The Effectiveness of Low-Level Light Therapy in Attenuating Vocal Fatigue

*Loraine Sydney Kagan and *,†James T. Heaton, *†Boston, Massachusetts

Summary: Objectives. Low-level light therapy (LLLT) is effective in reducing inflammation, promoting wound healing, and preventing tissue damage, but has not yet been studied in the treatment of voice disorders. The objective of this study was to investigate the possible effectiveness of LLLT in attenuating symptoms of vocal fatigue created by a vocal loading task as measured by acoustic, aerodynamic, and self-reported vocal effort.

Methods. In a randomized, prospective study, 16 vocally healthy adults divided into four groups underwent a 1-hour vocal loading procedure, followed by infrared wavelength LLLT (828 nm), red wavelength LLLT (628 nm), heat, or no heat–light (control) treatment targeting the laryngeal region of the ventral neck surface. Phonation threshold pressure (PTP), relative fundamental frequency (RFF), and the inability to produce soft voice (IPSV) self-perceptual rating scale were recorded (1) at baseline, (2) immediately after vocal loading, (3) after treatment, and (4) 1 hour after treatment.

Results. Vocal loading significantly increased PTP and IPSV and decreased onset and offset RFFs, consistent with a shift toward vocal dysfunction. Red light significantly normalized the combination of PTP, IPSV, and RFF measures compared to other conditions.

Conclusions. RFF is sensitive to a vocal loading task in conjunction with PTP and IPSV, and red LLLT may have a normalizing effect on objective and subjective measures of vocal fatigue. The results of this study lay the groundwork and rationale for future research to optimize LLLT wavelength combinations and overall dose.

Key Words: Low-level light therapy–Vocal fatigue–Vocal hyperfunction–Relative fundamental frequency–Dysphonia.

INTRODUCTION

Low-level laser therapy or low-level light therapy (LLLT) has been proven to be a noninvasive therapeutic procedure for reducing inflammation and pain, and for promoting faster wound healing and nerve regeneration.[1] Efficacious light wavelengths include red (approximately 633 nm) and infrared (IR) (approximately 830 nm), which can be emitted via laser or light-emitting diode (LED) light sources. Although LLLT is typically administered by licensed dermatologists and physical therapists, LLLT devices are also available over the counter (OTC) to rejuvenate aged skin or to treat inflammation or pain in pets and people. For example, the Omnilux New-U is approved by the Food and Drug Administration (without a prescription) to treat periorbital skin wrinkles (ie, "crow's-feet") with both red and IR LED lights in a handheld unit for self-administration to the skin surface. Similarly, the Willow Curve (Physicians Technology, LLC) is an array of red and IR LED lights for at-home treatment of pain and inflammation.

Speech–language pathologists (SLPs) at the Massachusetts General Hospital Center for Laryngeal Surgery and Voice Rehabilitation have anecdotally noted that the application of red light from a New-U unit placed on the neck surface overlying the larynx for 5–10 minutes can cause neck muscles to feel "more relaxed" as self-reported by some individuals receiving voice therapy for muscle tension dysphonia (T. Stadelman-Cohen, personal communication, April 4, 2014). An SLP at the Center has also noted that LLLT gives a similar feeling to having "warmed up" vocally (perhaps as a result of the heat generated by the red wavelength), although a placebo effect cannot be ruled out. Radiographic testing conducted at the Center revealed that both red and IR light wavelengths from the New-U LLLT device are capable of at least partially penetrating the ventral neck surface through to the laryngeal mucosa within the airway, showing the potential for LLLT to affect laryngeal physiology. Specifically, the vocal folds and paraglottic tissues glow brightly during IR LLLT application when viewed with an IR sensitive camera (*Microsoft LifeCam VX-3000*, Microsoft, Redmond Washington, USA) or during red LLLT when viewed with a rigid endoscope (without fiberoptic illumination). In addition, a photodiode radiometer (Nova II meter with PD300-TP probe, Ophir Optronics, North Andover, Massachusetts, USA) positioned in the canine glottis indicates that approximately 1.5% of the 633-nm (red) light and 4.8% of the 830-nm (IR) light reach the medial vocal fold surface from neck-placed New-U LLLT units (unpublished observation).

LLLT involves exposing cells or tissues to levels of light, usually in the red and IR wavelengths, that are relatively low in energy compared to what is used for purposes such as ablation, cutting, and thermally coagulating tissue. LLLT was discovered in 1967 by Mester et al,[2] who noticed that applying a low-level laser to the backs of shaven mice induced faster hair regrowth. Since the initial observations of Mester et al, the applications of LLLT have grown tremendously and now include wound healing, tissue repair, relief of inflammation and edema of injuries or chronic diseases, and nerve regeneration.

The cellular mechanisms of LLLT are not completely understood. The most promising theory is that LLLT acts on

Accepted for publication September 8, 2016.

From the *MGH Institute of Health Professions, Charlestown Navy Yard, Boston, Massachusetts; and the †Massachusetts General Hospital Department of Surgery, Harvard Medical School, Boston, Massachusetts.

