INFERRING VOCAL LOAD USING INFRARED THERMOGRAPHY: A PRELIMINARY STUDY

Lokheshwar S

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Dedicated to my dear parents

"There is no school equal to a decent home and no teacher is equal to a virtuous parent."

- *Mahatma Gandhi*

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I thank God Almighty for being with me all the time and showering his blessings and providing me a chance to help others ✨🙏✨

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CERTIFICATE

This is to certify that this dissertation entitled **"Inferring Vocal Load Using Infrared Thermography: A Preliminary Study "** is a bonafide work submitted in part fulfilment for degree of Master of Science (Speech-Language Pathology) of the student Registration Number: 15SLP016. This has been carried out under the guidance of a faculty of this institute and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

Mysore
May, 2017

Prof. S.R. Savithri
Director
All India Institute of Speech and Hearing
Manasagangothri, Mysore-570006

CERTIFICATE

This is to certify that this dissertation entitled **"Inferring Vocal Load Using Infrared Thermography: A Preliminary Study"** has been prepared under my supervision and guidance. It is also being certified that this dissertation has not been submitted earlier to any other University for the award of any other Diploma or Degree.

Mysore
May, 2017

Guide
Prof. S.R. Savithri
Director
All India Institute of Speech and Hearing
Manasagangothri, Mysore-570006

DECLARATION

This is to certify that this dissertation entitled **"Inferring Vocal Load Using Infrared Thermography: A Preliminary Study"** is the result of my own study under the guidance of Prof. S.R. Savithri, Director, All India Institute of Speech and Hearing, Mysore, and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

Mysore **Registration No.: 15SLP016**

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Vocal loading involves excessive voice use which leads to symptoms of vocal fatigue. Vocal loading has been defined as ***acoustic changes in the voice as a result of prolonged voice use*** by Scherer, Titze, Raphael, Wood and Blager (1991). Kelchner, Toner, and Lee (2006) defined vocal loading as "prolonged loud voice use and has four distinct phases: Warm up (adapting to the voice task), performance (continuance of the voicing task), vocal fatigue (perceived increase of physical effort associated with voicing; physical challenges to the larynx) and a rest of recovery". While these definitions emphasize on prolonged / loud voice use, Titze, Hunter, and Svec (2007) considered vocal loading as stress placed on the speech musculature while speaking for extended periods of time. Symptoms of dysphonia often occurred during or after vocal loading tasks. Further, vocal fatigue is the perceptual result of vocal loading tasks. Vocal loading inhibits optimal voice quality, and if persistent can lead to laryngeal pathology (Colton, 1988). In voice production, the rate of vocal loading is highly dependent on the individual characteristics of each person as individual vibratory properties of the vocal folds or the functional state of the laryngeal muscles are individualistic (Roy, Merill, Thibeault, Gray, & Smith, 2004; Vilkman, 2004).

Vocal load has been measured, in the past, using prolonged voice use (Hill, Oates, Healey, & Russell, 1988; Gelfer, Andrews, & Schmidt, 1991; Stemple, Stanley, & Lee, 1995; Vilkman, Lauri, Alku, Sala, & Shivo, 1999). It has been used extensively in the literature as a method to understand how vocal fatigue leads to laryngeal adjustments and the negative consequences (Welham & Maclagan, 2003). In the previous studies, inducing vocal fatigue ranged from 15 minutes (Linville, 1995) to 2 hours (Stemple, Stanley, & Lee, 1995; Solomon & DiMattia, 2000) in the regular or predetermined intensity, with or without vocal training, and on normal or symptomatic individuals. Results of these studies have indicated changes in voice quality (Boominathan, Rajendran, Nagarajan, Muthukumaran & Jayashree, 2008), reduction in maximum phonation duration and significant difference for some of the parameters using MDVP in acoustical analysis (Boominathan, Anitha, Shenbagavalli & Dinesh, 2010).

Cooper and Titze (1985) have stated that there is ***generation and heat dissipated*** in the vocal fold tissues during mechanical vibration and it was found to rise from 0.1 ºC to 0.8 ºC in an excised bovine larynx using fine-wire thermocouples. Thermometers were used to measure diurnal changes of temperature in normal subjects by Martine in 1740. Any change in the temperature of the body was an indicator of illness and in 1868, Wunderlich proved it by systematically studying the temperature of subjects suffering from fever and compared with that of normal subjects. He also established a normal range for temperature between 36.3 ºC and 37.5 ºC beyond which should be considered as an indicator of illness.

Herschel discovered Infrared radiation in 1800 and his son, Herschel was the first person to record the thermal image, which opened new dimensions in the field of temperature measurement (Ring, 2007). The first modern infrared detector made of lead-sulfide photo detector was originally made for military purpose in World War II (http://www.omega.com/literature/transactions/volume1/historical3.html). But later the technology was released to civilians and thereafter study of temperature has widely used medical science as well as in the field of non-destructive testing. Infrared thermography (IRT) is used to detect on the surface and sub-surface and on-line monitoring of process (Maldague, 2001). IRT has many applications in the medical field and has been extensively used for diabetic neuropathy (Ring, 2010; Bagavathiappan, Philip, Jayakumar, Raj, Rao, Varalakshmi, & Mohan, 2010), vascular disorder (Bagavathiappan, Saravanan, Philip, Jayakumar, Raj, Karunanithi, Panicker, Korath, & Jagadeesan, 2009), thermoregulation study

(Jones, 1998; Bouzida, Bendada, & Maldague, 2009), breast cancer detection (Ng & Kee, 2008; Wishart, Campisi, Boswell, Chapman, Shacleton, Iddles, Hallett, & Britton, 2010; Aweda, Ketiku, Ajekigbe, & Edi, 2010; Kosus, Kosus, Duran, Simavli, & Turhan, 2010), fever scanning (Ng, Kaw, & Chang, 2004; Ring, 2007; Ring & Mercer, 2007; Bitar, Goubar, & Desenclos, 2009), brain imaging (thermoencephaloscopy) (Shevelev, 1998), dentistry and dermatology (Gratt & Anbar, 1998; Fikackova & Ekberg, 2004; Carlo, 1995), muscular pain and shoulder impingement syndrome study (Park, Hyun, & Seo, 2007), diagnosis of rheumatologic disease (Will, Ring, Clarke, & Maddison, 1992; Cherkas, Carter, Sector, Howell, Black, & MacGregor, 2003), dry eye syndrome diagnosis (Zelichiwska, Rozycki, Tlustochowicz, Kujawa, Kalicki, & Murawski, 2005), treatment of parasitic liver disease (Milonov, Lebedeva & Pomelova, 1980), detection of metastatic liver disease (Mansfield, Farrell, & Asbell, 1970), bowel ischemia (Brooks, Perry, Putnam, & Karulf, 2000), renal transplantation (Kopsa, Czech, Schmidt, Zazgornik, Pils, & Balcke 1979), heart treatment (Manginas, Andreanides, Leontiadis, Sfyrakis, Maounis, Degiannis, Alivizatos, & Cokkinos, 2010), and gynecology (Birnbaum & Kliot, 1964; Gershon & Haberman, 1965; Loriaux 1975). IRT has also been used in acupuncture treatment (Lo, 2002), and forensic medicine (Cattaneo, Giancamillo, Campari, Martrille, & Jouineau, 2009; Al-Lousi, Anderson, Worster, & Land, 2001).

Cooper and Titze (1985) used excised larynx in which the effects of metabolic heat and airflow and circulation were left out of consideration. 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 on change in temperature in the vocal region using IRT in healthy adult males. The objectives of the study are multifold and as follows:

1) To examine the changes in temperature, if any, before, during, and after vocal loading,
2) To examine the duration of rest period required to attain the baseline temperature, and
3) To establish comparison of heat generation during reading and a non-reading muscle activity during lifting a 6 kg dumbbell.

CHAPTER II

REVIEW OF LITERATURE

The literature is reviewed under the following headings:

1) Vocal hyper function and vocal fatigue
2) Potential mechanisms contributing to vocal fatigue
3) Models of vocal fatigue
4) Approaches to study vocal fatigue
5) Thermal imaging

1) Vocal hyper function and vocal fatigue

Vocal fatigue is a frequent complaint noted in professional voice users and in voice pathological conditions. Professional voice users are those individuals who primarily depend upon their voice usage for their occupation namely teachers, actors, singers, lawyers, telephone operators, radio jackie and so on. The prevalence of voice problems is reported to be more in them. Vocal fatigue is considered as a symptom of a voice disorder with either an organic or a functional etiology. It is uncertain whether vocal fatigue largely contributes to, exists independently of, or results from other voice conditions (Welham & Maclagan, 2003). Kostyk and Roches (1998) summarized the information of several research studies and clinical anecdotes to list the symptoms of vocal fatigue (Table 1).

Symptoms of vocal fatigue
Hoarse/husky vocal quality
Breathy vocal quality
Loss of voice
Pitch breaks
Inability to maintain typical pitch
Reduced pitch range

Lack of vocal carrying power
Reduced loudness range
Need to use greater vocal effort
Running out of breath while talking
Unsteady voice
Tension in neck/shoulders
Throat/neck pain
Throat fatigue
Throat tightness/constriction
Pain on swallowing
Increased need to cough/throat clear
Discomfort in chest, cars, or back of neck

Table 1: Symptoms of vocal fatigue

Scherer et. al., (1991) defined vocal fatigue as a negative vocal adaptation that occurs as a consequence of prolonged voice use. The negative is viewed as perceptual, acoustic, or physiological concept indicating undesirable or unexpected changes in the functional status of the laryngeal system.

