¹ contended that the use of a hand-held vibrator on the neck reduces muscle tension that causes vocal fatigue. Kosztyła-Hojna and colleagues²² reported the use of a CyberBioMed LLC vibration massager (Palm Beach, Florida, USA), together with pharmacotherapy benefited

more post-radiotherapy (laryngeal cancer) participants with hyperfunctional dysphonia. The reported data, however, lack details and prevent in-depth interpretation.

In a more recent study, the immediate effect of localized vibration (SIRI; Lelo) (50-Hz setting) on five groups of head and neck muscle (masseter, suboccipital, sternocleidomastoid, submental/submandibular, paralaryngeal areas) was found to significantly reduced phonatory effort in a group of trained singers (N=14), compared to a control group (N=12) who received a sham intervention²³. In another study (N=11) by Barsties v. Latoszek²⁴, the effect of a five-week behavioral voice therapy with localized vibration using a Novafon vibrator at 100Hz (Novafon GmbH, Weinstadt, Germany) was reported²⁴ to be effective in improving Acoustic Voice Quality Index²⁵, Dysphonic Severity Index²⁶, and Voice Handicap Index²⁷ in dysphonic subjects. Barsties v. Latoszek²⁸ also reported another study which compared the effect of voice therapy with or without localized vibration (N=11) on voice production with two groups of dysphonic individuals. Large treatment effects were also demonstrated in narrowband spectrogram measures and Dysphonic Severity Index. Therefore, these studies point to the potential benefit of combination of localized vibration and voicing exercise in improving phonation.

Vibration, defined as mechanical oscillatory action²⁹, can either facilitate or inhibit muscle activity when applied externally to a muscle or its tendon^{30,31}. High-frequency vibration (100-300 Hz) is known to evoke tonic response like muscle contraction³⁰⁻³²; while lower frequency vibration (20-50 Hz) inhibits muscle activity and facilitates release of muscle tension^{30,31,33,34}. Hence, release of vocal fatigue associated extralaryngeal muscle tension, particularly that of the thyrohyoid, is possible with the use of external vibration on the muscles. Current knowledge on the inhibitory or facilitatory effect of localized vibration is based on studies on limb muscles^{30,31,35}. Studies based on laryngeal and peri-laryngeal musculature are still scarce.

Another form of facilitatory exercise for voice production commonly employed by performing artists is the enhancement of whole-body relaxation or elasticity to release their muscle tension. The concept of maximizing body elasticity has indeed been used in voice therapy to improve voice production^{36,37}. Our research team hypothesizes that the use of an external vibratory device could enhance whole-body elasticity to relieve symptoms of vocal fatigue and promote better voice production. Whole-body vibration (WBV), which involves a

mechanical vertical oscillation delivered by a vibrating platform to the body, has been used widely in physiotherapy and sports training²⁹. WBV has been found to strengthen muscles³⁸⁻⁴⁰, reduce muscle tightness and fatigue⁴¹, and reduce pain in muscles⁴². However, there is little information on what the relationship between the vibrating frequency, intensity and the body type, like height, weight or body mass index, of the individual undergoing whole-body vibration.

Methodological issues in studying vocal fatigue

Measurement of vocal fatigue

The threshold (identification) and quantification of fatigue level are two of the challenges that researchers have to deal with in studying vocal fatigue. As the definition of vocal fatigue relies on the self-perception of the speaker⁷, self-perception rating has been used as a means in identifying and tracking vocal fatigue. The Vocal Fatigue Index (VFI)¹⁰ is the only validated self-report questionnaire on vocal fatigue to date. The VFI consisted of 19 statements covering three areas of key symptoms of vocal fatigue: (1) tiredness of voice and avoiding voice use (2) physical discomfort, and (3) improvement of symptoms with rest. Users rate each statement according to their perception. The index reliably identifies vocal fatigue and estimate its severity¹⁰. The VFI, does not, however, assess instantaneous vocal fatigue perceived at a particular time. It takes into consideration about individuals' report whether there is relief of symptoms following rest.

Strobo-laryngoscopic image appearance is another subjective measurement of vocal fatigue has also been used to study vocal fatigue. However, this method has failed to provide a reliable indicator of vocal fatigue. Presence of atypical glottal configurations, like anterior glottal chink or a spindle-shaped glotti^{17,43} have been reported in individuals with vocal fatigue, but others did not find any changes in laryngeal appearance^{44,45} following vocal fatigue.