Address correspondence and reprint requests to James T. Heaton, MGH Center for Laryngeal Surgery and Voice Rehabilitation, 1 Bowdoin Square, 11th Floor, Boston, MA 02144. E-mail: James.Heaton@mgh.harvard.edu

Journal of Voice, Vol. ■■, No. ■■, pp. ■■-■■
0892-1997

http://dx.doi.org/10.1016/j.jvoice.2016.09.004

mitochondria to increase adenosine triphosphate (ATP) production and modulate reactive oxygen species, and creates downstream effects resulting in increased transcription.[1] Red and IR wavelengths absorbed by chromophores in mitochondria cause electrons within the chromophore to jump to a higher energy level, causing a reaction in the transmembrane complex in the electron transport chain. This photobiomodulation results in increased electron transport and thus increased production of ATP.[3,4] Upregulation of mitochondria causes increased generation of reactive oxygen species, which activate more transcription factors, leading to increased stimulatory and protective genes.[5] This induction of transcription factors causes downstream effects, including increased cell proliferation, growth factors, inflammatory modulators, and increased tissue oxygenation.[6]

There has been a great deal of evidence demonstrating the positive effects of LLLT on wound healing, tissue repair, relief of inflammation and edema of injuries or chronic diseases, and nerve regeneration. To promote wound healing, it is theorized that LLLT induces the local release of cytokines, chemokines, and other biological response modifiers that increase the wound strength and reduce the time to heal.[7–9] LLLT has also been found to promote collagen formation and induce neovascularization.[10,11] In sports medicine, a field that shares similarities to vocal performance, LLLT has been shown to increase endurance, strength, and speed of recovery for athletes as well as aid in the relief of inflammation and edema of injuries or chronic diseases.[12–15] Additionally, LLLT has been shown to improve neural regeneration after a stroke or traumatic brain injury, in neurodegenerative diseases, and after spinal cord and peripheral nerve damage.[16]

Although vocal fatigue is largely classified as a subjective phenomenon, it has both physiological and biological bases and can be measured accordingly. From a neuromuscular perspective, when skeletal muscle fatigue and force required exceeds available output, additional muscles are recruited. While true of skeletal muscles, this is not entirely the case for the laryngeal musculature. Although Boucher et al[17] found that lateral cricoarytenoid (LCA) muscles exhibited signs of EMG spectral compression (a marker of muscular fatigue) in subjects performing a vocal loading task over 12–14 hours, it is the prevailing opinion that the laryngeal musculature is composed mainly of fatigue-resistant muscle fibers and does not fatigue with normal speaking activities.[18] Reactive vocal hyperfunction of the intrinsic or extrinsic laryngeal musculature may occur, however, negatively impacting the voice. When an individual is vocally fatigued, reactive vocal hyperfunction of the intrinsic or extrinsic laryngeal musculature may occur, which negatively impacts the voice.[19,20] Stepp et al[19] found that the offset and onset relative fundamental frequencies (RFFs) surrounding a voiceless consonant were decreased for individuals with vocal hyperfunction, presumably because of excessive tension of the laryngeal muscles. Another source of vocal fatigue may result from mechanical stress placed on the vocal fold mucosa, which increases vocal fold viscosity.[21,22] Phonation threshold pressure (PTP), which is the lowest subglottal pressure needed to initiate and sustain vocal fold vibration, increases during vocally fatiguing tasks, largely because of the vocal folds' increased viscosity.[23,24] A less invasive measure of vocal fold viscosity, the inability to produce soft voice (IPSV), asks a subject to perform a specific soft voice task and to rate its difficulty on a 10-point scale.[25] Elevated IPSV values have been found for up to 24 hours following acute phonotrauma, but ultimately resolve completely.[26] Accordingly, RFF, PTP, and IPSV were used to objectively measure signs of vocal fatigue in the present study.

There has only been one previous study of LLLT on the laryngeal area. In a preliminary study of the application of LLLT to treat intubation-induced laryngopharyngeal reflux in rats, rats were intubated and given four irradiation sessions at 780 nm, 45-second durations (delivering 4.2 J) at 48-hour intervals. Larynges were then analyzed for myeloperoxidase (MPO) activity, which is an indicator of neutrophil migration, a negative effect triggered by intubation. The larynges of the group that had LLLT displayed significantly increased levels of MPO compared to controls that had not been intubated, but showed decreased levels of MPO compared to controls that had been intubated but untreated.[27] Therefore, the use of LLLT may be beneficial in the voice-disordered population, including for those whose pathologies encompass some alteration of the lamina propria (eg, trauma and fibrovascular changes).

Vocal fatigue has traditionally been classified as a symptom reported subjectively by individuals. Typical complaints associated with reported vocal fatigue include increased effort and discomfort, reduced pitch range and flexibility, reduced loudness or impaired quality, increased fatigue over the course of a day, and improvement after vocal rest.[28–31] Clinically, the treatment of vocal fatigue involves reducing muscular tension (if present) through exercises or palpation; preventing or limiting the inflammatory response through vocal hygiene, hydration, or warm-ups; or promoting wound healing through vocal rest.[32] Inflammation reduction and wound healing are both involved in treating vocal fatigue,[32–34] which is a typically temporary yet debilitating voice condition. Therefore, LLLT is an ideal candidate for a pilot study of a new therapy for the treatment of vocal fatigue.

Although LLLT has been widely used in other fields relating to inflammation and wound healing, no scientific study of the effectiveness of LLLT on the treatment of voice disorders has yet been undertaken. The purpose of the present study was to determine the effectiveness of LLLT in attenuating symptoms of vocal fatigue created by a vocal loading task as measured by acoustic, aerodynamic, and self-reported vocal effort. It was hypothesized that two common wavelengths of LLLT (red and IR) would each have a positive effect on measures associated with muscular fatigue and inflammation. If LLLT has a beneficial impact on vocal musculature and tissues, it could have wide clinical relevance to populations with voice disorders. Not only might LLLT speed the recovery of certain patients, but also it might relieve patients' discomfort during the healing process as well.

METHODS

Participants

The study was approved by the Massachusetts General Hospital Institutional Review Board. Sixteen vocally healthy adults participated in the present study (ages 22–35, $M = 26$, standard deviation [SD] = 3.7; 5 males, 11 females). Specific inclusion