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Original Research Article

A Preliminary Study Using Thermal Imaging on Voice and Throat Temperature under Induced Vocal Loading

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ABSTRACT

Purpose: The study aimed at measuring the effect of vocal loading (loud reading) on fundamental frequency (F0), throat temperature along with self-rating questionnaire before and after loud reading task.
Methods: 50 (25 men and 25 women) normo-phonic adults participated in the study. Phonation sample of vowel /a/ for 6 seconds, thrice, measurement of throat temperature and a self-rating questionnaire was collected as baseline. Participants were provided with an English novel and were instructed to read at 70-80 dB SPL for 45 minutes. Fundamental frequency, throat temperature and scores from the self-rating questionnaire were compared between pre-reading and post-reading conditions. Entire experiment was carried out in an air-conditioned room at 25 ℃.
Results: Statistically significant difference was observed within groups for fundamental frequency, throat temperature and scores of self-rating questionnaire. However, statistical significance was seen only in fundamental frequency and self-rating questionnaire.
Conclusion: This study describes the potential use of thermal imaging to be used alongside other measures (acoustics) in assessing vocal load.

Keywords: Thermal imaging, infrared thermography, vocal loading, fundamental frequency, self-rating questionnaire, throat temperature

INTRODUCTION

Speaking is the most common mode of communication and voice is one of the main mode for communication. It is noted that one indulges in overuse/misuse/abuse of voice resulting in voice problems most often. Vocal loading task is one of the methods where a person is asked to speak/read continuously for a longer duration at a constant intensity. Protocol for prolonged loud reading varies with tasks such as prolonged speaking, [1,2] speaking in background noise, [3,4] sustaining vowels, [5,6] and singing [7] at different loudness levels from 60-65 dB [8] to 85 dB [4] duration of the task from 15 minutes [9] to 2 hours [1] by comparing the conditions prior to reading and post reading. Vocal loading inhibits optimal voice quality, and if persistent it may lead to laryngeal pathology. [10] The possible outcomes measured from vocal loading are with respect to acoustic measures, [4,8,11] aerodynamic measures, [1,11-12] perceptual measures [2,12-13] and physiological measures. [14]

Thermal imaging is a technique which is capable of mapping the temperature distribution on the human skin.

[15] Average core body temperature is 37 ℃ and the surface temperature is around 33 ℃ which depends on the ambient conditions. There are many factors which lead to the difference between core and surface temperature such as the thermal properties of the tissues separate the organ from body surface, fat content, muscle tissues, volume of blood flow, amount of energy produced in homeostatically regulated metabolic processes and skin moisture. [16-18] According to Freitas, [19] the temperature difference between the symmetry of the body should not exceed 0.5 ℃. Alterations in the temperature provide the first signs of tissue lesions ahead of structural or functional changes that can be observed. [20] Infrared Thermography (IRT) has many applications in the medical field and has been extensively used for breast cancer detection, [21] diabetic neuropathy, [22] fever scanning, [23] brain imaging (thermoencephaloscopy), [24] dentistry and dermatology, [25] muscular pain and shoulder impingement syndrome study. [26] IRT has also been used in acupuncture treatment [27] and forensic medicine. [28] The effects of metabolic heat, airflow, and the blood circulation were not considered as factors as the study was carried out using an excised bovine larynx by Cooper and Titze. [29] Effects of vocal load have been measured using acoustic and aerodynamic measurements, in the past, but there are no published studies on using IRT as a measure to infer the change in temperature after vocal load. Therefore, the present study investigated the effects of controlled, prolonged reading using IRT in healthy adult males and females.

The objective of the study was to determine the effect of prolonged loud reading on fundamental frequency (F0), change in temperature at the throat region along with self-rating questionnaire before and after loud reading task. The questionnaire had five questions based on (1) vocal discomfort; (2) vocal pain; (3) vocal fatigue/tiredness; (4) effort of voicing/phonation/speech; and (5) voice quality; and the above parameters in the questionnaire were rated on a 3-point rating scale.