Identification of objective measures in identifying or quantifying vocal fatigue has also been controversial. Attempts to find the acoustic correlates (e.g. jitter and shimmer) of vocal fatigue have been have unsuccessful⁴⁵⁻⁴⁷. Contradictory findings with regard to the use of phonatory range, especially in the frequency domain, in detecting vocal fatigue have been reported⁴³. Stemple et al⁴³ found the pitches (comfortable, highest and lowest) in sustained vowels produced by non-dysphonic speakers were not different before and after vocal fatigue

while another study by Yiu and Chan⁸ found a significant reduction in the highest pitch after vocal fatigue in their non-dysphonic speakers. The discrepancy in the findings between these two studies could have been attributed to the different tasks and methodology used. Yiu and Chan⁸ employed a full voice range profile assessment whereas Stemple and colleagues⁴³ simply asked the participants to glide from a midrange pitch to their highest or lowest pitches in a continuous breath. A recent study reported that repeated trial practices and coaching as critical factors in producing maximum frequency range⁴⁸.

In summary, while self-perceptual rating stands as a valid tool in quantifying vocal fatigue, production of pitch range may be a useful measure for quantifying vocal function as long as the assessment ensures that the participants are coached to produce their maximum capability.

Induction of vocal fatigue

Another challenge in studying vocal fatigue is how to induce the condition. Research studies have utilized different types of vocal-loading tasks to induce vocal fatigue for their investigation. Prolonged and loud phonation are the main factors leading to vocal fatigue⁴⁹, hence, prolonged reading task has been commonly used in a number of studies⁴⁹⁻⁵². This task usually involves continuous oral reading for up to two hours and often required individuals to read at a designated high intensity, ranging from 70 to 85 dB^{49,51}. Another vocal-fatigue inducing method involves using vocally-demanding tasks that are part of daily activities, such as class-room teaching by teachers^{53,54}. A third vocal-fatigue inducing method is continuous singing task^{8,55}. Yiu and his colleagues⁵⁵ asked their participants to perform Karaoke singing continuously for at least 95 minutes without vocal rest or hydration. Karaoke singing is a popular leisure activity among the young population, which they sing through an amplifier with background music⁸. This method was adopted in the present study since Karaoke is a popular activity among the people in many places and vocal fatigue is a common phenomenon experienced by Karaoke singers. Karaoke singing task satisfies the prolonged duration and loud phonation principle in inducing vocal fatigue. Furthermore, using a singing task for studying fatiguing voice is clinically important as the task simulates a common leisure activity in young people. Hence, this is ecologically more valid when compared to extended reading aloud task, which is not a common activity. This could reflect the fatigue situation in a more functional way compared to oral reading task.

The objective of this study was to determine if vibrational therapy can effectively improve vocal fatigue in non-dysphonic young adults immediately. Both the whole-body vibration and localized peri-laryngeal vibration were included in the present study.

METHODS

Research Ethics Approvals were granted by Ethics Committee, Faculty of Education, The University of Hong Kong (U3035058812-16-12-2016 and U3505546-09-01-2017). All participants were given the objectives and procedures of the study and were given opportunities to ask question prior to the start of the study. Informed consent was signed by all participants.

Participants

A total of 44 young adults (24 males, 20 females) aged between 19-25 years (mean age=21.9 years S.D.=1.68 years) participated in this study. The participants: (1) had normal voice quality on the day of assessment and also for the previous three months as reported; (2) had no prior experience with vocal training; (3) had no medical conditions or taking medication that might affect voice production, such as respiratory or psychiatric conditions; (4) were non-smokers and (5) non-drinkers. Adults over the age of 40 years were excluded to prevent possible inclusion of individuals with presbylarynges.

Procedures

Vocal fatigue induction Karaoke singing was employed to induce vocal fatigue. The Karaoke took place in a quiet sound booth with a karaoke microphone system (Tuxun K068, Guangzhou, China) connected to an Apple iPad mini 2 using Bluetooth. ‘Tianlai K Songs’ (Tianlai 4.5.0, Beijing, China) App was used to provide background karaoke music for the singing. In two previous studies, it has been found that a mean of 85.48 minutes⁸ to 103.8 minutes⁵⁵ of continuous karaoke singing would induce vocal fatigue in vocally healthy individuals. Two participants were asked to sing together continuously at the same time. They were instructed to sing at least for 95 minutes until they reported they could not sing anymore. After that, they were further asked to sing one more song, which was at least 3 minutes long. This ensured they had reached the threshold of vocal fatigue. Throughout the

singing, no water was allowed. All but one participant were capable to sing beyond 95 minutes. The mean singing time was 107.6 minutes ($SD = 8.49$ minutes; range = 95-128 minutes).