2) Potential mechanisms contributing to vocal fatigue

Vocal fatigue is multifaceted. As stated by Titze in 1984 several neuromuscular and biomechanical factors such as fatigue of non-muscular vocal fold tissues, respiratory and laryngeal muscles and changes in the viscous properties of the vocal folds.

Neuromuscular fatigue: When the muscles remain active for extended period, particularly on higher levels, it can cause fatigue in the muscle and the peripheral nervous system that innervates. The muscles of both the phonatory and respiratory system might undergo exhaustion and contribute to the worsening of vocal function or the perception of increased vocal effort.

Neuromuscular adjustments of external and the internal posturing of the vocal folds, contribute to vocal fatigue. The vertical positioning of larynx, and overall increase in support and stiffness of the larynx can be altered by activities of strap muscles when force is applied on the laryngeal structures. Results from co-contraction of agonistic muscles, such that excessive laryngeal adductors are engaged than necessary or antagonistic muscles, thus exerting adductor forces or vocal fold lengthening and shortening forces simultaneously can lead to excessive tension in the intrinsic muscles. Such ineffective use of muscle tightening may lead to vocal fatigue, with its related increase in phonatory effort, or muscle tension dysphonia (MTD), with its characteristic strained vocal quality (Solomon, 2008).

This indicates the reduced capacity of laryngeal musculature to maintain stability in laryngeal posture and tension in the vocal folds. Peripheral fatigue process involves the reduction of energy composites (e.g. glycogen, creatine phosphates) and gathering of lactic acid within muscles.

Non-muscular tissue fatigue and viscosity: The configuration of fluids within the vocal folds may change due to prolonged periods of phonation, which might result in stiffness of the folds and elevation in the viscosity in them. The vocal fold mucosa is exposed to mechanical tension with each cycle of vocal-fold vibration during phonation, as its distortion of the lamina propria and the shear stress applied at the ends of the tissue (i.e. the macula flava). Vocal fatigue may also be due to frequent application of mechanical stress on both epithelial and lamina propia during oscillation of vocal folds. According to Titze (1994), increased tissue viscosity should result in proportionally greater friction and heat dissipation during vocal fold vibration.

Reduced blood circulation: There is reduction in blood stream to the vocal folds during prolonged phonation. This may be because of a constriction of blood vessels alongside increase in intramuscular pressure during contraction. Reduction in the blood flow to the vocal folds might behave as a fatigue-inducing mechanism in two ways. In the first place, as the circulatory system is like an organized network inside the body, decreased blood stream will bring about a hindered capacity to expel lactic acid from muscles in contraction, and renew drained oxygen level and vitality compound stores. Moreover, a gradual addition of lactic acid may be diluted by the formation of edema inside the vocal folds. It is obscure whether an aggregation of edema results in an expansion or diminishing in general viscosity of the vocal folds. Second, decreased blood stream will hinder the capacity of the circulatory system to transfer heat dissipated during phonation away from the vocal folds. If there is no effective transfer in heat away from the vocal folds towards the skin, then there may be an increase in temperature in the vocal folds. There can be damage to the laryngeal tissue if there is increase in temperature in vocal fold with respect to the temperature of the body (Welham & Maclagan, 2003).

Respiratory muscles fatigue: Speech is ideally inflated at close to 50% of vital capacity and singing is typically initiated at up to 100% of vital capacity (Welham & Maclagan, 2003). Respiratory muscle fatigue that might result in reduced sub glottal pressure capacity which may further act as a contributing mechanism in the onset of vocal fatigue (Titze, 1994). It is debatable whether respiratory fatigue can occur in individuals who are healthy. Respiratory mechanism may be task dependent in vocal fatigue (Welham & Maclagan, 2003).

Voice rest and recovery: The recovery from vocal fatigue may involve restoration of blood flow and re-distribution of fluids to the laryngeal tissues, or re-establishing baseline mechanical and physiological properties of active muscles. These mechanisms have different time courses which is estimated to be varied from seconds to minutes to hours (Titze et. al., 2007; Boominathan et al, 2010; and Rajasudhakar & Savithri, 2010).

3) Models of Vocal fatigue

There are models to explain the phenomenon of vocal fatigue. A model developed by Vilkman (2004) and colleagues which viewed vocal fatigue as a context of continuum. The range starts with vocal warm up and with continuous voice use leading to vocal fatigue. Vocal loading, or phonating at higher than usual levels and /or durations act as contributing factors to vocal fatigue.

Cyclic model of vocal fatigue as described by McCabe and Titze (2002) where there are neuromuscular changes due to phonation which includes typical physiologic responses to muscle shrinkage such as increased blood flow and glycogen depletion, and biomechanical changes with tissue stiffness and increased viscosity. These superficially fatiguing procedures might lead to variations in voice quality, which might also lead to the central fatigue phenomenon of increased vocal effort. The voice user may, consciously or subconsciously try to compensate changes in vocal function due to the feeling of increased effort. The hyper functional compensatory may cause neuromuscular changes. Threshold of soft tissue changes can occur leading to changes in lamina propria of vocal folds. There will be affect in the vocal quality and the cycle continues until phonation ceases.

4) Approaches to study vocal fatigue

In the contemporary research and clinical practice the study of vocal fatigue is viewed as a significant challenge. Vocal fatigue has been an interesting and persistent presence in the clinical realm, and is gaining attention in the scientific literature (Solomon, 2008).

There are two research paradigms employed to study vocal fatigue. One type is experimental studies where ***vocal fatigue is induced experimentally under laboratory conditions*** (Gelfer et. al., 1991; Laukkanen et. al., 2004; Boominathan et. al., 2010). The other type is ***occupational vocal loading research***. The field studies on the population of professional voice users such as teachers, singers, have been carried out at their workplaces (Laukkannen, Ilomaki, Leppanen, & Vilkman, 2008; Rajasudhakar & Savithri, 2010).

There are studies that compared the investigation of vocal fatigue in both field conditions and experimental situations on same set of participants. Rantala, Lindholm and Vilkman (1998) compared values of fundamental frequency (F0) recorded b laboratory situation with recordings made in a working environment in their pilot study. It was revealed from the study that F0 increased in both conditions; however, the changes during vocal loading were not linear. It was found that F0 was higher in field conditions than in the laboratory conditions between the beginning and end of the working day. The authors stated that the discrepancy of F0 between two conditions might be due to the psycho physiological arousal as the working day commenced. The situations like gaining attention from pupils and variation of teaching were asserted to be the cause of discrepancy in field conditions compared to laboratory condition.

Induced condition of fatigue is the paradigm used in majority of the studies on vocal fatigue for measuring changes in vocal function. The experimental approach has the advantage of adding more information on the onset and progression of fatigue as generally affects the normal voice, and also in determining which measures of vocal change are, most indicative of vocal fatigue. Artificiality is the central limitation in this experimental paradigm.

Most reported outcome data involved comparisons of pre and post vocal loading task on perceptual, stroboscopic, aerodynamic measures and acoustic measures (Stemple et. al., 1995; Kelchner et. al., 2006; Boominathan et. al., 2010; Remacle, Finck, Roche, & Morsomme, 2012).

In the Indian context, in a laboratory condition, Boominathan et. al., (2010) studied the effects of vocal loading on voice characteristics in Indian adult males and documented the vocal fatigue and vocal recovery patterns from vocal loading task. The study indicated that there was significant decrease in the lowest F_0 and increase in phonatory F_0 range, short and long term amplitude and frequency measurements, voice and noise irregularity related measures after vocal loading. They also reported that the maximum phonation duration (MPD) was reduced significantly and S/Z ratio was increased. Initial signs of vocal fatigue such as throat tightness, throat pain, and running out of breath were noted as early as 15 minutes. Subjects were not able to sustain loud reading beyond 30 minutes. The recovery pattern after vocal loading indicated that short and long term amplitude and frequency measures and noise to harmonics ratio revealed a significant recovery pattern within 20 minutes of voice rest after the vocal loading task. In the above study, the vocal recovery pattern was traced for every 5 minutes of interval or voice rest following 20 minutes of post reading task. It can be assumed that any finer changes in the measured parameters could be even documented, if lesser interval duration would have been considered.

5) Thermal imaging

“**Infrared thermography** (**IRT**), **thermal imaging**, and **thermal video** are examples of infrared imaging science. Thermographic cameras usually detect radiation in the long-infrared range of the electromagnetic spectrum (roughly 9,000–14,000 nanometers or 9–14 µm) and produce images of that radiation, called **thermograms**. Since infrared radiation is emitted by all objects with a temperature above absolute zero according to the black body radiation law, thermography makes it possible to see one's environment with or without visible illumination. The amount of radiation emitted by an object increases with temperature; therefore, thermography allows one to see variations in temperature. When viewed through a thermal imaging camera, warm objects stand out well against cooler backgrounds; humans and other warm-blooded animals become easily visible against the environment, day or night. As a result, thermography is particularly useful to the military and other users of surveillance cameras” (https://en.wikipedia.org/wiki/Thermography). Thermogram of a cat is shown below:

Figure 1: Thermogram of a cat

Some physiological changes in human beings and other warm-blooded animals can also be monitored with thermal imaging during clinical diagnostics. Thermography is used in allergy detection and veterinary medicine. It is also used for breast screening, though primarily by alternative practitioners as it is considerably less accurate and specific than competing techniques. Government and airport personnel used thermography to detect suspected swine flu cases during the 2009 pandemic [FLIR Infrared Cameras Help Detect the Spreading of Swine Flu and Other Viral Diseases. Applegate.co.uk (2009-04-29). Retrieved on 2013-06-18].