MATERIALS AND METHODS

Participants

The study included a total of 50 participants and was bifurcated into 2 groups, Group 1 consisting 25 men and Group 2 consisting 25 women. Age of the participants ranged from 18 to 40 years. Participants' voice was informally screened by the first author using perceptual analysis and only those who had perceptually normal voice in terms of loudness, pitch and quality contributed in the study. Language was not a barrier among the participants. Additionally, participants who had any form of voice disorder, exposure to alcohol, smoking, trauma/accidents/surgery to laryngeal system, exposure to medications for a longer duration irrespective of medical conditions were excluded from the study.

Procedure

All the participants were initially briefed about the study and informed consent was taken. There were three phases involved in the present study where; baseline assessment in Phase I, vocal loading task in Phase II and termination assessment in Phase III.

In Phase I, participants were made to sit comfortably in an air-conditioned room at a constant temperature of 25 ℃ for 10 minutes and subsequently, the temperature at the throat region was monitored using a thermal imaging camera. Repeated measurements were acquired until the throat temperature stabilized. Once the temperature stabilized, baseline temperature was noted down by measuring the temperature from the frontal and lateral views of the throat. Participants were asked to phonate the vowel /a/ steadily for 7-8 seconds for three times. The audio samples were recorded using a sound recorder which was kept at a constant distance of 15 cm from the mouth to the microphone. Later, they were instructed to fill a self-rating questionnaire [Appendix A] on 3-point rating scale (0 - Nil, 1 - Occasional and 2 - Persistent).

In Phase II, as a part of vocal loading task, participants were asked to read a novel by maintaining their loudness at 70-80 dB for 45 minutes in sitting position. Loudness was monitored throughout the vocal loading task using a sound level meter which was placed at mouth level at a distance of 15 cm. Visual cues were provided to the participants to maintain the loudness level (70-80 dB) as and when the reading loudness reduced. The experiment was terminated when the participants were no longer able to continue to read for 45 minutes.

In Phase III, termination assessment was carried out immediately after vocal loading. The phonation samples, throat temperature measurement and self-rating questionnaire were collected as in Phase I.

Instrumentation

Temperature was measured using a thermal imaging camera (Fluke) model Ti32 (Fluke, Everett, and Washington, USA) and sound recorder Olympus (LS100) to record phonation sample. Sound Level Meter (TECPEL DSL-331) was used to monitor the intensity of reading.

Analysis

The obtained audio files from the sound recorder were in .wav format which was analysed using the PRAAT [30] software for fundamental frequency (F0) measurement. The images from the thermal camera were extracted to the software SmartView (Version 4.0) and were stored in .IS2 format for temperature analysis. High contrast palette was set for analysis as it shows a wide distribution of colours representing different temperature. Emissivity was set at 0.99 for human skin. Laryngeal region was selected using a circular selection tool for frontal view images as in Figure 1 and polygon tool for lateral view images as in Figure 2 and Figure 3. The temperature of the selected regions (of three images) was averaged.