Interventions Following the karaoke singing, participants were randomly assigned to one of the three groups: a) 10-minute whole-body vibration (WBV group, N=15, seven females, eight males) b) 10-minute localized peri-aryngeal vibration (LPV group, N=14; eight females, six males); and c) 10-minute control group (Control group, N=15, nine females, six males) using a placebo hand-held device. All the participants were told that the intervention they received might reduce their vocal fatigue.

(a) Whole-body vibration (WBV) Each participant received 10 minutes of whole-body vibration (WBV) by standing on the platform of the machine (TurboSonic Ovation, Oregon, USA; Figure 1A). The vibrational frequency for each participant was determined before the start of the study by noting the frequency which produced the largest vibrational sensation on the individual's neck using frequencies from 8 to 15 Hz in a 0.5-Hz step. The mean vibrational frequency which produced the largest neck vibrational sensation was 10.8Hz ($SD=0.62$ Hz, range 10-11.5 Hz). A vibration amplitude of 25%, which was equivalent to a 1 mm of vertical displacement of the vibrational platform, was used. The dosage of 10-minute vibration was determined by reviewing the literature on WBV usage. Ten minutes has been reported to bring about positive effects to muscles²⁹; while prolonged vibration (over 30 minutes) caused more fatigue⁵⁶. The participants were asked not to talk throughout the 10-minute intervention. The height and weight of this group of participants were recorded to determine if the vibrational frequency causing greatest sensation at the neck region was correlated with them or not.

(b) Localized peri-aryngeal vibration (LPV) The Novafon Pro electric vibrational massager (Novafon GmbH, Weinstadt, Germany; Figure 1B) was used to provide vibration at 50Hz for 10 minutes. The manual pressure applied to the neck, which was between 0.8-1.5 newtons as measured by a digital force gauge (San Liang Digital Force Gauge, Model SL50, Shanghai, China), was first demonstrated by the examiner before the study. The participant was then asked to use similar amount of force as the examiner's demonstration for the subsequent 10 minutes of vibration on the following neck areas: (1) slowly gliding the

vibrator from the lower rim of the mandible along the peri-laryngeal muscles to the tip of the left and right clavicle respectively on either side of the larynx for 10 times in total (2) hold the vibrator at one side of the thyroid lamina for one minute; repeat on the other side (3) repeat the exercises for 10 minutes. The movement patterns were designed to apply external vibration to the peri-laryngeal muscles susceptible to the building up of excessive muscle tension during vocal fatigue. The participants were asked not to talk throughout the 10-minute therapy.

(c) Voice rest using a sham hand-held device (Control) The control group was given a hand-held vibrational device (Panasonic electric toothbrush, model EW DM81 with a tailor-made flat-shape head (see Figure 1C) placed on the laryngeal area for 10 minutes. The participants were instructed to alternate the placement the device head between the left and right side of the thyroid lamina every other minute. The participants were told that the device would emit ultrasonic pulses and relax the laryngeal muscles while in reality the device was never powered on. Therefore, this procedure was merely a vocal rest condition. The participants were asked not to talk throughout the 10-minute period.

Outcome measures

Two primary outcome measures were used: 1) vocal function test, measured as the highest pitch (Hi-F0) produced; and 2) self-rating of vocal fatigue at the time of study using a Vocal Fatigue Score (VFS) with selected items from the VFI¹⁰. In the vocal function test, the participants undertook a glissando task⁵⁷ by gliding an /a/ from C4 (261.6 Hz) to the highest pitch three times. The productions were captured by the Swell real-time DSP Phonetograph Version 2.0 (Phog 2.0, AB Nyvalla DSP, Stockholm, Sweden) with a head-mounted microphone (AKG Acoustics C420, Vienna, Austria) calibrated with a microphone-to-mouth distance of 5 cm. The Phog 2.0 registered a phonation with a minimum duration of 25 ms. In each trial, verbal encouragement and upward hand-sweeping gesture was used (by examiners CL and CC) to encourage the participant to produce the highest possible pitch⁴⁸. To ensure the highest pitch was reached, after the participant produced the highest pitch, each participant was asked to imitate a note (presented with a keyboard) which was two semitones above his/her highest pitch just produced. If a higher pitch was produced, it would be recorded as the highest pitch for that trial. The highest pitch among the three trials was noted for the final analysis. The self-rating of vocal fatigue was based on a four-item questionnaire

(Appendix) adopted from the Vocal Fatigue Index¹⁰ using a 10-point rating scale (1- no feeling of the symptom; 10-very strong feeling of the symptom). These four items pertained to the participants' perception of their fatigue level at the time of the study. A 10-point scale was used as the investigators would like to determine their perception with a finer scale. These two outcome measures were collected first before (pre-singing), and after karaoke singing (post-singing), and then after the vibrational or control intervention (post-intervention). Each round of measurement took approximately 15 minutes and the vocal function test was always taken before the self-rating of vocal fatigue.