Thermal imaging is a technique which is capable of mapping the temperature distribution on the human skin. The distribution of temperature on healthy human skin is highly distributed where the axis situated in the median plane of the body. It is presumed that the difference in temperature between symmetrical areas should not exceed 0.5 ºC (Freitas 1999). The visualization of temperature distribution on the surface of the human body can provide valuable diagnostic information, and is mostly a reflection of the processes inside the body. Altered temperature is often the first sign of tissue lesions, before structural or functional changes can be observed. Any disturbance of normal temperature patterns may be detected either as a hyperthermic or hypothermic area. Hyperthermic areas within medical thermal images may be caused by inflammation, increased blood flow, growing tumor, or other tissue lesions. They may also result from heat generation induced by muscle contraction during physical effort, or ambient temperature being higher than the thermal comfort limits. Hypothermic skin changes may be caused by decreased blood flow, loss of muscle contraction, sympathetic hyperactivity induced by partial nerve lesion, lymphedema or low ambient temperature.

There are few studies on the thermal maps of the body surface of healthy people and the range of normal temperatures, based on a representative sample of population. However, such studies could be used as a handy reference in medical and physiological diagnostics. Based on previous studies carried out on small groups of subjects, it is known that in the extremities, higher temperatures are normally observed at the proximal end of the limb rather than on the tips of fingers or toes (Ammer, Ring, Plassman, & Jones, 2002).

Another group of studies concerns the body surface temperature of people with various body compositions, especially obese individuals, in which the processes of heat exchange with the environment may be affected by a considerable thickness of fat – an insulator that impedes heat transfer to the surface.

With obesity, there is increase in weight without a relative increase in height, which results in a reduced body mass index (Verbraecken, Heyning, Backer, & Gaal, 2006) and, because superficial heat loss is relatively proportional to skin surface area (Sessler, McGuire, & Sessler, 1991), individuals who are obese might tend to lose their metabolic heat more slowly than those with normal body weight (Kurz, Sessler, Narzt, Lenhardt, & Lackner, 1995). Thus, in general, obesity lead to retention of body heat by reducing the ratio of heat loss to heat production. There must be compensation from the thermoregulatory reflexes and also it must be biased in individuals with excessive adiposity towards heat dissipation, as the core temperature in them is homeostatically regulated. Several physiological changes that accompany the development of obesity tend to increase heat production or impede heat loss. First, obese individuals have significantly greater resting metabolic heat production than in lean individuals. Fat-free mass (FFM) is responsible for greater heat production, i.e. muscle, that accompanies excessive adiposity. Second, fat tissue, because of its reduced thermal conductivity and increased insulator capacity, provides an insulating barrier to conductive heat flow and reduces the body's ability to respond to changes in the core temperature respectively (Havenith 2001; Landsberg, Young, Leonard, Linsenmeier, Turek, 2009; Landsberg 2012; Hoffmann, Rodriguez, Zeiss, Wachsberg, Kushner, Landsberg, & Linsenmeier, 2012; Heikens, Gorbach, Eden, Savastano, Chen, Skarulis, & Yanovski, 2011; Savastano, Gorbach, Eden, Brady, Reynolds, & Yanovski, 2009).

The surface temperature distribution in significantly malnourished individuals or people with eating disorders, such as anorexia nervosa or bulimia, is little known, but could provide additional valuable diagnostic information. Somatic symptoms of anorexia are the result of starvation, during which the body adapts to the reduced quantity of nutrients and dehydration, using reserves and slowing down metabolic processes and leaving the body in a slate of hypothermia (body temperature remaining at a level below 36 ºC). The hypothermia among anorexics is also influenced by hormonal imbalance (in particular the reduction in the level of thyroid hormones), the disorder of the circulatory system, the heart rate (reduced blood flow, circulation problems especially in the distal parts of the body, bradycardia, low blood pressure), a significant loss of body fat that serves as an insulator in the body, and muscle (heat generator due to the contraction of muscles) (Smith, Ovesen, Chu, Sackel, Howard, 1983; Wakeling & Russell 1970; Faje & Klibanski 2012; Luck & Wakeling 1980; Bock 1993).

Physiologically, homeothermia in the human body relates solely to body cavities and blood. Skin and extremities are poikilothermic (Rajewski, Lazowski, & Pisula, 2001). Therefore, human body can be divided into the homeothermic core and heterothermic shell. The average temperature inside the body is 37 ºC and 33 ºC on the surface (depending on individual characteristics), and it is a function of the temperature of an internal organ and the thermal properties of the tissue that separate the organ from body surface. For instance, the content of fat and muscle tissue, as well as the volume of blood flow and its temperature, skin moisture and amount of energy produced in homeostatically regulated metabolic processes (Aarts 1975; Kuzański 1993; Davidovits 2001). The body core is relatively stable in temperature, but the shell of the body (the surface tissues mainly the skin) forms part of the regulatory process. Human skin behaves as an almost blackbody with an emissivity of 0.96–0.98. In medicine, where the temperature range is more limited (typically 10 ºC) a 'rainbow' palette is preferred, with red as hot and blue/black as cold (Ring & Ammer 2012).

Individual human tissues and organs differ in their temperature. The highest temperature can be found in the heart, liver and brown adipose tissue. The most constant temperature prevails in the right ventricle of the heart and in the brain. In certain thermal conditions, the temperature inside the body may exceed the temperature of the surface of the skin by up to 20 ºC; a difference of 4 ºC is usually considered normal (Kozłowski and Nazar 1999). The thermoregulatory mechanism is based on the mutual feedback between body temperature and the reactions that modify the production and removal of heat. The heat balance of the body is maintained by thermogenic and thermolytic reactions.

Thermal imaging is used in physical activity and sports. In competitive sports, scientists are looking for new research and diagnostic methods, particularly non-invasive ones, that could help achieve higher training efficiency and success in sport. Among other things, physical fitness and adaptation to exercise depends on efficient thermoregulation, which, as shown by Afanaceva, Basargina, and Załugujewa (1985), can be evaluated based not only on the temperature inside the body, but also surface temperatures. Thermal imaging provides a quantitative and therefore objective assessment of changes in the surface temperature of the body, and may give an insight into factors affecting the removal of endogenous heat during exercise. For example, thanks to thermal imaging, it is known that the surface temperature of the body during physical activity increases, and stabilizes at a level higher in proportion to the intensity of exercise (Smorawiński, Grucza, & Kozlowski, 1990; Coh & Sirok 2007). It is also known that the effective removal of heat, generated during exercise, is influenced by physiological and morphological factors (Chudecka & Lubkowska 2012). Thermal imaging method can therefore be used as a tool for coaches to evaluate the dynamics of the body surface temperature of athletes, thereby monitoring the efficiency of thermoregulation. Any form of physical activity increases the metabolism, speeds up the delivery of oxygen through increased blood flow, and leads to an increase in body temperature due to the heat generation by the working muscles. An important physiological advantage of training, especially in competitive sports, is an increase in the ability to remove heat from the body (acceleration of response and dynamics of perspiration, and reducing the internal temperature increase), which allows the continuation of effort. Changes in the body surface temperature may therefore indicate the loading of the locomotor system, provide information on the efficiency of endogenous heat removal systems during exercise and metabolic changes associated with the return to homeostasis after exercise, and hence the usefulness of thermal imaging as a method of monitoring these phenomena.

In the past, Cooper and Titze (1985) used excised larynx in which the effects of metabolic heat and airflow and circulation were left out of consideration. 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.

CHAPTER III

METHOD

Participants: Ten healthy males in the age range of 20-30 years participated in the study. Only those participants who had perceptually normal voice in terms of pitch, loudness, and quality, and who did not have any experience with the dumbbells were considered. Further, participants who had history of smoking, laryngeal pathology, intubation, neurological disorders, and surgery/accidents/trauma, and history of sustained or prolonged use of medications for any medical conditions were excluded from the study.

Instrumentation: Temperature was measured using a Thermal Imaging Camera (Fluke model Ti32 – shown below) and was edited using a software called SmartView – Version 4 (Fluke, Everett, and Washington, USA).

Figure 2: Thermal imaging camera (Fluke Ti32)

Procedure: Informed consent was taken from the participants for the study and they were briefed initially about the study. The study had two activities – reading and weight lifting. The experiment had three phases – pre-experimental, experimental and post-experimental.

Activity 1: Pre-experimental phase involved baseline assessment of participants. The participants were made to sit in an air-conditioned room of 25 ºC for 10 minutes so that their body temperature gets adjusted to the room temperature. Baseline temperature at the vocal region was collected using a thermal camera by taking an image. The image was captured from front view between the chin and above torso level. The average temperature of the vocal region (between chin and collarbone) was extracted using SmartView which served as baseline. **Experimental phase** included prolonged reading task. Participants were asked to read a book of their interest at their comfortable loudness for a minimum of 40 minutes or till they exhibit signs of vocal fatigue. The duration of initial signs of vocal fatigue such as throat clearing, throat pain, dryness in throat etc., were noted. The change in temperature was tracked by capturing the vocal region using thermal camera for every 5 minutes. In the **post-experimental phase**, that is immediately after cessation of the activity, temperature change was collected using the thermal camera and also at the intervals of 5 minutes during voice rest to observe the change in temperature till it reached the baseline and the duration was noted down.