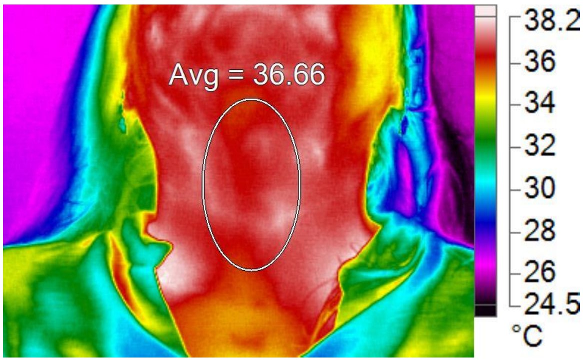

Figure 1. Average temperature of the neck from frontal view

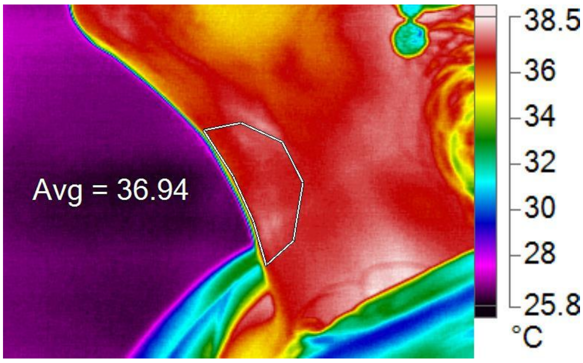

Figure 2. Average temperature of the neck from lateral (left) view

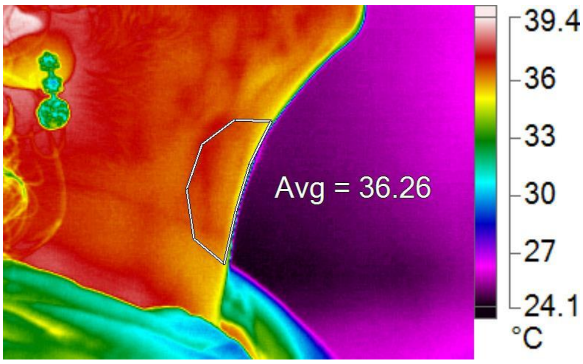

Figure 3. Average temperature of the neck from lateral (right) view

Statistical Analysis

Test of normality was carried out, and the data normalized after the removal of one participant. Within and between group comparison for fundamental frequency and temperature change was done using mixed ANOVA. Since only 3 out of 50 participants opted the score 2 for self-rating questionnaire (3-point scale), they were converted to a score of 1 for better statistical analysis and McNemar’s test was employed to find the significant change between pre and post reading scores of the self-rating questionnaire.

RESULTS

The mean and standard deviation of the fundamental frequency and temperature change for pre and post reading are tabulated in Table 1. All the parameters had shown an increase in values from phase I to phase III. F0 had an increase by 12.29 Hz and 10.58 Hz, and the temperature had an increase by 2.61 ℃ and 2.66 ℃ in group I and group II, respectively after loud reading. Results of mixed ANOVA are represented in Table 2. A significant difference was observed in within-group comparison for fundamental frequency and temperature in both the groups that is, from phase I to phase III. However, between groups significant difference is observed only concerning fundamental frequency and not for temperature change. Percentage responses for phase I and phase III in both the groups are mentioned in Table 3 where the highest change was detected for the vocal fatigue in both the groups. Group II had the least change in percentage for the voice quality which is not statistically different compared to other parameters. The results of the McNemar test are represented in Table 4. All the self-rating questions show significantly increased ratings after vocal load in group I.

Table 1. Mean and standard deviation (SD.) for change in temperature and F0 in both males and females.

Parameters	Group I		Group II	
	Pre-reading Mean (SD.)	Post-reading Mean (SD.)	Pre-reading Mean (SD.)	Post-reading Mean (SD.)
F0 (Hz)	119.24 (13.72)	131.53 (13.13)	215.65 (13.65)	226.23 (13.32)
Temperature (℃)	35.60 (0.76)	38.21 (0.58)	35.35 (0.69)	38.01(0.82)

Table 2. Results of mixed ANOVA.