Data Analysis

Analyses were carried out separately for the male and female gender subgroups in each experimental group. Since the sample size for each gender subgroup was small, normal distribution of the data could not be assumed, nonparametric statistics was used in the analyses. The changes between pre-singing baseline measurements and post-singing measurement (i.e. changes due to fatigue) were used in the analyses to determine how the singing task reduced vocal function (Hi-F0) and increased perception of vocal fatigue (VFS). The changes between post-singing measurement and post-intervention measurement (i.e. Intervention Change) signified the effect of the intervention in restoring vocal function (Hi-F0) and vocal fatigue perception (VFS). Bonferroni adjustment for each gender subgroup ($0.05/3=0.0166$) was used for repeated pairwise comparison.

RESULTS

The mean ages of the males and female subgroups in each of the experimental group were between 20.42 to 22.84 years (see Table 1). The three subgroups of males across the three experimental groups were not significant different in their age (Kruskal Wallis chi square=2.21, df=2, p=0.35). Neither were the female subgroups (Kruskal Wallis chi square=6.12, df=2, p=0.05).

Table 1 shows the mean Hi-F0 and VFS in each subject group and Table 3 shows the changes after the singing and intervention conditions. Figures 2 and 3 show the distribution and outliers of the changes in Hi-F0 and VFS in each subject group. The details will be described in the following sections.

In order to determine whether the participants all had similar phonatory abilities in producing Hi-F0 and similar degree of self-perceived vocal fatigue at the start of the study, Kruskal Wallis analyses were carried out on the pre-singing baseline measures. Neither the male (893.85 Hz to 951.87 Hz, chi square=0.31, df=2, p=0.87) nor the female subgroups (1373.07 Hz to 1541.15 Hz, chi square=1.42, df=2, p=0.51) were significantly different in their baseline Hi-F0 measure. The male and female subgroups also showed similar baseline VFS (mean VFS for males: between 12.33 and 12.87, chi square=0.11, df=2, p=0.95; mean VFS for females: between 10.43 and 13, chi square=1.07, df=2, p=0.6; see Table 1).

Vibration frequency of WBV group The mean, standard deviation, minimum and maximum value of the participants' height, weight, Body Mass Index (BMI) and vibrational frequency on the WBV machine that induced the maximum self-perceived vibration in the neck region are listed in Table 2. Pearson's *r* was used to examine the correlation between height, weight or BMI against vibration frequency. There was a significant positive correlation between height of participants and the vibration frequency ($r(15) = 0.7, p < 0.01, r^2 = 0.49$); and no significant correlation between the vibration frequency against weight ($r(15) = 0.31, p = 0.27, r^2 = 0.09$) or the BMI ($r(15) = 0.01, p = 0.97, r^2 = 0.01$).

Changes in vocal function (Hi-F0) following singing

Following singing, all subject groups showed significant reduction in Hi-F0 (1-tailed $p \leq 0.016$, see Table 1). The male subgroups demonstrated a reduction in Hi-F0 that varied between -97.31 Hz to -148.28 Hz (Table 3). These degrees of fatigue were not significantly different (Kruskal Wallis test: chi square=1.04, df=2, p=0.61; see Figure 2). Neither was there significant difference among the three female subgroups (mean Hi-F0 reduction between -182.64 Hz and -235.61 Hz; Kruskal Wallis chi square=1.38, df=2, p=0.52; see Figure 2).

Changes in vocal function (Hi-F0) after intervention

Following intervention, all subject groups, except the male and female Control groups, showed significant increase in Hi-F0 when compared to the post-singing condition ($p \leq 0.016$, see Table 1). The male LPV group showed a mean of 101.88 Hz increase in the Hi-F0, followed by the WBV group (mean 47.35 Hz increase) and the Control group (mean 16.93 Hz increase; see Table 3). However, there was no significant difference among these three groups in the Hi-F0 increases (Kruskal Wallis: chi square=5.48, df=2, p=0.06; see Figure 2).