Activity 2: This was carried out once the participant's reading task had completed. This activity was used to compare reading task with a non-reading muscle task. Baseline temperature of the biceps muscle was collected using the thermal camera. Participants were asked to do a hammer curl (holding a dumbbell with palms and weighs facing inwards and by keeping the elbow close to body, then curling the weight up towards the shoulder and lowering it back to starting position) using a 6 Kg dumbbell. Examiner demonstrated the activity and the participants were asked to imitate them. Participants were asked to do hammer curl as many times as they could till they were fatigued. The change in temperature in the biceps muscle was monitored till it matched with the change in temperature in reading task.

Analyses: The images captured using thermal camera were saved in .IS2 format and were extracted to the software SmartView (Version 4.0). The palette was set to Rainbow for better representations of range of temperatures. The average temperature of the vocal region (between chin and collarbone) and the biceps muscle was extracted by selecting the required region and are represented in figures 3-6.

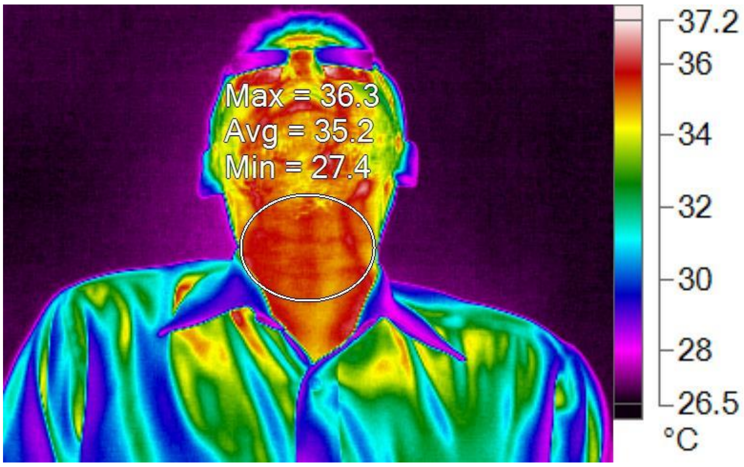

Figure 3: Temperature at vocal region pre-reading

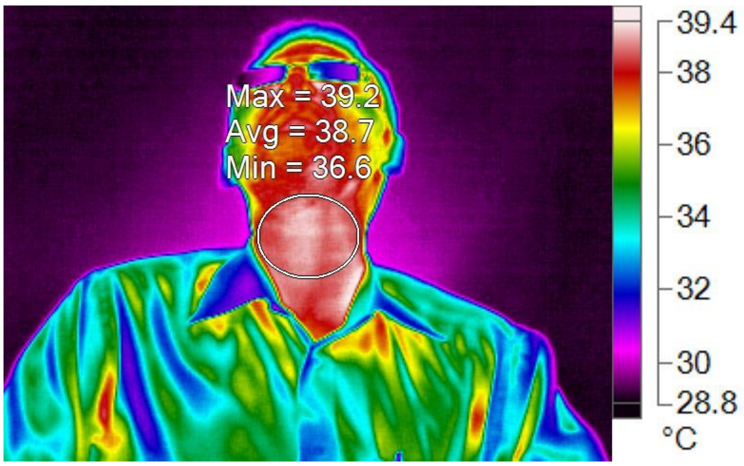

Figure 4: Temperature at vocal region post-reading

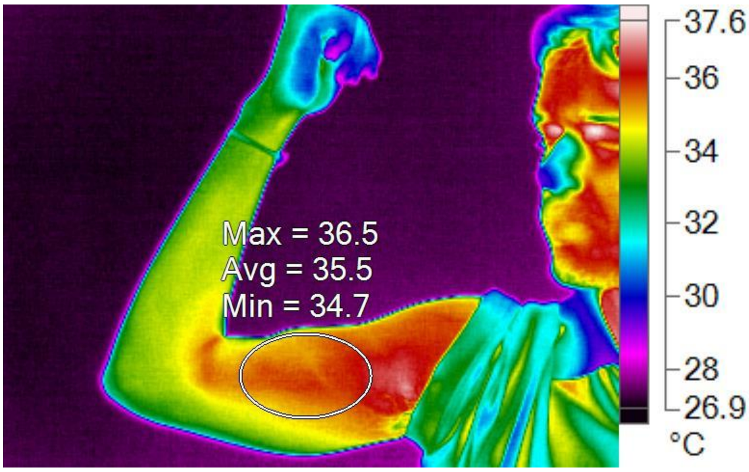

Figure 5: Temperature at biceps region before weight-lifting

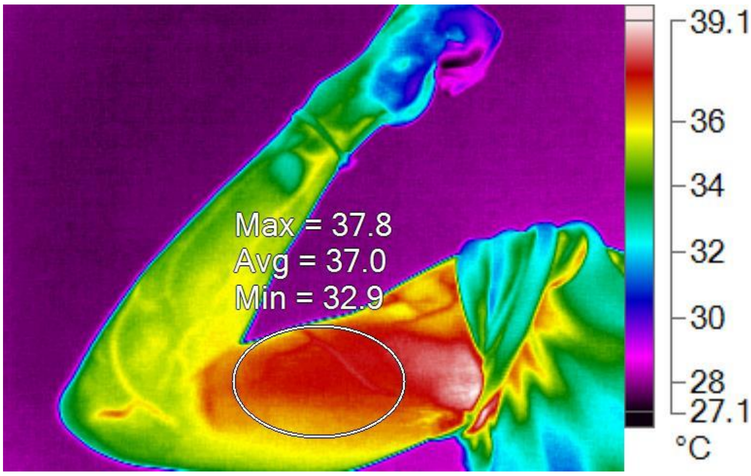

Figure 6: Temperature at biceps region after weight-lifting

The data was averaged for participants in two tasks and three phases.

CHAPTER IV

RESULTS

The aim of the study was to investigate the effect of vocal loading on changes in temperature at vocal region before and after vocal loading task. A non-reading task – hammer curl using 6 kg dumb bell – was also used for a comparison.

1) Effect of vocal loading on changes in temperature at vocal region

Experimental phase: Seven of the 10 participants, had increase in temperature from the baseline till 5 to 40 minutes, though not linearly. Participants 7, 9, and 10 were exceptions in that the temperature decreased from baseline onwards. On an average (without participants 7, 9, and 10) the baseline temperature was 37.07 ºC and a maximum temperature of 38.12 ºC was attained within 10 minutes.

Participant 1 had a temperature of 37.2 ºC to begin with and attained the maximum temperature of 38.3 ºC by 25 minutes. Participant 2 had a temperature of 37.5 ºC to begin with and attained the maximum temperature of 37.8 ºC by 10 minutes. Participant 3 had a temperature of 36.4 ºC to begin with and attained the maximum temperature of 38.0 ºC by 15 minutes. Participant 4 had a temperature of 35.2 ºC to begin with and attained the maximum temperature of 38.7 ºC by 40 minutes. Participant 5 had a temperature of 36.9 ºC to begin with and attained the maximum temperature of 38.6 ºC by 25 minutes. Participant 6 had a temperature of 37.5 ºC to begin with and attained the maximum temperature of 38.0 ºC by 35 minutes. Participant 8 had a temperature of 38.8 ºC to begin with and attained the maximum temperature of 39.0 ºC by 5 minutes. Table 2 shows changes in temperature at vocal region over a period of time in all 10 participants during experimental phase.

Participants	1	2	3	4	5	6	7	8	9	10	Average without 7, 9, 10.
Baseline	37.2	37.5	36.4	35.2	36.9	37.5	38.2	38.8	38.1	38.8	37.07
05 min	38.2	37.9	37.1	37.8	37.9	38.8	37.7	**39.0**	36.2	36.7	38.10
10 min	38.3	**37.8**	37.2	37.6	38.2	38.8	38.2	**39.0**	35.7	36.3	**38.12**
15 min	38.0	**37.8**	**38.0**	38.1	38.5	39.2	36.0	36.7	35.9	36.2	38.04
20 min	37.8	37.7	37.5	37.1	38.4	37.3	35.3	35.8	36.0	36.0	37.37
25 min	**38.3**	37.7	37.8	37.8	38.0	38.1	35.1	35.6	36.0	36.0	37.61
30 min	37.5	37.6	37.7	38.1	38.2	37.8	35.4	35.7	36.2	36.5	37.51
35 min	37.6	37.7	37.6	38.2	38.1	**38.3**	35.5	36.2	36.2	35.6	37.67
40 min	37.8	37.7	37.5	**38.7**	**38.6**	38.0	35.5	36.2	35.9	36.1	37.78

Table 2: Change in temperature (degree Celsius) at vocal region over a period of time in all 10 participants during experimental phase

2) Duration of rest period to achieve baseline

Post- Experimental phase: In the post-experimental phase, that is immediately after cessation of the activity, temperature change was collected using the thermal camera and also at the intervals of 5 minutes during voice rest to observe the change in temperature till it reached the baseline and the duration was noted down. Participant 1 reached the baseline by 15 minutes; participant 2 reached by 5 minutes; participant 3 by 10 minutes; participant 4 by 30 minutes; participant 5 by 25 minutes; and participant 6 by 10 minutes. On an average, participants took 15.83 minutes to attain baseline. Table 3 shows the change in temperature post experimental phase in 6 participants.