Parameters	F (1.47)	*p* value
F0prepost	614.796	0.000*
F0prepost*Group	0.058	0.811
Group	1.618	0.210
Tprepost	95.807	0.000*
Tprepost*Group	0.533	0.469
Group	679.583	0.000*

*indicates level of significance (p<0.05)

Table 3. Percentage scores of self-rating scale

Parameters	Group I		Group II	
	Pre-reading (%)	Post-reading (%)	Pre-reading (%)	Post-reading (%)
Vocal discomfort	4	56	12	68
Throat pain	0	44	0	28
Vocal fatigue	0	84	4	80
Effort while speaking	0	56	0	56
Voice quality	0	56	0	12

Table 4. Results of McNemar test

Parameters	Group I		Group II	
	McNemar (χ^2)	*p* value	McNemar (χ^2)	*p* value
Vocal discomfort	12.07	0.000*	15.05	0.000*
Throat pain	09.09	0.002*	05.14	0.023*
Vocal fatigue	19.04	0.000*	18.05	0.000*
Effort while speaking	12.07	0.000*	12.07	0.000*
Voice quality	12.07	0.000*	01.33	0.248

*indicates level of significance (p<0.05)

DISCUSSION

Fundamental frequency

Mean F0 values were increased in phase III among the participants in both group I and group II. The results of the present study agree with Whitling et al., and Xue et al., [4,11] who also found an increase in F0 after loud reading task. The reason for the increase in F0 after loud reading may be due to the continued use of voice at high intensity (70-80 dB) for a longer duration (45 minutes) without voice rest. According to Stemple et al., [1] increase in F0 is due to weakness in the thyroarytenoid muscle.

During prolonged vibration of vocal folds, the cover and transition layer of vocal folds become stiff due to loosening of muscle portion of the thyroarytenoid muscle resulting in increased rate of vibration of vocal folds leading to rising in F0.

Temperature change

Significant difference is seen within groups on throat temperature and no significant difference is observed between groups. Overall, the temperature has increased by 2.6 ℃ which can lead to trauma if unattended. When subjected to movement of the vocal muscles, the neck region is defied to regulate the core temperature. Increased blood flow leads to cutaneous vasoconstriction. [31] But, when the duration of use of muscles prolong, the core temperature increases where the vasodilation is caused due to the central regulatory mechanism and heat is dissipated through the skin. [32] Human body temperature remains almost the same across genders, and the results of this study corroborate with Mackowiak, Wasserman and Levine's [33] observation.

Self-rating

An unceasing collision between the vocal folds for a longer duration leads to fatigue. Continuous vibration of vocal folds might be the reason for both the groups rated vocal fatigue as being the highest percentage among the five parameters. All the parameters had a significant difference in post-reading except voice quality in group II. This can be attributed to the fact that females are more talkative than males [34] due to which only 3 out of 25 females, perceived change in voice quality. However, since males talk comparatively less, a continuous use of voice for 45 minutes brought about a self-perception of change in voice ratings in 14 out of 25 males.

CONCLUSION

In the present study, IRT was used to document the throat (skin) temperature in normal individuals before and after vocal loading. All the participants had an increase in fundamental frequency, temperature at throat region along with increase in scores on self- rating questionnaire in termination assessment. Increase in these values can lead to phono-trauma if voice is used for a longer duration without any breaks. Since IRT shows physiological change rather than anatomical changes, further studies can be carried out using infrared thermography on disordered population. IRT could help as a diagnostic tool to detect presence of any pathology at the vocal folds indirectly. IRT could also be included in the protocol for assessing vocal loading along with other tests.

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Appendix A

Self-Rating Scale

Name:	**Age:**	**Height/Weight:**
0 represents 'Nil', 1 represents 'Occasionally' and 2 represents 'Persistent'		
	Pre-reading	
Presence of discomfort in throat		
0	1	2
Presence of pain in the throat		
0	1	2
Presence of vocal fatigue/tiredness		
0	1	2
Effort of voicing/phonation/speech		
0	1	2
Voice quality		
0 (Normal)	1 (Mild-Mod hoarseness)	2(Severe hoarseness)
	Post-reading	
Presence of discomfort in throat		
0	1	2
Presence of pain in the throat		
0	1	2
Presence of vocal fatigue/tiredness		
0	1	2
Effort of voicing/phonation/speech		
0	1	2
Voice quality		
0 (Normal)	1 (Mild-Mod hoarseness)	2 (Severe hoarseness)

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