For the female subgroups, the WBV and LPV groups showed a mean increase of 140.58 Hz and 163.09 Hz respectively in the Hi-F0, while the ControlL group showed a mean increase of 46.48 Hz. Kruskal Wallis test confirmed a significant difference among these three groups Hi-F0 increases (chi square=5.87, df=2, p=0.048). Planned post-hoc tests showed significantly more Hi-F0 increases in the WBV (Mann Whitney U=11, Z=-2.19, 1-tail p=0.01) and LPV (Mann Whitney U=16, Z= -1.93, 1-tail p=0.02) groups when compared to the CONTROL groups. There was, however, no significant difference in the Hi-F0 changes between the WBV and LPV groups (Mann Whitney U=27, Z= -0.12, p=0.93). It should also be noted there were two outliers in the female Control subgroup, one showing a nearly 300 Hz increase in Hi-F0, while the other demonstrated a reduction of 200 Hz (see Figure 2).

Changes in self-perceived vocal fatigue (VFS) following singing

Following singing, the VFS changed from a mean around 10-13 to more than 24-30 (Table 1). The changes were all significant ($p \leq 0.016$, except in the male Control group ($p=0.03$)). Three male subgroups demonstrated an increase of VFS between +11.67 to +17.87, while the female subgroups showed an increase between +13 to +15.28 (Table 3). Figure 3 shows the box plots with similar distributions among the male subgroups (Kruskal Wallis: chi square=1.91, df=2, p=0.4) and female subgroups (Kruskal Wallis: chi square=0.85, df=2, p=0.67).

Changes in self-perceived vocal fatigue (VFS) after intervention

Following the intervention, the VFS reduced from around 24-30 to 16-26. The male Control group did not show a significant reduction in VFS ($p=0.06$, see Table 1) while all other subgroups showed a significant reduction in VFS ($p \leq 0.016$, see Table 1). Figure 3 shows clearly that the male and female Control subgroups demonstrated very little change in the VFS when compared to the other two experimental groups. Significant difference was found among the three male subgroups (Kruskal Wallis: chi square=12.61, df=2, $p<0.0001$), with post-hoc Mann-Whitney U tests showed significant difference between the WBV and the Control groups ($Z=-3.12$ $p<0.0001$), and the LPV and the Control groups ($Z=-2.9$, $p=0.002$), but not between WBV and LPV groups ($Z=-1.03$, $p=0.33$). Similar significant finding was found with the female subgroups (Kruskal Wallis: chi square=14.32, df=2, $p<0.0001$). Post-hoc planned contrast using Mann-Whitney showed significant difference between the WBV and Control groups ($Z= -3.26$, $p<0.0001$), as well as the LPV and Control groups ($Z=-3.2$,

p=0.00). No significant difference was found between the WBV and LPV groups (Z= -0.41, p=0.72)

DISCUSSION

This study investigated the effect of vibrational therapy on young adults (age: 19-25 years) that showed similar baseline in phonatory function (Hi-F0) and perception of vocal fatigue (VFS). Vocal fatigue was induced using karaoke singing for more than 95 minutes. The karaoke singing was successful in inducing vocal fatigue with the phonatory ability in producing Hi-F0 and perception of vocal fatigue (VFS) being reduced significantly.

Following intervention, both the WBV and LPV groups (female and male) all showed significantly increased ability in producing Hi-F0 and reduced perception of vocal fatigue (VFS) than the Control female and male groups respectively. It should be noted that while the female Control group did not show a significant increased Hi-F0 production following voice rest, they did, however, perceived significantly less vocal fatigue after the rest (Table 1). Voice rest has often been recommended for dealing with vocal fatigue^{17,51}. In the present study, it has been shown the recovery in the Control group, which was merely voice rest without vibrational intervention, but was made to believe the hand-held vibratory device had some effect on the neck muscles, was not as efficient as those who were given vibrational therapy. Therefore, it is reasonable to conclude that both whole-body and localized perilyngeal vibration therapies resulted in significant better recovery from vocal fatigue when compared to voice rest *per se*.

It should be noted that although the WBV and LPV groups showed better recovery of phonatory functions than the Control group, only the female subgroups showed significant differences in these changes while the three male subgroups showed no such significant differences (see Figure 2). There are two possible explanations: either that the females responded better to the vibrational therapies or the sample size in the present study was too small that did not allow the male subgroups to show statistical significance.