Post vocal load	1	2	3	4	5	6
Baseline	37.2	37.5	36.4	35.2	36.9	37.5
05 min	37.7	37.5	37.4	38.0	38.9	38.8
10 min	37.6		35.4	37.1	38.4	37.0
15 min	37.2			36.7	37.9	
20 min				36.2	37.4	
25 min				35.8	36.7	
30 min				35.1		

Table 3: Change in temperature (degree Celsius) post experimental phase in 6 participants

Effect of loading on changes in temperature in non-reading task: Participants were asked to do a hammer curl (holding a dumbbell with palms and weighs facing inwards and by keeping the elbow close to body, then curling the weight up towards the shoulder and lowering it back to starting position) using a 6 Kg dumbbell. Examiner demonstrated the activity and the participants were asked to imitate them. Participants were asked to do hammer curl as many times as they could till they were fatigued. The change in temperature in the biceps muscle was monitored till it matched with the change in temperature in reading task. The post-muscle load temperature was higher compared to that of baseline in participant 1, 2, 5 and 8. The post-muscle load temperature was lower compared to that of baseline in all other participants. Table 4 shows the change in temperature for a non-reading muscle activity.

Participants	**Non-reading muscle activity**	
	Base line	**Post muscle load**
1	**35.5**	**37.0**
2	**35.3**	**35.5**
3	34.0	33.3
4	34.0	33.4
5	**35.4**	**35.8**
6	34.8	34.6
7	37.3	36.2
8	**34.4**	**35.5**
9	35.9	34.8
10	35.3	34.8
Average without 3,4,6,7,9 & 10	**35.15**	**35.95**

Table 4: Change in temperature for a non-reading muscle activity

3) Comparison of heat generation between reading and non-reading task

The temperature in non-reading task matched with that of reading task in participant 1 only; however, the temperature of non-reading task was no were near the baseline of reading task in the remaining 9 participants. Table 5 shows the change in temperature for the reading and a non-reading muscle activity.

	Base line	**Post vocal load**	**Base line**	**Post muscle load**
1	37.2	37.8	35.5	37.0
2	37.5	37.7	35.3	35.5
3	36.4	37.2	34.0	33.3
4	35.2	38.7	34.0	33.4
5	36.9	38.6	35.4	35.8
6	37.5	38.0	34.8	34.6
7	38.2	35.5	37.3	36.2
8	38.8	36.2	34.4	35.5
9	38.1	35.9	35.9	34.8
10	38.8	36.1	35.3	34.8
Average	35.19	35.09	37.46	37.17

Table 5: Comparison of heat generation (degree Celsius) between reading and non-reading task

Seven of the 10 participants, had increase in temperature from the baseline till 5 to 40 minutes, though not linearly. Participants 7, 9, and 10 were exceptions in that the temperature decreased from baseline onwards. Most of the participants presented with dryness, throat clearing, throat pain and strain. Table 6 shows the profile of each of the participants in this study.

Participant	1	2	3	4	5	6	7	8	9	10
Age (years)	23	20	22	30	29	26	**27**	24	**21**	**22**
Reading Intensity (dB)	55-60	50-55	55-60	55-65	55-60	55-60	**45-50**	50-55	**50-55**	**50-55**
Rate of reading (perceptually)	Average	Average	Average	Average	Average	Average	**Average**	Average	**Average**	**Average**
Body Mass Index (BMI)	21.5	23.1	23.6	23.4	24.8	23.2	**23.7**	25.4	**18.4**	**24.5**
Vocal fatigue signs	Dryness Throat clearing	Dryness	Dryness Throat clearing	Dryness Throat clearing Throat pain	Strain	Dryness	**Dryness**	Dryness	**Dryness**	**Dryness Throat clearing**
Reading material	English	English	English	English	Kannada	Kannada	**Kannada**	Kannada	**Kannada**	**Kannada**
Hammer curl (number of times)	18	20	17	20	20	23	**25**	18	**17**	**19**

Table 6: Profile information of participants in this study

Participant 1: A 23-year-old healthy participant read a book of his interest in English at his comfortable level (55 – 60 dB). Body mass index of the participant was 21.5. Usage of voice in day to day activities was around 7-8 hours. In the reading task, there were indication of vocal fatigue seen from 20 minutes; vocal dryness at 20 minutes and throat clearing at around 30 minutes. Fluctuation in temperature was seen throughout the activity. For the weight lifting task, participant could do 18 hammer curls using dumb bells and felt fatigue in the bicep muscle. ***There was increment in temperature seen in both the activities.*** Figures 7 and 8 show the changes in temperature throughout the activity and a comparison of reading, and non-reading task.

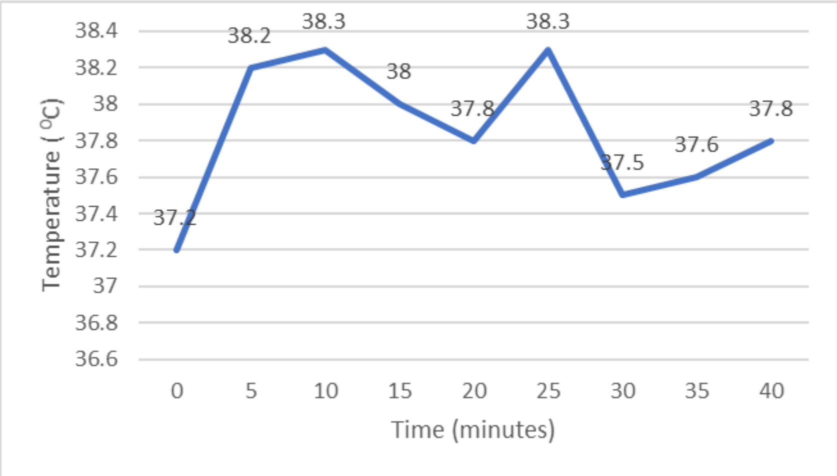

Figure 7: Change in temperature (degree Celsius) over a period of time in participant 1

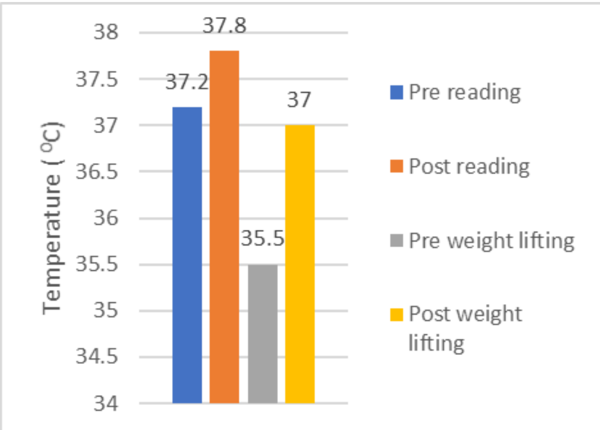

Figure 8: Comparison of temperature in both reading and weight lifting task in participant 1

Participant 2: A 20-year-old healthy participant read a book of his interest in English at his comfortable level (50dB-55dB). Body mass index of the participant was 23.1. Usage of voice in day to day activities was around 5-6 hours. In the reading task, there were indications of vocal fatigue like dryness at 30 minutes. Minimal fluctuation in temperature was seen throughout the activity. For the weight lifting task, participant could do 20 hammer curls using dumb bells and felt fatigue in the bicep muscle. ***There was increment in temperature seen in both the activities.*** Figures 9 and 10 show the changes in temperature throughout the activity and a comparison of reading, and non-reading task.

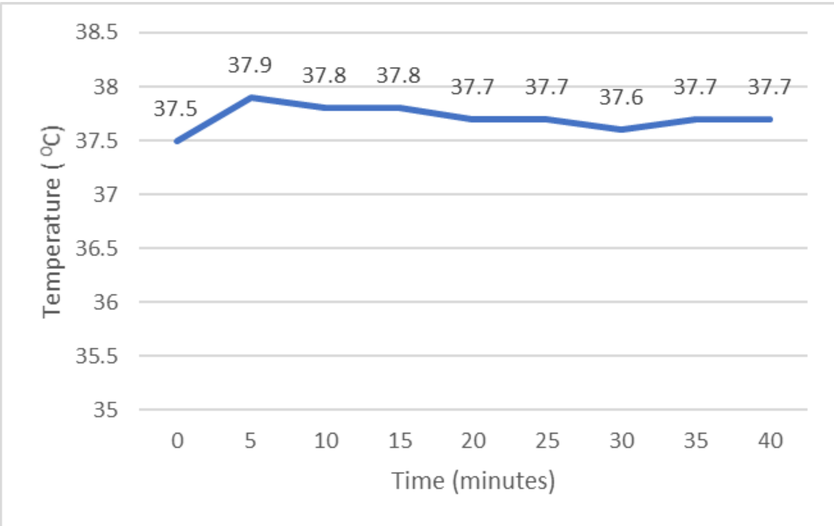

Figure 9: Change in temperature (degree Celsius) over a period of time in participant 2

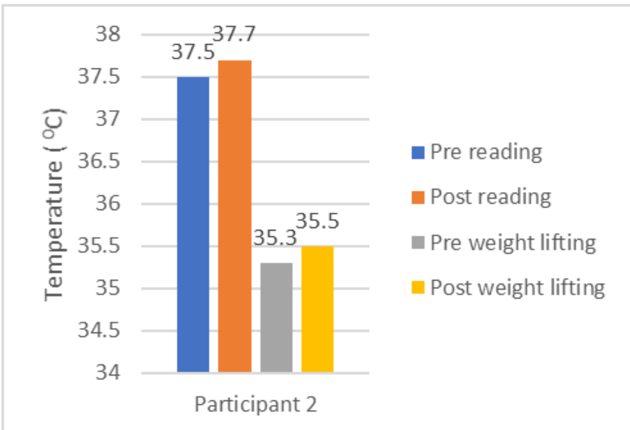

Figure 10: Comparison of temperature both reading and weight lifting task in participant 2

Participant 3: A 22-year-old healthy participant read a book of his interest in English at his comfortable level (55 – 60 dB). Body mass index of the participant was 23.6. Usage of voice in day to day activities was around 7-8 hours. In the reading task, there were indication of vocal fatigue seen from 10 minutes; vocal dryness at 10 minutes and throat clearing at around 20 minutes. Fluctuation in temperature was seen throughout the activity. For the weight lifting task, participant could do 17 hammer curls using dumb bells and felt fatigue in the bicep muscle. ***There was increment in temperature in reading task and decrement in temperature in weight lifting task.*** Figures 11 and 12 show the changes in temperature throughout the activity and a comparison of reading, and non-reading task.

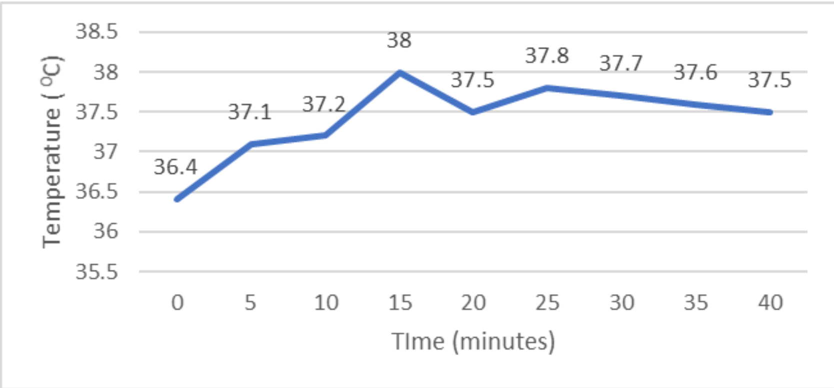

Figure 11: Change in temperature (degree Celsius) over a period of time in participant 3

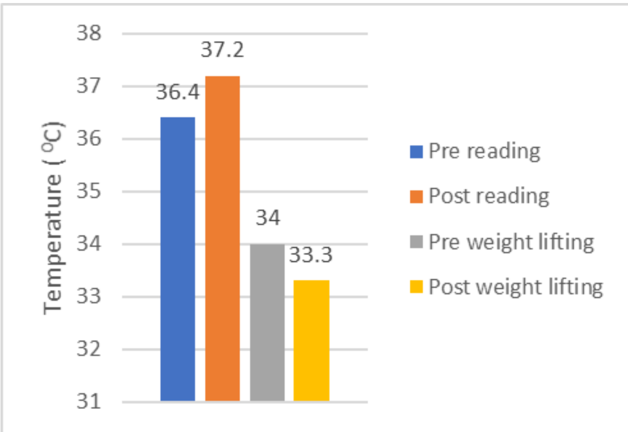

Figure 12: Comparison of both reading and weight lifting task in participant 3

Participant 4: A 30-year-old healthy participant read a book of his interest in English at his comfortable level (55 – 65 dB). Body mass index of the participant was 23.4. Usage of voice in day to day activities was around 9-10 hours. In the reading task, there were indication of vocal fatigue seen from 10 minutes; vocal dryness at 10 minutes, throat clearing at around 20 minutes and throat pain at around 25 minutes. Increment in temperature was seen throughout the activity. For the weight lifting task, participant could do 20 hammer curls using dumb bells and felt fatigue in the bicep muscle. ***There was increment in temperature in reading task and decrement in temperature in weight lifting task.*** Figures 13 and 14 show the changes in temperature throughout the activity and a comparison of reading, and non-reading task.

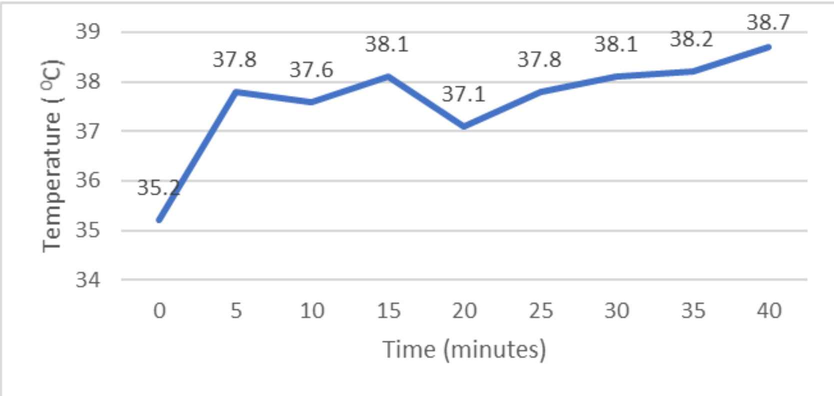

Figure 13: Change in temperature over a period of time in participant 4

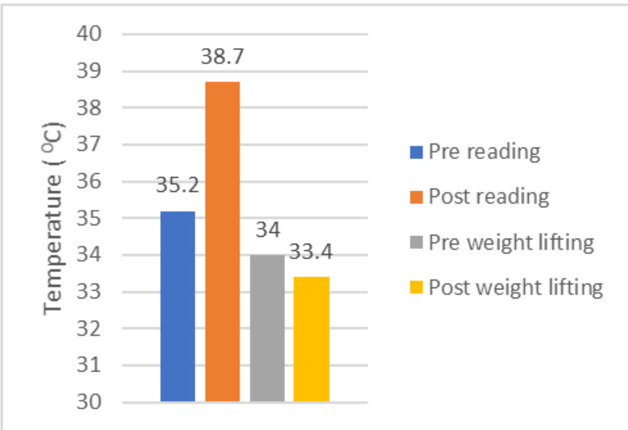

Figure 14: Comparison of both reading and weight lifting task in participant 4

Participant 5: A 29-year-old healthy participant read a book of his interest in Kannada at his comfortable level (55 – 60 dB). Body mass index of the participant was 24.8. Usage of voice in day to day activities was around 7-8 hours. In the reading task, there were indications of vocal fatigue seen like strain at around 30 minutes. Increment in temperature was seen throughout the activity. For the weight lifting task, participant could do 20 hammer curls using dumb bells and felt fatigue in the bicep muscle. ***There was increment in temperature seen in both the activities.*** Figures 15 and 16 show the changes in temperature throughout the activity and a comparison of reading, and non-reading task.

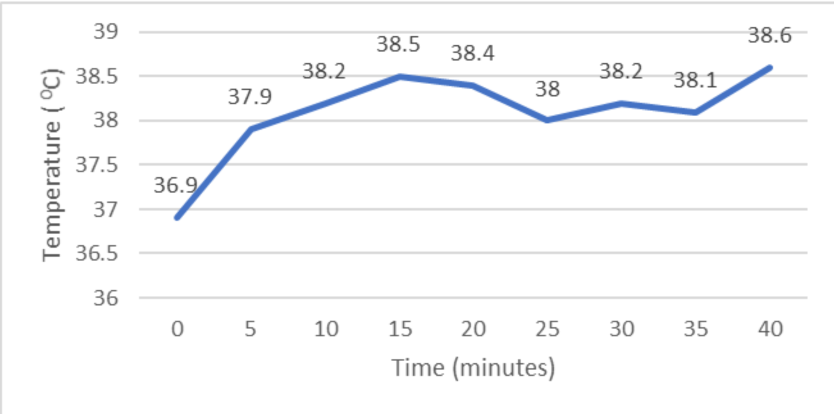

Figure 15: Change in temperature (degree Celsius) over a period of time in participant 5

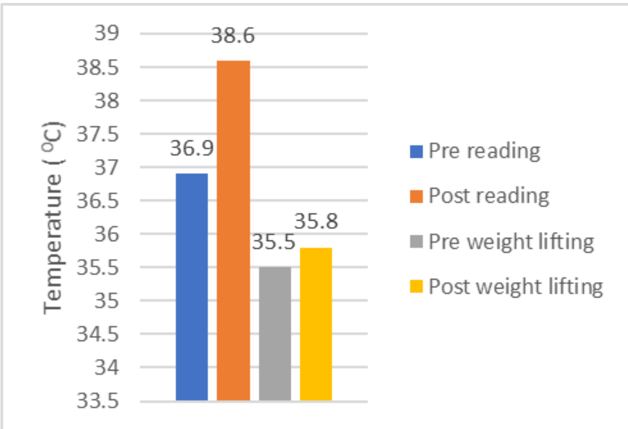

Figure 16: Comparison of both reading and weight lifting task in participant 5

Participant 6: A 26-year-old healthy participant read a book of his interest in Kannada at his comfortable level (55 – 60 dB). Body mass index of the participant was 23.2. Usage of voice in day to day activities was around 7-8 hours. In the reading task, there were indications of vocal fatigue seen like dryness at around 25 minutes. Fluctuation in temperature was seen throughout the activity. For the weight lifting task, participant could do 23 hammer curls using dumb bells and felt fatigue in the bicep muscle. ***There was increment in temperature in reading task and decrement in temperature in weight lifting task.*** Figures 17 and 18 show the changes in temperature throughout the activity and a comparison of reading, and non-reading task.