Furthermore, the usefulness of whole body vibration and localized vibration appears to be of similar effect as there was no significant difference among the groups that used whole body vibration or localized vibration. If one were to consider clinical applicability, the localized

vibration is obviously a preferable choice for it is a more mobile and cheaper option, which users can use anytime and anywhere at their own convenience. However, the exact location and the amount of pressure to be applied to the peri-laryngeal surface would not be easy to control. On the other hand, the whole-body vibration would have a more definitive setting (frequency and intensity) to be manipulated and there is no concern of whether the site of vibration is appropriate or not.

There are at least three other reports to date that suggested that localized vibration has the potential of improving vocal conditions in human.^{23,24,28} The present study adds further evidence to that. Furthermore, the present study also found whole-body vibration demonstrated similar effect as the localized vibration. The potential of vibrational therapy in voice should not be underestimated and more studies should be needed in this.

Hypothesis why vibration helps to relieve vocal fatigue

It has been suggested⁷ that excessive peri-laryngeal muscle tension develops following vocal fatigue. This increased muscle tension is likely to impact on the laryngeal adjustments required in producing high pitch. In addition, in vocal fatigue, vocal folds tissue viscosity would have increased, the velocity of the mucosal wave would be affected which makes soft and high phonation difficult⁵⁸. We postulate that vibration, whether through a whole-body platform or localized on the peri-laryngeal muscles, relieved this excessive muscle tension and permitted the production of relatively higher pitches. We also hypothesize that external vibration also causes increased blood flow and metabolism in the fatigued muscles. Based on the literature, whole-body vibration facilitates improvement in gross motor functions by increasing blood flow and metabolism to the muscles⁵⁹. It has been argued that a reduction in blood circulation to the laryngeal area as one of the possible underlying physiological mechanisms causing vocal fatigue⁶. Increase of blood flow to the muscles helps to remove lactic acid⁶⁰ and to enhance recovery of muscle fatigue. Obviously, more studies, especially those involved muscle physiology, will be needed in order to test these hypotheses.

Limitations

There are a few methodological issues which need to be pointed out here so that caution can be used to generalise these results. First, one might argue that the experimenters were not blinded to the eliciting procedure of Hi-F0. We admit that possible bias could not be completely ruled out. However, such procedure had been validated in a separate study by

Barrett et al⁵⁷ (in press) and the elicitation procedure reduces possible examiner's bias. Second, the present study included only participants with induced vocal fatigue using karaoke singing and not those with chronic vocal fatigue. It is unclear if the effect on induced vocal fatigue would be different from that on the vocal fatigue experienced chronically by many professional voice users in real life. Thus, the usefulness of vibrational therapy in individuals with chronic vocal fatigue should be tested clinically. Third, this study was only preliminary in nature and did not explore other intervention variables, such as vibrational intensity, frequency or duration of each vibrational intervention. Further studies will be needed to determine how the different treatment variables might affect the effectiveness. Fourth, given the small sample size, only non-parametric statistics were used and this admittedly had lower power. Larger sample size would have allowed the use of more powerful parametric statistics. However, since significant results were found with the non-parametric statistics, it is believed that similar significant results will be obtained with a design that allows parametric statistics. Fifth, the VFS is not a validated test and it was only four-item long. This may not be adequately reflecting the vocal fatigue. Finally, a word of caution about the long-term use of vibrational devices. There is also limited information on the long-term effect of these vibrational mechanism on human in general. The trade-off between risk and benefits can only be considered with more available information.

Conclusion

The present study is an initial attempt to evaluate the effects of WBV and localized perilyngeal vibration on vocal fatigue. Results demonstrate that the localized vibration treatment used in this study can relieve sense of phonatory effort and vocal fatigue symptoms as well as facilitate recovery of maximum pitch level. Further research with a larger sample size could be carried out to investigate the effects of WBV on other phonatory measurements such as maximum phonation time or vocal intensity. In addition, in order to maximize effects of WBV on laryngeal area, vibrational frequency could be individualized for different gender.

Appendix

Self-rating Vocal Fatigue Questionnaire

Original item number
in Vocal Fatigue Index
(Nanjundeswaran et al., 2015)

- | | |
|--|------|
| 1. My voice feels tired when I talk. | (2) |
| 2. My voice gets hoarse with voice use. | (4) |
| 3. I find it difficult to project my voice with voice use. | (10) |
| 4. I experience discomfort in my neck with voice use. | (16) |

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