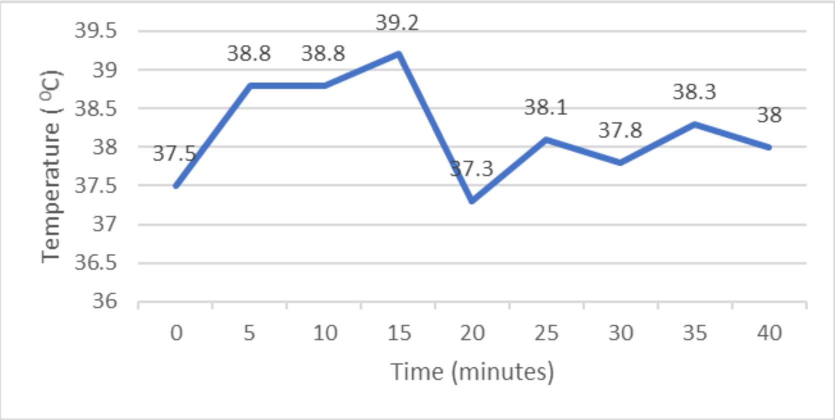

Figure 17: Change in temperature (degree Celsius) over a period of time in participant 6

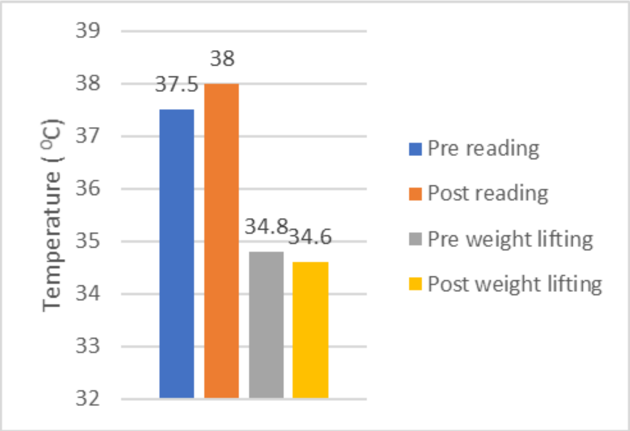

Figure 18: Comparison of both reading and weight lifting task in participant 6

Participant 7: A 27-year-old healthy participant read a book of his interest in Kannada at his comfortable level (45 – 50 dB). Body mass index of the participant was 23.7. Usage of voice in day to day activities was around 5-6 hours. In the reading task, there were indications of vocal fatigue seen like dryness at around 15 minutes. Decrement in temperature was seen throughout the activity. For the weight lifting task, participant could do 25 hammer curls using dumb bells and felt fatigue in the bicep muscle. ***There was decrement in temperature seen in both the activities.*** Figures 19 and 20 show the changes in temperature throughout the activity and a comparison of reading, and non-reading task.

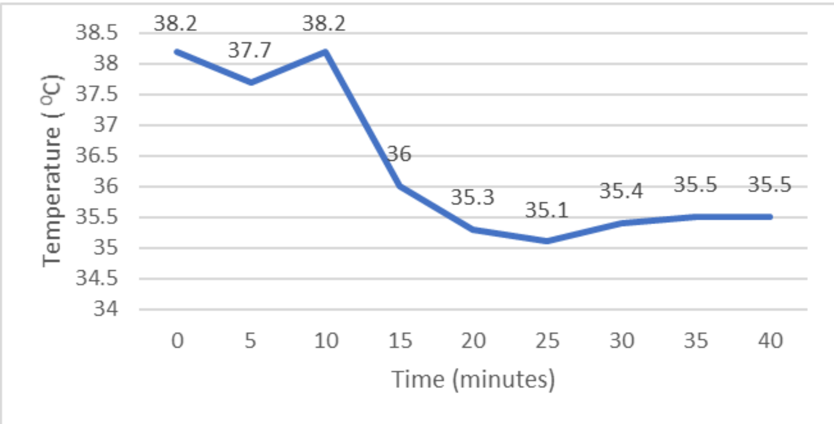

Figure 19: Change in temperature (degree Celsius) over a period of time in participant 7

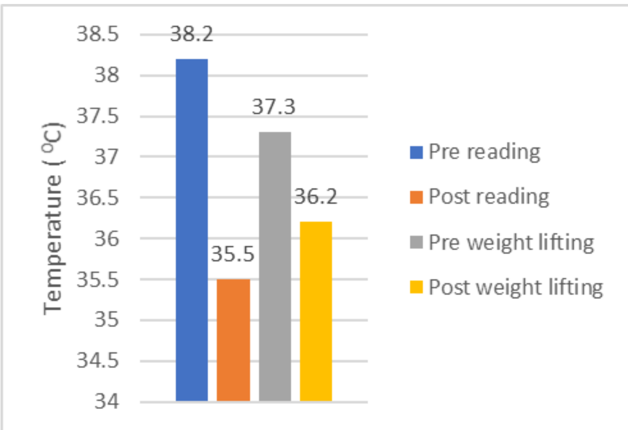

Figure 20: Comparison of both reading and weight lifting task in participant 7

Participant 8: A 24-year-old healthy participant read a book of his interest in Kannada at his comfortable level (50 – 55 dB). Body mass index of the participant was 25.4. Usage of voice in day to day activities was around 6-7 hours. In the reading task, there were indications of vocal fatigue seen like dryness at around 20 minutes. Decrement in temperature was seen throughout the activity. For the weight lifting task, participant could do 18 hammer curls using dumb bells and felt fatigue in the bicep muscle. ***There was decrement in temperature in reading task from baseline to 30 minutes and increment in temperature in weight lifting task.*** Figures 21 and 22 show the changes in temperature throughout the activity and a comparison of reading, and non-reading task.

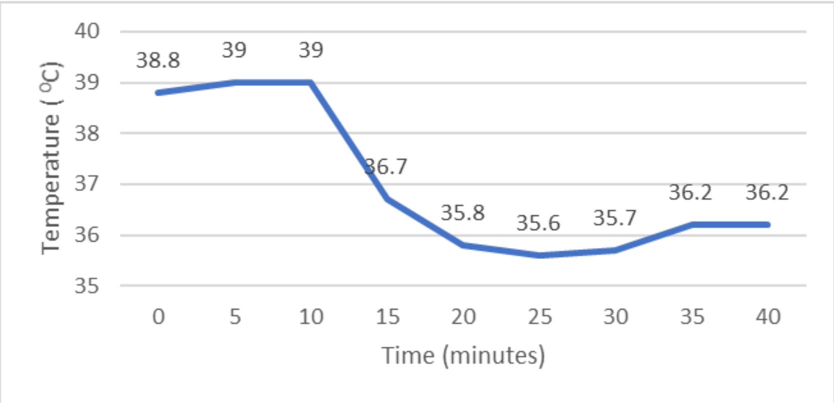

Figure 21: Change in temperature (degree Celsius) over a period of time in participant 8

Figure 22: Comparison of both reading and weight lifting task in participant 8

Participant 9: A 21-year-old healthy participant read a book of his interest in Kannada at his comfortable level (50 – 55 dB). Body mass index of the participant was 18.4. Usage of voice in day to day activities was around 5-6 hours. In the reading task, there were indications of vocal fatigue seen like dryness at around 30 minutes. Decrement in temperature was seen throughout the activity. For the weight lifting task, participant could do 17 hammer curls using dumb bells and felt fatigue in the bicep muscle. ***There was decrement in temperature seen in both the activities.*** Figures 23 and 24 show the changes in temperature throughout the activity and a comparison of reading, and non-reading task.

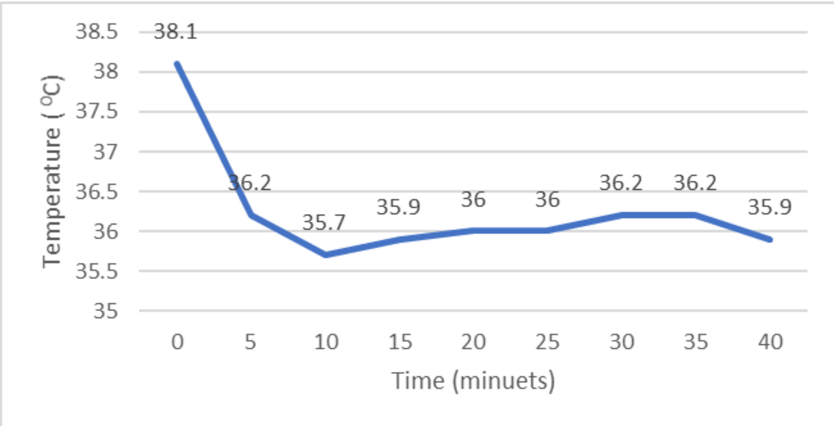

Figure 23: Change in temperature over a period of time in participant 9

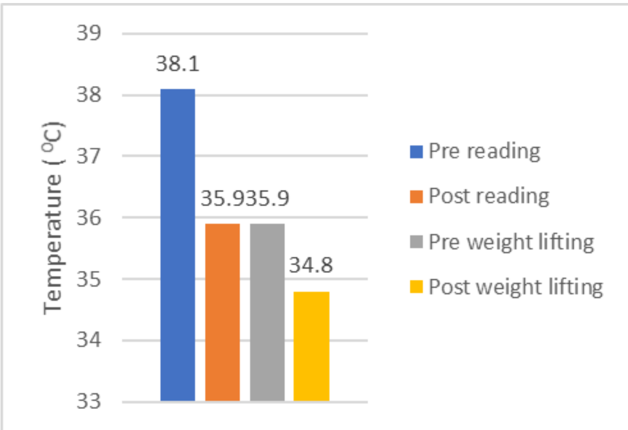

Figure 24: Comparison of both reading and weight lifting task in participant 9

Participant 10: A 22-year-old healthy participant read a book of his interest in Kannada at his comfortable level (50 - 55 dB). Body mass index of the participant was 24.5. Usage of voice in day to day activities was around 5-6 hours. In the reading task, there were indication of vocal fatigue seen from 15 minutes; vocal dryness at 15 minutes and throat clearing at around 20 minutes. Decrement in temperature was seen throughout the activity. For the weight lifting task, participant could do 19 hammer curls using dumb bells and felt fatigue in the bicep muscle. ***There was decrement in temperature seen in both the activities.*** Figures 25 and 26 show the changes in temperature throughout the activity and a comparison of reading, and non-reading task.

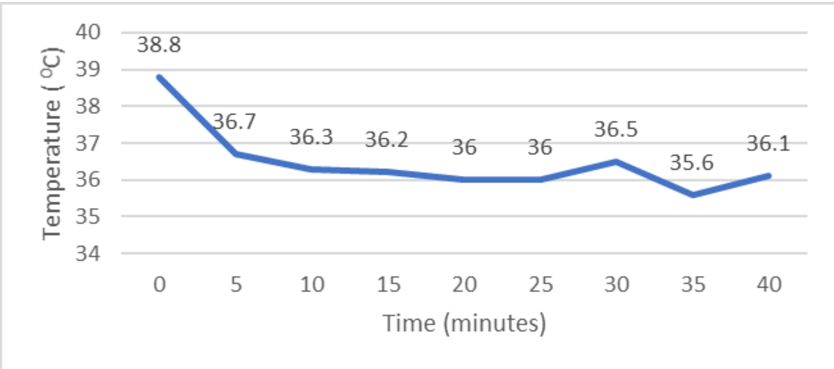

Figure 25: Change in temperature over a period of time in participant 10

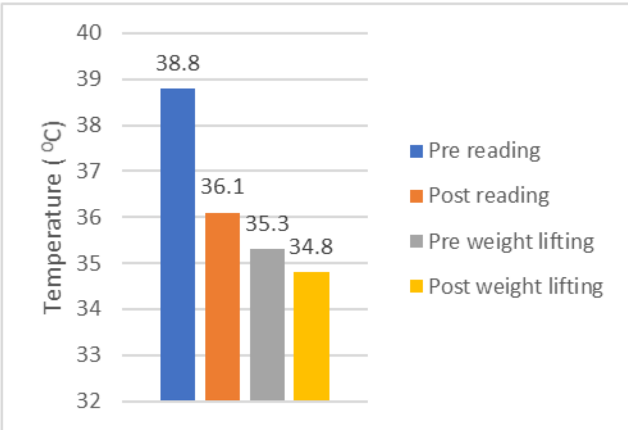

Figure 26: Comparison of both reading and weight lifting task in participant 10

CHAPTER V

DISCUSSION

The results revealed several interesting points. First of all, the temperature increased in 7 of 10 participants on vocal loading task. On an average, baseline temperature in these 7 participants was 37.07 ºC and a maximum temperature of 38.12 ºC was attained within 10 minutes. The possible factors affecting increase in temperature in 7 participants increase in fatigue (Boominathan et. al., 2010) which may be due to increase in intensity of reading compared to other participants. The rate of reading might be another variable as vocal fold vibration may be more in faster rates of reading compared to slower rates. Further, speakers used either English or Kannada and therefore, language might play a role for reduction in temperature as the amount of mouth opening and fronting varies with language. For example, English is more fronted and has more mouth opening compared to Kannada. However, when analyzed according to language, participants 1 to 6 and 8 no specific language influence was evident as they neither consistently used English nor Kannada bur had a mixture of English and Kannada, in that participants 1-4 used English for reading and the remaining used Kannada for reading. Reduction in temperature from baseline in 3 participants can be attributed to frequent inhalations. Temperature is a measure of the average speed of the moving molecules. The temperature of a mass of air depends on the average velocity of the air molecules and their mass, and so temperature generally increases with air density and decreases with decrease in air density (https://www.st-andrews.ac.uk/~dib2/climate/pressure.html). Wearing tight or artificial clothing may trap water and produce ineffective decrease in heat; and an increased activity on the thyroid which raises the metabolic activity by the body processes, and strenuous workout or physical exercise causes production of excess heat (https://beautyhealthtips.in/tips-to-reduce-body-heat-food-controls-your-body-heat/).

These participants took 15.83 minutes to reach the baseline in the post-experimental phase. Short-term recovery Index (I_S) calculated by using the following formula, indicated an I_S {[(40-13.33)/40] = 26.67/40 = 0.67} of 0.67.

$$I_s = \frac{performance\ time - phonation\ time}{performance\ time}$$

Second, all participants showed signs of vocal fatigue by about 10 – 30 minutes. The results of the present study are in consonance with that of Krishna and Nataraja (1995) who 30 minutes of reading was sufficient to induce fatigue, and Boominathan et. al., (2010) who reported that duration of 35 minutes was sufficient enough to induce vocal fatigue in their study. In the present study, the duration of reading was for 40 minutes. All the participants were able to complete the prolonged reading task maintaining the intensity range of 48-60 dB. Participants started to show signs of fatigue by minimum of 10 minutes and maximum of 30 minutes.

Third the main symptoms reported by the participants were throat dryness, throat clearing and pain sensation during the oral reading task. These complaints correlate with some of the primary symptoms of vocal fatigue listed by Kostyk and Rochet (1998, as cited in Welham and Maclagan, 2003).

Fourth, the temperature at bicep muscle region during action in the present study was varying. This may be due to the intensity of exercise (Smorawiński et. al., 1990; Coh & Sirok 2007), or once the heat is transferred from core to surface temperature, heat can be lost to the surrounding environment by radiation, conduction, convection and evaporation. There are different mechanisms by which heat can be gained or lost which are defined by the balance equation; metabolism ± radiation ± conduction ± convection – evaporation = heat storage (Cheuvront & Haymes 2001).

Lastly, a comparison between change in temperature at vocal and bicep region revealed differences. The temperature in the bicep region never approximated the baseline temperature at vocal region except participant 1. The two muscles; vocal cord and bicep have a great difference in size. Hence the amount of work done by both the muscles vary. In the present study, both increase and decrease in temperature at both the muscles which did not follow a particular pattern was evident. These differences were highly individualistic. Temperature of the person keeps changing over time which is difficult to stabilize (Guyton & Hall 1996). Since the heat dissipated by both the muscles are varying, it is assumed to be majorly due to their respective size, composition and amount of blood flow, presuming different size muscles dissipate different amount of heat. The temperature in the vocal region was higher than that in the biceps region. Hence, temperature at vocal region during reading activity and bicep region, a non-reading activity did not yield any correlation.

To summarize, the present study examined the changes in temperature, if any, before, during, and after vocal loading, the duration of rest period required to attain the baseline temperature, and compared the heat generation during reading and a non-reading muscle activity during lifting a 6 kg dumbbell. This is the first kind of study that has measured the temperature by using a Thermal Imaging Camera. The results of the study have contributed to the understanding of vocal loading by way of temperatures generated at the vocal region. The study was restricted to 10 male participants owing to the time constraints. Future studies in all points of the vocal region including females in speaking, reading and singing, and clinical population is warranted.

CHAPTER VI

SUMMARY AND CONCLUSIONS

The present study investigated the changes in temperature at vocal region and at bicep muscle region; prior and following an induced vocal loading task in healthy adult male individuals and weight lifting. The study also investigated the recovery pattern with change in temperature after vocal loading for a period of 40 minutes. A total of 10 healthy adult male participants with an age range of 20 to 30 years participated in the study. An induced vocal loading task of oral reading for a duration of 40 minutes a comfortable loudness level and by doing hammer curl using 6 kg dumb bell.

The study included 2 activities: (1) Oral reading and (2) Weight lifting. Oral reading task was conducted in three phases: (i) Pre-experimental phase involved placing the participant in an air-conditioned room of 25 ºC and baseline measurement of temperature at vocal region was taken; (ii) Experimental phase included prolonged reading task at comfortable level and changes in temperature was measured at an interval of 5 minutes; and (iii) In post experimental phase, the post reading temperature was measured after oral reading at an interval of every 5 minutes till it reached the baseline temperature after the cessation of prolonged reading. Participants were made to do a hammer curl using 6 kg dumb bell as many times as they can until they get fatigue. Both pre and post temperature was measured.

Results indicated increase in temperature in vocal reading task in 7 participates and decrease in the remaining which was attributed to different factors such as reading intensity, rate of reading, body mass index, reading material, amount of times the person swallows and indications of vocal fatigue. Results of temperature before and after hammer curl indicated that an increase in 4 participants but decrease in 6 participants.

Comparison of change in temperature at vocal region and at bicep muscle region yielded no correlation as the size, mass, composition of tissues, amount of blood flow and sweat glands vary between them. The study was limited to 10 male participants with varying Body Mass Index, reading material and the language use for reading. Future studies in all points of the vocal region including females in speaking, reading and singing, and clinical population is warranted.

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